No

JAPAN INTERNATIONAL COOPERATION AGENCY
MINISTRY OF RURAL DEVELOPMENT, CAMBODIA

THE STUDY ON GROUNDWATER DEVELOPMENT
IN
SOUTHERN CAMBODIA

FINAL REPORT

MAIN REPORT

JANUARY 2002

KOKUSAI KOGYO CO., LTD.

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PREFACE

In response to a request from the Government of Kingdom of Cambodia, the Government of Japan decided to conduct a study on Groundwater Development in Southern Cambodia and entrusted to the study to the Japan International Cooperation Agency.

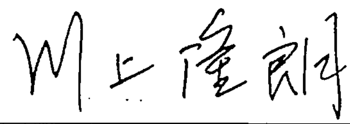
JICA selected and dispatched a study team headed by Dr. Kamata Akira of Kokusai Kogyo Co., Ltd. to Cambodia, seven times between December 1996 and January 2002.

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

I hope that this report will contribute to the promotion of this 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 Government of Cambodia for their close cooperation extended to the study.

January 2002



Kawasaki Takao
President
Japan International Cooperation Agency

Mr. Kawakami Takao

President
Japan International Cooperation Agency
Tokyo, Japan

LETTER OF TRANSMITTAL

Dear Sir:

We are pleased to officially submit herewith the final report of "The Study on Groundwater Development in Southern Cambodia".

This report compiles the results of the study which was undertaken in the Kingdom of Cambodia, from December 1996 to January 2002 by the Study Team, organized by Kokusai Kogyo Co., Ltd.

We would like to express our deep appreciation and sincere gratitude to all those who extended their kind assistance and cooperation to the Study Team, particularly the officials concerned of Department of Rural Water Supply, Ministry of Rural Development, and other members of the Cambodian Counterpart Team.

We also acknowledge and appreciate greatly the excellent support given by your agency, the JICA Advisory Committee and the Embassy of Japan in the Kingdom of Cambodia.

We sincerely hope that this report will be of help for the socio-economic development of the country as a whole. This report would be able to contribute really to Cambodian people and socio-economic development in the future.

Very truly yours,

Akira Kamata

Kamata Akira
Team Leader
The Study Team for the Study
on Groundwater Development
in Southern Cambodia

The Study on Groundwater Development in Southern Cambodia

Study Period: December 1996 to January 2002
Counterpart Agency: Department of Rural Water Supply of the Ministry of Rural Development

Summary

1. Background

Located on the southwestern region of Indochina, Cambodia is made up of mountains in the north, east and southwest, and a vast central plain where Mekong River and Tonle Sap River flow. The nation has a population of 11.42 million, more than 80 % of which is rural. Rural areas are mostly without water supply facilities. The residents use natural water sources such as rivers, ponds and lakes, as well as shallow wells and ponds. Many of these sources, however, dry up in the dry season or seriously contaminated. Severe water shortage conditions in rural are as significantly hamper improvements in public health and the rural development. This condition, therefore, makes the formulation of the water supply plan through groundwater development extremely urgent.

2. Study Objectives

The objectives of the Study are as follows:

(1) Evaluate the potential for the development of groundwater resources in the Study area.
(2) Select and prioritize the villages to be developed.
(3) Formulate the groundwater development plan and water supply plan for the selected villages.
(4) Transfer technology to the counterparts throughout the Study.

3. Study Area

The Study was carried out in the 472 villages in the 5 southern provinces of Cambodia including the 3 districts (Peri Urban Area) in the outskirts of Phnom Penh.

5 southern provinces: Svay Rieng, Prey Veng, Kandal, Ta Keo, Kompong Speu
Peri-Urban Areas: Dangkor, Mean Chey, Russey Keo

4. Study Results

(1) Natural Environment

The Study area is situated in the plains of the Mekong River basin. The central and eastern sections are located in a low-lying alluvial plain where quaternary deposits of sand, gravel and clay are distributed. The western section is a flat diluvial plateau where isolated hills of basement rocks (i.e. sandstone, slate) and thin quaternary layers are distributed. The Study area has two (2) seasons, dry and rainy, and an annual rainfall ranging from 1,400 to 1,700 mm.

(2) Existing Water Sources

Existing water sources in the Study area are rivers, ponds, shallow wells, combined wells, and tube wells (with hand pump). Groundwater is exploited through shallow wells, combined wells, and tube wells. However, the coverage of these facilities in the five (5) southern provinces is estimated at only 34 %. Hand pump wells in the villages in the study area total 269, only 222 of which are operative. The existing ponds, shallow wells, and combined wells contain colon bacilli; many of the ponds and shallow wells dry up in the dry season.

(3) Hydrogeology

Multi-layered aquifers can be found in quaternary layers in the eastern section of Mekong River. Groundwater development potential is, therefore, considered high in this area. In the western section, aquifers are found in the weathered zone and fissures of basement rocks. The groundwater development potential in this area is comparatively low.

(4) Optimal Well Yield

The results of the test drilling and pumping tests in the 24 villages were used to determine the optimal well yield in the hydrogeological units (see table below).

Optimal Well Yield

Hydrogeological Divisions	Area	Optimal Well Yield
Quaternary Aquifers	Svay Rieng, Prey Veng, southern Kandal	500~800 m^3/day
Basement Rock Aquifers	Peri-Urban Areas, northern Kandal, Kompong Speu, Ta Keo	1.5~150 m^3/day

(5) Groundwater Quality

Existing water resources are high in iron, many with levels exceeding the standard stipulated by WHO. Colon bacilli were also detected in all existing water sources. Water in test wells is also high in iron, many with levels exceeding the standard stipulated by WHO. Some aquifers in basement rock layers are high in salinity.

(6) Pilot Study

A sociological survey by means of PRA was carried out in the 30 candidate pilot villages to determine village socio-economy, water use and gender related issues. Water supply facilities, e.g. hand pumps and incidental facilities, were installed in 24 of the 30 candidate pilot villages where test wells were drilled.

To ensure the sustainable operation and maintenance of the water supply facilities, TRT was carried out for the DRWS staff and the staff of PDRD, and a VWC and WPC were formed in each village concerned. The WPC members were trained in hand pump operation and maintenance and proper sanitary practices. Of the 24 villages, 20 were selected for O&M monitoring which lasted until December 2001.

(7) Groundwater Development Plan

For groundwater development, tube wells will be constructed in 1,049 places. The wells will be 4 inches in diameter (with hand pump) and have a depth of 60 m on average and a screen opening ratio of over 3 %. The design pumpage of the wells is 7,800 m^3/day in total. In consideration of rechange conditions, this pumpage is negligible and will have no adverse impacts on the entire groundwater basin.

(8) Water Supply Plan

Of the 472 villages in the Study area, those considered to have an urgent need for new water sources totaled 241. The water supply plan, which entails the construction of deep wells with hand pumps, was formulated for these prioritized villages.

- Target Year: 2005
- No. of Target Villages & Population: 241 villages, total population of 194,964
- Water Supply Facilities: Deep wells with hand pumps in 1049 places
- Equipment & Materials:
  Equipment and materials for deep well construction and O&M
- Project Cost:
  The Project cost is estimated in two (2) ways. Original project cost is estimated in the condition that the works of the Project is only done by contractor. And the alternative project cost is estimated in the condition that the some part of the works is done by the MRD under the management of contractor. The costs of the both are as follows,

Project Cost

(Unit: US$ 1,000)

Plan	Original	Alternative
Works of the Project by	Contractor	Contractor with MRD
Project Cost	18,069	18,690

(9) Project Evaluation

The Project aims not only to meet the basic human needs of the residents of the 241 villages in the five (5) southern provinces, but also to bring about economic benefits through the reduction of water collection time and improvements in health and sanitation. The implementation of the project is also expected to improve the standard of living of the residents, and increase resident participation in the development of the community.

(10) Environmental Impact Assessment

The implementation of the project will hardly adversely affect the groundwater basin environment. It is, however, important to take the location of existing wells into consideration during the groundwater development activities as well as to prevent intrusion of salty groundwater into the wells.

(11) Monitoring

As a result of monitoring at 20 pilot wells, the water supply systems are being operated and maintained by the residents generally very well. These facilities are being utilized for various purpose of water use throughout the year, raised convenience in water utilization remarkably and reduced workload of the women. However, as the pilot well water is utilized together with the existing water sources, more assistance from the government agencies should be extended in regard to use of safe water through the sanitary campaign and guidance and training of the hand pump and iron removal device (IRD) .

(12) Arsenic Survey in Existing Wells

As a result of the water quality survey in the 260 villages including the target villages of the water supply plan, arsenic of more than 0.01 mg/ℓ (WHO guideline) was found at 9 target villages. High arsenic zone is located in the alluvial lowland along the Mekong and Tonle-Bassac Rivers. It is necessary to conduct a detailed survey in the non-target villages in this area. Arsenic contaminated well should be prohibited to use for drinking, if deemed necessary. A guidance should be given to the residents on the utilization of the IRD.

5. Recommendations

(1) Early Project Implementation

As a basic human need, the supply of clean drinking water will improve public health and sanitation, factors that are fundamental to socio-economic development. Since a clean drinking water supply is expected to bring about enormous long-term benefits, the early implementation of the Project is desired. In particular, areas on the right bank of Mekong River, i.e. the Peri-Urban Areas, Kandal, Ta Keo, and Kompong Speu, should be given priority in the implementation of the Project, as the need for water is high in these areas due to their geological make-up (basement rocks).

(2) Hydrogeological Map

The use of the hydrogeological map produced in this Study is strongly desired for groundwater development.

(3) Water Quality Control

Some groundwater resources in the Study area contain iron and salinity levels slightly higher than the WHO standards. Water quality monitoring should be regularly carried out therefore. In addition, guidance should be extended to the villagers in the installation of water treatment facilities, e.g. sand filters.

(4) Sanitary Education Method, Standardization and Joint Use of Materials

Contact with relevant and international agencies should be established for information exchange and to standardize methods and materials. The simultaneous implementation of the water supply plan and sanitary campaign is also recommended.

(5) Promote Village Development

Every PDRD should actively participate in the establishment of the VDC, improve the village environment through the provision of water and activate agricultural production.

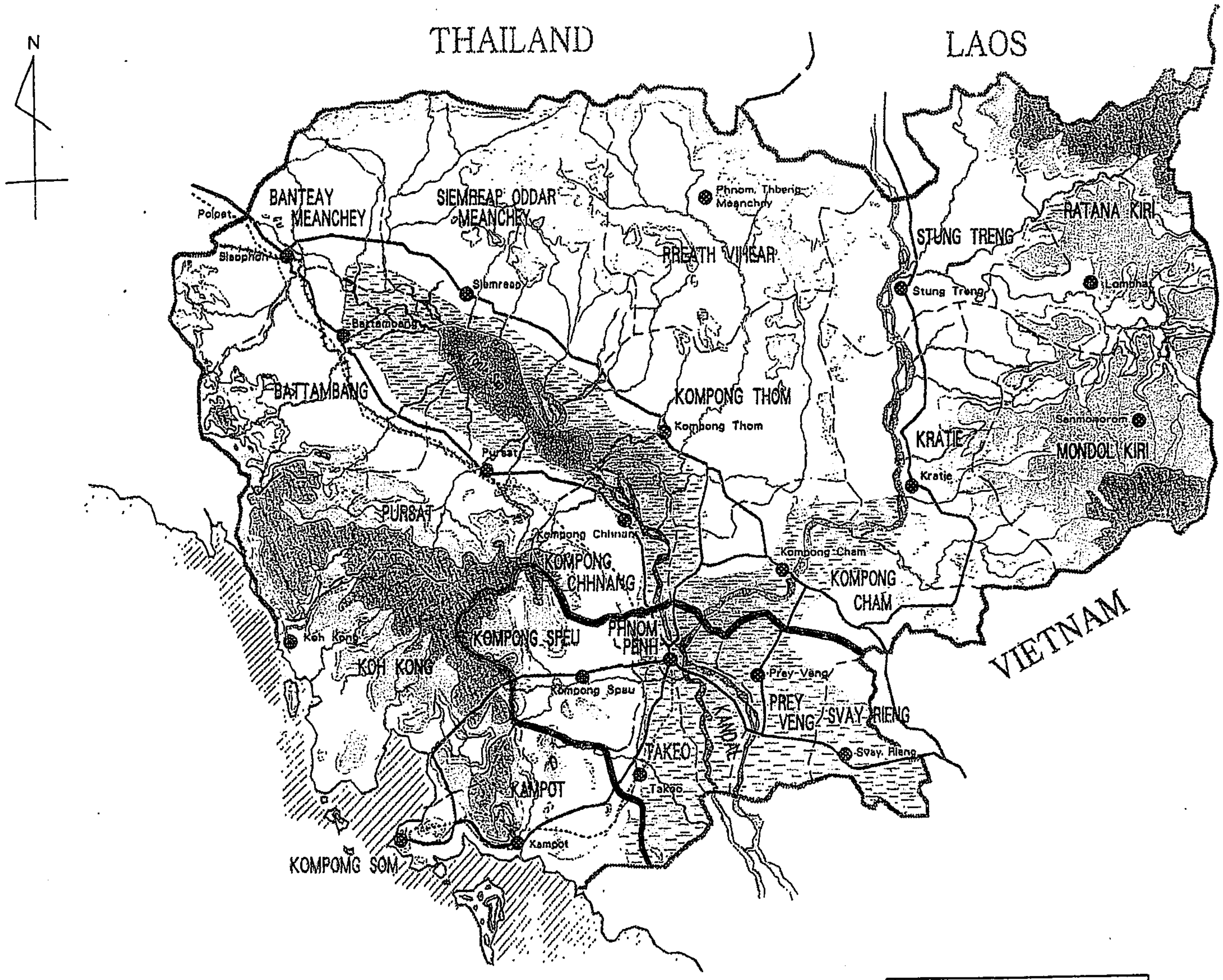
(6) Recommendations from Monitoring

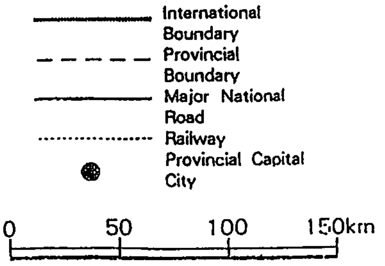
The following 4 points are recommended.

1) Water Fee Collection
2) Incidental Facilities
3) VWC/WPC Members
4) Strengthening of Assisting Capacity

CAMBODIA

LOCATION MAP OF THE STUDY AREA





The Study Area
Kandal
Kompong Speu
Takeo
Prey Veng
Svay Rieng
Urban Districts of Phnom Penh

EXCHANGE RATE

(April, 1999)

US$ 1.00 = 3,780 Riel = 123 Yen

l Riel = 0.033 Yen = US$ 0.0003

1 Yen = US$ 0.0081 = 30.73 Riel

ABBREVIATION

ADB:	Asian Development Bank
AICF:	Action Internationals Contre la Faim
B/C:	Benefit Cost Ratio
CARD:	Committee for Agricultural and Rural Development
CASD:	Community Action for Social Development
CCC:	Cooperation Committee for Cambodia
CWB:	Central Water Base
DCD:	Department of Community Development
DOH:	Department of Hydrology
DPB:	Department of Road and Bridges
DPWS:	Department of Provincial Water Supply
DRWS:	Department of Rural Water Supply
EIRR:	Economic Internal Rate of Return
EC:	Electric Conductivity
FHH:	Female-Headed Household
FSEDP:	First Socio-Economic Development Plan 1996~2000
GDP:	Gross Domestic Product
GRET:	Group de Recherche et d’Enchanges Technologiques
JICA:	Japan International Cooperation Agency
LWS:	Lutheran World Service
MAFF:	Ministry of Agriculture, Forestry and Fisheries
MIME:	Ministry of Industries, Mines and Energy
MOH:	Ministry of Health
MPWT:	Ministry of Public Works and Transport
MRD:	Ministry of Rural Development
NCHE:	National Center for Hygiene and Epidemiology
NIS:	National Institute of Statistics
NPRD:	National Program to Rehabilitate and Development Cambodia
NPV:	Net Present Value

PADEK:	Partnership for Development in Kampuchea
PDRD:	Provincial Department of Rural Development
PDRC:	Provincial Rural Development Committee
RGC:	Royal Government of Cambodia
PMU:	Project Management Unit
PRA:	Participatory Rapid Appraisal
PRASAC:	Program de Rehabilitation et Aqqui au Secteur Agricole du Cambodge
PRK:	People's Republic of Kampuchea
PWSA:	Phnon Penh Water Supply Authority
RGC:	Royal Government of Cambodia
S/W:	Scope of Work
TRT:	Trainer's Training
UNHCR:	United Nations High Commissions for Refugees
UNICEF:	United Nations Children's Education Fund
UNPA:	United Nations Population Fund
UNTAC:	United Nation's Transitional Authority in Cambodia
VDC:	Village Development Committee
VLOM:	Village Level Operation & Maintenance
VSC:	VLOM Steering Committee
VWC:	Village Water Committee
WATSAN:	Water and Sanitation
WES:	Water and Sanitation Program
WHO:	World Health Organization
WPC:	Water Point Committee
WUHE:	Water Use and Hygiene Education

The Study on Groundwater Development in Southern Cambodia
Final Report

Main Report

SUMMARY
LOCATION MAP
ABBREVIATION

CONTENTS

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

This Final Report on the Study on Groundwater Development in Southern Cambodia (hereinafter referred to as “the Study”) presents the results of the studies conducted from April 1997 to January 2002. It contains the hydro-geology and status of water supply in the target villages as well as the evaluation of groundwater potential and the rural water supply development plan. The pilot water supply systems were constructed at the 24 villages where the test wells were drilled.

Due to the break out of civil war in July 5, 1997, the Study, including the pilot projects, was suspended. After it was resumed in March 1999, pilot studies, including the forming of village water committees and implementation of operation and maintenance education programs for the villagers, were conducted. Although the Study was suspended for nearly two (2) years, the hand pump wells were found to have been used properly and effectively by the villagers for domestic purposes.

This report details the present state of the hand pump wells, particularly focusing on water quality, and operation and maintenance. A future groundwater development and water supply plan based on the findings obtained from the pilot studies is also detailed herein. For the effective planning and implementation of rural water supply services in the five (5) southern provinces, monitoring of the pilot villages will be continued until 2002 to gather sufficient relevant information.

The Study team, which was organized by the Japan International Cooperation Agency (JICA), conducted an intensive survey in the five (5) southern provinces that cover about 22,000 km^2. Launched in mid-December 1996 in accordance with the Scope of Work (S/W) agreed upon between the Cambodian Ministry of Rural Development (MRD) and JICA, the Study has been completed in January 2002.

1.1 Background

Cambodia occupies the southwestern region of the Indochina peninsula and covers about 180,000 km^2. As of 1993, it was estimated to have a population of 11,420,000 people. This agricultural country is the poorest in southeast Asia, with a per capita GDP of merely US$ 240.00 (1994). In 1965, Cambodia severed its relations with the United States, and in 1970 the General Lon No.1 Administration was established. The country was ruled by Pol

Pot from 1975 to 1979, then by the Kampuchea coalition of three political factions from 1982. Twenty (20) years of civil war have devastated the country and caused the people great suffering. The Peace agreement of Paris in 1991 marked the end of the civil war and general elections were held in May 1993 with the support of the United Nations' Transitional Authority in Cambodia (UNTAC). With the new government, troubles progressively ended in Cambodia.

Following the end of hostilities, the National Program to Rehabilitate and Develop Cambodia (NPRD) was designed in 1994, and with the cooperation of international organizations and other countries the reconstruction of devastated territories and social infrastructure commenced. In 1995, the First Socioeconomic Development Plan (1996~2000) was devised for the midterm reconstruction of the country by 2000.

To overcome poverty, the country's most basic problem, the Plan particularly puts emphasis on the development of the agricultural sector which generates 45 % of the GDP (1994) and employs 85 % of the total population. It aims to eradicate poverty in urban areas by conducting improvements in the agricultural production of rice and cattle parallel with the development of human resources. For this purpose, MRD was established in 1993, for the supervision of development projects implemented through the participation of the rural population.

MRD and other Cambodian authorities are currently making a lot of efforts to improve water supply, sanitary and social conditions in rural areas. However, the preservation of people's health and the formation of operative rural infrastructures are greatly impeded by many factors. The extensive civil war has weakened the rural sector, ruined and rendered agricultural facilities obsolete, and the increase in households headed by women has resulted in a drop in the labor force and impoverishment of farmlands. Moreover, waterborne diseases are also prevalent in the area because of poor water supply and sanitary conditions.

To completely change this situation and provide the rural area with a stable supply of safe water, MRD founded the Department of Rural Water Supply (DRWS), which took over the rural water supply sector of the Ministry of Health (MOH). DRWS is in charge of the implementation of water supply projects in rural areas with the assistance of international organizations such as UNICEF.

UNICEF started extending assistance for the improvement of the water supply and sanitation conditions in Cambodia in 1983. By July of 1993, the organization has drilled 7,172 boreholes (deep wells) equipped with hand pumps in 15 provinces, supplied equipment and conducted training in operation and maintenance, installed latrines and executed education programs on hygiene. Furthermore, with the end of hostilities in Cambodia, 30 organizations including NGOs from various countries provided assistance and constructed shallow and deep wells. After receiving the equipment provided by UNICEF, DRWS strove to carry out water supply works. Nevertheless, the water supply ratio in Cambodia (including the percentage of the rural population having access to rehabilitated or new water supply facilities) is only estimated at 32 to 36 %, and the vast majority of the rural population still live in very poor conditions.

The Study area is made up of the five (5) southern provinces of Cambodia, extends from the capital city, Phnom Penh, to the Viet Nam boundary, and occupies approximately 22,000 km^2. The total population in this rural area is comparatively high at 3,500,000. A total of 5,262 boreholes have been already dug in this area and the water supply rate is estimated at 36 %. Also, the three (3) Peri-Urban Areas of Phnom Penh lie between the urban and rural areas, and full scale water supply projects have never been conducted in these areas until now.

Given these circumstances, the Royal Government of Cambodia requested assistance to the Government of Japan in September 1995 for the conduct of a groundwater development study in the five (5) southern provinces of Cambodia and three (3) Peri-Urban Areas of Phnom Penh, to supply water in rural areas. In response to this request, JICA sent a preliminary Study team in September 1996 to clarify the background and specifics of the request. MRD was the appointed executing agency. S/W for the implementation of the Study was concluded on September 11, 1996 by representatives of the said two (2) agencies and, as stipulated in the S/W, the Study team was dispatched to undertake the study on December 10, 1996.

1.2 Objectives and Scope

1.2.1 Objectives

The Study on the groundwater resources of the five (5) southern provinces in Cambodia is a coordinated program of research on the groundwater resources potential in the lower Mekong area. The Study will finally contribute to the construction of water supply systems in the villages located in the Study area. Specifically, the Study aims to achieve the following objectives.

(1) Evaluate groundwater resource potential in the Study area
(2) Select and prioritize the villages to be developed

(3) Formulate a groundwater development and water supply plan for the selected villages
(4) Transfer technology to the Cambodian counterparts during the course of the Study

1.2.2 Scope

The Study will be carried out from December 1996 to January 2002. The Study period was divided into four (4) phases covering all the major subjects of the Study. The Study items are as follows.

Phase I: Basic Survey/Field Survey

<u>Work in Cambodia</u>
(1) Explanation of the Inception Report
(2) Additional data collection and analysis
(3) Aerial photo interpretation
(4) Hydrogeological reconnaissance survey
(5) Village survey
(6) Geophysical prospecting for the siting of test wells
(7) Assessment of previous water supply projects
(8) Measurement of groundwater level at existing wells
(9) Confirmation of the pilot study methodology
(10) Preparation and explanation of the Progress Report

Phase II: Analysis and Evaluation of Groundwater Resource Potential, Pilot Study

<u>Work in Cambodia</u>
(1) Detailed survey of villages
(2) Selection of target 300 villages
(3) Geophysical prospecting for hydrogeologic structure
(4) Test well drilling, borehole logging and pumping tests
(5) Social/WID analysis
(6) Initial Environmental Examination
(7) Water balance analysis
(8) Hydrogeological Map
(9) Evaluation of groundwater resource
(10) Enforcement of the pilot study

Phase III: Groundwater Development Planning

Work in Cambodia

(1) Supplemental survey
(2) Water demand projection
(3) Basic components of water supply plan
(4) Well drilling program
(5) Alternative water source
(6) Water supply program
(7) Preparation and explanation of the Interim Report (IT/R)

Work in Japan

(1) Preliminary design of water supply facilities
(2) Procurement plan for materials and equipment
(3) Operation, maintenance and organization
(4) Monitoring program
(5) Sanitary education program
(6) Project cost/Investment plan
(7) Sanitary improvement plan
(8) Project evaluation
(9) Environmental Impact Assessment
(10) Development priority
(11) Implementation plan
(12) Preparation of the Final Draft Report (1)

Work in Cambodia

(1) Explanation of the Final Draft Report (1)

Work in Japan

(1) Preparation and Submission of the Final Draft Report (2)

Phase IV: Pilot Study Monitoring

Work in Cambodia

(1) Pilot study monitoring (No.1)
(2) Preparation and submission of the Monitoring Progress Report (1) (MP/R (1))
(3) Pilot study monitoring (No.2)
(4) Preparation and submission of the MP/R (2)

<u>Work in Japan</u>

(1) Preparation of the Final Report (F/R)

1.3 Study Area

Located on the southwestern region of Indochina, Cambodia lies between 10° 44’ and 14° 44’ of north latitude and 102° and 107° of east longitude. It covers 181,035 km^2 and is bordered by Thailand and Lao P.D.R. to the west and north, by Viet Nam on the east and south, and the Gulf of Thailand on the southwest. From north to south, it is about 470 km long and has a width of 570 km.

Mekong River flows southward through the country from the border of Lao P.D.R. to Kratie Province, then westward through Phnom Penh to join the Tonle Sap River. The Mekong and Bassac Rivers flow southward from Phnom Penh to the border of Viet Nam, passing the Mekong Delta on its way to the South China Sea.

The Study area is located in the southern alluvial plain along the Mekong and the Bassac Rivers. It comprises an area of 22,962 km^2 and lies between 10° 40’ and 11° 40’ of the north latitude, and between 104° and 106° of the east longitude.

The Study area covers the following five (5) provinces and Peri-Urban Areas of Phnom Penh (see Location Map).

- 5 southern provinces: Kandal, Kompong Speu, Ta Keo, Prey Veng, Svay Rieng
- Peri-Urban Areas: Dangkor, Mean Chey, Russey Keo

The population and number of villages in the Study area are as shown in Table 1.1. The Study area is made up of 5,500 (5,300 for the 5 provinces) villages and a total population of about 3,800,000 (3.5 million for the 5 provinces). Out of these 5,500 villages, the Study will only cover the 500 villages the Royal Government of Cambodia requested the Study implementation for.

Table 1.1 Population and Number of Villages in the Study Area

Province	Area (km^2)	District	Commune	Village	Population	Population Density
Peri-Urban Area	243	3	33	230	275,930	1,135
Svay Rieng	2,966	7	81	690	406,626	137
Ta Keo	3,818	10	98	1,107	739,033	194
Kandal	3,813	11	147	1,092	942,064	247
Prey Veng	4,883	12	116	1,132	936,388	192
Kompong Speu	7,016	8	86	1,260	473,649	68
Total	22,739	51	561	5,511	3,773,690	167

1.4 Study Framework

PHASE I: Basic Survey/Field Survey (December 1996 to March 1997)

Data collection and analysis, village survey and assessment of previous water supply projects will be conducted at the beginning of this phase. Based on these survey results, the target villages for the drilling of test wells will be selected and survey items for the proposed 500 villages will be confirmed. Geophysical prospecting will be conducted at the selected villages to determine the drilling locations. Concurrent with the village survey, the villagers will be informed of the pilot study plan in order to organize a village water committee and prepare education programs on sanitation, operation and maintenance. Based on the hydrogeological reconnaissance and aerial photo interpretation results, a preliminary hydrogeological map will be produced. The Study team will also select 150 existing wells for simultaneous groundwater level measurements, and 20 of the wells will be measured continuously from January to December 1997.

PHASE II: Analysis and Evaluation of Groundwater Resource Potential, Pilot Study (April 1997 to September 1997)

Detailed survey of the proposed 500 villages and test well drilling at 25 selected villages will be conducted in this phase. The 300 villages for groundwater development and water supply planning will be selected based on the analysis of the village survey results. Analysis will also take into consideration the commitment of Women in Development (WID), considering the impacts of water supply services on rural communities. The test wells will be converted into production wells equipped with hand pumps. The pilot study will take place in the villages where production wells have been constructed. The draft hydrogeological map will be completed and hydro-geological data will be used to determine water balance in the groundwater basin and assess groundwater resource potential.

PHASE III: Groundwater Development Planning (March 1999 to July 1999)

A groundwater development and water supply plan covering about 300 villages in the Study area will be formulated based on the groundwater resource evaluation results. The water supply plan (well drilling, facility construction, equipment and materials procurement, operation and maintenance, sanitary education, investment and implementation program) will be prepared. During this phase, the team will assist the operation and maintenance activities, e.g. water fee collection, periodical check up and repair of water supply facilities. Project cost estimation and evaluation will be carried out, villages to develop will be prioritized, and the implementation plan and environmental impact assessment will be prepared.

PHASE IV: Pilot Study Monitoring (August 1999 to December 2001)

The pilot water supply systems will be monitored, operation and maintenance conditions and the villagers' behavior will be observed. Monitoring results will be integrated into the groundwater development plan and included in the final report.

1.5 Study Team

Being the counterpart agency for the Study, DRWS will work hand in hand with the Study team and the Provincial Department of Rural Development (PDRD) of each province in the implementation of the Study.

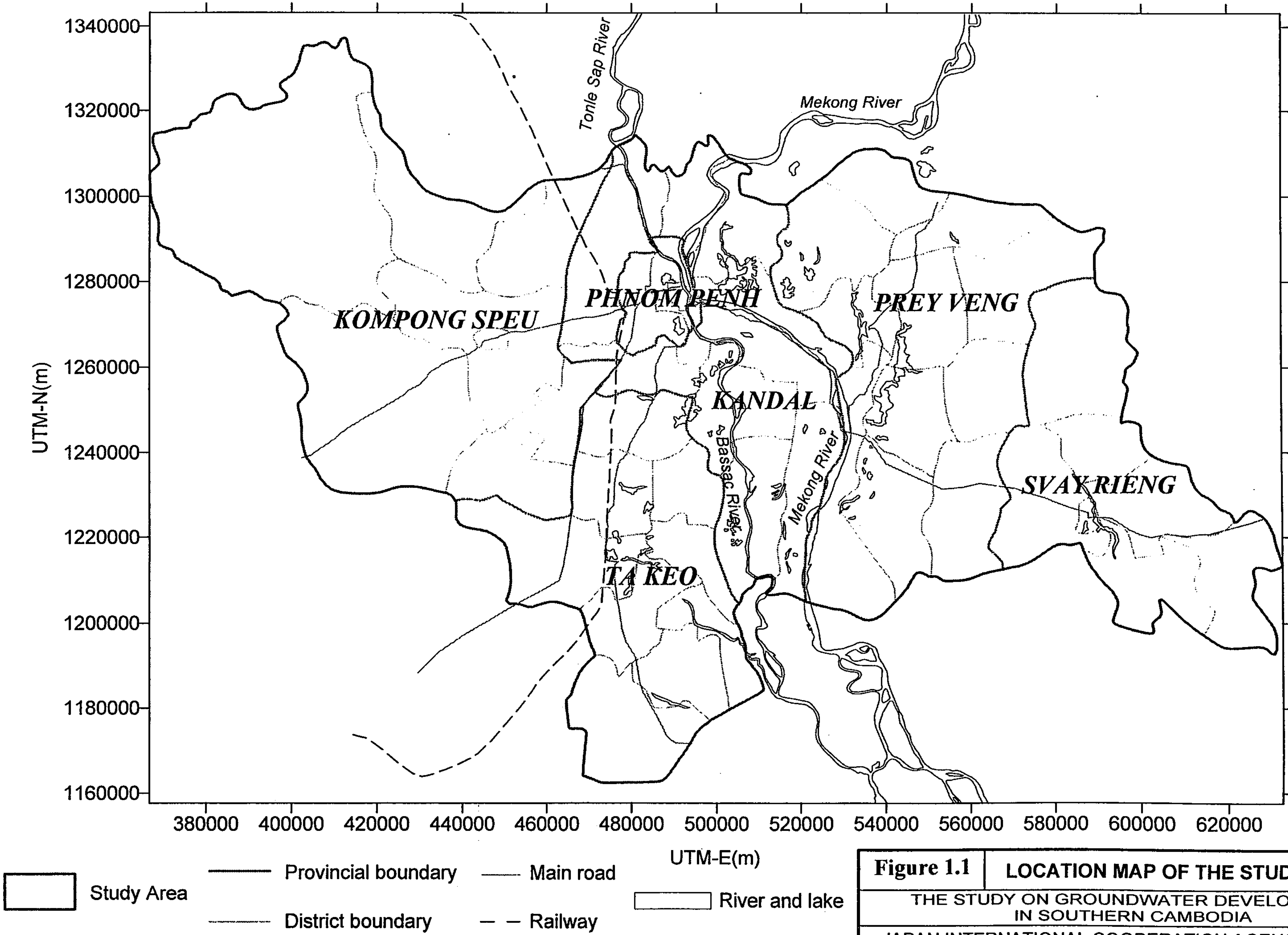


Figure 1.1 LOCATION MAP OF THE STUDY AREA

THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CHAPTER 2

NATURAL ENVIRONMENT

CHAPTER 2 NATURAL ENVIRONMENT

2.1 Climate

2.1.1 General

The climate in the Study area is tropical, dominated by seasonal winds or monsoons. The wet southwest monsoon arrives around May with heavy clouds and thundershowers, and usually continues until November, with rains occurring almost daily during this season. The dry northeast monsoon normally starts from November and continues until April. From November to February, the weather is generally dry and relatively cool, while from March until the onset of the southwest monsoon in May, the Study area experiences very hot weather.

2.1.2 Rainfall

The Study team has obtained from the Department of Meteorology the daily rainfall data at Phnom Penh, Svay Rieng, Ta Keo, Kandal, Prey Veng, and Kompong Speu from 1985 to 1995. To understand general rainfall conditions, mean monthly values and long term records compiled by the Mekong Secretariat (1994) were also used.

Figure 2.1 shows the mean annual rainfall distribution in the Study area. The central part of the Study area including Phnom Penh, Kandal, Ta Keo, and a part of Kompong Speu has relatively small annual rainfall (less than 1,300 mm/year). Annual rainfall in Svay Rieng and the western part of Kompong Speu exceeds 1,800 mm.

The mean monthly rainfall patterns in Phnom Penh and the five (5) provinces are shown in Figure 2.2. Naturally, monthly rainfall from May to November is bigger than that in the dry season. Monthly rainfall in the rainy season peaks at the beginning (May) and the latter part (September and October) of the rainy season. Rainfall in October and September exceeds 200 mm at all stations. Monthly rainfall peaks in May at Phnom Penh, Kandal, Prey Veng, and Kompong Speu. Rainfall records in Svay Rieng and Ta Keo do not clearly indicate peak seasons.

The monthly rainfall in the dry season is considerably smaller throughout the Study area, particularly in January and February (about 5 to 15 mm).

2.1.3 Evaporation

Evaporation in the Study area was measured at three (3) meteorological stations as shown in Figure 2.3. The source used for the observation was “Le Climat du Cambodge” (Khiou-Bonthonn, 1965), which was summarized in English by the Mekong Secretariat (1994).

Evaporation values are higher than rainfall during the dry season, from December to April. Evaporation is highest in March at all stations. At Phnom Penh, evaporation in March and April is 170.5 mm and 150.0 mm, respectively. In the rainy season, monthly evaporation ranges between 69.0 and 105.4 mm/month. The mean annual evaporation and rainfall at Phnom Penh are 1,347.8 mm and 1,370.7 mm, respectively.

At Svay Rieng, evaporation in March and April is 155.0 mm/month and 135.0 mm/month, respectively. In the rainy season, monthly evaporation ranges between 71.3 and 93.0 mm. The mean annual evaporation and rainfall are 1,222.3 mm and 1,778.1 mm, respectively.

2.1.4 Temperature and Relative Humidity

The Study team collected data on the monthly maximum and minimum temperatures at Pochentong, Phnom Penh from 1985 to 1995. The Study team used the long term temperature and relative humidity data recorded at three (3) stations around the Study area summarized by Mekong Secretariat (1994) based on “Le Climat du Cambodge” (Khiou-Bonthonn, 1965) to review those monthly characteristics.

Figure 2.4 shows the mean monthly maximum and minimum temperatures and relative humidity measured at Phnom Penh, Svay Rieng, and Kompong Cham. The mean monthly maximum temperatures in the dry season, particularly from March to May, are higher at the three (3) stations. The mean monthly minimum temperatures in the rainy season are higher than those in the dry season. The difference between mean monthly maximum and minimum temperatures is bigger in the dry season.

The mean monthly relative humidity from January to April in the dry season is less than 75 %. In the rainy season, relative humidity increases gradually and shows a maximum value of about 85 % in September or October.

2.2 Hydrology

Data on the water level of the Mekong, Tonle Sap, and the Bassac Rivers is available in the "Lower Mekong Hydrological Year Book" and summarized by the Mekong Secretariat (1994). The Mekong River water level was measured at three (3) stations: Kompong Cham, Chrouy Changvar, and Neak Luong. The water level of Tonle Sap River was monitored at Prek Kdam station, and the water level of Bassac River was measured at Chaktomul and Koh Khel stations.

Figure 2.5 shows the average monthly river water level measured at the above six (6) stations. Measurements at each station indicated that river water level is at its lowest in April and May, and highest in August to September. At Kompong Cham station, the lowest average monthly water level is in April at 1.05 m, and the highest is in August at 12.27 m, showing a discrepancy of 11.22 m. The water level decreases as the flow moves downstream.

At Chrouy Changvar and Neak Luong, the monthly water levels were high in September at 8.35 m and 6.19 m, respectively. At Prek Kdam station along the Tonle Sap River, water level was at its highest in October at 8.33 m. The water level in Bassac River also decreases as the flow moves downstream.

The mean monthly river flow data on Mekong and Tonle Sap rivers are summarized by the Mekong Secretariat (1994) and shown in Figure 2.6. Maximum monthly river flow was observed in September at Kompong Cham (38,710 m^3/s) and Phnom Penh (37,680 m^3/s) stations. On the same month, a maximum river flow of only 24,780 m^3/s was observed at Neak Luong located downstream of Mekong River as the river flows into the Tonle Sap and Bassac Rivers. Observation carried out at the Prek Kdam station shows that backflow from Mekong River in September flows into Tonle Sap Lake at a maximum rate of 4,560 m^3/s.

2.3 Topography

The Study area occupies a part of the Mekong Delta. About 4,185 km long, Mekong River is the third longest river in Asia. Originating from the Tanglha Range of eastern Tibet, it flows through the mountain gorges and valleys of China, Myanmar, Thailand, and Lao P.D.R., then through the lowlands of Cambodia and Viet Nam, before finally emptying into the South China Sea through distributaries.

The topography of the Study area is broadly divided into the flat areas in the central and eastern parts and the mountainous areas in the western part. Figure 2.7 shows the distribution of bedrock outcrops and topographic contour lines [elevation (EL) = 10 m]. Aerial photos were used to identify the location of the bedrock outcrops and 1:50,000 topographic map sheets were used for the topographic analysis.

Bedrock mountains are mainly distributed in the provinces of Kompong Speu and Ta Keo. There are several mountain ranges having N-S to NW-SE orientation in Kompong Speu. In the southern part of Ta Keo Province, there are some isolated mountain bodies. The rest of the Study area is generally flat, except for several isolated mountains or hills on the right bank of Mekong River. On the left bank of Mekong River, the mountainous area can be seen in Prey Veng Province.

The contour lines are move in the N-S direction, from northern Kandal to Ta Keo, passing through Phnom Penh toward southern Kandal on the right bank of Mekong River. On the left bank of the Mekong River, the contour lines can be seen from the northern Prey Veng to northeastern Svay Rieng. Thus, it can be said that about 50 % of the Study area is situated on flatlands lower than 10 m in elevation.

Figure 2.8 shows the geomorphological map of the Study area, prepared by the Study team based on the results of the aerial photo interpretation, satellite imagery analyses, and field hydrogeological investigations. The flat areas can be subdivided into alluvial lowland, old river course, alluvial valleys, flood plain of the Prek Thnaot River, terrace & platform, higher platform, and basalt plateau.

2.4 Geology

The general geology of Cambodia is summarized in the “Atlas of Mineral Resources of the ESCAP Region, vol. 10, Cambodia” (ESCAP, 1993). From a hydro-geological point of view, Anderson (1978) described the Mekong Delta region. The brief hydrogeological conditions of a part of the Study area are mapped in the “Hydrogeological Map of Lower Mekong Basin” (Mekong Secretariat, 1992).

2.4.1 Stratigraphy

The stratigraphy of the Study area is represented by metamorphic units, sedimentary units, igneous bodies, volcanic rocks, and sedimentary formations from the Precambrian through Quaternary periods. Figure 2.9 shows the principal geologic features of Cambodia and the

Study area. The geological units in the Study area are briefly described hereafter.

The mountainous areas in the western part of the Study area belong to the zones of Indosinian Folding. The metamorphic rocks of Precambrian to Silurian age (DC) are distributed in the southwestern perimeter of the Study area, forming the anticlinorial zones in Indosinian fold-belts. The sedimentary rocks, i.e. sandstone and slate, mainly of the Carboniferous to Triassic (CT) periods are distributed in the western part of Kompong Speu and partly in Ta Keo. These sedimentary rocks compose the synclinorial zones in Indosinian fold-belts.

Granitic intrusive rocks are widely distributed in northwest Kompong Speu. Small granitic bodies can be partly found in eastern Kompong Speu and Ta Keo Provinces. A granite mountain can be found in Prey Veng Province.

Although not indicated in the geological map of Figure 2.9, there are small mountain ridges composed of volcanic sedimentary rocks near the Kandal - Kompong Cham border north of Phnom Penh. According to the field observations, massive andesite and andestic pyroclastic rocks are distributed at the mountain ridges. These volcanic sedimentary rocks are estimated to originate mainly from the Triassic period.

Platform basaltic rocks were detected in a wide area in Kompong Cham, a part of which protrudes toward northeastern Prey Veng. The plateau basaltic rocks are estimated to originate from the Pliocene to Quaternary periods.

The above hard rocks are overlain by the Pliocene - Quaternary sedimentary formations. Deposits distributed from 25 to 150 m are often referred to as “Alluvions Anciens” or “Older Alluvium”. The layers overlying these sediments are sometimes strongly laterized. The “Older Alluvium” is estimated to originate from the Upper Pliocene to Lower Pleistocene period.

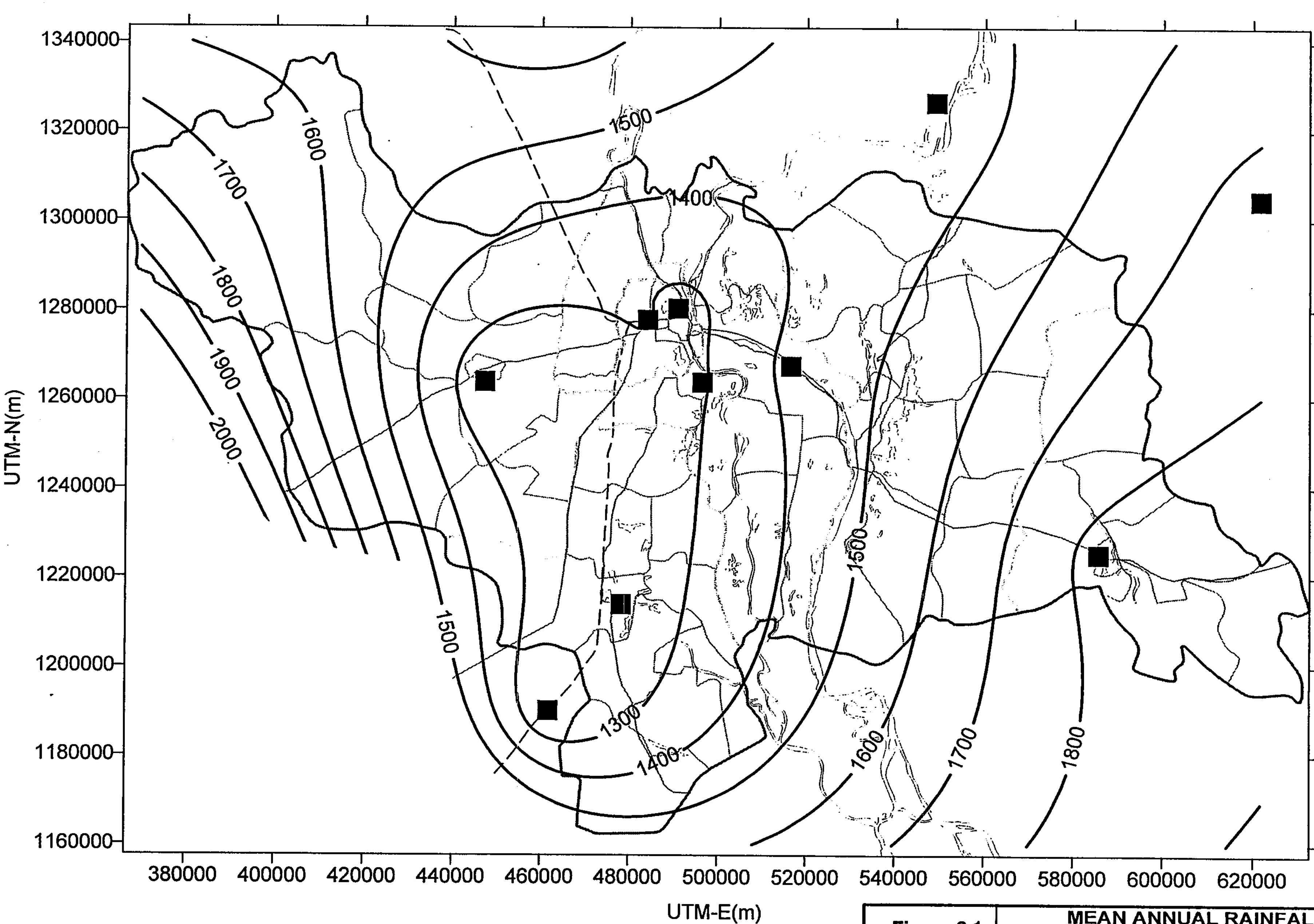
The Lower Quaternary consists of sand, silt, and clay of both fluvial and marine origin. The Middle Quaternary of the plains comprises red sandy sediments occupying terraces above 15 m in elevation. Middle - Upper Quaternary formation is widespread in the terraces in the study area. Along the Mekong River, the Upper Quaternary is recognized as the Mochoa formation, occupying 10 to 15 m terraces in southeastern Phnom Penh.

The Holocene is represented on the alluvial lowland and alluvial valleys in the Study area. The formation consists of unconsolidated deposits of fluvial, lacustrine, and shallow-sea origin. The alluvial valleys are marked by fluviotile fill materials of recent origin. According to some drilling logs in southern Kandal Province, soft clay is dominant in the upper portion of Holocene sediments. The thickness of the clay bed ranges from 20 to 30 m.

2.4.2 Structure

The principal tectonic elements of Cambodia and the Study area are shown in Figure 2.10. The western part of the Study area belongs to the Pursat-Kampot Indosinian II Fold-Belt, whereas the eastern part belongs to Tonle Sap-Mekong Platform. In the right bank of the Mekong River, occurrence of a synclinorial axis having NW-SE orientation is estimated.

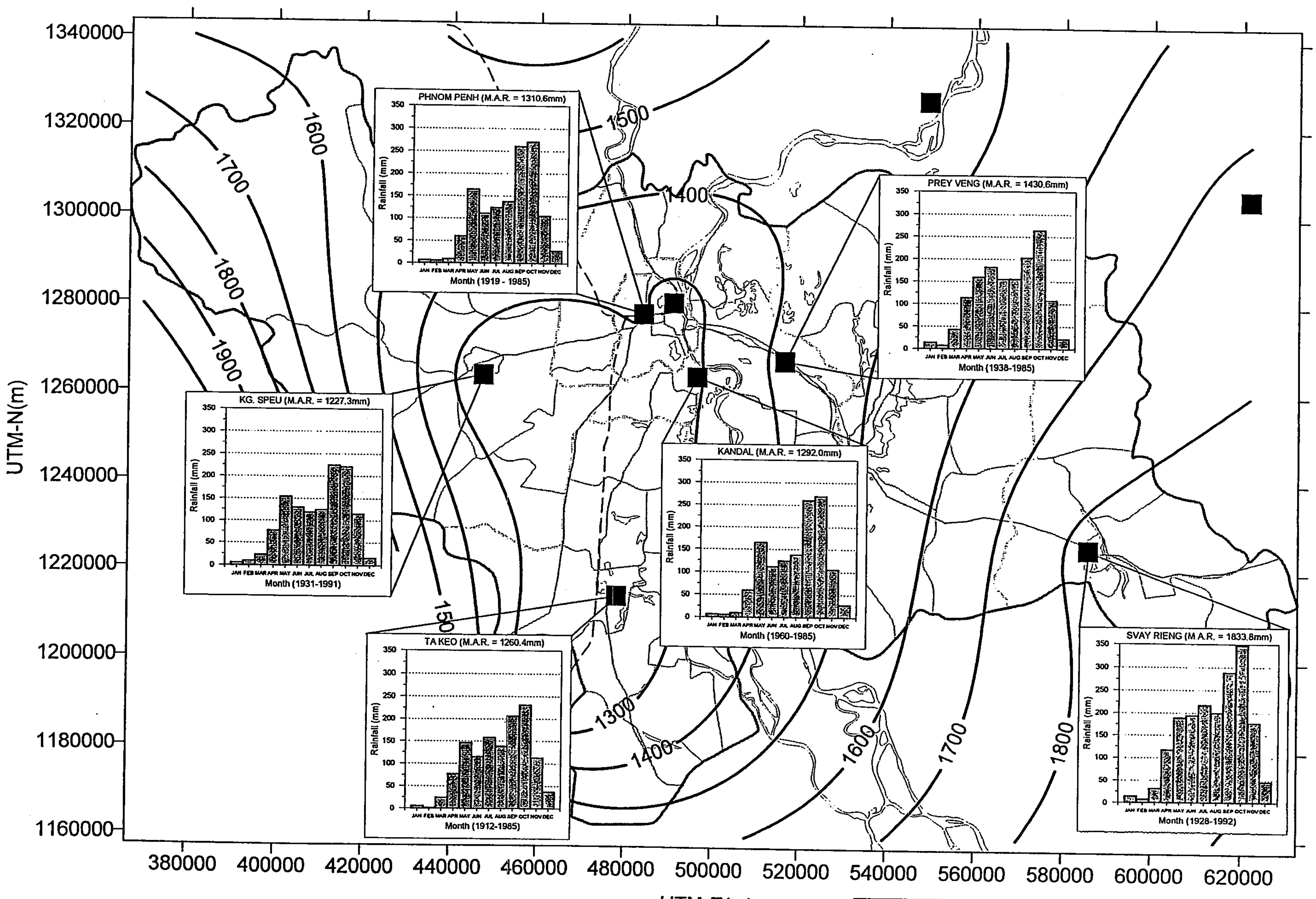
Two (2) Regional lineaments (or inferred faults) having WNW-ESE direction are indicated in the eastern part of the Study area. The area to the north of the northern lineament is called "Prey Veng basin", as shown in Figure 2.9.



■ Rainfall station   1500 Mean annual rainfall (mm)

(Data source: Mekong Secretariat, 1994)

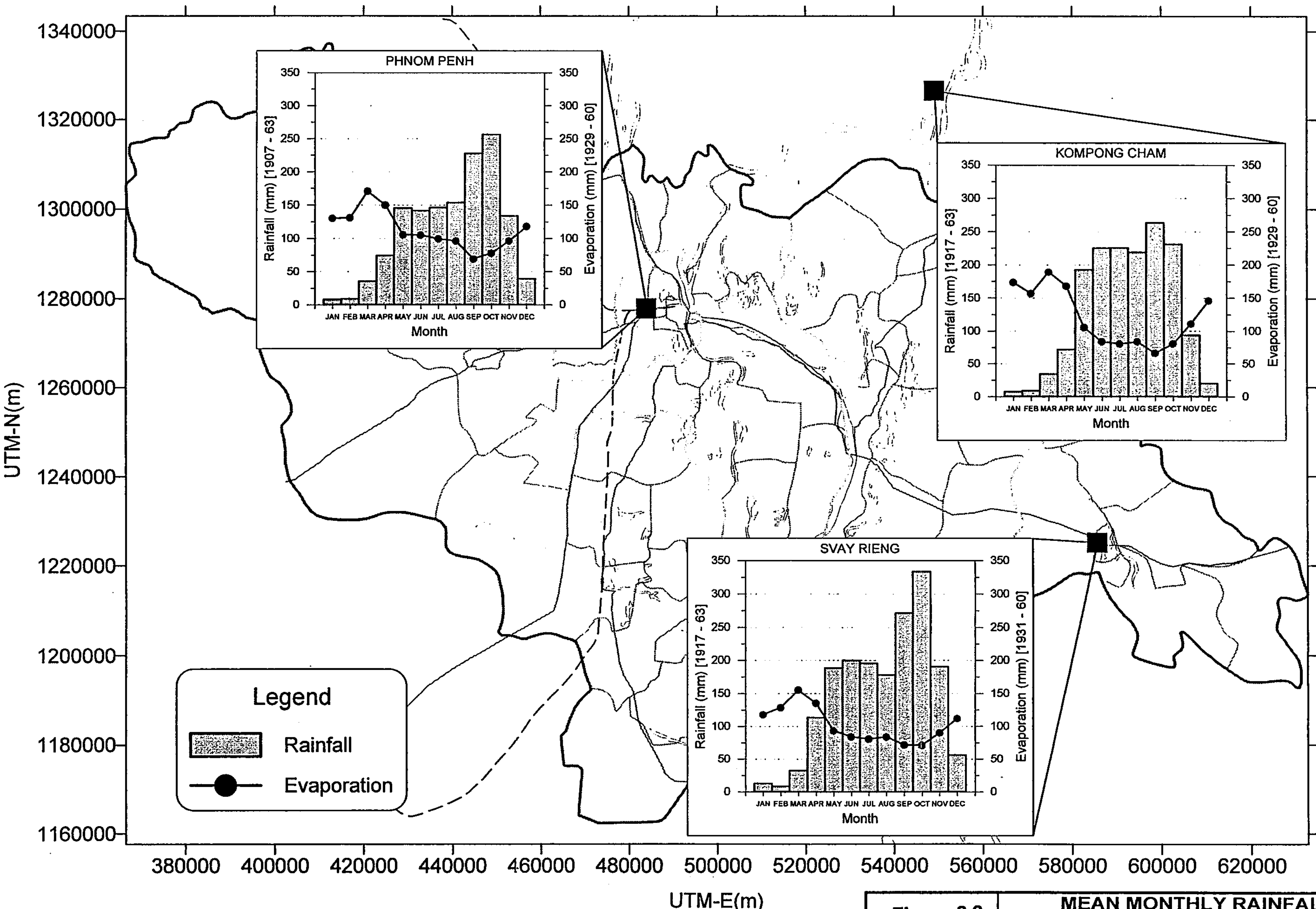
Figure 2.1	**MEAN ANNUAL RAINFALL IN THE STUDY AREA**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



■ Rainfall station   1500 Mean annual rainfall (mm)

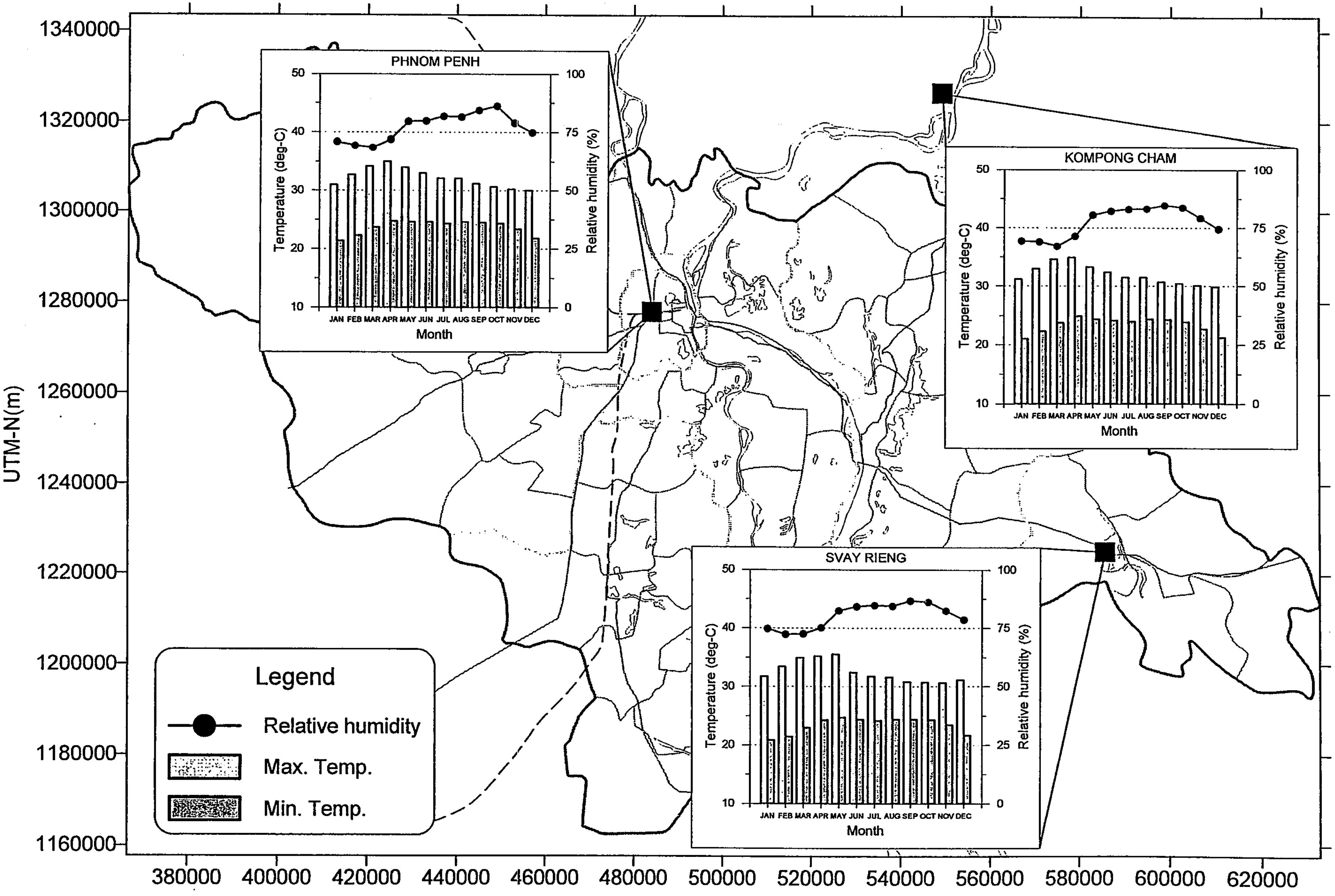
(Data source: Mekong Secretariat, 1994)

Figure 2.2	MEAN MONTHLY AND ANNUAL RAINFALL IN THE STUDY AREA
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



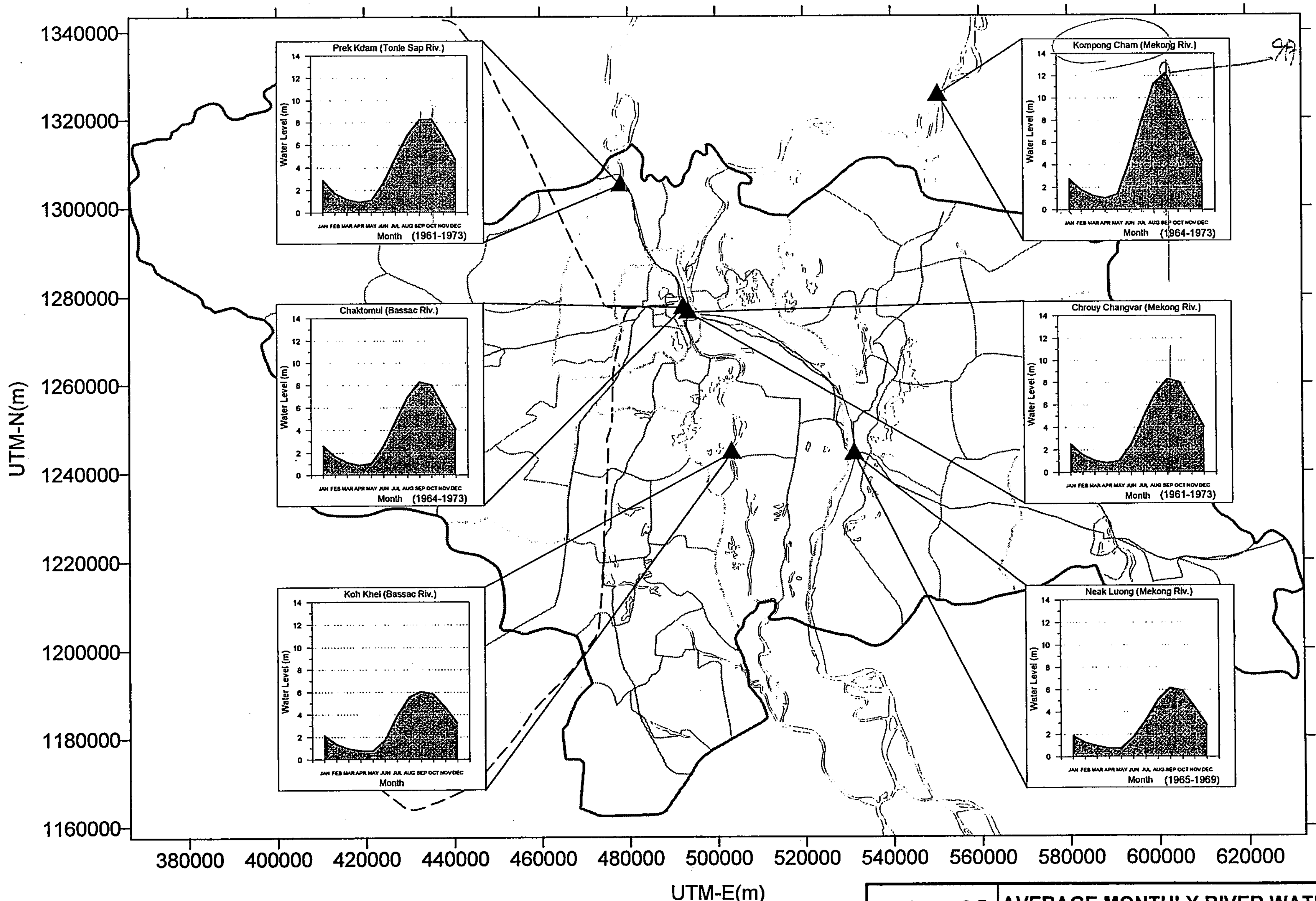
(Data source: Le Climat du Cambodge, Khiou-Bonthonn, Ministere Des Travaux Publics, 1965)

Figure 2.3	MEAN MONTHLY RAINFALL AND EVAPORATION
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



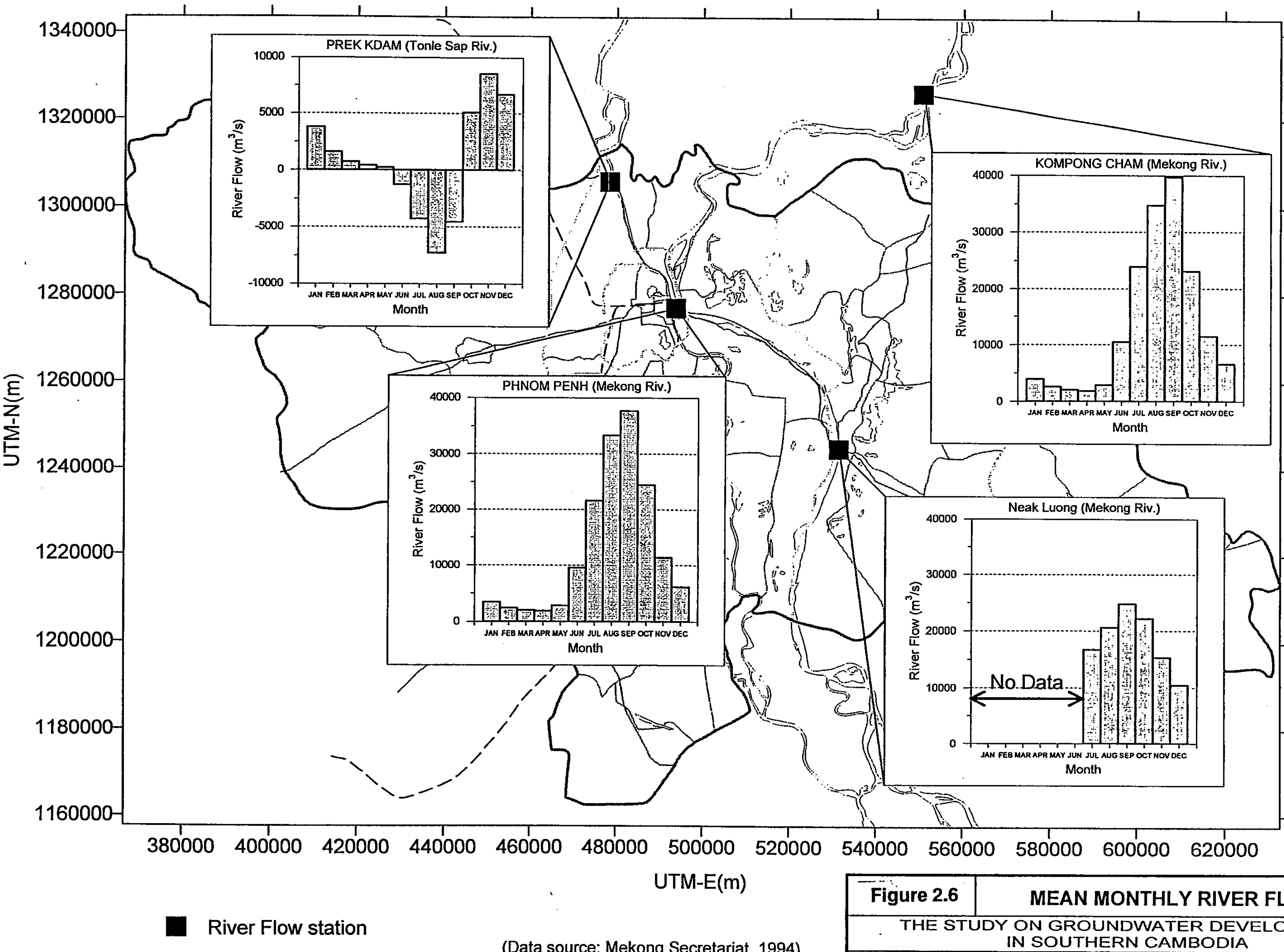
(Data source: Le Climat du Cambodge, Khiou-Bonthonn, Ministere Des Travaux Publics, 1965)

Figure 2.4	MEAN MONTHLY MAX. & MIN. TEMPERATURE AND RELATIVE HUMIDITY
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



(Data source: Lower Mekong Hydrological Yearbook)

Figure 2.5	AVERAGE MONTHLY RIVER WATER LEVEL
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



(Data source: Mekong Secretariat, 1994)

Figure 2.6	MEAN MONTHLY RIVER FLOW
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

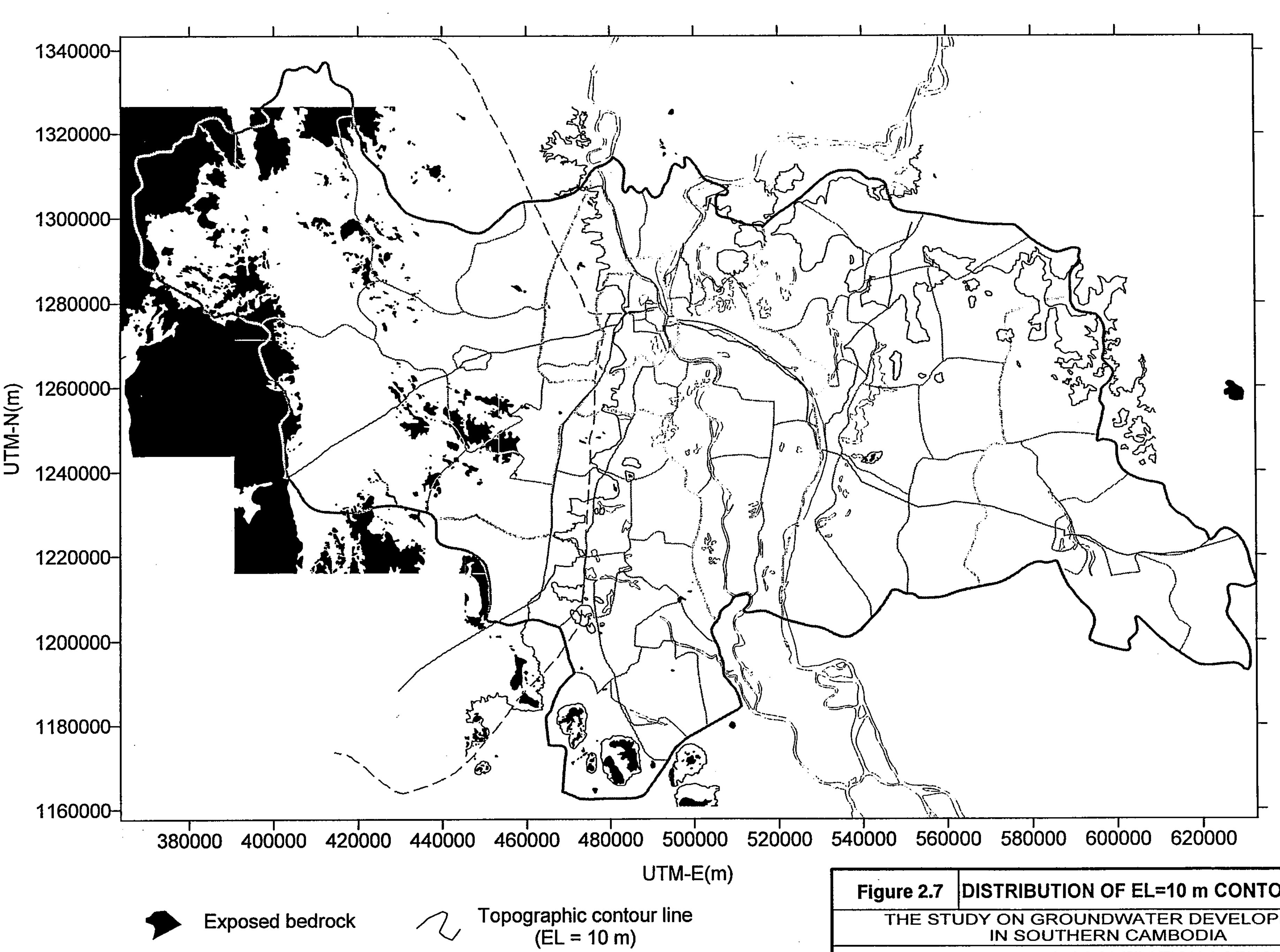


Figure 2.7	DISTRIBUTION OF EL=10 m CONTOUR LINE
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

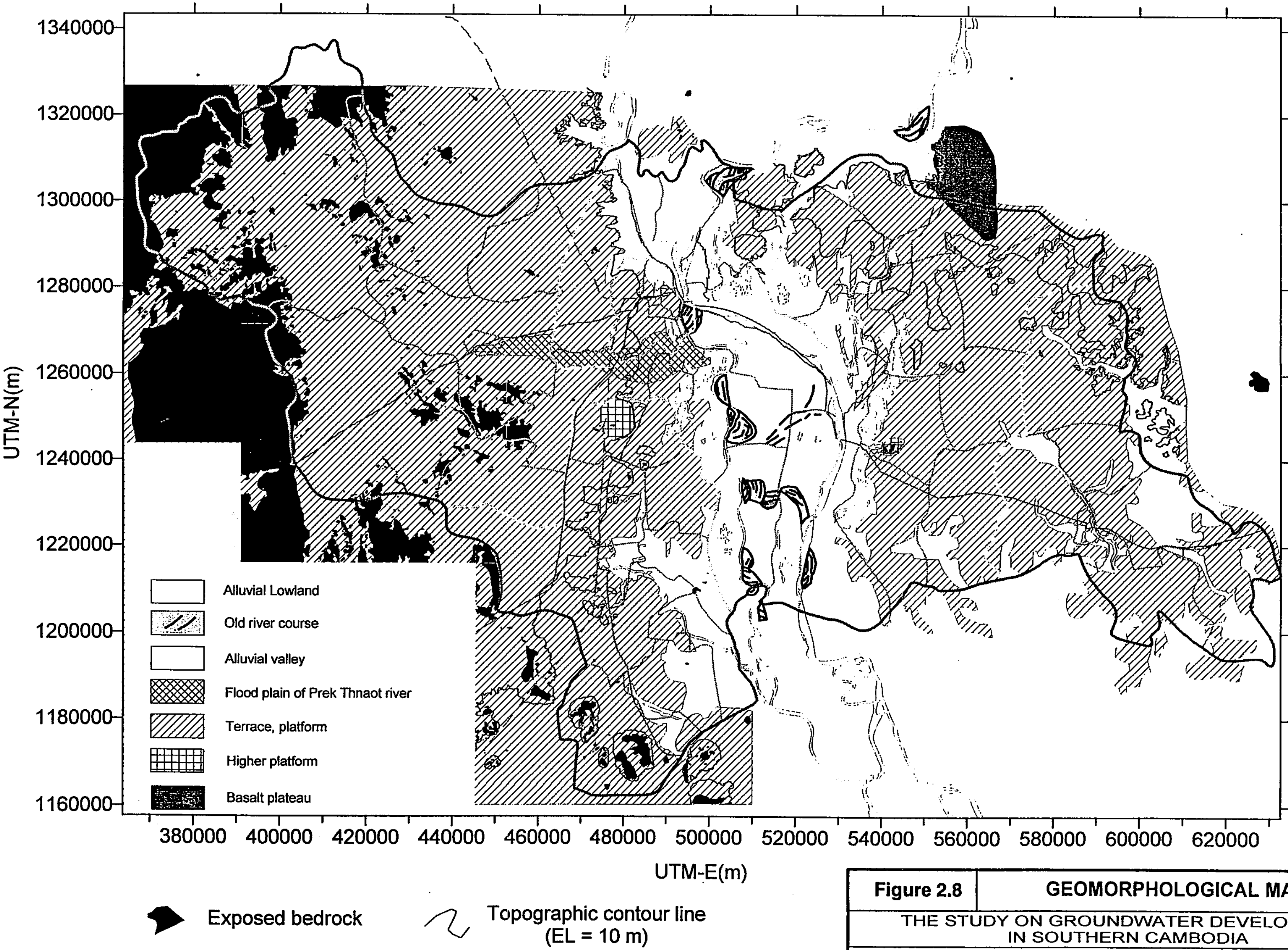
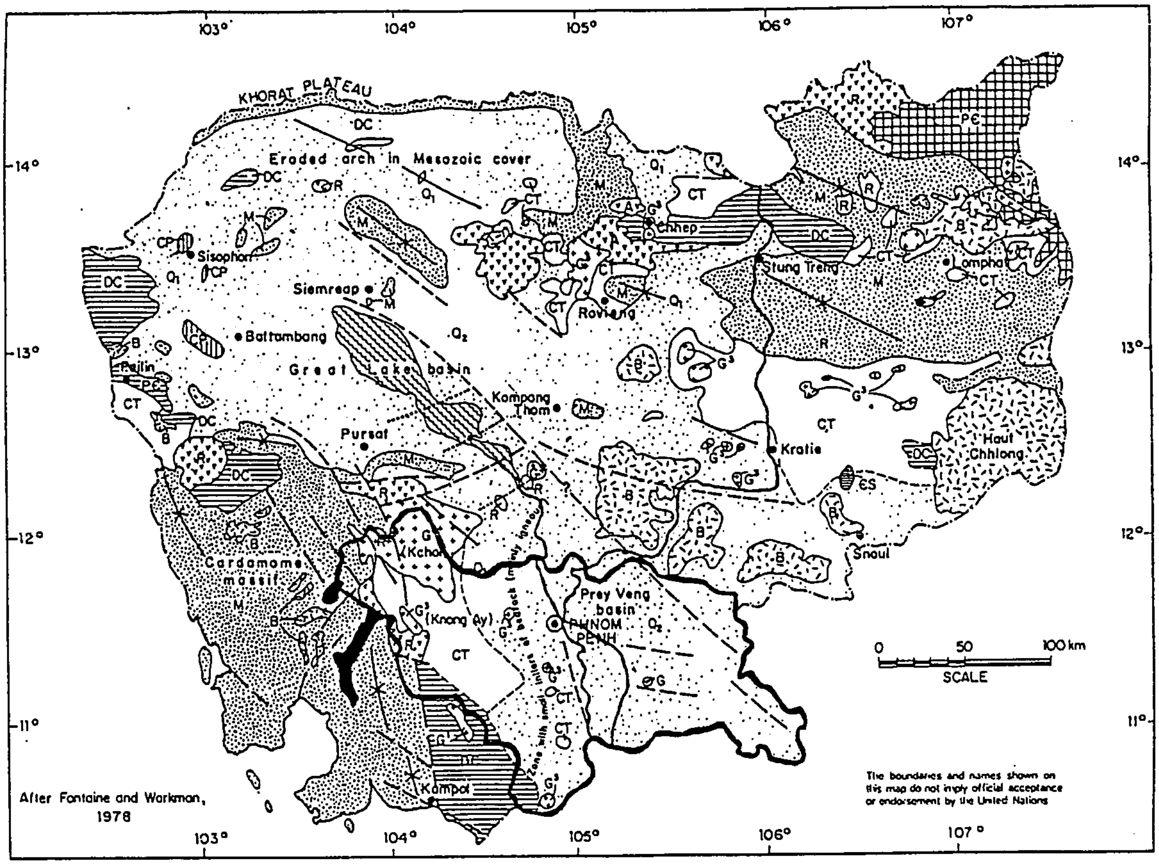


Figure 2.8	GEOMORPHOLOGICAL MAP
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



LEGEND

TERRANES

UNDEFORMED OR GENTLY FOLDED COVER STRATA

Q — Quaternary sedimentary rocks and unconsolidated sediments. 1: Pleistocene; 2: Holocene. Includes some small Neogene basins

B — Neogene – Quaternary platform basaltic rocks

M — Mesozoic sedimentary units (upper Triassic-Cretaceous)

Volcano-sedimentary units (mainly Triassic, some Paleozoic). A: andesitic; R: rhyolitic.

C-P — Paleozoic sedimentary units (mainly Carboniferous-Permian).

ZONES OF INDOSINIAN FOLDING

CT — Synclinorial zones in Indosinian fold-belts (mainly Carboniferous-Triassic).

DC — Anticlinorial zones in Indosinian fold-belts (Precambrian-Silurian medium to high-grade metamorphics; Devonian-Carboniferous rocks, deformed and slightly metamorphosed).

EXPOSED BASEMENT ROCKS OF THE KONTUM MASSIF

PC — Precambrian-Early Paleozoic granites and high-grade metamorphics.

INTRUSIVE ROCK GROUPS

G — Acid – Intermediate intrusive suites
G_1 – Pre-Carboniferous
G_2 – Carboniferous
G_3 – Triassic-Jurassic
G_4 – Cretaceous

STRUCTURE SYMBOLS

Regional faults, known and inferred

Geographical lineament

Axes of Cenozoic epeirogenic folding

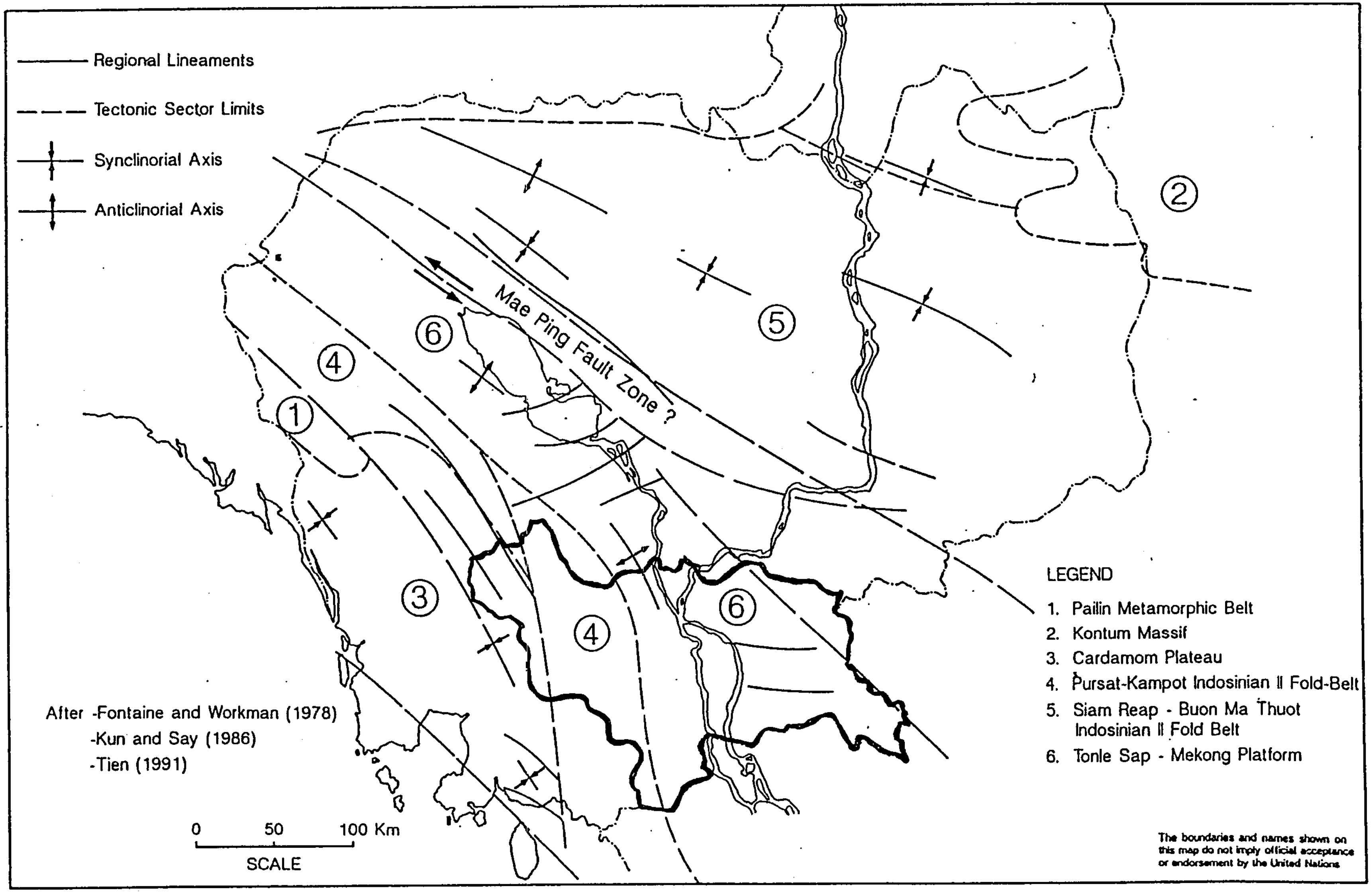
Limits of terranes, known and inferred

Axis of swell in buried pre-Tertiary basement

Intramontane grabens (Neogene)

(Source: "Atlas of Mineral Resources of the ESCAP Region, volume 10, Cambodia", 1993)

Figure 2.9	GEOLOGIC FITURES OF CAMBODIA AND THE STUDY AREA
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



(Source: "Atlas of Mineral Resources of the ESCAP Region, volume 10, Cambodia", 1993)

Figure 2.10	PRINCIPAL TECTONIC ELEMENTS OF CAMBODIA AND THE STUDY AREA
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

CHAPTER 3

SOCIO-ECONOMY AND WATER SUPPLY

CHAPTER 3 SOCIO-ECONOMY AND WATER SUPPLY

3.1 Socio-Economy in the Country

3.1.1 Population and Demographic Characteristics

(1) Statistical Data on Population

According to the 1962 census, Cambodia had a population of 5,728,771 in April 1962. There has been no further censuses and no systematic national surveys until 1998.

In 1980, the newly established Government of the People's Republic of Kampuchea carried out a population count. The official total was put at 6,589,954 at the end of 1980. The extrapolated population estimated by the Socio-Economic Survey of Cambodia conducted by National Institute of Statistics (NIS) was 9,870,000 based on a sample of 20,000 households.

The NIS carried out the Demographic Survey of Cambodia in March 1996, with sample size of approximately 20,000 households in different parts of Cambodia. As a result, the population was estimated at 10,702,329 in 1996.

After a laps of more than three (3) decades, a National Census was conducted in March 1998 by the NIS with technical and financial support of United Nations Population Fund (UNPA). The preliminary results of the 1998 census indicated a total population of Cambodia as 11,426,223 with 5,509,204 males and 5,917,019 females (refer to Table 3.1). Although preliminary results of the population at national and provincial levels have been announced, detailed computation of the population at village level is still under process.

Table 3.1 Statistical Data on Population in Cambodia

Source of Information	Male	Female	Total
1962 Census	2,862,939	2,865,832	5,728,771
1980 General Demographic Survey	3,049,450	3,540,504	6,589,954
1993~1994 Socio-Economic Survey	4,714,000	5,156,000	9,870,000
1996 Demographic Survey	5,119,582	5,582,742	10,702,324
1998 Census	5,509,204	5,917,019	11,426,223

Source: General Population Census of Cambodia 1998

(2) Population Characteristics

The Cambodian population presents several important features. First, due to the baby boom after 1979, younger generation under 19 years of age account for 54 % of the total population. Secondly, the proportion of women in the adult population is high, due mainly to the civil war and political turmoil. This is evidently reflected on the sex ratio (number of males per 100 females) and percentage of Female-Headed Households. The sex ratio was ideally balanced in 1962. It drastically fell to 86 in 1980 due to heavy mortality among men. From that year onwards it is showing an increasing trend, reaching 93 in 1998. Sex ratio is higher in urban areas (96.0) than that in rural areas (92.6). Percentage of Female-Headed Households (FHHs) is 30.1 % in urban and 25 % in rural area. Almost one-fourth of the households in Cambodia are FHHs.

Table 3.2 Sex Ratio in Cambodia, 1962~1998

Source of Information	Sex Ratio
1962 Census	99.9
1980 General Demographic Survey	86.1
1993~1994 Socio-Economic Survey	91.4
1996 Demographic Survey	91.7
1998 Census	93.1

Source: General Population Census of Cambodia 1998

(3) Population Density

In 1962, the population density was 32 persons per km^2. With a density of 64 in 1998, it has doubled between the two (2) censuses. In 1998, Phnom Penh had the highest density with 3,441 persons per km^2. The provinces with higher density are Kandal (301), Ta Keo (222), Kompong Cham (164), Svay Rieng (161), and Kampot (108). The provinces with lower desnity are Mondol Kiri (2), Stung Traeng (7), Rotana Kiri (9) and Otdar Mean Chey (11) (refer to Table 3.10).

(4) Population Size by Province

The 1998 census indicates that the biggest province by population size is Kompong Cham with a population of 1,607,913 which account for 14.1 % of the total population. The second biggest is Kandal with 1,073,586, followed by Phnom Penh with 997,986, Prey Veng with 945,129, Battambang with 791,958, and Ta Keo with 789,710 (refer to Table 3.3).

Table 3.3 Population Ranking in Top 12 Provinces

Ranking	Province	Population (1998)
1	Kompong Cham	1,607,913
2	Kandal *	1,073,586
3	Phnom Penh *	997,986
4	Prey Veng *	945,129
5	Battambang	791,958
6	Ta Keo *	789,710
7	Siem Reap	695,485
8	Kompong Speu *	598,101
9	Banteay Meanchey	577,300
10	Kompong Thom	568,454
11	Kompot	527,904
12	Svay Rieng *	478,099

Note: The Study Area is included in the 6 provinces with asterisk (*).
Source: General Population Census of Cambodia 1998, NIS

(5) Urban and Rural Population

In the National Census in 1998, all provincial towns (headquarters of the 24 provinces) have been treated as urban areas. In the case of Phnom Penh Municipality, four (4) out of seven (7) districts are treated as urban. Sianouk Ville (Krong Preah Sihanouk), Krong Kep, and Krong Pailin are totally urban. All the remaining areas of the country are treated as rural. The result of the census shows that 84.3 % of the population live in rural areas, while 15.7 % live in urban areas.

(6) Growth Rate of Population

The country has an estimated rate of population growth of between 2.5 to 3.0 % per annum (World Bank 1992). The annual growth rate of the population is estimated to be 2.8 % by government of Cambodia.

It is expected that population growth in Cambodia will remain at high level at least for coming 10 to 15 years. With its extremely young age population structure, currently about half of the female population has not reached fertile age. In 15 years, female population in fertile age in Cambodia will be doubled from current level.

The Crude Birth Rate (number of live births in a year per thousand populations) is currently estimated to be 38.0 in the whole country.

With population growth rate of 2.8 to 3.0 %, population will increase approximately by 30 % by the year 2005, and increase by 50 % by the year 2010.

(7) Household Size

Preliminary results of 1998 census indicates that number of household in Cambodia is 2,187,238 with average household size of 5.2. Out of these households, 1,865,357 (85.3 %) are located in rural areas. Average household size is higher in urban area (5.5) than in rural area (5.1).

(8) Ethnic Group

Ethnically the population consists of about 90 % Khmer, 5 % each of Chinese and Vietnamese and small numbers of hill tribes (Chams and Burmese). Khmer is the country's official language. It is spoken by more than 95 % of the population.

3.1.2 Local Administrative Divisions

Cambodia is administratively divided into 21 provinces and three (3) municipalities. These provinces and municipalities consists of 172 districts which are further sub-divided into 1,566 communes. Under each commune, there are about eight (8) villages in average (refer to Table 3.11).

Administrations at the province as well as the district and the commune are weak due to personnel and financial constraints. Those factors are such as inadequately and insufficiently trained personnel, insufficient financial resources, and difficulties of communication between districts and provinces.

3.1.3 Economic Situation

(1) General Economic Condition

Despite the recent improvements in the economy's performance, Cambodia is one of the poorest countries in the world with a per capita income of US$ 260. While Cambodians' economic condition has improved since 1989 when the Government implemented its market-oriented economic reforms, the country is not clearly better off than in the late 1960s yet, reflecting the traumatic events of last two (2) decades.

(2) Economic Growth Rate

The economic reforms that was gradually initiated towards the end of 1980s and after the election of 1993 the RGC has accelerated its economic and public sector reform.

The result of such reform was largely favorable to the economic growth.

Real GDP of Cambodia (at 1989 fixed prices) was 292.1 billion Riel in 1993 which increased to 351.7 billions Riel in 1997, recording average annual growth rate of 4.8 %. Industry sector and services sector recorded higher rates than agriculture sector in these five (5) years (refer to Tables 3.4 and 3.12).

Table 3.4 GDP Growth in 1993~1997

Unit: Billion Riel

	1993	1997	Annual Growth Rate
Agriculture	137.1	151.2	2.5 %
Industry	51.7	70.0	7.9 %
Services	103.3	130.5	6.0 %
GDP Total	292.1	351.7	4.8 %

Source: Annual Report 1998, National Bank of Cambodia

The industry and services sectors have been the major source of GDP growth. Much of the investment has been concentrated in urban sector, especially in Phnom Penh. Growth of agricultural sector has been much slower, which increased the gap of economic and social conditions between urban and rural area.

(3) Inflation

The hyper inflation which reached almost 200 % in 1992 has been brought under control by the government successfully. The cause of such inflation was the domestic money creation to finance large fiscal deficit. Restrictive fiscal policy, as well as the high level of financial support from international community which reduced the expansionary financing of the budget, has contributed to the growth without inflation for the recent years.

(4) Public Finance

Cambodia's fiscal situation is characterized by its high dependence on foreign aid. The total amount of tax and non-tax revenues even less than current expenditures. This means that in Cambodia relies on virtually all of its capital expenditures on foreign aid flows (refer to Table 3.5).

Table 3.5 Public Financing

Unit: Million US$

	1995	1996
Revenue	642.9	797.5
Expenditure	1,221.5	1,395.1
Deficit	-578.6	-597.6
Foreign financing	536.8	593.1

Source: From Recovery to Sustained Development, The World Bank, May 1996

Approximately 72 % of tax revenue was derived from taxes on traded items such as petroleum in 1995. Although the government has been making some effort to increase the revenue from turnover tax and profit tax, these tax revenues remain at low level. In order to make transition from emergency management mode to sustainable economic growth mode, Cambodia faces the challenge of making fundamental reform on its revenue collection mechanism.

(5) Urban-Rural Gap

Urban-rural gap can be seen from several socioeconomic indicators. Access to infrastructures and social services are far better in urban areas than rural area as indicated in the following table.

Table 3.6 Access to Infrastructures and Social Services

	Phnom Penh	Other Urban	Rural
Mortorable Road	92 %	83 %	72 %
Electricity	87 %	55 %	15 %
Piped Water Supply	70 %	33 %	3 %
Doctor	43 %	26 %	4 %

Source: Cambodia Socio-Economic Survey 1997

The gap is also reflected on the average household expenditures in which Phnom Penh was 3.3 times that of the rural areas at the time of the Cambodia Socio-Economic Survey 1997. The gap between urban and rural area in their access to social and economic infrastructure is large and possibly growing. With 86 % of population living in rural area, accelerated rural development is essential to raise Cambodia's standard of living and reducing poverty.

Table 3.7 Average Monthly Household Consumption

Phnom Phen	Other Urban	Rural	Cambodia
727,282 Riel (US$ 262.90)	403,253 Riel (US$ 145.80)	220,037 Riel (US$ 79.50)	286,585 Riel (US$ 103.60)

Source: Cambodia Socio-Economic Survey 1997

3.1.4 Economic Development Plan

(1) The First Socio-Economic Development Plan

After the general election in 1993, the Royal Government of Cambodia (RGC) presented the NPRD in 1994 and its objectives and strategy was detailed in the Implementing the National Program to Rehabilitate and Develop Cambodia in 1995. These two (2) documents showed the Cambodia's short-term reconstruction programs including various priority investment and technical assistance projects as an integral part of them. These programs were also supported by the Socio-Economic Rehabilitation Plan, 1994~1995.

Taking these documents into account, the RGC formulated the First Socio-Economic Development Plan 1996~2000 (FSEDP) in February 1996. In the FSEDP, main objectives of the development plan are defined as poverty alleviation and rural development. To achieve these objectives, the following development strategies are presented.

a) Achievement of poverty alleviation through participatory approach in rural development
b) Widening access to social services, particularly for women and vulnerable groups
c) Macro-economic stability and sound economic management
d) Reform of public administration and judicial institutions
e) Upgrading and developing physical infrastructure
f) Upgrading human skills for a modern market economy
g) Development of economic productive base through increase of rice production, promotion of livestock production, and diversification of commercial agricultural sector
h) Employment generation with focus on labor-intensive, small scale industries and tourism
i) Sustainable utilization of the natural resource base
j) Reintegration of the Cambodian economy into the global economies

Annual GDP growth rate is targeted as 7.5 % through 1996 to 2000, projecting annual growth of 5.2 % in agricultural sector, 9.8 % in industrial sector and 9.0 % in service sector (refer to Table 3.13).

On rural development, which is one of the priority cross-sector thematic issues, the FSEDP suggests strengthening community management structure by creating VDC. The target is to set up VDC in 2,500 villages (20 % of all villages), and 7,500 by year 2000 (70 % of all villages). The committee member should be selected by election, and 40 % of them should be women.

The focal areas for rural development are defined as follows:

a) Rural roads
b) Primary health care, sanitation and water supply (65 % of rural population and 90 % of urban population will have access to safe water by year 2000)
c) Community development
d) Household farming system
e) Rural credit
f) Improved information through village socio-economic survey

(2) Macro Economic and Investment Plan

The government plans to reduce dependence on external financing of current expenditure through reduction of current expenditure and widening tax base and improvement of tax collection system. In 1997, the total revenue will exceeds the current expenditure, and the government regain its capability to finance at least certain portion of capital expenditure.

However, heavy dependency on foreign financing for capital expenditure cannot be changed, expecting 77 % of government investment will be financed by international community.

On private sector, the government intends to promote inflow of foreign capital through pursuing liberal investment policy and joining ASEAN. Approximately 36 % of investment in non-government sector is expected to be from foreign sources.

Total public investment (total of domestic and foreign finance) is projected to be US$ 2,200 million, of which 65 % is allocated to rural area. The investment for Water Supply & Sanitation Sector is 8 % of such investment, of which 25 %, or 44 million is allocated to rural area (refer to Table 3.14).

3.1.5 Health Sector

(1) Overall Health Condition

The health condition of Cambodia is one of the lowest in the world. In spite of some improvement in recent years, infant mortality rate still remains at alarmingly high level, 113 per 1,000 live births. Compared with neighboring countries, Cambodia stays at the lowest level in its access to safe water, health service, and basic medicine. The following figure indicates the percentage of population with access to basic social services (refer also to Table 3.15).

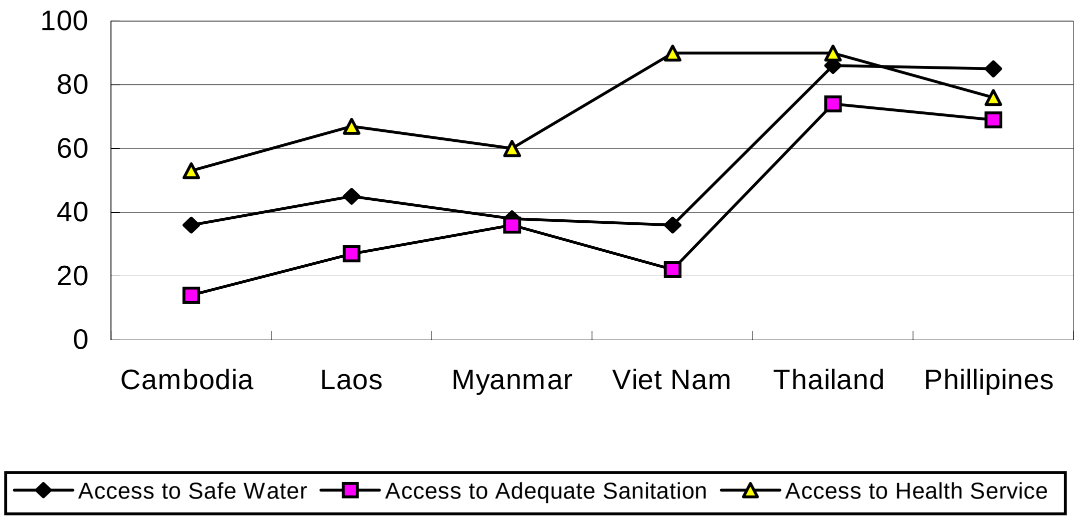


Figure 3.1 Access to Social Services

Malaria is regarded as the top health problem in the country. The infectious agent responsible for most cases is Plasmodium falciparum, which can be fatal in 40 % of cases if untreated. The leading causes of hospital admissions are: diarrhea, malaria, acute respiratory infections, dysentery, tuberculosis, malnutrition, anaemia, dengue and accidents.

As a result of the scarcity of clean water and absence of sanitary facilities throughout the country, diarrhea diseases and related communicable diseases continue to be major causes of child morbidity and mortality[1].

On average, each child in Cambodia experiences four (4) to five diarrhea per year. Over 20 % of the under-five mortality rate is due to diarrhea.

(2) Level of Health Service

During the Pol Pot regime, the whole system of health care and majority of practitioners were virtually demolished. As an emergency approach to deal with unusual situation, crash courses were prepared in 1980 to increase number of medical practitioners.

Quality and credibility of public health care service is low, and access to such facilities are limited especially in rural area. Even when the physical infrastructure exist, the facilities are in poor condition and lacking in basic supplies. Combination of lack of physical infrastructure, lack of basic supplies, and lack of expertise and training of staffs are the major problem of Cambodia's health service.

WHO estimates that less than 25 % of the rural population have access to even basic health care. Villagers tend to rely on self-medication or unregulated private practice, which is expensive and potentially risky. It is estimated by UNICEF that current household expenditures on health, especially self-medication, is US$ 16 in rural and US$ 40 in Phnom Penh[2].

(3) Urban-Rural Gap on Health Sector

In health service, the gap between urban and rural area is quite significant. According to MOH statistics, about half of medical doctors in the country is concentrated in Phnom Penh. In terms of the number of doctors per each 100,000 persons, the people in Phnom Penh has 25 times more doctors than people in Svay Rieng as presented in Table 3.16.

3.2 Rural Development

3.2.1 Rural Development Policy

The development of the rural areas in Cambodia is a main objective of the FSEDP. Since

[1] Health in Cambodia, MOH & WHO

[2] Developing Rural Cambodia, SIDA 1996

85 % of the population is in the rural areas, raising of the standard of living and promotion of the quality of life are key components for future economic growth in Cambodia.

Because the RGC put a great emphasis on the rural development, the MRD was established in 1993 in order to improve the socio-economic status, the production and marketing system in the rural areas, and rehabilitate and reconstruct the rural infrastructure as well as provision of primary health care and clean water.

To achieve the above objective, the FSEDP focuses on the following critical elements:

(1) Rural road construction
(2) Primary health care and rural water supply
(3) Community development including training of village staff
(4) Extension of household farming system
(5) Provision of rural credit
(6) Improvement of rural information

3.2.2 Organization of MRD

Before MRD was established, there was a tendency that each ministry worked for rural development in their own sectors with limited emphasis on cross sectoral collaboration and formulate integrated rural development policy. Therefore, the MRD responsibility was set for coordinating, cooperating, monitoring and evaluating rural development programs/projects to rehabilitate and develop the country's rural areas, and undertaking developmental initiatives of its own.

In order to achieve these purposes, the MRD consists of eight departments, i.e., Administration and Personnel, Procurement and Finance, Planning and Public Relations, Training and Research, Rural Water Supply, Rural Health Care, Community Development, and Rural Economic Development (refer to Figure 3.2).

3.2.3 Rural Development Coordination Structure

In order to provide a net work of coordination among various ministries which makes decision for rural development for specific sector, the government established a Committee for Agricultural and Rural Development (CARD) in 1994. CARD is the steering committee in charge of inter-ministerial coordination composed of representatives from all line agencies, chaired by the co-prime ministers.

At provincial level, co-prime ministers of RGC decided to create the Provincial Rural Development Committees (PDRC). Just like CARD at national level, PRDC consists of representatives from all line provincial agencies and chaired by the governor. Provincial Department of Rural Development (PDRD) is to play core role as a Vice President or Secretary of the PDRC. Structure of PDRD is presented in Figure 3.3.

For district and commune level, same type of committees, i.e., District and Commune Rural Development Committees are planned to be developed. For each committee, District Office of Rural Development (DORD) and Rural Development Officer at commune level is to be the Vice President or Secretary of such a committee.

As opposed to the provincial, district, and commune level development committees for which members are nominated and appointed, at the village level, the committee members are elected by the villagers for better mobilization of the local human resources, getting support from the villagers. The villagers' voluntary participation in decision making process is expected to enhance the self-reliance of village people and contribute to more rational and integrated project designing at the village level.

3.2.4 Village Development Committee

After the end of development stage for which "Quick Impact" approach was appropriate, a number of organizations has tried to establish village committee for each specific project or program, recognizing the importance of participation and "Ownership" of project by villager for sustainable development.

Although it was important to have such voluntary committee for each development project to be sustainable, one village could have multiple committees, each one specialized in specific sector.

In order to reduce the duplication and confusion that could be created by the existence of multiple village committees in charge of different but interrelated development issues, MRD is taking initiative to organize more stable organization, Village Development Committee (VDC) which is in charge of wider range of development issues in the village.

In its First Socio-Economic Plan, the Government set a target to establish VDC in 2,500 villages by March 1998 (20 % of villages) and 7,500 villages by 2000 (70 % of villages). The VDC member should be selected through democratic process and 40 % of the committee member should be women. The Department of Community Development in MRD is in charge of facilitating organization of VDC.

Under leadership of MRD, standardized VDC programs are developed.

Although the roles and duties are not clearly defined yet, followings are listed by MRD to be included:

a) Identifying and analyzing the problems and needs in the village
b) Prioritizing the problems according to importance and urgency
c) Finding out about the means and possibilities to solve the problems of the community first
d) Representing the villagers with regard to the presentation of their needs and problems towards government institutions, international organizations and NGOs.
e) Assigning responsibilities for each activity and organize task force.
f) Monitoring and evaluation of village-based development activities
g) Transferring information and experience to the near-by villages
h) Possibility to administer and manage a village development fund

According to the MRD, the establishment of the VDC in the Study area is as follows:

Table 3.8 Establishment of VDC in the Target Provinces

Province	Total Number of Villages	Village Number of Establishment of VDC	Establishment Ratio
Peri-Urban Area	496	28	5.6 %
Svay Rieng	690	350	50.7 %
Ta Keo	1,114	292	26.2 %
Kandal	1,090	9	0.1 %
Prey Veng	1,138	333	29.3 %
Kompong Speu	1,275	386	30.3 %
Total	5,803	1,398	24.1 %

3.3 Rural Water Supply

3.3.1 Water Supply Organizations

There are three (3) different ministries which are responsible for water supply in Cambodia. They are the Ministry of Industries, Mines and Energy (MIME), the Ministry of Agriculture, Forestry and Fisheries (MAFF) and the MRD.

The MIME is responsible for water supply in urban area, such as the headquarters towns in the provinces through the Department of Provincial Water Supply (DPWS). However, water supply in Phnom Penh City is being operated and managed by the Phnom Penh Water Supply Authority (PWSA), a semi-autonomous state enterprise under the Governor of Phnom Penh City. The MRD is responsible for overall development and management of rural water supply systems in the country. On the other hand, the MAFF is promoting the development of surface and groundwater for irrigation purposes, though some of these wells are being utilized for domestic purposes in the rural area.

Water supply is one of the major activities of the MRD aiming at the provision of the basic need of the rural community. The DRWS has been established under the MRD. Before 1993, the MOH was responsible for rural water supply with the assistance of UNICEF and implemented the rural water supply projects through the Central Water Base (CWB). The staff, equipment and materials were transferred to DRWS at the time of establishment of the MRD after the general election in 1993.

3.3.2 Rural Water Supply Situation

In the rural areas of Cambodia, people traditionally resort to the use of rivers, ponds and shallow dug wells for their domestic water needs. In the rainy season, people use rain water mostly for drinking and cooking. Water sources usually dry up in the dry season and are also exposed to contamination of human and livestock wastes. This contamination causes high infant mortality and water-borne diseases, which hinders having a healthy population in the rural areas. Shortage of clean water eventually impedes the development of active rural communities.

In order to overcome such conditions, the RGC has been implementing rural water supply programs. The program started in response to the urgent need of clean water in 1983. However, the program has been relying almost totally on external sources of financing. Technical expertise provided by external agencies, such as UNICEF and NGOs, as well as materials and supplies procured by them, constituted essential part of the rural water supply projects.

(1) Assistance by UNICEF

UNICEF assistance to Cambodia began in 1972, and was interrupted only during the Khmers Rouges regime (1975~1979). Thus UNICEF has had the longest presence in

Cambodia of the international aid organization[3].

In 1979, when the Khmer Rouge regime was ousted, UNICEF established an emergency program to provide drinking water. Between 1983 to 1985, the UNICEF focused on the repair and installation of water systems for selected public institution - hospitals, school, orphanage, teacher training colleges etc.

In 1985, in cooperation wit the National Center for Hygiene and Epidemiology (NCHE) of the MOH, UNICEF established a rural water supply program at seven (7) districts in Kandal and Kompong Speu Provinces and in the municipality of Phnom Penh, aiming at both drilling new wells and rehabilitating existing ones.

In 1986, UNICEF program was expanded to the additional provinces of Kampot, Ta Keo and Kompong Chhnang. By the end of 1987, two (2) mechanical rigs and two (2) manual drilling teams had provided water facilities to 300 villages.

In 1987, a CWB was established in Phnom Pen within NCHE. This became operational center of UNICEF Water and Sanitation Program (WES). Facilities for water analysis and hydrogeological mapping were also provided (After the end of UNICEF support, these analytical activities has not been carried out.).

In 1987, WES was extended to seven (7) provinces. In 1990, the UNICEF program began to change from centrally administered supply-oriented assistance to one of cooperation with provincial offices of NCHE. Focus was placed on training, managerial and organizational support. By 1991, WES program had been expanded to 11 provinces.

The peace agreement was signed in October 1991. UNICEF reoriented its program to drill wells in response to the emergency situation brought about by the Internally Displaced Persons. Water supply project was extended to cover four northern provinces of Battambang, Pursat, Bantey Meanchey, and Siem Reap, in cooperation with UNHCR[4]. In 1993, as mentioned previously, the CWB was transformed into the DRWS and the rural water supply program has been succeeded to the MRD.

As of June, 1995, the MRD and MOH (before 1993) have been constructed 10,185 tube

[3] Developing Rural Cambodia, Swedish International Development Cooperation Agency

[4] Water and Environmental Sanitation in Cambodia, UNICEF

wells with assistance of UNICEF. In addition, NGOs have drilled 2,082 tube wells in 12 provinces of the country (refer to Table 3.17). Present coverage for the rural population is about 25 % if the number of user assumed to be 180 per well (Except Phnom Penh and Sihanouk Ville) and all these wells are functioning and being used. The actual cost per well is reported to be about US$ 2,000.

UNICEF has formulated a plan of operation for the period 1996 to 2000. The program focuses on the enhancement of the capacity of the community, with particular emphasis on women's and youth organization in order to achieve basic social goals. The program comprises four major sub programs, i.e. 1) community development, 2) basic education, 3) health care, 4) advocacy, planning and support. Water supply projects are now a part of community development program, which emphasis on initiative and participation of the community. With emphasis on such bottom-up approach, UNICEF has ceased to set numerical target on well construction.

(2) Assistance by EC

Program de Rehabilitation et Appui au Secteur Agricole du Cambodge (PRASAC), the Rehabilitation and Support Program for the Agricultural Sector of Cambodia, is a rural development Program focusing on irrigation schemes, domestic water supplies, credit schemes and small enterprise promotion. It comprises the major part of EC development assistance to Cambodia, with a budget of approximately US$ 44 million. The financing agreement for PRASAC signed in September 1994 specified 30-month project in six (6) provinces in the south and east of Cambodia: Kompong Cam and Kompong Chhnang (PRASAC I); Ta Keo and Kompong Speu (PRASAC II); and Prey Veng and Svay Rieng (PRASAC III).

The project is to provide over 3,000 wells, claiming a beneficiary rate of 40 families per well, as well as 450 village ponds. The PRASAC scheme also include a plan of establishing about 1,000 'village bank', benefiting an estimated 60 families per bank. Irrigation schemes is planed to cover 30,000 to 36,000 hectares. Microenterprise promotion would benefit 3,000 to 4,000 small entrepreneurs.

PRASAC is working through various level of Cambodian government structure, primarily through provincial government authorities, principally from the MAFF and MRD. About one thousand government staff, majority of such is in relevant provincial departments, have received substantial salary supplements from PRASAC, and to a great extent have come under PRASAC expatriate management team (6 members for each PRASAC, i.e. 18 in total)[5].

PRASAC has significant impact on rural water supply in Cambodia in its scale and its timing. The number of wells that is planned to be constructed is about 30 % of wells that has been constructed by UNICEF for the last decade. In addition, because UNICEF and NGOs in general is now shifting from capital intensive "Rapid Impact Approach" to community based approach with recognition that emergency period is over, PRASAC scheme is outstanding in its scale oriented approach. Although there are criticism on PRASAC for its differing approach from other organizations which has been working in the area of rural water supply, the scale and speed of the PRASAC is considered to be important for Cambodia government in order to increase percentage of population with access to clean water.

1) OXFAM

In 1980, OXFAM started to be involved in the provision of drinking water for both rural and urban communities. Initially, OXFAM worked in Ta Keo Province with the MOH and constructed some 40 wells up to 1983. In 1984, the program expanded to Svay Rieng and later Prey Veng, through the Ministry of Public Works and Transport (MPWT), Department of Road and Bridges (DPB). The urban program focused on supporting the upgrading and operation of the Municipality of Phnom Penh's water works and a one project in 1985 to repair the water tower and distribution system in Svay Rieng town.

In 1989, OXFAM switched the counterpart ministry from MPWT to MAFF, Department of Hydrology (DOH). With UNICEF working with NCHE under MOH, two (2) separate authorities were working on rural water supply.

Throughout this period, the OXFAM program has been project based: that is a number of specific project activities with a central, provincial or emergency focus. OXFAM has taken advantage of the opportunity to work directly with Provincial Agricultural Service in Prey Veng/Svay Rieng and Battambang/Banteay Mean Chey[6].

From 1984 to 1994, OXFAM constructed number of boreholes fitted with India Mark II hand pump and open wells in Prey Veng and Svay Rieng Provinces as shown in Table

[5] Study on Differing Approaches to Development Assistance in Cambodia; NGOs and the European Commission. August 1996. INTRAC

[6] Joint UNICEF/Oxfam Evaluation, Rural Water Supply Projects, Cambodia. December 1992.

3.18.

OXFAM drilled the borehole fitted with a hand pump initially as UNICEF did, however, the system was changed to the combination of hand dug well with a bore hole (so-called “Combined Well”: mentioned as “Open Well” in the above table) since 1990.

2) Groupe de Recherche et d’Echanges Technologiques (GRET)

Since 1989 GRET has been working in Prey Veng Province with DOH of the MAFF. The GRET have been involved in the development of large diameter wells for small scale irrigation, although the wells are also used for domestic water supplies. Most of the wells constructed by GRET are so-called “Combined Well” with a hand dug well lined with the concrete rings and a borehole cased with the PVC tube.

By 1994, 310 wells had been completed in Prey Veng. In addition, there are 18 completed wells in the provinces of Kandal, Kompong Speu and the municipality of Phnom Penh as of June 1992 (refer to Table 3.19).

3) Action International Contre la Faim (AICF)

Action International Contre la Faim (AICF) was working with the DOH on a program of dug/drilled wells in Preah Vihear, Ta Keo and Siem Reap Provinces. The construction method is similar to that used by GRET and OXFAM in Prey Veng. By June 1992, AICF had completed 32 wells in Ta Keo Province. AICF/USA was working in water supply and sanitation in Kratie Province from 1992 to 1995.

4) Other NGOs Activity in Rural Water Supply

In addition to the above NGOs, various NGOs are working in the filed of water supply in this country. Table 3.20 summarizes those NGOs activities and shows the coverage of the NGOs water supply projects in the Study area as of 1993.

Structures for NGO coordination in Cambodia are quite well developed through the Cooperation Committee for Cambodia (CCC) and through NGO Forum. These organizations are not only serving to promote dialogue among NGOs but also to promote communication between NGOs and multilateral and bilateral agencies.

In order to promote cooperation and avoid possible duplication of projects among NGOs, international organizations and bilateral agencies working in the rural water supply and sanitation area, Water Supply and Sanitation Sectoral Working Group Meeting is held on monthly basis at MRD.

3.3.3 Organization and Capacity of DRWS and PDRD

(1) Department of Rural Water Supply (DRWS)

As was mentioned in the previous section, the DRWS became the main implementing agency for rural water supply in Cambodia since 1993. It has the following functions.

a) overall planning, designing and coordination of rural water supply activities including import, transport and storage of supplies and their distribution to the provinces;
b) drilling of tube wells upon request from the villages in the provinces; and
c) training of technicians in the design and construction of water supply.

DRWS consists of five (5) sections; (i) Administration Section; (ii) Supply and Finance Section (iii) Design and Planning Section, (iv) Drinking Water Section and (v) Small Scale Irrigation Section (refer to Figure 3.3). Total number of the personnel and their functions are shown in Tables 3.21 and 3.22.

The majority of the personnel belong to technical sections which conducts well drilling, hand pump installation and repair. Presently, the DRWS owns 18 drilling rigs and allocates them to each province (refer to Table 3.23). Seven (7) drilling rigs out of 18 are not operated because of repair. Most of drilling rigs are PAT 201 type simple machine, which is capable of drilling up to maximum depth of about 50 m in 4 inch hole-diameter in case of soft formation.

Monthly budget of DRWS in December 1996 is also shown in Table 3.24. As seen in this table, it is impossible to implement the projects without external financial assistance though UNICEF is providing some office expenses for stationary and equipment.

In order to keep its drilling team working, part of the money collected by DRWS from villagers are used for compensation for the drilling team. The following is the example of such scheme.

Typically, they collect 3,000 to 5,000 Riel per household when they construct a well.

For each well, for example;

Table 3.9 Example of Villagers' Contribution

	Riel	Ex. Rate	US$
Amount Paid by Each Household	3,000	2,500	1.2
Number of Households	50		
Total Amount Paid by Villagers	150,000	2,500	60
MRD's Machine Maintenance/ Staff allowance	120,000	2,500	48
Saved for Water Committee for O&M	30,000		12

The actual cost of the drilling is estimated between US$ 900 to 1,600 including the casing pipes and a hand pump. The total amount paid by the villagers is approximately 4 to 7 % of the drilling cost.

(2) Provincial Department of Rural Development (PDRD)

PDRD provides promotion of small enterprise, credit, public health and water supply services to the rural communities. Its organization is mirrored the MRD's organization and consists of the following five (5) offices (refer to Figure 3.4).

- Administration, Finance and Planning
- Rural Water Supply
- Primary Health Care
- Community Development
- Rural Economy

Typically, PDRD has about 120 to 160 staffs, of which about 15 to 30 are in the Rural Water Supply Office. Drilling equipment is not owned but leased from DRWS. Stock of spare parts for hand pumps are not constantly kept at the provincial level.

There are about 10 staffs in each district, and at least one of them is in charge of rural development. On commune level, currently there are no permanent staffs.

It is MRD's policy to shift various functions regarding well construction, monitoring, operation and maintenance from national level to provincial and district level. The demarcation of responsibilities among national, provincial and district level is summarized in Table 3.25.

3.3.4 Five Year Rural Water Supply Plan

Access to water supply, which is defined as a basic level of service for drinking water requirements throughout the year, varies significantly by regions of the country. Across all regions of the country, about 5.7 million people in the rural areas lack access to clean water. With an estimated population growth of 2.8 % per annum, it is estimated that approximately 6.9 million people should be covered by water supply projects by the year 2000 in order to attain universal coverage.

It is estimated by MRD that in order to supply clean water to 6.8 million people by the year 2000, 77,600 water points sources needed. The development strategy is to mix technologies depending upon the hydrological situation and consumer preference thus optimizing the available resources. MRD estimates that the per capita cost vary from US$ 5 for a hand-dug wells and gravity fed schemes to US$ 9 for a drilled deep well with a hand pump. The total cost of providing universal coverage in water supply through a mix of technologies (with almost 50 % of the population covered using the lower cost options of a hand-dug well or dug/drilled well) is estimated at US$ 55 million by MRD.

Due to the limitation of available fund and operational capacity of the Government during the five (5) year period between 1996 and 2000, MRD has set a goal to increase the water points by 39,000, rather than 77,600, during the five (5) year between 1996 and 2000. If this goal is achieved, targeting 65 % of the rural population will have access to safe water by the year 2000.

The costs of providing safe water supply to 65 % of the rural population by the year 2000 are presented in Table 3.26. A capital investment of nearly US$ 36 million, or an average of about US$ 7.2 million per year, will be required to achieve the target. According to the FSEDP, the cost will be met from multiple sources, including the RGC, international organizations, NGOs as well as the communities themselves through labor and material contributions.

3.3.5 Financial Constraints

Apart from the fund from foreign aid, almost all of the MRD's budget (domestic budget) was allocated to current expenditures such as salary and other administrative expense.

For capital expenditures such as construction of wells and small irrigation system in the rural villages, MRD must rely on funds from other sources. DRWS has been supported by

UNICEF, which provided most of the equipment for drilling, well construction material, pumps and spare parts, as well as some portion of office expense.

MRD's domestic budget (mostly current expenditure) decreased from 2,198 million Riel in 1995 to 1,310 million Riel in 1997. This is caused by decrease in number of personnel administered by MRD. The responsibility for budget of PDRD has been transferred to chief of each provinces from MRD as a process of decentralization. On the other hand, budget for capital expenditure which is allocated to MRD (mostly foreign grant aid) is controlled and allocated to projects in each province by MRD (refer to Table 3.27).

Of its 1,579 million Riel domestic budget for 1996, 360 million Riel or 23 % is allocated to salary for MRD personnel. Average salary is about US$ 10 for workers, US$ 20 for staffs and US$ 30 for directors.

Important questions that should be taken into consideration in designing sustainable development project in Cambodia is the institutional weakness of the current government. Most of the government employees' salaries are insufficient to maintain effective institution. It is recommended by many observers that drastic government restructuring whilst also recognizing that such reform would be the enormously risky and difficult form political point of view.

3.4 Present Rural Water Supply Projects

3.4.1 Coverage of Rural Water Supply

The coverage of the rural water supply is estimated to be 25 % in the whole country. However, this coverage figure is based on the assumption that:

(1) all existing well are working
(2) each well is used by 180 villagers (with average household size of 5.3, this means that a well is used by 34 households).

The Demographic Survey of Cambodia 1996 has shown strikingly different picture of water use. In rural area, only 9.8 % of the household answered that "Tubed/Piped Well" as their main source of drinking water (refer to Table 3.28). If this statistics reflects the real picture of water use in rural area, the following figure can be obtained.

The usage / Coverage ratio = 9.8 / 25 = approx. 40 %

If this ratio remain unchanged, the actual use of clean water might be only 40 % even after MRD achieved "Universal Coverage" of clean water in rural area.

In 1992, an evaluation by the respected International Water and Sanitation Center claimed that the rate of functioning wells constructed by UNICEF was 80 to 90 %[7]. Although there is no up to date statistical data available on the actual condition and use of existing well, UNICEF currently estimates that around 30 % of the existing well is not functioning. Some NGO estimates much higher rate of unused/broken wells.

3.4.2 Status of Hand Pumps in the Previous Projects

Table 3.29 presents the status of the hand pump and their evaluation in 30 villages in the Study area as an example. These water supply systems were constructed by UNICEF/MOH, MRD and NGOs mostly in late 1980's. About 40 % of hand pumps are not functioning any more. The hand pumps are mostly India Mark II, which was used widely for rural water supply in 1980's.

The VWC exists only in Snao Lich village in Kandal Province, where UNICEF constructed a tube well fitted with a India Mark II hand pump in 1986. About 30 families are using this well for all purposes and they never use pond water even in the rainy season. The system is maintained very well. The platform is big enough compared to other platforms generally seen in the Study area and its environments are clean. They appointed the caretakers, however, they do not collect any money from villagers even monthly or annually. This hand pump was once broken. At that time, the VWC collected money from villagers and repaired it. It cost about 500,000 Riel (US$ 200). This is a very rare case and an exceptional one in the Study area.

On the other hand, VWC does not exists in almost all villages in the Study area. In most of the villages, the broken hand pumps are left abandoned. The reasons of abandonment are lack of knowledge and skills for repair, and unavailability of spare parts. In addition, in many cases, the hand pump is not frequently utilized because of the taste of water from the beginning. Therefore, people are not so enthusiastic to repair the pump. However, in several villages, people tried to repair the pump by themselves. They collect money from villagers at that time and repaired it once or twice, although they finally abandon it.

[7] Developing Rural Cambodia, 1996 SIDA

NGOs constructed many tube wells and hand dug wells in the Study area. Particularly, in Prey Veng Province, OXFAM constructed many tube wells fitted with India Mark II from 1984 to 1988. The number of broken hand pump is not a little. They are left abandoned, removed and/or occasionally replaced to No.6 pump. No.6 is a suction pump made in Viet Nam. The spare parts of this pump or the pump itself are sold in the shop in the headquarters town of the province. However, the pump is easily broken and the lift is limited to 5 to 6 m, though it is very cheap (about US$ 25).

From 1990, OXFAM changed the well design and constructed “Combined Well”, which is the combination of a shallow dug well and a tube well. And this well design was thought to improve the taste of water, especially if the slab was not fully sealed and air could come in to the well. This might be related with the oxidization of the dissolved iron in the water. Normally, the well cover is placed on the top. However, this is opened in order to draw water with bucket in case of break down of No.6 hand pump. As long as observed in the several villages in Prey Veng Province, the hand pump is removed or broken and the well was opened and the cover was not placed back. Although the well could supplies water, it is often contaminated by tampering of foreign matters and unhygienic use of the buckets.

3.4.3 Discrepancy between Coverage and Actual Use

If 9.8 % of the population is actually using tubed/piped wells and 25 % of the coverage is valid, 60 % of existing tubed/piped wells are not being used (or 40 % is being used) as mentioned previously. If the breakdown rate of the existing hand pump is assumed to be 30 %, another 30 % should be explained. There are following two (2) possibilities;

a) The assumption of the population per well, 180, was overestimated. People were not willing to travel long distance to fetch clean water. They tend to use other water source, such as pond and river, when available.
b) There are significant number of wells that are functioning but not used by villagers, because the quality of water is not good enough.
c) Percentage of broken hand pump is underestimated.

Reality would be the combination of these reasons. It is suspected that fundamental cause of the discrepancy between the actual use and the water supply coverage is lack of demand for the water from the existing drilled well, particularly, in case of salty or iron taste water.

Actually, the village survey of the Study revealed that the village people do not use water for drinking and cooking if the water is salty. According to the field observation, a permissible limit of salinity for drinking is approximately 1,500 micro S/m of Electric Conductivity (EC). If the water from hand pump is not permissible for them for drinking, they go to collect water from pond, river or other available traditional water sources. In case of iron, people put water in the pot overnight and after that they use it for cooking. However, for washing of clothes, they use another water source. In several villages, they did not want to use such bad-tasty water from the beginning.

3.4.4 Aspects for Future Water Supply

In order to promote effective and sustainable rural water supply projects in this country, coordinated effort from various aspects is indispensable. The following are the main issues raised by the outsiders. These problems should be solved in the near future.

(1) Operation and Maintenance Issue

a) Lack of access to spare parts
b) Lack of financial resources to repair the well
c) Difficulty in access to experts
d) Lack of village water committee to take initiative for repair and maintenance

(2) Water Use and Hygiene Education Issue (WUHE)

a) Lack of proper understanding of importance of safe water for health
b) Other traditional water source is readily available (although unsafe)

(3) Water Quality/Well Design Issue

a) Taste of water is bad due mainly to high content of iron and/or salt. Some villagers feel the water ”Unsafe” for their health.
b) Quantity of water from the well is too small, especially in dry season.

In order to promote the use of clean water from the drilled well by villagers, MRD/UNICEF and other organizations are increasingly putting more emphasis on VLOM and Water Use and Hygiene Education (WUHE). In addition to this, effort must be made to develop groundwater of good quality and quantity, where access to other traditional water sources are relatively easy except for the limited period of the dry season.

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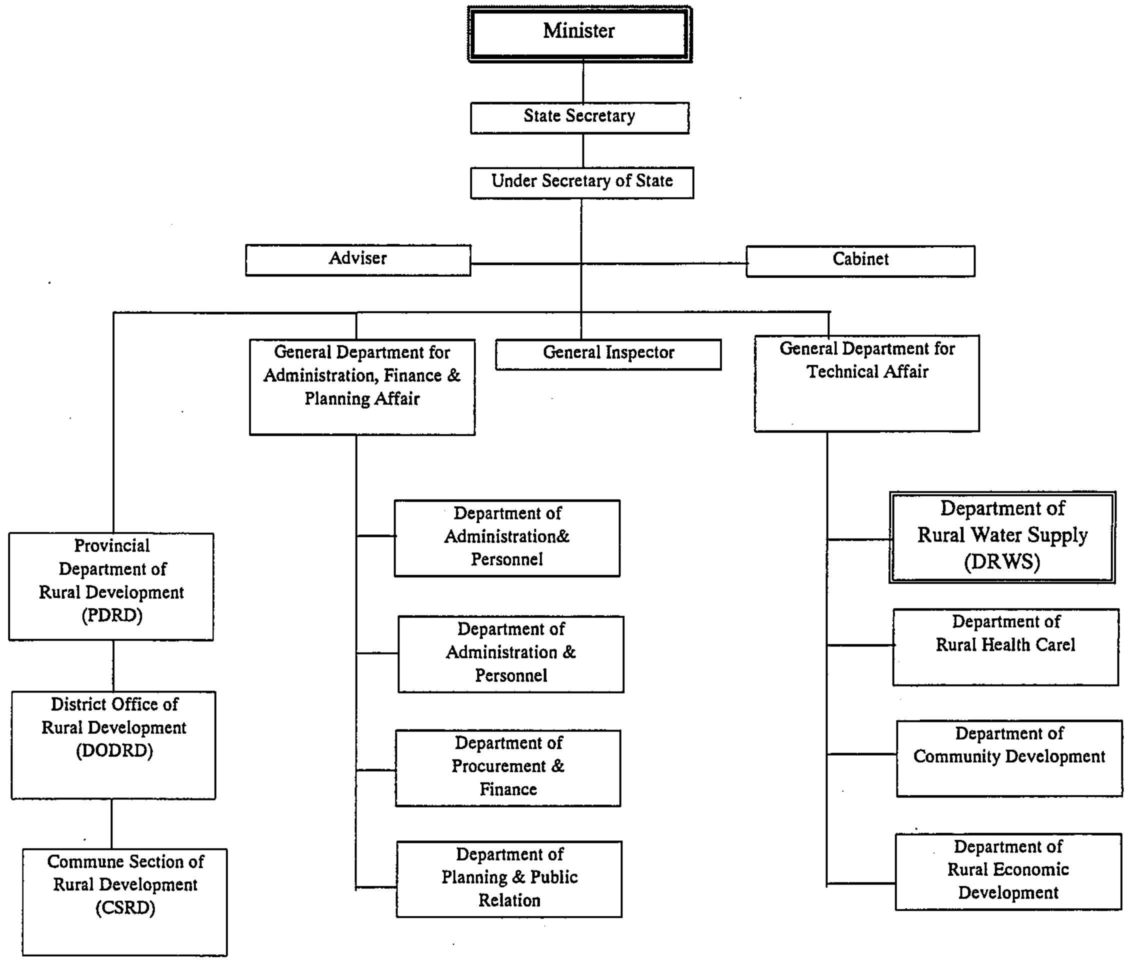
Structure of Ministry of Rural Development



Source: MRD/DRWS

Figure 3.2 Structure of Ministry of Rural Development

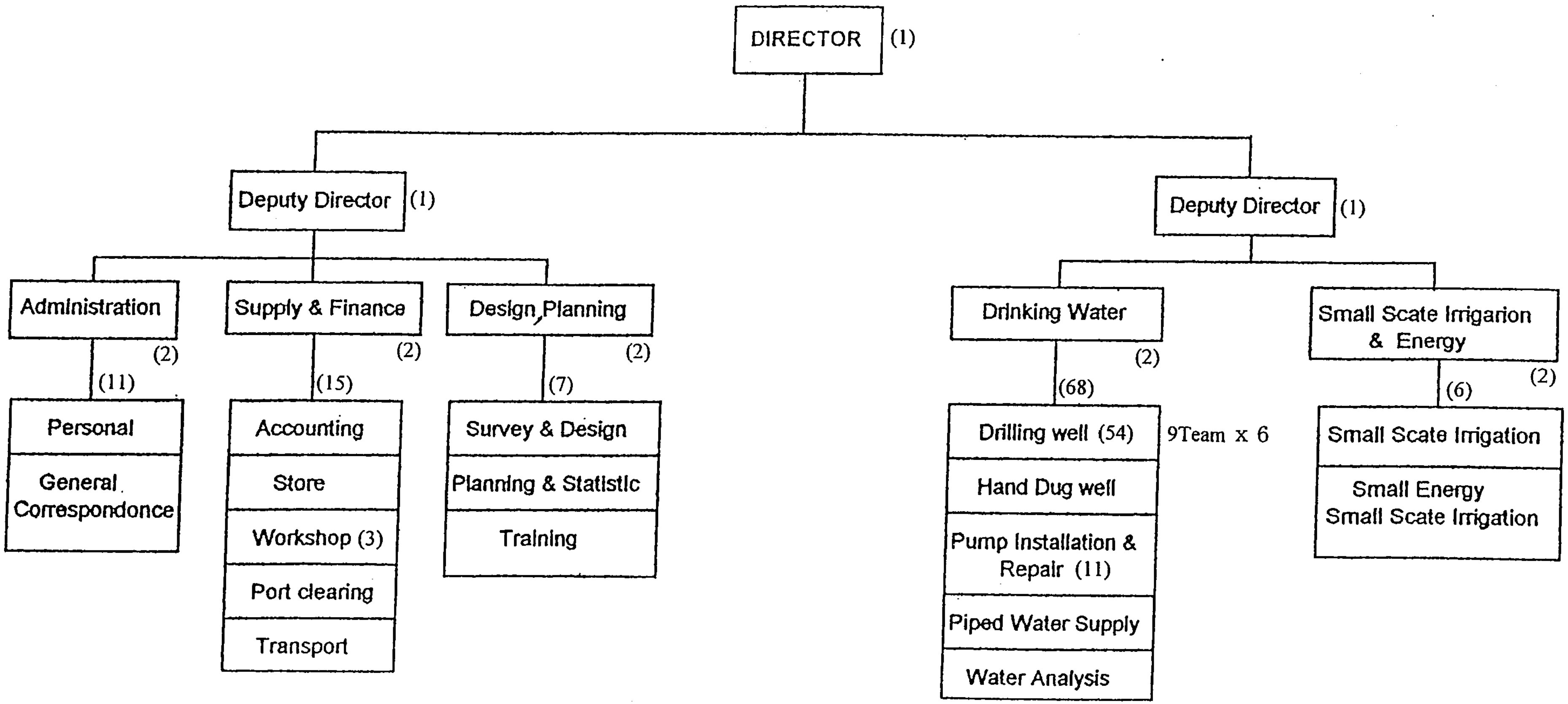


Figure 3.3 Structure of Department of Rural Water Supply

Structure of
Provincial Department of Rural Development
(PDRD)

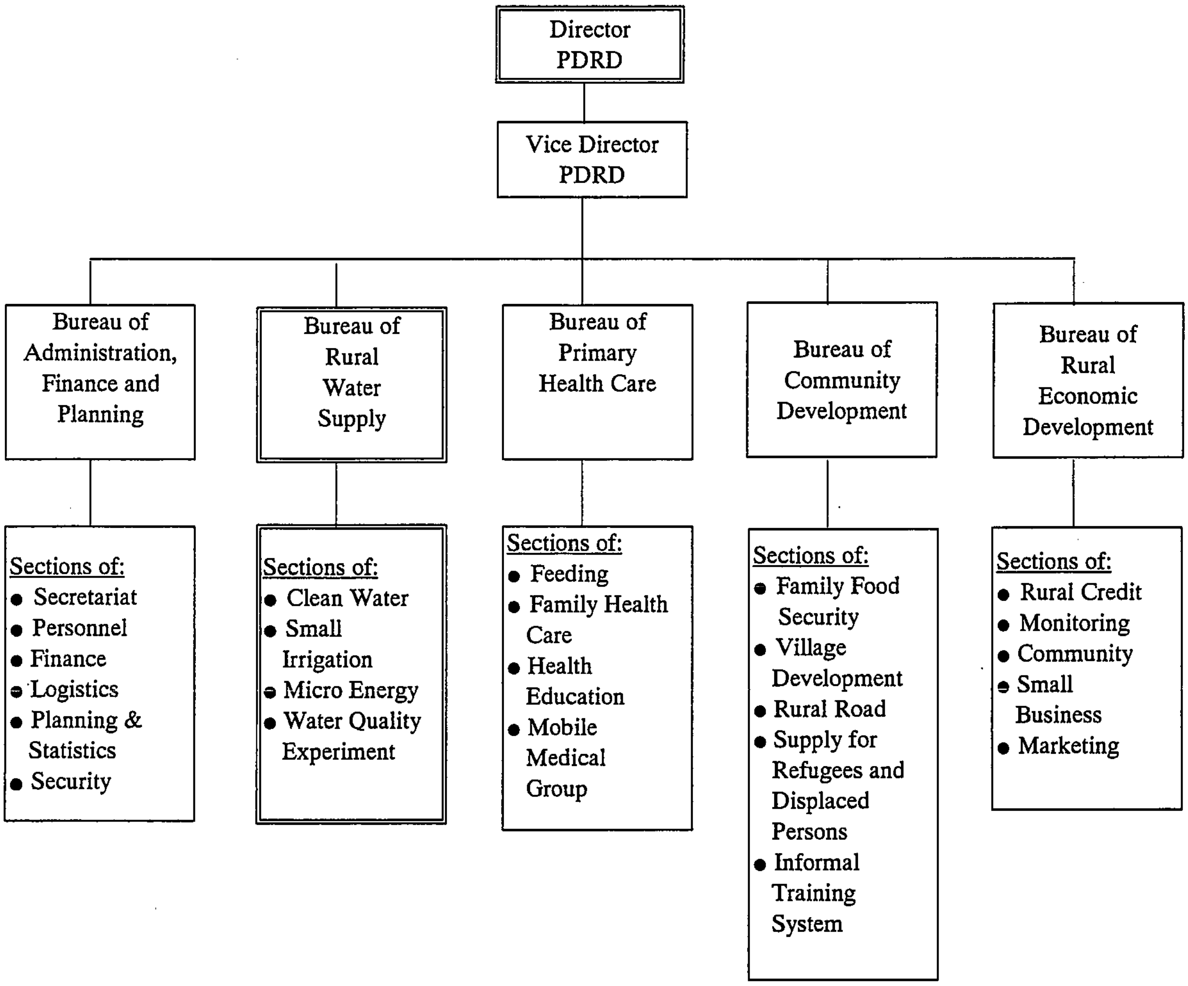


Figure 3.4 Structure of PDRD

Table 3.10 Population Statistics by Province for 1998

No.	Name of the Province	House-holds	Family Size	Male	Female	Total	Area (km2)	Density
1	Banteay Meanchey	111,866	5.2	283,242	294,058	577,300	6,679	86
2	Battambang	148,315	5.3	388,338	403,620	791,958	11,702	68
3	Kompong Cham	313,019	5.1	775,329	832,584	1,607,913	9,799	164
4	Kompong Chhaing	82,452	5.1	197,299	219,700	416,999	5,521	76
5	Kompong Speu	115,576	5.2	287,299	310,802	598,101	7,017	85
6	Kompong Thom	106,835	5.3	272,676	295,778	568,454	13,814	41
7	Kompot	104,920	5.0	252,818	275,086	527,904	4,873	108
8	Kandal	205,992	5.2	515,809	557,777	1,073,586	3,568	301
9	Koh Kong	24,962	5.3	67,629	64,283	131,912	11,160	12
10	Kratie	49,297	5.3	130,021	132,924	262,945	11,094	24
11	Mondol Kiri	5,673	5.7	16,367	16,025	32,392	14,288	2
12	Phnom Penh	173,232	5.8	481,385	516,601	997,986	290	3,441
13	Preath Vichear	21,481	5.5	59,232	59,928	119,160	13,788	9
14	Prey Veng	194,019	4.9	445,139	499,990	945,129	4,883	194
15	Pursat	68,206	5.3	172,945	187,346	360,291	12,692	28
16	Ratana Kiri	16,754	5.6	46,399	47,789	94,188	10,782	9
17	Siem Reap	127,086	5.5	336,740	358,745	695,485	10,299	68
18	Kompong Som	28,013	5.5	76,858	78,518	155,376	868	179
19	Stung Treng	14,304	5.7	40,115	40,863	80,978	11,092	7
20	Svay Rieng	98,219	4.9	225,094	253,005	478,099	2,966	161
21	Ta Keo	154,971	5.1	377,037	412,673	789,710	3,563	222
22	Oodar Meanchey	12,563	5.5	35,027	33,809	68,836	6,158	11
23	Kep City	5,367	5.3	14,046	14,631	28,677	336	85
24	Pailin City	4,116	5.6	12,360	10,484	22,844	803	28
	Tonle Sap Lake						3,000	
Total		2,187,238	5.2	5,509,204	5,917,019	11,426,223	181,035	63

Source: Genral Population Census of Cambodia 1998

Table 3.11 Local Administrative Divisions

	Province	Districts	Commune	Villages		Province	Districts	Commune	Villages
1	Banteay Meanchey	7	57	554	12	Phnom Penh	7	76	496
2	Battambang	8	66	481	13	Preah Vihear	7	49	197
3	Kampot	8	95	476	14	Prey Veng	12	116	1,138
4	Kandal	11	147	1,090	15	Pursat	5	44	440
5	Koh Kong	7	30	119	16	Ratanakiri	9	50	243
6	Kg. Cham	16	193	1,713	17	Siem Reap	14	108	915
7	Kg. Chhang	8	69	538	18	Sihanouk Ville	3	21	82
8	Kg. Speu	8	86	1,275	19	Stung Treng	5	34	129
9	Kg. Thom	8	81	718	20	Svay Rieng	7	80	690
10	Kratie	6	45	243	21	Takeo	10	98	1,114
11	Mondulkiri	6	21	87		Total	172	1,566	12,738

Table 3.12 Real Gross Domestic Product by Sector, 1993~1997

Unit: Billion Riel (1989 Basis)

	1993	1994	1995	1996	1997 (Estimate)	Annual Growth Rate
Agriculture						
Rice	48.2	38.6	47.9	48.0	46.8	-0.7%
Rubber and other crops	29.0	32.4	34.3	35.4	36.3	5.8%
Livestock	38.0	39.5	41.1	44.2	46.4	5.1%
Fisheries	12.0	11.8	12.2	12.1	11.9	-0.3%
Forestry	9.9	14.9	10.4	9.7	9.8	-0.2%
Sub-Total	137.1	137.2	145.9	149.4	151.2	2.5%
Industry						
Mining	3.4	3.7	4.0	4.8	4.5	7.5%
Manufacturing	20.5	22.1	24.3	27.4	29.5	9.5%
Electricity and water	0.7	0.7	0.8	0.9	1.0	10.2%
Construction	27.1	29.1	32.0	39.0	34.9	6.6%
Sub-Total	51.7	55.6	61.1	72.1	70.0	7.9%
Services						
Transport and communication	8.9	9.7	10.7	11.8	12.4	8.7%
Wholesale and retail trade	42.3	44.8	48.8	53.3	54.8	6.7%
Hotels and restaurants	1.4	1.7	1.8	2.2	2.1	11.3%
Government services	11.5	12.5	12.9	12.7	12.8	2.8%
Home ownership	18.8	20.3	21.8	23.1	23.6	5.9%
Other services	20.4	22.1	23.7	25.1	25.6	5.8%
Sub-Total	103.3	111.1	119.7	128.2	130.5	6.0%
GDP Total	292.1	303.9	326.7	349.7	351.7	4.8%

Source: Annual Report 1998, National Bank of Cambodia

Table 3.13 Key Macro Economic Targets 1996-2000

	1996	1997	1998	1999	2000
Projected GDP Growth Rate	7.50%	7.50%	7.50%	7.50%	7.50%
Consumer Price Index	5%	5%	5%	5%	5%
Domestic Export (Million USD)	53	59	65	72	80
Retained Import (Million USD)	490	510	540	600	700

Projected Budgetary Operations as % of GDP					
	1996	1997	1998	1999	2000
Budget Revenue	9.9	10.4	10.8	11.2	11.6
Budget Expenditure	17.0	16.2	16.1	16.4	16.9
of which current expenditure	10.2	9.8	9.7	9.8	10.0
of which capital expenditure	6.8	6.4	6.4	6.6	6.9
Current Budget Surplus (Deficit)		0.6	1.1	1.4	1.6
Overall Budget Surplus (Deficit)	(7.1)	(5.8)	(5.3)	(5.2)	(5.3)
Foreign Financing (Budget Support and Project Aid)	6.9	5.6	5.1	5.2	5.3
Domestic Financing	0.2	0.2	0.2	0.0	0.0
Total Domestic Investment	22.6	23.0	22.8	24.8	26.5
of which investment by public sector	6.4	6.1	6.1	6.5	6.9
Projected Investment as Percentage of GDP					
Government Investment	6.4	6.1	6.1	6.5	6.9
of which domestically financed	1.0	1.0	1.0	1.2	1.6
of which foreign financed	5.4	5.1	5.1	5.2	5.3
Non-Government Investment	16.2	17	16.7	18.4	19.7
of which domestically financed	12.4	11.9	11.5	12.5	12.7
of which foreign financed	3.7	5.1	5.2	5.9	7
Total Investment	22.6	23.1	22.8	24.9	26.6
of which domestically financed	13.4	12.9	12.5	13.7	14.3
of which foreign financed	9.1	10.2	10.3	11.1	12.3

Source : First Socioeconomic Plan 1996 - 2000

Table 3.14 Allocation Plan for Public Investment 1996-2000

	Allocation in Million US Dollars			Allocation in Percentage (%)		
	Urban	Rural	Total	Urban	Rural	Total
Agriculture	7	213	220	3%	97%	10%
Manufacturing and Mining	66	22	88	75%	25%	4%
Transport and Communication	76	430	506	15%	85%	23%
Electricity	130	46	176	74%	26%	8%
Water Supply and Sanitation	**132**	**44**	**176**	**75%**	**25%**	**8%**
Education and Training	73	169	242	30%	70%	11%
Health	55	165	220	25%	75%	10%
Social and Community Service	46	108	154	30%	70%	7%
Religious and Cultural Affairs	26	40	66	40%	60%	3%
Adm./Special Programs	121	121	242	50%	50%	11%
Unallocation	39	72	110	35%	65%	5%
Total	770	1,430	2,200	35%	65%	100%

Source : First Socioeconomic Development Plan 1996-2000

Table 3.15 Health Situation of Cambodia in Comparison with Other Countries

	Under5 Mortality Rate	Infant Mortality Rate	Life Expectancy at Birth	% of Population with Access to: Safe Water	Sanitation	Health Service
	1994	1994	1994	1990-1995	1990-1995	1990-1996
Cambodia	177	113	51	36	14	53
Laos	138	94	51	45	27	67
India	119	79	60	81	29	85
Bangladesh	117	91	55	97	34	45
Indonesia	111	71	62	62	51	80
Myanmar	109	79	57	38	36	60
Philippines	57	44	66	85	69	76
Vietnam	46	35	65	36	22	90
China	43	35	68	67	24	92
Thailand	32	27	69	86	74	90
Malaysia	15	12	71	78	94	n.a.

Source : The State of The World's Children 1996, UNICEF

Table 3.16 Health Infrastructures by Province

Province	No. of Medical Doctors	Doctor per 100,00	No. of Hospital			Commune Dispensa-ries	No. of Beds	Populat-ion per Bed	Bed per 100.000
			Provincial	District	District Hosptl. Annex				
Svay Rieng	34	8	1	6	0	11	426	1,039	96.2
Prey Veng	24	3	2	10	0	84	418	2,233	44.8
Kandal	32	4	1	10	9	121	497	1,720	58.1
Phnom Penh	406	50	9	6	2	21	2.130	381	262.5
Kg. Cham	58	4	4	14	4	51	627	2,335	42.8
Kg. Chhang	16	5	1	7	0	27	278	1,172	85.3
Kg. Speu	42	9	1	7	0	25	279	1,757	56.9
Takeo	27	4	1	9	1	71	598	1,163	86.0
Sihanouk	16	13	1	2	0	12	142	853	117.2
Ville	20	7	1	4	1	36	446	677	147.7
Pursat	47	7	1	7	0	45	655	990	101.0
Battambang	27	6	1	8	0	39	472	1,035	96.6
B. Meanchey	23	3	1	14	0	51	698	974	102.7
Siem Riep	23	5	1	7	0	31	488	1,004	99.6
Kg. Thom	10	10	1	4	0	0	115	855	117.0
Preach	18	8	1	5	0	22	282	751	133.2
Vihear	11	20	1	4	0	0	66	842	118.8
Kratie	6	9	1	8	0	1	130	491	203.7
Strung Treng									
Ratanak Kiri									
Total	840	9	30	132	17	648	8,747	1,043	95.9

Source: National Health Statistics, MOH 1994

Table 3.17 Status of the Drilled Wells by Province (1995)

	Province	UNICEF/ MRD	Others (NGOs)	Total	No. of Users per Well	Populat-ion served	Rural Population (Estimate)	Coverage Rate
1	Banteay Meanchey	83	348	431	180	77,580	389,095	20%
2	Battambang	488	315	803	180	144,540	448,650	32%
3	Kampot	551	86	637	180	114,660	468,717	24%
4	Kandal	1,896	171	2,067	180	372,060	904,103	41%
5	Koh Kong	4	0	4	180	720	27,445	3%
6	Kg. Cham	927	0	927	180	166,860	1,455,617	11%
7	Kg. Chhnang	923	0	923	180	166,140	280,115	59%
8	Kg. Speu	1,090	30	1,120	180	201,600	445,759	45%
9	Kg. Thom	4	0	4	180	720	467,760	0%
10	Kratie	35	281	316	180	56,880	151,108	38%
11	Mondulkiri	0	0	0	180	0	15,401	0%
12	Phnom Penh	1,043	0	1,043	180	187,740	0	NA
13	Preah Vichear	20	0	20	180	3,600	80,681	4%
14	Prey Veng	903	199	1,102	180	198,360	890,586	22%
15	Pursat	140	350	490	180	88,200	202,961	43%
16	Ratanakiri	4	0	4	180	720	55,547	1%
17	Siem Reap	253	50	303	180	54,450	565,018	10%
18	Sihanuuk Ville	79	0	79	180	14,220	0	NA
19	Strung Treng	0	52	52	180	9,360	38,894	24%
20	Svay Rieng	382	170	552	180	99,360	391,127	25%
21	Takeo	1,360	30	1,390	180	250,200	710,961	35%
	Total	10,185	2,082	12,267	180	2,208,060	7,989,545	25%

Note: Coverage rate excludes Phnom Penh and Sihanouk Ville

Source: DRWS

Table 3.18 Number of Open Well and India Mark II Constructed by OXFAM

	Prey Veng			Svay Rieng		
Year	Water Point	Open Well	India MK II	Water Point	Open Well	India MK II
1984	9		9			
1985	15		15			
1986	68		68			
1987	20		20	27		27
1988	76		76	-		-
1989	-		-	-		-
1990	14		14	9	9	
1991	74	74		70	70	
1992	68	68		108	10	
1993	69	69		36	36	
1994	76	76		45	45	
Total	489	287	202	295	268	27

Source : OXFAM, 1996

Table 3.19 Well Constructed by GRET in Prey Veng Province

No.	Name of District	Number of Wells by Year					Total
		1990	1991	1992	1993	1994	
1	Prey Veng	3					3
2	Kompoung Trobek	1	4	31	6	7	49
3	Ba Phnom	-	5	40	13	11	69
4	Preak Sdach	-	2	30	4	8	44
5	Kah Poung Learv	-	3	16	5	-	24
6	Peach Ro	-	1	-	-	-	1
7	Kah Chhay Mear	-	-	9	6	9	24
8	Kagn Chrearch	-	-	26	10	-	36
9	Si Yhor Kandal	-	-	23	16	3	42
10	Dear Ring	-	-	6	-	12	18
	Total	4	15	181	60	50	310

Source: GRET

Table 3.20 NGO Activities in the Study Area (1/2)

Province	District	Name of NGOs	Activities			Other Projects			
Kandal	Muk Kampoul	CRC		RW	GW	World Educat.	WUE		
		CIDSE	WUE		GW	WFP		RW	GW
	Khsach Kandal	CRC		RW	GW				
	Phnom Penh	GRET	WUE		GW				
		JVC	WUE		GW				
		JRS	WUE	RW	GW				
		LWS	WUE		GW				
		WVI	WUE	RW	GW				
	Ponhea Leu	CRC		RW	GW				
		GRET	WUE		GW				
		LWS	WUE		GW				
Prey Veng	Sithor Kandal	GRET	WUE		GW	UNICEF			GW
		OXFAM	WUE		GW	WFP			GW
	Kahn Chreach	GRET	WUE		GW	PRASAC III			GW
		OXFAM	WUE		GW				
	Peareang	GRET	WUE		GW				
	Kamchey Mear	GRET	WUE		GW				
	Prey Veng	COR	WUE		GW				
		GRET	WUE		GW				
		OXFAM	WUE		GW				
	Mesang	CRC		RW	GW				
		MCC	WUE		GW				
		OXFAM	WUE		GW				
	Ba Phnom	GRET	WUE		GW				
		OXFAM	WUE		GW				
	Preach Sdech	OXFAM	WUE	RW	GW				
	Kompong	CRC			GW				
		GRET	WUE		GW				
		OXFAM	WUE		GW				
	Kompong Mear	GRET	WUE		GW				
Takeo	Samrong	AICF	WUE		GW	WFP		RW	GW
		LWS	WUE		GW	PRASAC II			GW
	Tram Kak	AICF	WUE		GW				
		CRC			GW				
		VSA	WUE		GW				
		Interaid	WUE						
		International	WUE						
	Prey Kabbas	CRC		RW	GW				
		LWS	WUE		GW				
	Treang	ACR	WUE						
		CRC		RW	GW				
	Bati	CRC		RW	GW				
		LWS	WUE		GW				

(to be continued to the next page)

Table 3.20 NGO Activities in the Study Area (2/2)

Province	District	Name of NGOs	Activities			Other Projects			
Svay Rieng	Svay Teap	CRC		RW	GW	UNICEF	WUE		GW
		OXFAM	WUE		GW	WFP		RW	GW
	Svay Rieng	CIDSE		RW	GW	PRASAC III			GW
		OXFAM	WUE		GW				
	Romduol	CRW	WUE	RW	GW				
		OXFAM	WUE		GW				
	Kompong Ro	CRW	WUE	RW	GW				
		OXFAM	WUE		GW				
	Romeas Hek	CRC		RW	GW				
		OXFAM	WUE		GW				
	Chan Trea	OXFAM	WUE		GW				
Kompong Speu	Samrong Tong	Concern	WUE	RW	GW	WFP		RW	GW
		GRET	WUE		GW	PRASAC II			GW
		LWS	WUE		GW				
	Phnom Surouch	CRC		RW	GW				
	Srok Thpong	CRC		RW	GW				
Phnom Penh	Dangkor	CRC		RW	GW	UNICEF			GW
		GRET	WUE		GW				
		Bama	WUE	RW	GW	WFP		RW	GW
	Mean Chey	Enfants du Cam.	WUE		GW				
		GRET	WUE		GW				
		Redd	WUE		GW				
		Barna	WUE	RW	GW				
	Russei Keo	CRC		RW	GW				

Note: GW = Groundwater, RW = Rain water, WUE = Water Use Education

Table 3.21 Personnel of DRWS by Function

Position/Duty	Number of Staff
Director	1
Deputy Director	2
Technical advisor Technical assistance Drilling team Hand pump installation team Hand pump repair team Small scale irrigation, etc	87 in total
Administration Planing and design Monitoring team Supply and finance Store and garage Transport Computer Training Water use education Survey	30 in total

Source : DRWS / MRD

Table 3.22 Manpower in DRWS

Number of Years in Service	Gender	University Degree in Engineering or Science	Other University Degree	Some University Education	High School Degree	Less than High School Degree	Total
10 or more	Male	1	3	9	0	73	86
	Female	0	0	3	0	3	6
	Total	1	3	12	0	76	92
7 to 9	Male	8	0	2	0	0	10
	Female	0	0	0	0	0	0
	Total	8	0	2	0	0	10
3 to 6	Male	0	0	7	0	0	7
	Female	0	0	3	0	0	3
	Total	0	0	10	0	0	10
Less than 3	Male	4	0	0	0	0	4
	Female	0	0	0	0	0	0
	Total	4	0	0	0	0	4
Total	Male	13	]3	18	0	73	107
	Female	0	0	6	0	3	9
	Total	13	3	24	0	76	116

Source: DRWS / MRD

Table 3.23 Drilling Facilities Owned by MRD

		PAT210	PAT301	BORND RILL	EDSO N2000	EDSO N5000	HYD RES	INGE RSOL	TOTAL
DRWS (National)		3	2	3(-1)	1(-1)	1	1	2	11
Provincial (leased by Natinal)									
1	Banteay Meanchey								0
2	Battambang	1(-1)							0
3	Kampot	1							1
4	Kandal	1							1
5	Koh Kong								0
6	Kg. Cham	1							1
7	Kg. Chhnang	1							1
8	Kg. Speu								0
9	Kg. Thom								0
10	Kretie	1(-1)							0
11	Mondulkiri								0
12	Phnom Penh								0
13	Preah Vichear								0
14	Prey Veng	1							1
15	Pursat								0
16	Ratanakiri	1(-1)							0
17	Siem Reap	1(-1)							0
18	Sihanouk Ville								0
19	Stung Treng								0
20	Svay Rieng	1							1
21	Takeo	1							1
	Total	10	2	2	0	1	1	2	18

Source: DRWS

Table 3.24 Budget for Department of Rural Water Supply

	1996	1998
Number of personnel at DRWS	120	130
Total budget for personnel payroll (per month)	4,900,000	5,301,331
Average Salary per month	40,833	40,779
Exchange Rate	2,500	3,800
Average Salary per month	16	11

Note:
(1) UNICEF is providing some office expense for stationary and repair of office equipment.
(2) Due to low level of monthly salary, most of personnel are actively seeking secondary jobs.

Table 3.25 Existing Roles and Responsibilities

No.	Activity	Government Organization					Others	
		Ministry Rural Development				Other Government Agency	Community Organization	Private Sector
		National	Provincial	District	Commune			
1	Selection of target village	O						
2	Selection of water point in the village						O	
3	Selection of technology	O	O					
4	Training and water use education	O	O			MOH		
5	Community organization , establishment and collection of initial contribution	O	O				O	
6	Construction of water point	O	O					
7	Allocation and installation of hand pumps to user communities	O	O					
8	Quality control - construction work and water quality	O				MOH		
9	Community training - hand pump maintenance	O	O					
10	Hand pump repair			O				
11	Monitoring community organization and hand pump performance	O	O					
12	Manufacture of pumps and parts							O
13	Marketing of spare parts	O	O					O
14	Technical back-up/well maintenance	O						
15	Support to pump caretakers - technical and financial						O	
16	Coordination between MRD and Community				O			

Source: DRWS/MRD

Table 3.26 Rural Water Supply Investment by Technology

Unit: US$'000

Technology	1996	1997	1998	1999	2000	Total
Hand-dug wells	900	900	1,050	1,050	1,050	4,950
Dug-Drilled well	900	900	1,050	1,050	1,050	4,950
HP shallow well	1,350	1,800	1,800	1,800	1,800	8,550
HP Deep well	1,120	1,200	1,760	1,760	1,760	7,600
Gravity fed schemes	30	30	30	30	30	150
Capital investment (rigs and equipment)	3,870	3,270	2,460	0	0	9,600
Total	8,170	8,100	8,150	5,690	5,690	35,800

Source : MRD

Table 3.27 MRD Budget (1/2)

	1996	1997	1998
Budget (Million Riel)			
Current Expenditure	2,198	1,579	1,310
Capital Expenditure (Foreign aid)	29	3,165	n.a.
Total	2,227	4,744	n.a.

Note: 1998 figure is tentative. Budget for capital expenditure is not yet determined.

Table 3.27 MRD Budget (2/2)

Expenses	In million Riels	Percentage	In US$
Salary and compensation			
Salary, compensation, and benefit of officials and staff	353	22%	141,200
Salary for temporary worker	7	0%	2,800
Payment for Cntractor	0	0%	0
Sub-Total	360	23%	144,000
Administrative expenses			
Expense on equipment and administrative management	931,9	59%	372,760
Travel expense	237.2	15%	94,880
	1169.1	74%	467,640
Public work			
Intervention in socio-culture sector			
Direct intervention	40	3%	16,000
Indirect intervention (assist village and community)	10	1%	4,000
Sub-Total	50	3%	20,000
Grand Total	1579.1	100%	631,640

Source : Ministry of Rural Development

Table 3.28 Main Source of Drinking Water

	Total	Urban	Rural
Piped Water	4.7	28.3	1.2
Tubed / Piped well	10.0	11.6	9.8
Dug Well	45.8	2.3	49.4
Spring, River, etc.	30.3	15.9	32.1
Bought	7.9	20.8	6.2
Other	1.3	0.4	1.3
Total	100.0	100.0	100.0

Source: Demographic Survey of Cambodia, 1996

Table 3.29 Status of the Hand Pumps Installed in the Previous Projects

Province	No.	Village Name	Population	Constructed by	Facility	Year	Hand Pump	Quantity	Quality	O&M Evaluation
Peri Urban	13	Chak Chrouk	276	UNICEF/MOH	Tube Well	1988	India MKII	good	salty	good,used for washing
	15	Srae Rocheak	394	UNICEF/MOH	Tube Well	1988	India MKII	good	salty	broken
	17	Beak Bak	224	UNICEF/MOH	Tube Well	1988	India MKII	good	salty	bad, used for all purpose
	18	Kab Srov Touch	485	UNICEF/MOH	Tube Well	1988	India MKII	good	salty	broken
	57	Pou Rolum	174	UNICEF/MOH	Tube Well	1990	India MKII	good	fair	good
Svay Rieng	122	Trapaing Thmor	604	OXFAM	Tube Well	1992	India MKII	good	fair	broken
	137	Kraham Kar	234	OXFAM	Tube Well	1985	India MKII	good	fair	broken
	138	Mream Thbong	353	PADEK	Dug Well	1993	No.6	poor	good	usable in wet season
	140	Pramath Pram	235	PADEK	Dug Well	1993	No.6	good	good	one dry up
	153	Kandal	1380	OXFAM	Tube Well	1984	India MKII	good	fair	removed
Takeo	181	Prech	1031	UNICEF/MOH	Tube Well	1990	India MKII	good	salty	broken
	188	Russey Chum	1247	UNICEF/MOH	Tube Well	1988	India MKII	good	iron,salty	one broken
	220	Prey Prum	625	UNICEF/MOH	Tube Well	1989	India MKII	good	fair	broken, 1995
	223	Dang Met	708	UNICEF/MOH	Tube Well	1989	India MKII	good	iron, salty	good, used dry season only
	237	Ang Roka	678	MRD	Tube Well	1995	India MKII	good	fair	broken, used for drinking
	254	Moeang Prachen	715	MRD	Tube Well	1993	India MKII	good	salty	operating, platform broken
Kandal	258	Svay Kandal	1519	UNICEF/MOH	Tube Well	1988	India MKII	good	salty	operating
	260	Prek Kouk	2028	MRD	Tube Well	1996	Tara	good	good	operating
	261	Chung Prek	2005	UNICEF/MOH	Tube Well	1989	India MKII	good	iron	broken
	262	Prek Ta Mem	2612	UNICEF/MOH	Tube Well	1989	India MKII	good	iron	operating
	314	Snao Lech	280	UNICEF/MOH	Tube Well	1986	India MKII	good	good	VWC
	321	Kul Krasna	281	UNICEF/MOH	Tube Well	1986	India MKII	good	salty	operating
Prey Venh	353	Ta Kreab	917	OXFAM	Combined Well	-	none	good	good	contaminated
	409	Kok Sampou	377	MRD	Tube Well	1995	Afridev	poor	salty	VWC is being discussed
	412	Toul Mean Koun	973	GRET	Combined Well	-	none	good	good	
Kg.Spue	428	Tum Noub	285	MRD	Tube Well	1995	Afridev	good	fair	broken, still new pump
	442	Sleng	378	UNICEF/MOH	Tube Well	1988	India MKII	good	fair	broken, repaired 3 times
	443	Sam Bonr	446	UNICEF/MOH	Tube Well	1988	India MKII	good	salty	good, repaired 2 times
	448	Toul	436	UNICEF/MOH	Tube Well	1988	India MKII	good	salty	good , repaired 2 times
	459	Chrak Khal	388	UNICEF/MOH	Tube Well	1988	India MKII	good	fair	broken

CHAPTER 4

GROUNDWATER INVESTIGATION

CHAPTER 4 GROUNDWATER INVESTIGATION

4.1 Hydrogeology

4.1.1 Hydrogeologic Features

The geology of the Study area is represented by metamorphic units, sedimentary units, igneous bodies, volcanic rocks, and sedimentary formations from the Precambrian through Quaternary in age. Hydrogeologic features of the Study area are characterized by occurrence of bedrock and Quaternary sediments (refer to Figure 4.1). The Study area can be divided into two (2) parts from the hydrogeologic features; one is the western side of the Mekong River - Bassac River where bedrock occurs in shallow depth, the other is the eastern side of the Mekong - Bassac Rivers where thick Quaternary sediments occur. A sharp linear structure of bedrock depth, that may be a fault, can be seen along the Bassac River based on the estimated bedrock depth map prepared from the results of resistivity soundings and test well drillings.

(1) Western Part of the Study Area

1) Bedrock

The provinces of Phnom Penh, Kompong Speu, Ta Keo, and the western part of Kandal belong to this area. The mountainous areas in the western part of the Study area belong to the Zones of Indosinian Folding (ESCAP, 1993). The metamorphic rocks of Precambrian to Silurian age (DC) are distributed in the southwestern perimeter of the Study area. This forms the anticlinorial zones in Indosinian fold-belts. The sedimentary rocks of mainly Carboniferous to Triassic (CT) such as sandstone and slate occur in the western part of Kompong Speu Province and some parts in Ta Keo Province. These sedimentary rocks compose the synclinorial zones in Indosinian fold-belts. The granitic intrusive rocks are widely distributed in the northwestern part of Kompong Speu Province. Small granitic bodies can be found in some parts of eastern Kompong Speu and Ta Keo Provinces.

2) Quaternary sediments

The thickness of Quaternary sediments in the western part is generally thinner than that in the eastern part. The thickness (= depth to bedrock) ranges from 9 to 76 m in Phnom Penh, 7 to 56 m in Ta Keo, and 12 to 36 m in Kandal. In Kompong Speu, the thickness of Quaternary sediments is within 30 m in most places, however, the thickness of 60 to 84 m is estimated at Treng Trayeung in the western Kompong Speu. According to the results of test well drillings, the Quaternary sediments consist of clay, sand, and gravel. Relatively hard laterite layers are found in the "Old Alluvium".

3) Aquifer

In the western part of the Study area, the bedrock and the Quaternary sediments could be aquifers. The bedrock in the area is mainly composed of sandstone and shale. Granitic rocks are reported to occur in the area, however, the test wells drilled by the Study did not encounter any granitic rocks. Gravel and sandy layers of the Quaternary sediments could be aquifers in the area, however, groundwater quality and quantity are generally poor. Groundwater in the aquifers is unconfined to semi-confined conditions.

(2) Eastern part of the Study Area

1) Bedrock

The provinces of Prey Veng, Svay Rieng, and the eastern part of Kandal belong to this area. There is an isolated granite mountain (Ba Phnom) in Prey Veng. The rest of the area shows flat topography, and bedrock was not detected by the test well drilling and the resistivity soundings.

2) Quaternary sediments

The thickness of Quaternary sediments in the area is estimated more than 160 m by the test well drilling and resistivity soundings. The Quaternary sediments consist of clay, silt, sand, and gravel layers. In the northern part, some lateritic soils are found in the "Old Alluvium" (Anderson, 1978).

3) Aquifer

In the eastern part of the Study area, sandy layers of the Quaternary sediments form a multiple aquifer system. There are several horizons of aquifer layers. The aquifers are generally productive and groundwater quality is better than the western part of the Study area. Groundwater in the aquifers is confined to semi-confined conditions.

4.1.2 Hydrogeologic Unit and Structure

(1) Hydrogeologic unit

Based on the hydrogeological investigations of the Study and some related literatures, hydrogeologic units in the Study area are identified as shown in Table 4.1. In this table, several hydrogeological terms are used based on the definitions by Todd (1980). A term "aquitard" means a saturated but poorly permeable stratum that impedes groundwater movement and does not yield water freely, such as sandy clay. A term "aquiclude" represents a saturated but relatively impermeable material that does not yield appreciable quantities of water to wells, such as clay. "Aquifuge" means a relatively impermeable formation neither containing nor transmitting water, such as solid granite.

Table 4.1 Hydrogeologic Units in the Study Area

Geologic Age		Geology	Hydrogeologic Unit	Remarks
Quaternary	Holocene	Alluvial deposits	Mainly aquiclude	
		Old river course deposits	Mainly aquiclude	
		Alluvial valley deposits	Mainly aquiclude	
		Flood plain deposits	Aquifer/Aquiclude	
	Pleistocene	Terrace & platform deposits	Aquifer/Aquitard	Old Alluvium (?)
		Higher platform deposits	Aquifer/Aquitard	
		Plateau basalt	Aquifer (?)	Not confirmed by Test well drilling
Tertiary	Pliocene			
Mesozoic~Pre-Cambrian		Volcano-sedimentary units Granitic rocks Sedimentary rocks Metamorphic rocks	Aquifer	Weathered rock Fractured rock
			Aquifuge	Fresh rock

Most of alluvial deposits, old river course deposits, alluvial valley deposits are hydrogeologically classified as aquiclude, because the deposits mainly consist of soft clay. Flood plain deposits are composed of both coarse materials and fine materials, therefore the layers behave as aquifer or aquiclude. Terrace & platform deposits and higher platform deposits, that is called as "Old Alluvium" by Anderson (1978), consist of a complex of gravel, sand, silt, and clay layers. The gravel and sandy layers form aquifers, but silt and clayey layers form aquitards.

Plateau basalt, which occurs in the northern part of Prey Veng, may be classified as an aquifer, but that is not confirmed by test well drilling in the Study. The rocks of Mesozoic to Precambrian age are called bedrocks. The bedrocks in the Study area consist of volcano-sedimentary units, granitic rocks, sedimentary rocks, and metamorphic rocks. Generally those fresh bedrocks are solid, massive and compact so that they are treated as an impermeable basement or a hydrogeologic basement. However, weathered rocks and fractured rocks can be classified as aquifers when they yield significant quantities of water to wells and springs.

(2) Hydrogeologic Structures

The main hydrogeologic structure in the Study area is the top surface of bedrock. To estimate bedrock depths at different places, geophysical survey was carried out by the Study. The Wenner's electrode configuration was employed for the resistivity sounding and its average investigation depth was about 160 m.

Figure 4.2 shows the estimated bedrock depth based on the results of resistivity sounding and test well drilling. The contour lines of depth to bedrock were drawn considering the bedrock exposures in and around the Study area. In the eastern part of the Study area, such as Prey Veng and Svay Rieng, the resistivity sounding cannot detect occurrence of bedrock within 160 m in depth, except the place near Ba Phnom in Prey Veng. No test wells drilled by the Study encountered bedrock in Prey Veng and Svay Rieng.

The estimated depths to bedrock in Phnom Penh range from 9 to 76 m below ground surface. In Ta Keo, the estimated bedrock depths range from 7 to 56 m. The depths to bedrock in northern Kandal are 12 to 36 m. However, the resistivity soundings carried out along the Bassac River in southern Kandal show the bedrock depth is more than 160 m. The test well drilled at Svay Kraom (village No.259) did not encounter bedrock within 72.0 m in depth. In Kompong Speu, the estimated depths to bedrock are shallow, ranging from 1 to 30 m in most places. However, the bedrock depths at Treng Trayeung in western Kompong Speu are estimated as 60 to 84 m. It is presumed that relatively thick sediments occur in such intermountain basins.

From the contour lines of estimated bedrock depth, a sharp linear structure of bedrock, that may be fault, can be seen along the Bassac River. It is predicted that this bedrock structure controls occurrence of groundwater and aquifer characteristics in the Study area.

4.1.3 Aquifer Constants

(1) Pumping Test

Pumping tests were carried out at the test wells to obtain aquifer constants. The list of the test wells is shown in Table 4.2. The tests were performed after installation of casing/screen pipes and well development. The pumping test comprises three (3) types of test; viz. step-drawdown test, continuous drawdown test, and recovery test. The step-drawdown test was conducted prior to the continuous pumping test. Four (4) steps with pumping duration of three (3) hours for each step were conducted in each step-drawdown test. The duration of continuous pumping test was 1,440 minutes (24 hours). The recovery test was started just after the continuous pumping test for a duration of 480 minutes (8 hours).

(2) Step-drawdown Test

The results of step-drawdown test at test wells are tabulated in Table 4.3. It is noted that step-drawdown tests could not be carried out at No.22 well (village No.426, Samrong Cheung Phnom) and No.24 well (village No.470, Treng Trayeung II), because the wells were abandoned due to no water. Specific capacity value of each step was obtained from the test, then aquifer loss coefficient (B) and well loss coefficient (C) were computed. Well efficiency of each pumping step was also calculated. The results show that the values of B and C in Phnom Penh, Ta Keo, northern Kandal, and Kompong Speu are higher than that in Svay Rieng and Prey Veng. The 4th step of step-drawdown test could not be performed at some wells in Phnom Penh, Ta Keo, and Kompong Speu due to large drawdown with relatively small pumping rate. The graphical interpretations of step-drawdown test are presented in **Chapter 2** of the **Supporting Report**.

(3) Continuous Pumping Test and Recovery Test

The results of continuous pumping test and recovery test are summarized in Table 4.4. The values of transmissivity are obtained by Cooper-Jacob method, Theis method, and Recovery method. The values of storativity are obtained by Cooper-Jacob method and Theis method. At No.20 well in Prek Phdau (village No.401), the step-drawdown test was carried out on June 20, 1997, but the submersible pump was broken after the test, then the contractor sent the pump to Phnom Penh for repairing. However, unfortunately, the war started and the pump could not be repaired. Because of the reason, a continuous pumping test and a recovery test were not carried out at No.20 well.

(4) Transmissivity

Figure 4.3 shows the distribution of transmissivity (T) by analyzing method and by province. It is understood that the distribution patterns of T by province are almost same by the analyzing method. Figure 4.4 shows a result of statistical analysis of T distribution by province. It is assumed that the T values have a logarithmic normal distribution. T values obtained from Recovery method, Cooper-Jacob method, and Theis method were used for the statistical analysis. A logarithmic average value (AVG) and a logarithmic standard deviation (STD) were obtained. A range between (AVG-STD) and (AVG+STD) could be treated as a reliable range of T distribution.

The *T* values of Svay Rieng show the highest among the six (6) provinces, having an AVG of 981.2 m^2/day. The reliable range of *T* distribution is from 522.6 to 1842.2 m^2/day. The *T* values in Prey Veng also show higher in the Study area, having AVG value of 283.1 m^2/day. The reliable range of *T* distribution is from 125.6 to 638.3 m^2/day. The *T* values in Kandal take a wide range of distribution. Although the AVG value is 9.69 m^2/day, but the reliable range is from 0.31 to 299.5 m^2/day. The higher *T* values are obtained from southern Kandal.

The *T* values of northern Kandal, Phnom Penh, Ta Keo, and Kompong Speu are relatively low. The AVG values of Ta Keo, Kompong Speu and Phnom Penh are 4.29, 1.62, and 0.82 m^2/day, respectively. The reliable range of T distribution in Ta Keo is from 0.87 to 21.15 m^2/day. In Kompong Speu, the reliable range is from 0.27 to 9.59 m^2/day. The AVG value and the reliable range of *T* values in Peri-Urban Areas of Phnom Penh show the lowest among the six (6) provinces. The reliable range is from 0.25 to 2.67 m^2/day.

Figure 4.5 shows the distributions of *T* values by aquifer geology. The Aquifer geology was identified from the result of test well drilling. Logarithmic average (AVG) and logarithmic standard deviation (STD) values were obtained by the statistical analysis. It is clearly shown that the Quaternary aquifers have higher *T* values; the AVG value is 100 to 1,000 times higher than that of bedrock aquifers. The reliable range of *T* in Quaternary aquifers is from 236.6 to 1,548 m^2/day.

The bedrock aquifers can be classified into four (4) types; “Quaternary + Sandstone”, “Sandstone”, “Sandstone + Shale”, and “Shale”. The “Quaternary + Sandstone” type means the screen pipe(s) was installed at sandstone and Quaternary sediments portions. There are three (3) test wells in the “Quaternary + Sandstone” type. The AVG value is 0.68 m^2/day and the reliable range is from 0.23 to 2.00 m^2/day, showing the lowest T distribution among the bedrock aquifers. The reason is that those Quaternary sediments consist of clayey materials so that the T values may reflect the aquifer productivity of sandstone. The “Sandstone” aquifers have an AVG value of 1.69 m^2/day and the reliable T range is from 0.46 to 6.29 m^2/day. Although some screen pipes are located at weathered sandstone, the distribution range of T is not significantly wide. Although there are two (2) test wells in “Sandstone + Shale” aquifer type, the T values seem to be higher than that of “Sandstone” aquifer. The AVG value is 5.68 m^2/day and the reliable range is from 2.35 to 13.72 m^2/day. The data of “Shale” type are also inadequate, but the distribution range is wider, from 0.34 to 35.72 m^2/day.

(5) Hydraulic conductivity

Hydraulic conductivity can be obtained if thickness of the aquifer is known. In the Study, it was assumed that thickness of the aquifer is a total length of the screen pipes, then apparent hydraulic conductivity (k) values were computed by the following equation:

$$k=T/b$$

where b is a total length of screen pipes. The apparent hydraulic conductivity describes average hydraulic conductivity of the aquifer materials of the screen portions. The apparent hydraulic conductivity values are useful for evaluating aquifer permeability as well as designing well structure. The k values were computed by using T values obtained from Recovery method, Cooper-Jacob method, and Theis method.

Figure 4.6 shows the distributions of k values by aquifer geology. The Aquifer geology was identified from the result of test well drilling. Logarithmic average (AVG) and logarithmic standard deviation (STD) values were obtained by the statistical analysis.

The Quaternary aquifers have an AVG value of 33.8 m/day. The reliable range of k values is from 12.4 to 92.2 m/day. On the contrast, k values of bedrock are lower, ranging from 0.015 to 2.237 m/day. Among the bedrock aquifers, “Sandstone + Shale” aquifer type tends to have higher k values than “Sandstone” type aquifer. The k values of “Shale” aquifer type take a wider range of distribution. According to the observation of cutting samples, some shale has many small cracks. It is presumed that the intensity of weathering and occurrence of cracks may affect permeability of shale significantly.

(6) Storativity

Storativity (or storage coefficient, S) values were obtained from Cooper-Jacob method and Theis method. The obtained values are presented in Table 4.4. It can be seen that S values are very small when T values are higher. However, it is known that large changes in S cause comparatively small changes in T.

(7) Specific capacity map

Values of specific capacity (Sc) can be easily obtained from pumping rate and final drawdown of the continuous pumping test. Sc values are used not only to evaluate well performance but also to evaluate aquifer productivity.

The distribution map of Sc is prepared as shown in Figure 4.7. The Sc values more than

100 m^2/day are found in Svay Rieng, central to eastern part of Prey Veng, and southern Kandal. The *Sc* values of Phnom Penh, northern Kandal, and Kompong Speu range from 0.5 to 3.8 m^2/day.

(8) Average transmissivity map

The distribution map of average transmissivity was prepared as shown in Figure 4.8. For each test well, a logarithmic average was computed from the *T* values obtained from the three (3) methods. It is clearly seen that the *T* values are higher in Svay Rieng and Prey Veng. On the other hand, *T* values are lower in the western side of the Bassac River. It is concluded that aquifer productivity in the eastern part of the Study area is higher, whereas aquifer productivity in the western part is lower.

4.2 Groundwater Levels

4.2.1 Groundwater Contour

Groundwater levels of existing wells have been measured during a period from February 1997 to March 1997. A total number of 181 wells were measured during the period. The numbers of measured dug wells and combined wells are 102 and 68, respectively. It is difficult to measure groundwater level of the tube well in which hand pump is installed, the Study team measured 11 tube wells which hand pumps were broken or removed.

The results of groundwater level measurements as well as the results of water quality measurements are tabulated in the **Supporting Report**. Figure 4.9 shows locations of measured wells.

The measured groundwater levels are shown in Figures 4.10 and 4.11 by province and by well type. Generally the groundwater levels measured at dug wells show shallow aquifer’s water level because the well depths of most dug wells range from 5 to 10 m. On the other hand, groundwater levels in tube wells show deeper aquifer’s water level because the well depths of most tube wells are 30 to 40 m. The combined well, which is composed of dug well and bore hole, show a mixed water level of shallow water level and deeper water level.

In Peri-Urban Areas of Phnom Penh, groundwater levels of 13 wells out of 38 wells show 3 to 4 m below ground elevation. The groundwater levels of most tube wells also show 3 to 4 m from ground elevation. In Svay Rieng Province, most dug wells and combined wells have shallow groundwater levels ranging from 1 to 3 m. The distribution of groundwater levels in

Ta Keo Province is irregular, however, the water levels of combined wells seem to be deeper than those of dug wells. In Kandal Province, the groundwater levels of dug wells are distributed in 1 to 3 m, however, some dug wells and combined wells have deeper water levels of 5 to 6 m below ground surface. About 40 % of measured wells in Prey Veng show 4 to 5 m in groundwater level. In Kompong Speu, 7 wells out of 12 measured wells show groundwater level between 2 and 3 m from ground elevation.

Figure 4.12 shows the distribution of groundwater level measured at dug wells. The areas having groundwater levels deeper than 4 m can be seen in Phnom Penh, Kandal, Ta Keo, and Prey Veng Provinces. On the other hand, shallow groundwater levels within 2 m from ground surface are distributed in some part of Peri-Urban Areas, western part of Ta Keo, and eastern part of Svay Rieng.

The distribution pattern of groundwater levels measured at combined wells is similar to that of dug well as shown in Figure 4.13. The areas having water levels deeper than 4 m below ground elevation distributed in central Kandal, Prey Veng, and northern Svay Rieng. The water levels in eastern Svay Rieng and a part of Ta Keo show less than 2 m.

Compared with dug wells and combined wells, the number of measured tube wells is limited due to difficulties to remove installed pump. However, Figure 4.14 may suggest that the water levels of about 30 m-zone aquifer have similar distribution pattern to those of shallower aquifers.

4.2.2 Seasonal Change

Groundwater levels of existing wells had been measured since February 1997. The monthly base measurements continued until November 1997. Twenty-six (26) wells were selected as monthly monitoring wells in the First Stage of the Study. Most wells are dug well or combined well.

The results of groundwater level measurements as well as the results of water quality measurements are tabulated in the **Supporting Report**. Figures 4.15 and 4.16 show the changes in groundwater levels by province. The minimum groundwater levels are observed in June or July, and the maximum groundwater levels are observed in October or November.

Seasonal changes in groundwater are higher in Kandal, parts of Phnom Penh and Ta Keo, and Kompong Speu. On the other hand, the changes in Svay Rieng and Prey Veng are relatively small. The groundwater levels along the Bassac River show steep rise from June to July in

1997. It is presumed that those groundwater levels are influenced by the water level changes of Bassac River.

Figure 4.17 shows the distribution of groundwater levels measured in June 1997. The depths to the groundwater level are more than 6 m in central Kandal and northern Ta Keo. Figure 4.18 shows the groundwater levels measured in October 1997. The groundwater levels near the Mekong and the Bassac Rivers become shallow, showing less than 2 m below ground surface. The relatively deep groundwater levels are observed in Prey Veng and northern Ta Keo. Figure 4.19 shows the difference of groundwater levels between June 1997 and October 1997. The fluctuation of groundwater level is larger in the area along the Mekong and Bassac Rivers. On the other hand, the seasonal fluctuation of groundwater levels is relatively small in Prey Veng, Svay Rieng, and parts of Ta Keo and Kompong Speu.

4.3 Groundwater Quality

4.3.1 Field Survey

The Study team conducted existing wells' water quality survey at 284 wells in and around the Study area. Out of the 284 wells, the numbers of investigated dug wells, combined wells, and tube wells were 86, 66, and 132, respectively. Detailed results of the water quality measurements are tabulated in **Chapter 3** of the **Supporting Report**. Location of the measured wells is shown in Figure 4.9.

During the existing well survey, the following water quality parameters were measured at each well:

- Groundwater Temperature
- Electric Conductivity (EC)
- pH
- Oxidation-Reduction Potential (ORP)

(1) Electric Conductivity (EC)

Figures 4.20 and 4.21 show the distribution of EC values by province and well type. From the graphs, it is understood that the values of EC take different ranges by province and well type. Generally, EC values in Svay Rieng and Prey Veng Provinces are lower than that in the western provinces of the Study area.

In Peri-Urban Areas in Phnom Penh, 13 wells out of 48 wells fall in the EC range from 100 to 149 mS/m*. The EC values of dug wells are distributed in wide ranges from 10 to 499 mS/m. The water quality of Svay Rieng Province is better than that of Peri-Urban Areas from the view point of EC values. The EC values of 53 wells out of 64 wells show smaller than 50 mS/m. In Ta Keo Province, EC values are higher than other five (5) provinces. Although some dug wells show lower EC values, water quality of tube wells and combined wells seems to be worse than that of dug wells. In Kandal Province, most EC values fall into 50 to 149 mS/m. In Prey Veng Province, about 2/3 of wells show less than 50 mS/m in EC. It can be seen that water quality of tube wells and combined wells is better than that of dug wells. The distribution pattern of EC values in Kompong Speu Province is similar to that in Kandal Province.

Figure 4.22 shows the distribution of EC values measured at dug wells. The areas having EC values more than 150 mS/m occur in Peri-Urban Areas, Kandal, Ta Keo, and central part of Prey Veng Province. The better water quality areas can be seen in northwestern part of Ta Keo Province and central part of Svay Rieng Province.

The EC distribution measured at combined wells is shown in Figure 4.23. Eastern part of Ta Keo Province and Central part of Prey Veng Province show EC values more than 150 mS/m. The EC values in northern to eastern part of Svay Rieng Province are less than 20 mS/m.

Figure 4.24 shows the distribution of EC values measured at tube wells. It can be seen that the areas located in the right bank of the Mekong River have higher EC values more than 200 mS/m. On the other hand, most parts of Svay Rieng and Prey Veng Provinces show less than 50 mS/s in EC.

(2) pH

Figures 3.25 and 3.26 show the distribution of pH values by province and well type. From the graphs, it is understood that the values of pH take different ranges by province and well type. Generally, pH values in Svay Rieng and Prey Veng Provinces are lower than that in the provinces in western sector. By well type, shallow groundwater shows more acidic than that of deeper aquifers.

In Peri-Urban Areas in Phnom Penh, 42 wells out of 47 wells fall in the pH range from 6.00 to 7.49. The pH values of dug wells are distributed in wide ranges from 4.86 to

* Unit conversion from (µS/m) to (mS/m) is; 1 mS/m = 10 µS/m

8.01. The groundwater quality of Svay Rieng Province is more acidic than that of Peri-Urban Areas. The pH values of 63 wells out of 64 wells show smaller than 7.00. It can be said that the pH values of dug wells are more acidic than those of combined and tube wells. In Ta Keo Province, pH values take wide range from 5.00 to 7.99. In Kandal Province, most pH values fall into 7.00 to 8.39, showing the quality is more alkaline than other five (5) provinces. In Prey Veng Province, about 3/4 of wells show smaller than 7.00 in pH. The pH values in Kompong Speu takes a range from 5.50 to 7.49.

Figure 4.27 shows the distribution of pH values measured at dug wells. The northeastern marginal areas of the Study area have low pH values. The pH values at western Ta Keo Province and a part of Kompong Speu Province also show low pH values less than 5.00. On the contrast, pH values in northern and southern Kandal Province are higher than 7.00.

The pH distribution measured at combined wells is shown in Figure 4.28. Similar to the pH distribution of dug wells, pH values in northeastern Prey Veng Province and northeastern part of Svay Rieng Province near Vietnamese border show lower pH values less than 6.00. The wells in the western part of Ta Keo Province also show lower pH values. The area having more than 7.00 in pH can be seen only in Peri-Urban Areas.

Figure 4.29 shows the distribution of pH values measured at tube wells. The distribution pattern of pH is rather complicated compared with that of dug wells and combined wells. It is still observed that lower pH values area exist in the northeastern part of Prey Veng Province. However, the areas having alkaline water distribute more widely in Peri-Urban Areas and in Kandal Province.

(3) Oxidation-Reduction Potential (ORP)

The oxidation-reduction potential (ORP) is one of the parameters to indicate groundwater quality. Barcelona et al. (1989) studied the oxidation-reduction conditions in aquifers. According to the Study, ORP values decrease with depth. A positive value of ORP expresses that the water is under oxidation condition, whereas a negative ORP value indicates that the water is under reduction condition. In addition, Barcelona et al. (1989) pointed out that when ORP value decreases, the concentration of ferrous iron Fe^{2+} increases. Therefore, the Study team decided to measure ORP values as many as possible to understand oxidation-reduction conditions of groundwater.

Figures 4.30 and 4.31 show the distribution of ORP values by province and well type.

From the graphs, it is understood that the values of ORP take different ranges by province and well type. Generally, ORP values of tube wells are lower than that of dug wells and combined wells. By province, ORP values in Kandal Province is significantly lower than those in other provinces. This phenomenon may be correlated with the geologic conditions of the area. Because it is known that the groundwater in clayey Alluvial deposits used to show reduction conditions in Japan (Shimada, 1996).

The ORP values of dug wells and combined wells in Svay Rieng and Prey Veng are higher than those of other four (4) provinces. Because the pH values of dug wells and combined wells in the two (2) provinces show lower than the other provinces. The relationship between ORP and pH will be discussed in the following section.

Figure 4.32 shows the distribution of ORP values measured at dug wells. The northeastern marginal areas of the Study area have high ORP values more than +200 mV. The ORP values at Kandal and Ta Keo Provinces are smaller than +50 mV. However, most dug wells in the Study area show positive values of ORP.

The ORP distribution measured at combined wells is shown in Figure 4.33. Similar to the ORP distribution of dug wells, values of ORP in northeastern Prey Veng Province and northeastern part of Svay Rieng Province near Vietnamese border show more than +200 mV. However, negative ORP values are observed in Peri-Urban Areas and central Kandal Province.

Figure 4.34 shows the distribution of ORP values measured at tube wells. The distribution pattern of ORP is rather different from the patterns of dug wells and combined wells. Especially in central Kandal Province, it is noted that very low negative values below -150 mV are observed. The areas having negative values in ORP can be seen in Kandal, Ta Keo, Peri-Urban Areas, Prey Veng, and some parts of Kompong Speu and Svay Rieng Provinces.

(4) ORP-pH Relation

It was already mentioned that if the ORP value decreases, the concentration of Fe^{2+} increases. According to the filed survey results, iron smell is felt when ORP value shows negative value. Many tube well users who feel iron smell from tube well water keep the water at least one (1) night in a jar so as to decrease iron smell. It may be effective to oxidize the water and subsequently to reduce iron smell.

Figure 4.35 shows ORP-pH relation of groundwater in the Study area. The graph indicates that ORP values decrease with increasing pH values. Most tube well samples having negative values in ORP are plotted in a range from 6.2 to 7.2 in pH. Similar relationship is presented by Shimada (1996) based on the analysis of arsenic-containing groundwater in southern part of Fukuoka Prefecture in Kyushu Island, western part of Japan. Shimada (1996) suggested that shallow groundwater samples are plotted in the zone of $Fe(OH)_3$, however, the samples taken from deeper aquifers show reduction environment, being plotted in the zone of Fe^{2+}. Shimada (1996) predicted that if the groundwater environment becomes reduction condition, the arsenic absorbed in $Fe(OH)_3$ may be released in groundwater with changing from $Fe(OH)_3$ to Fe^{2+}.

So far there are no data about arsenic concentration of groundwater in the Study area. The Study team shall collect water samples from 25 new test wells and 50 existing wells to analyze detail chemical composition including arsenic of groundwater during the next field survey period.

Figure 4.36 shows the ORP-pH relations by province and by well type. It is obvious that the patterns of ORP-pH plots differ from province to province. In the provinces of Svay Rieng and Prey Veng are characterized by higher ORP values and low pH values. The samples of Kompong Speu and Ta Keo Provinces are plotted in smaller zones. The plots of Kandal Province is characterized by negative values of ORP and higher values of pH.

(5) Seasonal Changes of EC, pH, and ORP

As mentioned in **Section 4.2.2**, groundwater levels and water quality of existing wells have been monitored at twenty-six (26) wells since February 1997. The monthly base measurements continued until November 1997. Parameters of electric conductivity (EC), pH, and oxidation-reduction potential (ORP) were measured at the well site. The results are tabulated in **Chapter 3** of the **Supporting Report**.

Figure 4.37 shows the changes in EC in Phnom Penh, Svay Rieng, and Ta Keo. Similarly, Figure 4.38 shows the changes in EC in Kandal, Prey Veng, and Kompong Speu. The groundwater of dug wells in Phnom Penh, Ta Keo, and Prey Veng show that the EC become high in rainy season. However, some dug wells in Kandal and Kompong Speu show that the EC values become low in rainy season. The changes in EC of combined wells are relatively small compared with that of dug wells. Some wells show that the EC values are high in rainy season, but some other wells tend to have lower EC in rainy season.

Figures 4.39 and 4.40 show the changes in pH by province. Most wells show that pH values become lower in rainy season. But some dug wells show that pH value increase in latter part of rainy season.

Figures 4.41 and 4.42 show the changes in ORP by province. It is obvious that ORP values become high in rainy season. This may indicate that the oxidized water from rainfall or surface water recharge to the groundwater during rainy season. Therefore, is it presumed that the ORP values will decline after rainy season.

4.3.2 Laboratory Test

Groundwater samples for chemical analysis were collected from 54 existing wells and 24 test wells in May and June 1997. Table 4.5 shows the results of laboratory tests. The WHO Guideline Values for Drinking Water is also shown in the table. Measured values exceeding the guideline values are indicated with colored shadow.

(1) Trilinear Diagram

Based on the results of chemical analysis, several trilinear diagrams were prepared to understand the chemical properties of groundwater in the Study area. Figures 4.43 to 4.48 show the trilinear diagrams of Phnom Penh, Svay Rieng, Ta Keo, Kandal, Prey Veng, and Kompong Speu by well type.

The most groundwater taken from combined wells and tube wells in Phnom Penh shows Na-HCO_3 water. One water sample from dug well shows Na-Cl water. In Svay Rieng, most water samples are dominated by Na in cations, however, the anion type is divided into HCO_3 type, HCO_3+Cl type, and Cl type. But, as shown in the diamond-shape diagram, the total dissolved ions are small in any types. In Ta Keo, about 60 % of the samples show Na-Cl water. Most samples taken from Kandal show Ca+Mg+Na - HCO_3 water. In Prey Veng, cation type is Na to Ca+Mg+Na type the anion type is divided into HCO_3 type Cl. In Kompong Speu, most samples are dominant in Ca and HCO_3.

Figure 4.49 shows the trilinear diagram of groundwater taken from the test wells. Most samples are plotted in the lower-left domain of the diamond-shape diagram, characterized by Na or Ca+Mg+Na type in cations and HCO_3 type in anions. However, samples of Nos. 222 and 181 of Ta Keo, 406 of Prey Veng, and 71 of Phnom Penh show different chemical composition. The Cl ion is dominant anion in the samples 222 and 181.

(2) Stiff Diagram

Several Stiff diagrams were drawn based on the results of laboratory chemical analysis. Figure 4.50 shows the Stiff diagram of existing dug wells. It is obvious that the quality of groundwater in Svay Rieng and Prey Veng is better than that of western part of the Study area. In the western part of the Study area, the samples of No.59 in Ta Keo and No.94 in Kompong Speu are characterized by Na-Cl type water, but the samples of southern Kandal and central Kompong Speu are characterized by rich HCO_3 in anions.

The similar difference in chemical composition between eastern part and western part of the Study area can be seen in existing combined wells as shown in Figure 4.51. The area of Stiff pattern in Prey Veng and Svay Rieng is very much smaller than that of Ta Keo, Kandal, and Phnom Penh.

The size of Stiff patterns is generally larger in tube well water than those of dug well and combined well water as shown in Figure 4.52. However, the quality of groundwater in Prey Veng and Svay Rieng is better than that in the right side of the Mekong River.

Figure 4.53 shows the Stiff diagram of groundwater taken from the test wells. The groundwater of Ta Keo is characterized by high concentration of Cl. It can be said that the groundwater quality of test wells in Ta Keo, Kandal, and Phnom Penh is poorer than that in Svay Rieng, Prey Veng, and Kompong Speu.

4.3.3 Comparison with WHO Guidelines

The results of the laboratory chemical analysis were compared with the Guideline Values for Drinking Water by WHO (1993). Figures 4.54 to 4.62 show the location of measured existing wells and areas having more than the guideline value for the specified chemical parameter.

(1) Existing Wells

1) Na (Figure 4.54)

The guideline value of Na is 200 mg/L. The numbers of wells having more than the guideline value in dug wells, combined wells, and tube wells are 2, 2, and 5, respectively. In dug wells, the groundwater having more than 200 mg/L in Na was found from Ta Keo and Kompong Speu. In combined wells, high concentrations of Na were found from Phnom Penh and Ta Keo. In tube wells, high concentrations of Na were found from Phnom Penh, Kandal, and Ta Keo.

2) NH_4 (Figure 4.55)

The guideline value of NH_4 is 1.5 mg/L. The numbers of wells having more than the guideline value in dug wells, combined wells, and tube wells are 2, 2, and 4, respectively. In dug wells, the groundwater having more than 1.5 mg/L in NH_4 was found from Svay Rieng and Kompong Speu. In combined wells, high concentrations of NH_4 were found from Phnom Penh and Prey Veng. In tube wells, high concentrations above the guideline value were found from Ta Keo and Svay Rieng.

3) Fe (Figure 4.56)

The guideline value of Fe is 0.3 mg/L. The numbers of wells having more than the guideline value in dug wells, combined wells, and tube wells are 10, 7, and 18, respectively. In dug wells, the groundwater having more than 0.3 mg/L in Fe is found from most of the Study area. The maximum concentration of Fe as 8.3 mg/L was found from Kompong Speu. In combined wells, high concentrations of Fe were found from Phnom Penh, Svay Rieng, Ta Keo, Kandal, and Prey Veng. The maximum concentration of 7.4 mg/L was found from Phnom Penh. In tube wells, high concentrations of Fe were found from wide areas. The concentrations particularly in Svay Rieng and Ta Keo are higher than that in dug wells and combined wells. The maximum concentration of Fe is 17.0 mg/L, which was found from Ta Keo.

4) Mn (Figure 4.57)

The guideline value of Mn is 0.1 mg/L. The numbers of wells having more than the guideline value in dug wells, combined wells, and tube wells are 4, 1, and 12, respectively. In dug wells, the groundwater having more than 0.1 mg/L in Mn was found from Phnom Penh, Svay Rieng, Prey Veng, and Kompong Speu. In combined wells, the concentration of 0.97 mg/L was found from Ta Keo. In tube wells, high concentrations above the guideline value were found from Phnom Penh, Svay Rieng, Ta Keo, and Kandal. The maximum concentration of Mn as 2.0 mg/L was found from Ta Keo.

5) Cl (Figure 4.58)

The guideline value of Cl is 250 mg/L. The numbers of wells having more than the guideline value in dug wells, combined wells, and tube wells are 2, 1, and 6, respectively. In dug wells, the groundwater having more than 250 mg/L in Cl was found from Ta Keo and Kompong Speu. In combined wells, the concentration of 1,210 mg/L was found from Ta Keo. In tube wells, high concentrations above the guideline value were found from Ta Keo and Kandal. The maximum concentration of 1,265 mg/L was found from Ta Keo.

6) SO_4 (Figure 4.59)

The guideline value of SO_4 is 250 mg/L. The numbers of wells having more than the guideline value in dug wells, combined wells, and tube wells are 0, 0, and 2, respectively. In dug wells and combined wells, the groundwater having more than 250 mg/L in SO_4 was not found from the Study area. In tube wells, high concentrations above the guideline value were found from Ta Keo and northern perimeter of Kandal. The maximum concentration of 520 mg/L was found from Ta Keo.

7) NO_3 (Figure 4.60)

The guideline value of NO_3 is 50 mg/L. The numbers of wells having more than the guideline value in dug wells, combined wells, and tube wells are 0, 0, and 2, respectively. In dug wells and combined wells, the groundwater having more than 50 mg/L in NO_3 was not found from the Study area. In tube wells, high concentrations above the guideline value were found from Kompong Speu and northern perimeter of Kandal. The maximum concentration of 306 mg/L was found from Kompong Cham, located at 1 km from Kandal - Kompong Cham boundary.

8) F (Figure 4.61)

The guideline value of F is 1.5 mg/L. The numbers of wells having more than the guideline value in dug wells, combined wells, and tube wells are 0, 1, and 3, respectively. In dug wells, the groundwater having more than 1.5 mg/L in F was not found from the Study area. In combined wells, high concentration of F was found from Phnom Penh. In tube wells, high concentrations above the guideline value were found from Kandal, Ta Keo, and Kompong Speu. The maximum concentration of F as 6.63 mg/L was found from northwestern Kandal.

9) TDS (Figure 4.62)

The guideline value of TDS is 1,000 mg/L. The numbers of wells having more than the guideline value in dug wells, combined wells, and tube wells are 1, 2, and 5, respectively. In dug wells, the groundwater having more than 1,000 mg/L in TDS was found from Kompong Speu. In combined wells, high concentration of TDS were found from Phnom Penh and Ta Keo. In tube wells, high concentrations above the guideline value were found from Kandal and Ta Keo.

10) As (Figure 4.63)

The guideline value of As is 0.01 mg/L. The wells having more than the guideline value were not found from the Study area. However, the maximum As concentration of 0.004 mg/L was found from a dug well in Ta Keo. The As concentration of another tube well in Ta Keo shows 0.003 mg/L.

(2) Test Wells

Figure 4.64 shows the distributions of Na, NH_4, and Fe in groundwater taken from the test wells. The high Na concentrations above the guideline value (= 200 mg/L) were found from 7 wells in Phnom Penh, Kandal, and Ta Keo. The maximum Na concentration of 625 mg/L was found from BH-071 well in Phnom Penh.

The high NH_4 concentrations above the guideline value (= 1.5 mg/L) were found from 7 wells in Svay Rieng, Ta Keo, and Kandal. The maximum NH_4 concentration of 2.9 mg/L was found from BH-113 well in Svay Rieng.

The high Fe concentrations above the guideline value (= 0.3 mg/L) were found from 13 wells in Svay Rieng, Prey Veng, Ta Keo, and Kompong Speu. The maximum Fe concentration of 5.0 mg/L was found from BH-162 well in Svay Rieng.

Figure 4.65 shows the distributions of Mn, Cl, and SO_4 in groundwater taken from the test wells. The high Mn concentrations above the guideline value (= 0.1 mg/L) were found from 15 wells in Svay Rieng, Prey Veng, Ta Keo, and Kandal. The maximum Mn concentration of 2.8 mg/L was found from BH-181 well in Ta Keo.

The high Cl concentrations above the guideline value (= 250 mg/L) were found from 4 wells in Phnom Penh, Ta Keo, and Prey Veng. The maximum Cl concentration of 2,130 mg/L was found from BH-222 well in Ta Keo.

The high SO_4 concentrations above the guideline value (= 250 mg/L) were found from one (1) well in Phnom Penh. The SO_4 concentration of 383 mg/L was found from BH-071 well.

Figure 4.66 shows the distributions of NO_3, F, and TDS in groundwater taken from the test wells. The high NO_3 concentrations above the guideline value (= 0.1 mg/L) were found from one (1) well in Phnom Penh. The NO_3 concentration of 267 mg/L was found from BH-071 well.

The high F concentrations above the guideline value (= 1.5 mg/L) were found from 2 wells in Phnom Penh and Kandal. The concentrations of 2.33 mg/L were found from BH-056 well in Phnom Penh and BH-322 well in Kandal.

The high TDS concentrations above the guideline value (= 1,000 mg/L) were found from 5 wells in Phnom Penh, Ta Keo, and Kandal. The maximum TDS concentration of 3,462 mg/L was found from BH-222 well in Ta Keo.

Figure 4.67 shows the distribution of As in groundwater taken from the test wells. No wells have As concentration above the guideline value (= 0.01 mg/L). The As concentration of 0.001 mg/L was detected in Svay Rieng, Kandal, Ta Keo, and Kompong Speu.

4.3.4 Water Quality in 1999

Groundwater samples of test wells were collected in March 199, then analyzed in a laboratory to investigate the latest groundwater quality conditions. The laboratory is the same one where previous groundwater samples were analyzed. The results of laboratory analysis were shown in Table 4.6. Based on the results, a trilinear diagram of test well groundwater was prepared as shown in Figure 4.68.

Compared with the trilinear diagram shown in Figure 4.49, which was drawn by the data of 1997, it is recognized that there is no significant change in chemical composition of groundwater. However, following differences can be found by comparing the values presented in Table 4.6 with that in Table 4.9.

(1) Fe Concentration

Changes of Fe concentration in the test wells are shown in Table 4.7. Out of 24 groundwater samples from the test wells, 13 samples exceeded the WHO guideline value of 0.3 mg/L in 1997. In 1999, 9 samples were exceeded the guideline value. There are some regional characteristics of changes in Fe concentration. In Svay Rieng, Fe concentrations have increased significantly except BH-175 well. The highest Fe concentration of 10.0 mg/L was measured at BH-139 well; it is 7.5 mg/L higher than the previous analysis. It is also found that the water of BH-113 well shows 9.6 mg/L.

Fe concentrations in BH-181 well and BH-242 well have decreased, showing below the WHO guideline value in 1999. But Fe concentration of BH-222 well increased from 0.10 to 1.00 mg/L. In Kandal, Fe concentration of BH-322 well increased from 0.13 mg/L in 1997 to 2.50 mg/L in 1999.

In Prey Veng, BH-401 well shows significant increase of Fe concentration, from 0.88 mg/L in 1997 to 7.6 mg/L in 1999. But the concentration at BH-406 well has decreased from 5.2 mg/L to 4.5 mg/L. The concentrations of BH-367 and BH-388 decreased below the guideline value.

The Fe concentrations of BH-454 well in Kompong Speu and BH-25/1 well in Ta Keo decreased below the guideline value.

(2) Cl concentration

Table 4.8 shows changes of Cl concentration in the test wells. The number of samples exceeded the WHO guideline value (= 250 mg/L) is four (4) both in 1997 and 1999. The Cl concentrations in Phnom Penh and Svay Rieng do not show significant changes.

In Ta Keo, Cl concentrations of BH-181 well increased from 1,690.0 mg/L to 2,132.0 mg/L. The concentration of BH-222 well also increased from 2,130.0 mg/L to 2,245.0 mg/L.

The Cl concentrations of all the test wells in Kandal have decreased. In Prey Veng, there are no significant changes in Cl concentration. The Cl concentration of BH-454 well in Kompong Speu has increased from 135.0 mg/L to 222.0 mg/L.

4.4 Water Balance Analysis

The climate in the Study area is tropical, dominated by seasonal winds or monsoons. The wet southwest monsoon arrives about May with heavy clouds and thundershowers. The southwest monsoon usually continues until November, with rains occurring almost daily during this season. The dry northeast monsoon normally starts from November then continues until April. During a period from November to February, the weather in the Study area is generally dry and relatively cool. However, from March until the onset of the southwest monsoon in May, the Study area experiences very hot weather.

4.4.1 Rainfall

The Study team has collected daily rainfall data at Phnom Penh, Svay Rieng, Ta Keo, Kandal, Prey Veng, and Kompong Speu for a period from 1985 until 1995 from Department of Meteorology. To understand the general conditions of rainfall, mean monthly values and long term records compiled by Mekong Secretariat (1994) were also used.

The central part of the Study area including Phnom Penh, Kandal, Ta Keo, and a part of

Kompong Speu has relatively small annual rainfall less than 1,300 mm/year. The rainfall in Svay Rieng and the western part of Kompong Speu is more than 1,800 mm/year.

The monthly rainfall during May to November is obviously bigger than that in the dry season. There are two (2) peaks of monthly rainfall during the rainy season; one is the latter part of the rainy season (September and October), and the other is the beginning of the rainy season (May). The rainfall in October and September exceeds 200 mm at all stations. Another peak of monthly rainfall occurs in May at Phnom Penh, Kandal, Prey Veng, and Kompong Speu, however, the peak is not clear in Svay Rieng and Ta Keo. The monthly rainfall in dry season is considerably smaller throughout the Study area. Particularly, the rainfall in January and February ranges only from 5 to 15 mm/month.

4.4.2 Evaporation

Evaporation had been measured at three (3) meteorological stations around the Study area. The data source is "Le Climat du Cambodge" (Khiou-Bonthonn, 1965) and which was summarized by Mekong Secretariat (1994).

The evaporation values are higher than rainfall during the dry season from December to April. The highest evaporation is recorded in March at all stations. At Phnom Penh, the evaporation in March and April is 170.5 mm/month and 150.0 mm/month, respectively. From May to November in rainy season, the monthly evaporation ranges between 69.0 and 105.4 mm/month. The mean annual evaporation and rainfall at Phnom Penh are 1,347.8 mm and 1,370.7 mm, respectively.

At Svay Rieng, the evaporation in March and April is 155.0 mm/month and 135.0 mm/month, respectively. From May to November in rainy season, the monthly evaporation ranges between 71.3 and 93.0 mm/month. The mean annual evaporation and rainfall are 1,222.3 mm and 1,778.1 mm, respectively.

4.4.3 Water Balance

Based on the above data, the water balance in the Study area can be computed with reasonable accounting from the following water balance equation:

$$P = Int + Rof + AP + ATP + SM + RE \qquad (4.4.1)$$

where

P: rainfall
Int: interception loss
Rof: surface runoff
AP: actual evaporation from soil surface
ATP: actual evapotranspiration
SM: soil moisture recharge
RE: groundwater recharge

In equation (3.1), the rainfall could be measured directly, but the rest of the components are difficult to be measured in the field satisfactorily. In the Study area, all these parameters except rainfall are not measured or available daily. Therefore, it becomes imperative to estimate these parameters in some scientific manner before proceeding to the water balance computation.

(1) Measured parameters

1) Rainfall

Generally the rainfall is measured by a rain gauge. In the Study area, daily rainfall data at Phnom Penh, Svay Rieng, Ta Keo, Kandal, Prey Veng, and Kompong Speu for a period from 1985 until 1995 were measured by the Department of Meteorology.

2) Pan-evaporation

The most common method of measuring evaporation is by means of evaporation pans. There are various types of evaporation pans but the U.S. Class A pans are most widely used. There are three (3) stations measuring pan-evaporation in and around the Study area; viz. Phnom Penh, Svay Rieng, and Kompong Cham. The original data were presented in "Le Climat du Cambodge" (Khiou-Bonthonn, 1965) and monthly evaporation data are summarized by Mekong Secretariat (1994).

The measured pan-evaporation data can be used to estimate actual soil evaporation and actual evapotranspiration components.

(2) Estimated parameters

1) Interception loss

Some amount of rainfall captured by vegetation and trees does not reach the ground surface and evaporates from the leaf surface. This interception loss can be determined by comparing the precipitation in gauges beneath the vegetation with that recorded nearby under the open sky. But generally interception loss is not measured. Therefore

0.5 mm per rainfall event is estimated as the interception loss. It is important not to ignore this small loss, because when all the small quantities are totaled they may well amount to a significant component of the water balance.

2) Surface Runoff

Surface runoff occurs when the soil is fully saturated and the rainfall intensity exceeds the infiltration rate of the soil. The surface runoff can be measured by stream gauges, but it is not available in the Study area. Therefore the estimation of surface runoff is required. There are some methods for estimating surface runoff. In the Study the SCS curve number model (Soil Conservation Service, 1972) was employed.

The SCS (1972) developed a method for computing abstraction from storm rainfall. For the storm as a whole, the depth of excess precipitation or direct runoff P_e is always less than or equal to the depth of precipitation, P; likewise, after runoff begins, the additional depth of water retained in the watershed, F_a, is less than or equal to some potential maximum retention S. There is some amount of rainfall I_a (initial abstraction before ponding) for which no runoff will occur. So the potential runoff is P - I_a. The hypothesis of the SCS method is that the ratios of the two (2) actual to the two (2) potential equations are equal, that is:

$$\frac{F_a}{S} = \frac{P_e}{P - I_a} \tag{4.4.2}$$

From the continuity principle,

$$P = P_e + I_a + F_a \tag{4.4.3}$$

Combining (4.4.2) and (4.4.3) to solve for P_e gives:

$$P_e = \frac{(P - I_a)^2}{P - I_a + S} \tag{4.4.4}$$

which is the basic equation for computing the depth of direct runoff from a storm by the SCS method. By Study of results from many small experimental watersheds, an empirical relation was developed:

$$I_a = 0.2\, S \tag{4.4.5}$$

On this basis,

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{4.4.6}$$

Plotting the data for P and P_e from many watershed, the SCS found curves of the type. To standardize these curves, a dimensionless curve number CN is defined such that $0 \leq CN \leq 100$. The curve number and S are related by:

$$S = \frac{1000}{\mathrm{CN}} - 10 \tag{4.4.7}$$

where S is in inches The curve numbers presented in the SCS runoff type curves apply for normal antecedent moisture conditions (AMC II). For dry conditions, (AMC I) or wet conditions (AMC III), equivalent curve numbers can be computed by:

$$\mathrm{CN(I)} = \frac{4.2\mathrm{CN(II)}}{10 - 0.058\mathrm{CN(II)}} \tag{4.4.8}$$

and

$$\mathrm{CN(III)} = \frac{23\mathrm{CN(II)}}{10 + 0.13\mathrm{CN(II)}} \tag{4.4.9}$$

The range of antecedent moisture conditions for each class is described by Chow (1988).

The curve numbers have been tabulated by SCS on the basis of soil type and land use. Four (4) soil groups are defined as follows:

Group A: Deep sand, deep loess, aggregated silts

Group B: Shallow loess, sandy loam

Group C: Clay loams, shallow sandy loam, soils low in organic content, and soils usually high in clay

Group D: Soils that swell significantly when wet, heavy plastic clays, and certain saline soils

The values of CN for various land uses on these soil types were given by SCS. For a watershed made up of several soil types and land uses, a composite CN can be calculated. In the Study, Group B was selected for the Study area, and CN(II) = 71, which is a runoff curve number for cultivated land with conservation treatment, was chosen to estimate average water balance of the Study area. From equations (4.4.8) and (4.4.9), CN(I) and CN(III) are calculated as 51 and 85, respectively.

3) Actual Evaporation from Soil Surface

The loss of water by evaporation from the soil surface is a major component of the annual water balance under the tropical monsoon conditions. The actual evaporation from soil surface is nearly equal to the potential evaporation when the soil surface is saturated with water. As the soil surface dries up, soil evaporation gradually diminishes, until eventually it ceases altogether when the water vapor pressure in the soil interstices equals that in the atmosphere. The maximum depth of the soil where soil evaporation will occur depends upon the texture of the soil. The soil evaporation from a greater depth is possible in clayey soils with a high capillary rise. But it is very difficult to measure the actual soil evaporation in the field.

The daily actual soil evaporation *AE* can be estimated as a function of the daily pan-evaporation value E_p, the number of days *t*, following a rain of sufficient amount to recharge the surface 10 cm of soil and fraction *B* of incoming solar radiation reaching the soil surface (Russel, 1978). The following equation is used to compute the daily actual soil evaporation from the daily rainfall data and pan-evaporation data:

$$AE = B\frac{E_p}{t}$$

$$\mathrm{CN(III)} = \frac{23\mathrm{CN(II)}}{10 + 0.13\mathrm{CN(II)}}$$

(4.4.10)

Under uncropped conditions or barren land *B* = 1.0, but under cropped conditions it is a time-dependent function of crop growth that can be measured directly or estimated from the leaf area index (LAI).

4) Actual Evapotranspiration

It is difficult to separately measure the actual water losses by soil evaporation and transpiration. From the definition, obviously if there is no vegetation in the area, the transpiration is zero. Also in case of that the moisture content of the root zone is less than the wilting point, the transpiration does not occur. The actual transpiration depends manly upon the species of plant, density of vegetation, stages of crop growth, climatic conditions and moisture holding capacity of the soil.

The ratio of evapotranspiration (moisture not limiting) of a particular crop to pan-evaporation CTR throughout the growing season has been reported. So if the CTR of the vegetation is known and assuming moisture is not limiting, the evapotranspiration can be computed using daily pan-evaporation data.

In the actual field conditions, the area is not fully covered by vegetation and the soil moisture is also limited so that the actual evapotranspiration is smaller than the potential evapotranspiration. For calculation of the actual evapotranspiration in a particular area, the ratio of vegetation covered area to no vegetation area has to be taken into account as well as the available water in the root zone. In the Study, it was assumed that 70 % of the Study area is covered with vegetation. The CTR values by cropping stage were estimated from the values of paddy and maize.

5) Soil Moisture

The maximum amount of water that the soil can hold against the force of gravity is termed the field capacity, which is measured as the ratio of weight of water retained by soil to the weight of the soil when dry. The lowest amount of moisture that is held by the soil, not available for transpiration by vegetation, is the wilting point. The difference between the field capacity and the wilting point constitutes the available soil moisture. The field capacity varies with types of soils and the thickness of the soil zone.

When sufficient rainfall occurs and the soil zone is assumed to fill up to the field capacity, the surplus water leaves the soil zone. The water, which has remained in the soil zone as the available soil moisture, will be extracted as the soil evaporation and the transpiration by plants. After the available soil moisture becomes zero, neither actual soil evaporation nor actual evapotranspiration will occur until next rainfall event, which supplies soil moisture.

The depth of the soil to which the soil evaporation occurs may vary with the physical properties of soil. In sandy soils, this should probably be less than 10 cm, and in clay soils it should be more. The transpiration from plants occurs from the root zone that varies with vegetation and root growth.

In the Study, two (2) layer model of the soil zone was developed for the soil moisture calculation. In the upper layer up to 20 cm depth from the surface, it is assumed that the soil evaporation and transpiration will occur, whereas in the second layer below 20 cm depth, the available soil moisture will be extracted as transpiration from plants.

6) Groundwater recharge

The component of the groundwater recharge, which is *RE* in equation (4.4.1), can ultimately be obtained from the water balance computation in the soil moisture zone.

(3) Result of computation

Although available data for the water balance computation are limited, each water balance component in equation (4.4.1) was computed using actual daily rainfall data from 1986 to 1995 and average monthly evaporation data for a period from 1929 to 1960 in Phnom Penh. The computation was carried out for a period from January 1, 1986 until December 31, 1995 on daily basis. A daily evaporation value was uniformly given throughout a month from the monthly evaporation value.

Table 4.9 and Figure 4.69 show the result of water balance computation from 1986 to 1995. Annual groundwater recharge is estimated from 315.4 mm in 1,992 to 649.6 mm in 1987. The ratio of groundwater recharge to rainfall ranges from 28.2 to 41.9%. An average groundwater recharge from 1986 to 1995 is estimated as 448.3 mm/year, that is 34.1 % of the rainfall.

In the water balance estimation, the biggest component is actual transpiration ATP, it's average value is 510.9 mm/year (= 38.8 % of rainfall). The average actual evaporation is computed as 233.0 mm/year (= 17.7 % of rainfall). The average surface runoff is estimated as 102.0 mm/year (7.7 %), however, it ranges widely from 34.1 to 183.2 mm/year.

It is noted that the accuracy of the water balance estimation has limitations because there are several assumptions and estimations in the input parameters. More accurate water balance estimation could be done if it is available to obtain more data qualitatively and quantitatively, such as daily evaporation data, transpiration data, soil data, etc by area. Water balance analysis by Tank Model method could be done if daily groundwater levels were monitored. It is also noted that quantitative relation between groundwater and surface water, such as river water and lake water, should be studied for detailed water balance analysis.

4.5 Evaluation of Groundwater Resource

4.5.1 Hydrogeological Map

Based on the preliminary hydrogeological map prepared in the First Stage of the Study, hydrogeological map has been prepared by adding some important data obtained from test well drilling and the investigations in the Second Stage. In 1999, some additional data were collected and analyzed. Summarizing the above-mentioned various kinds of geologic and hydrogeologic data and information, a revised hydrogeological map was prepared as shown in Appendix 11. The map shows the distribution of bedrocks, topographic and geologic features, groundwater levels, distribution of bedrock depths, distribution of aquifer parameters, and related information to understand the hydrogeologic settings and groundwater potentials of the Study area.

4.5.2 Quantitative Evaluation

As far as the groundwater quantity is concerned, the Study area is divided into a high groundwater potential zone in the eastern part and a low potential zone in the western part. The aquifer productivity is closely related to the hydrogeological conditions. Groundwater potential in the areas of Svay Rieng, Prey Veng, and southern part of Kandal is higher because the exploitable aquifers are sand and gravel layers of Quaternary formations. There are several horizons of confined aquifers within a depth of 100 m from ground surface. According to the results of pumping tests, submersible pumps can be used in the test wells with pumping rate of more than 1,000 m^3/day.

On the other hand, groundwater potential in Peri-Urban Areas of Phnom Penh, Ta Keo, northern part of Kandal, and Kompong Speu is lower. Because the Quaternary sediments are generally thin in the areas and groundwater must be extracted from the bedrock aquifers. However, the productivity of bedrock aquifer is poor, because the bedrock mainly consists of sandstone and shale. According to the results of pumping tests, possible pumping rate ranges from 10 to 100 m^3/day. In Kompong Speu Province, there was no water in two (2) test wells and those were abandoned.

As a result, it is concluded that groundwater development is easier in Svay Rieng, Prey Veng, and southern part of Kandal Provinces from the viewpoint of groundwater quantity. It would be difficult in the western part of the Study area to exploit large amount of groundwater unless the well encountered good aquifer portions of bedrock, such as permeable weathered zone and fractured zone. It is not easy to detect such favorable zones for groundwater development, even carrying out more detailed geophysical prospecting and hydrogeological investigations due to the actual hydrogeologic conditions.

4.5.3 Qualitative Evaluation

Groundwater quality conditions in the Study area is complex compared with the quantitative conditions. However, it is obvious that groundwater quality is generally poor in the Study area. Out of twenty-four (24) test wells in which the groundwater samples were analyzed both in 1997 and 1999, only one (1) well, that is BH-429 well in Kompong Speu, was good for drinking compared with the WHO Guideline Values. If the WHO Guideline Values were strictly applied to the test well groundwater, all the wells except BH-429 well are not good for drinking without treatment.

The characteristics of groundwater quality differ by area. According to the chemical analysis of test well water in 1999, all the three (3) wells in Phnom Penh are contaminated by Na. The water of BH-57 well has high concentration of F. The groundwater of BH-71 well is contaminated not only by Na but also Cl, SO_4, NO_3, and TDS. In Svay Rieng, all the five (5) test wells are contaminated by Fe. High Mn concentrations more than the guideline value are also found from four (4) test wells.

In Ta Keo, five (5) test wells out of six (6) have higher Na concentrations more than the WHO Guideline Value. Saline water is found from BH-181 and BH-222 wells. These two (2) wells are also contaminated by NH_4, Mn, and TDS. Fe and Mn concentrations are also high in BH-222 well.

The groundwater of BH-259 in southern Kandal is contaminated by Mn. The two (2) test wells located in northern Kandal are polluted by Na, Fe, F, and TDS. All the five (5) wells in Prey Veng have higher Mn concentrations above the guideline value. Two (2) wells are also contaminated by Fe, and one (1) well is contaminated by Cl. In Kompong Speu, BH-454 has a higher TDS value than the guideline value.

As a result, it is concluded that most test well water in Svay Rieng and Prey Veng is contaminated by Fe and Mn. Most test well groundwater in Ta Keo, Kandal, and Peri-Urban Areas of Phnom Penh is saline or contaminated by Na. From the viewpoint of quality, groundwater in Kompong Speu seems to be best in the Study area.

There are some cost-effective methods to reduce iron in water. Treatment of Mn is more difficult than Fe. It is not easy to treat saline water from the viewpoints of technical and cost-effective methodology.

The results of chemical analysis of groundwater indicate that groundwater quality of deep aquifers is not always better than that of shallow aquifers in the Study area. The groundwater of Svay Rieng and Prey Veng can be treated to remove Fe and Mn for drinking purpose, but it is difficult to treat saline water in Ta Keo, Kandal, and Phnom Penh for the drinking purpose.

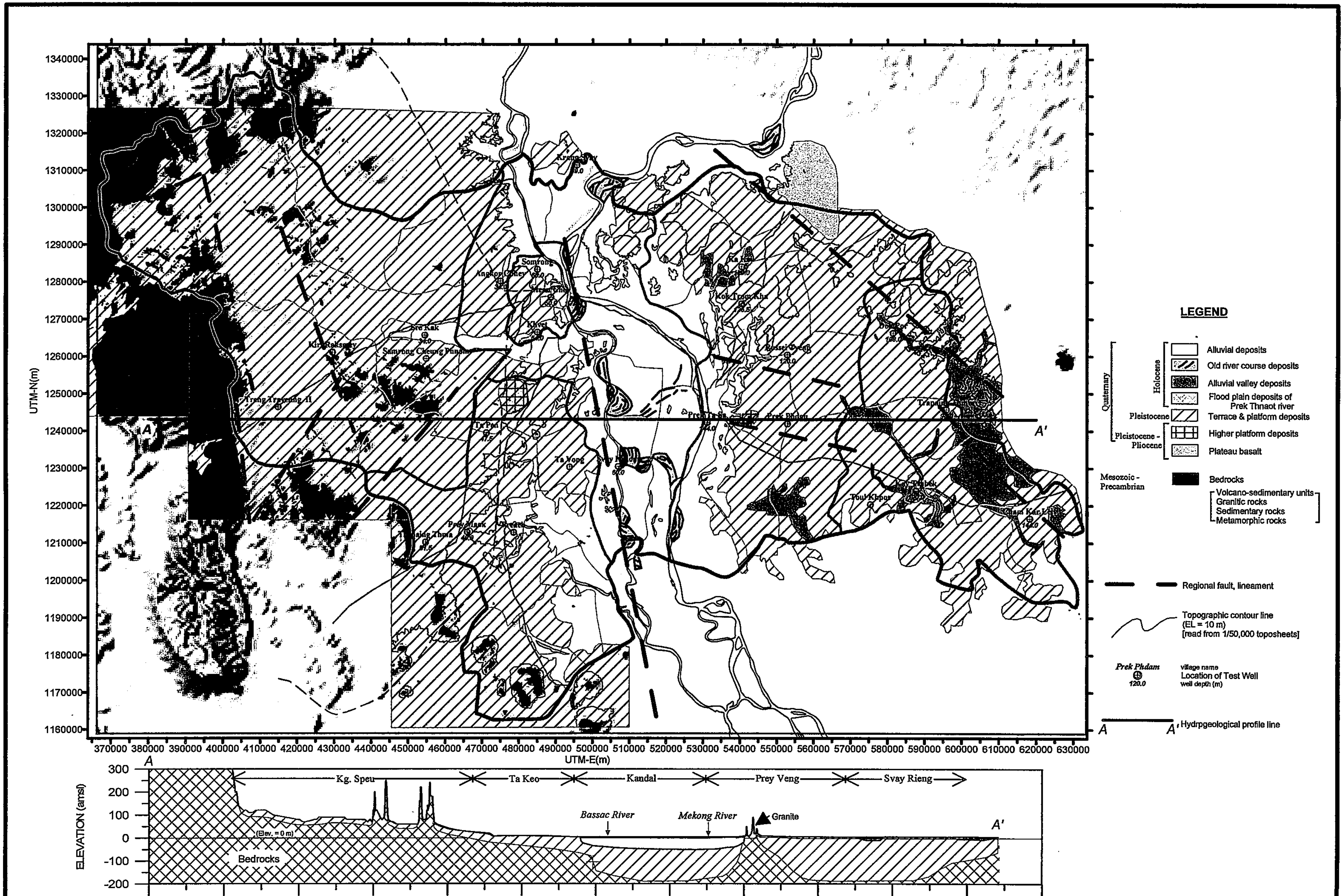
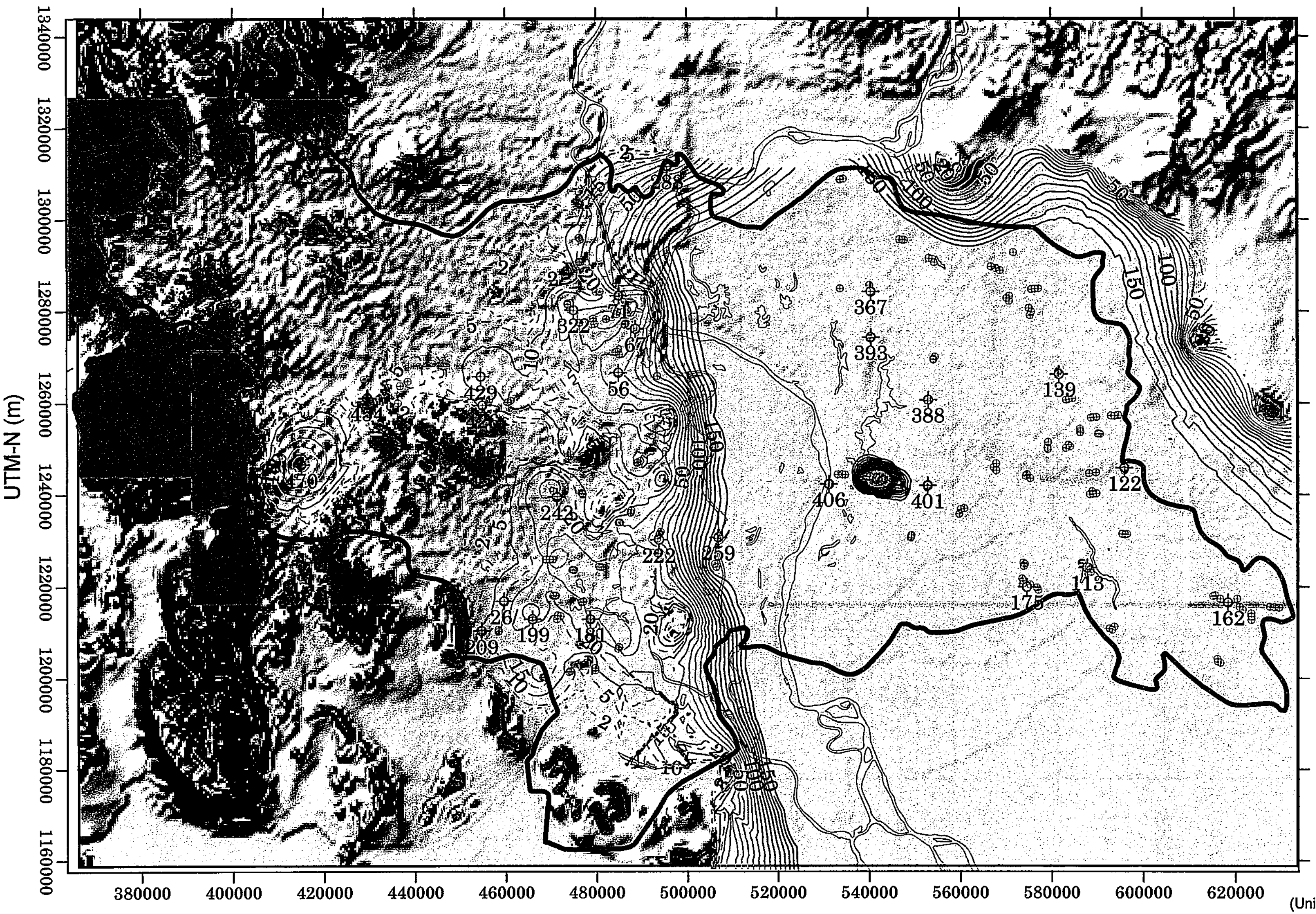


Figure 4.1	HYDROGEOLOGICAL FEATURES OF THE STUDY AREA
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



Bedrock exposure ⌖ Test well ⊕ Resistivity sounding

Figure 4.2	**ESTIMATED BEDROCK DEPTH**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

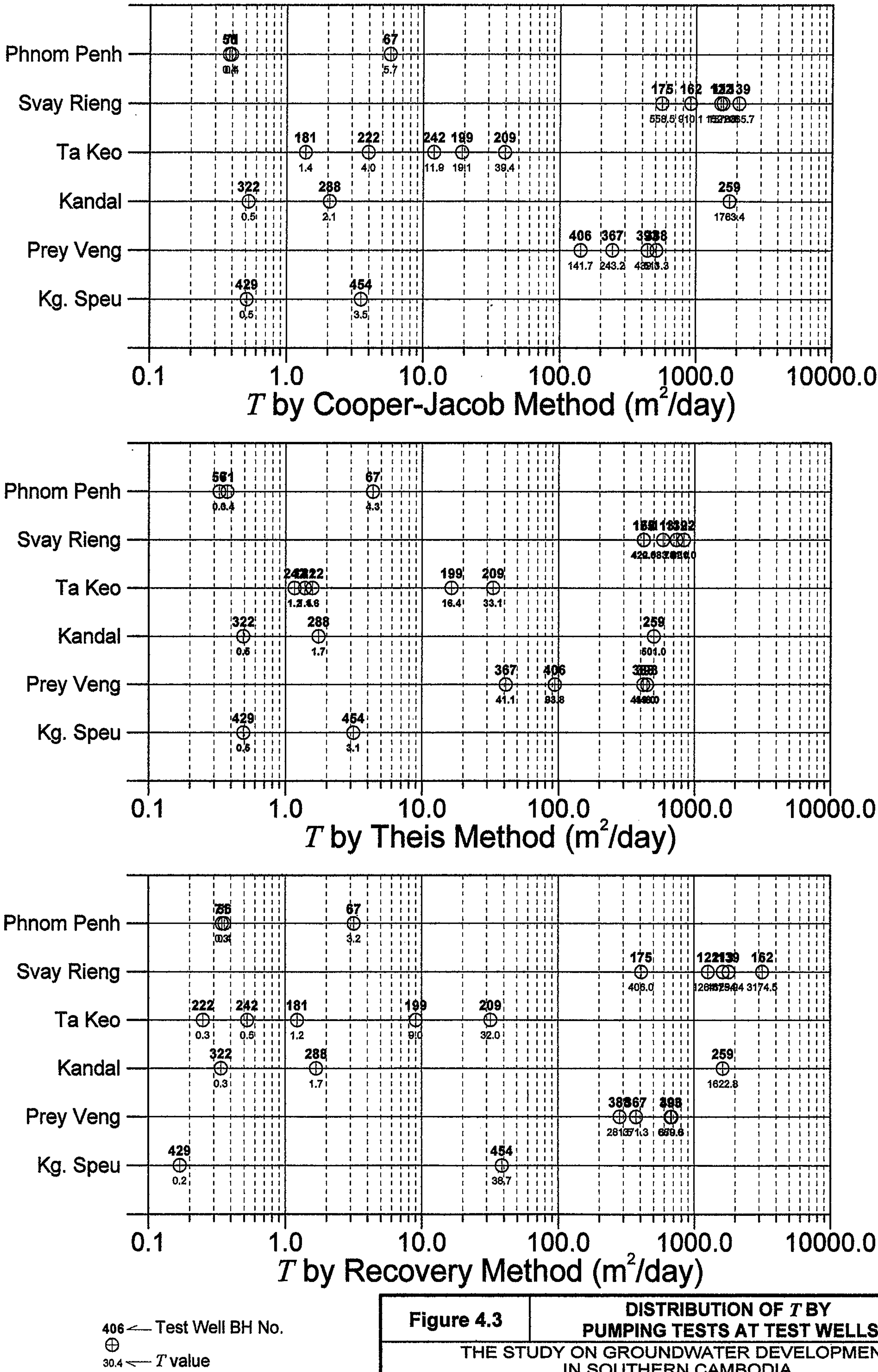


Figure 4.3	**DISTRIBUTION OF *T* BY PUMPING TESTS AT TEST WELLS**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

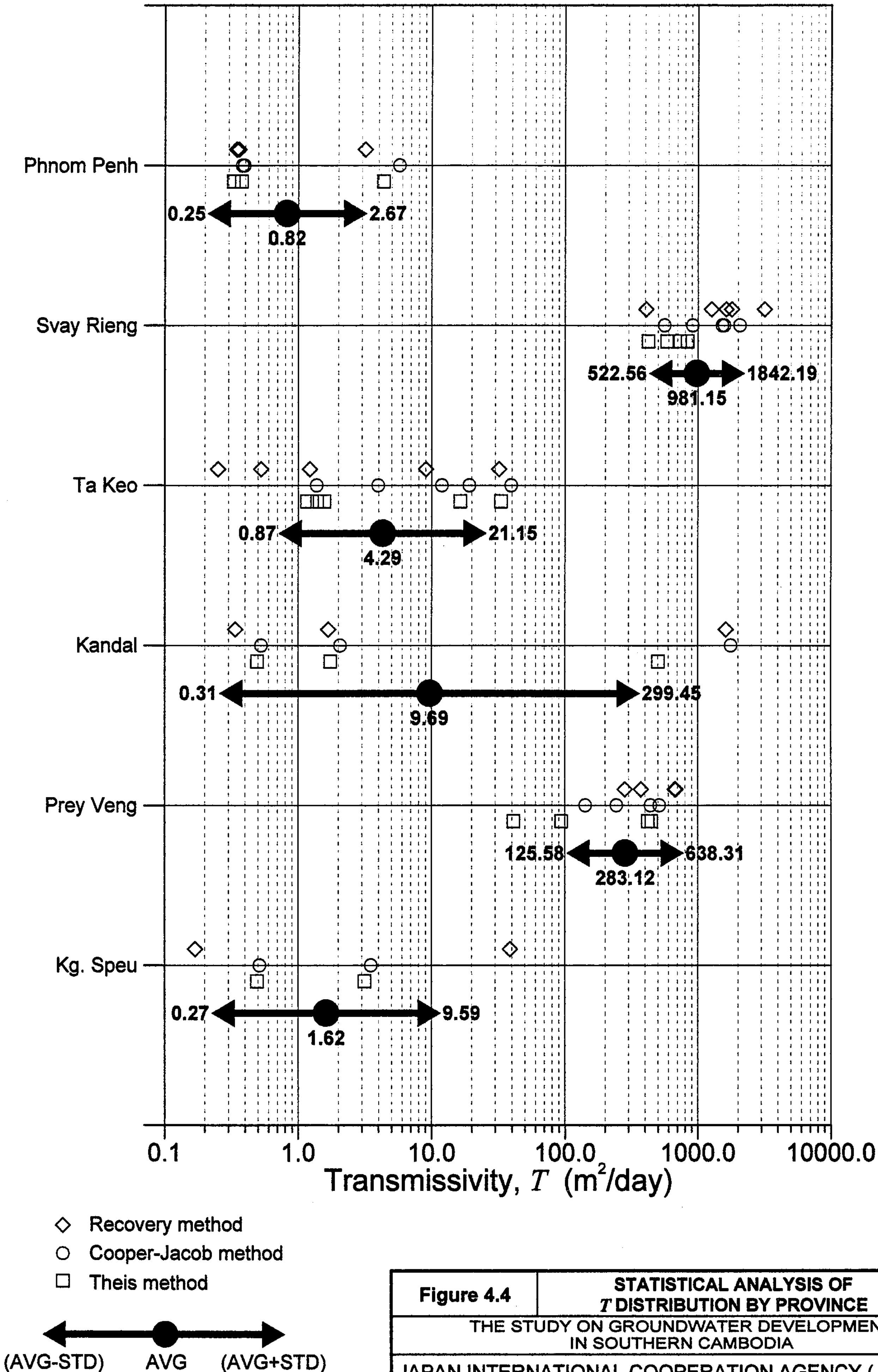


Figure 4.4	STATISTICAL ANALYSIS OF T DISTRIBUTION BY PROVINCE
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

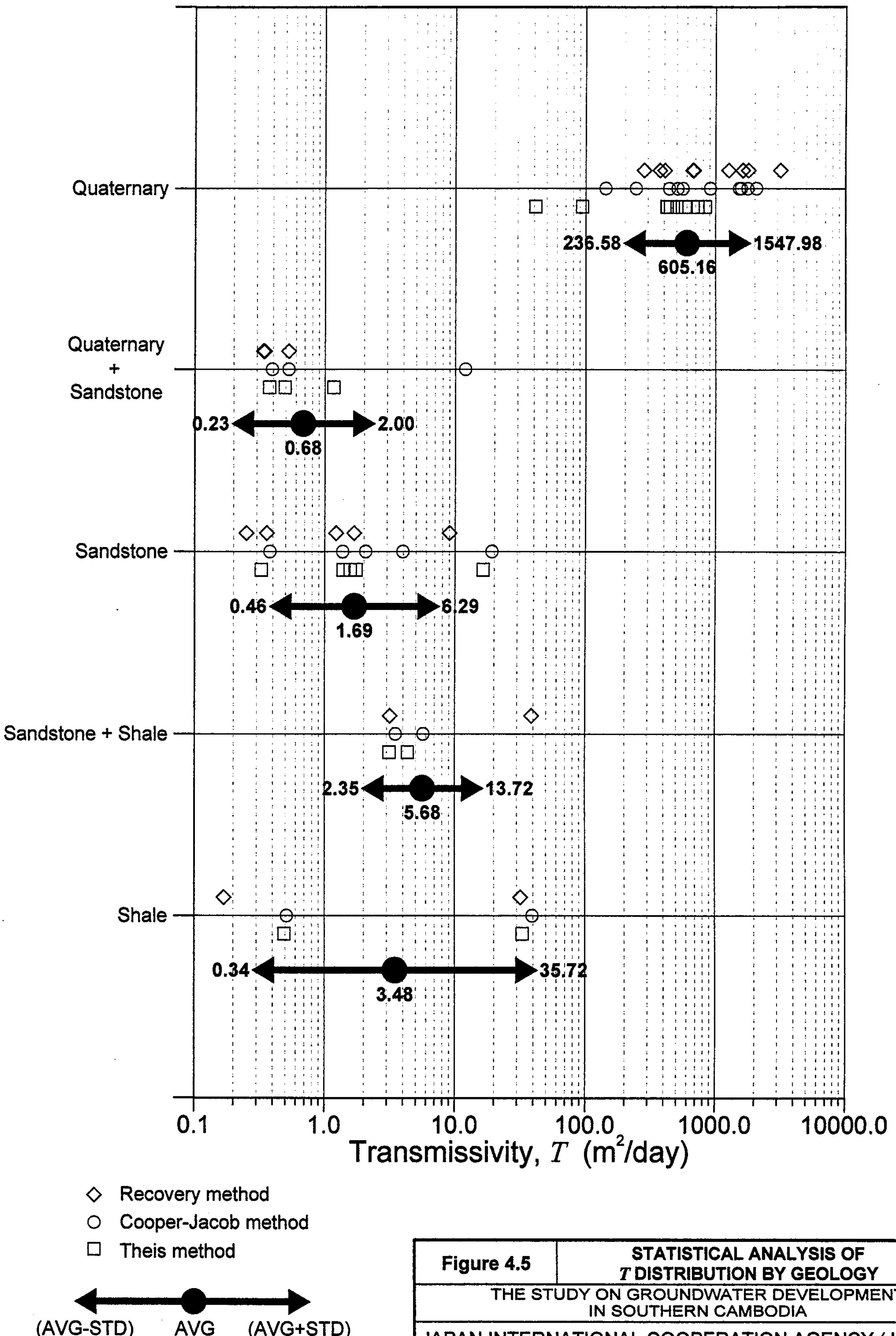


Figure 4.5	STATISTICAL ANALYSIS OF *T* DISTRIBUTION BY GEOLOGY
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

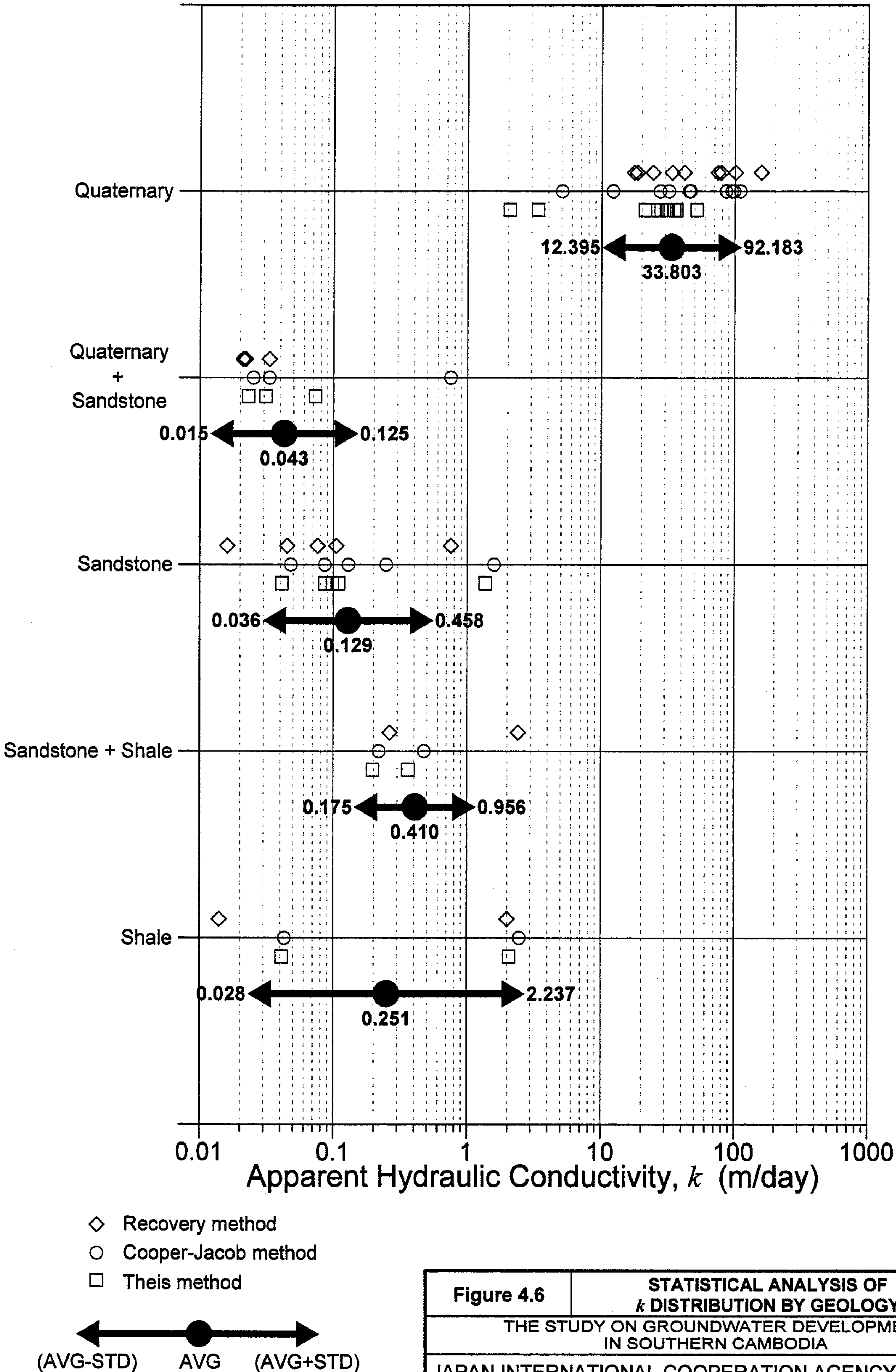
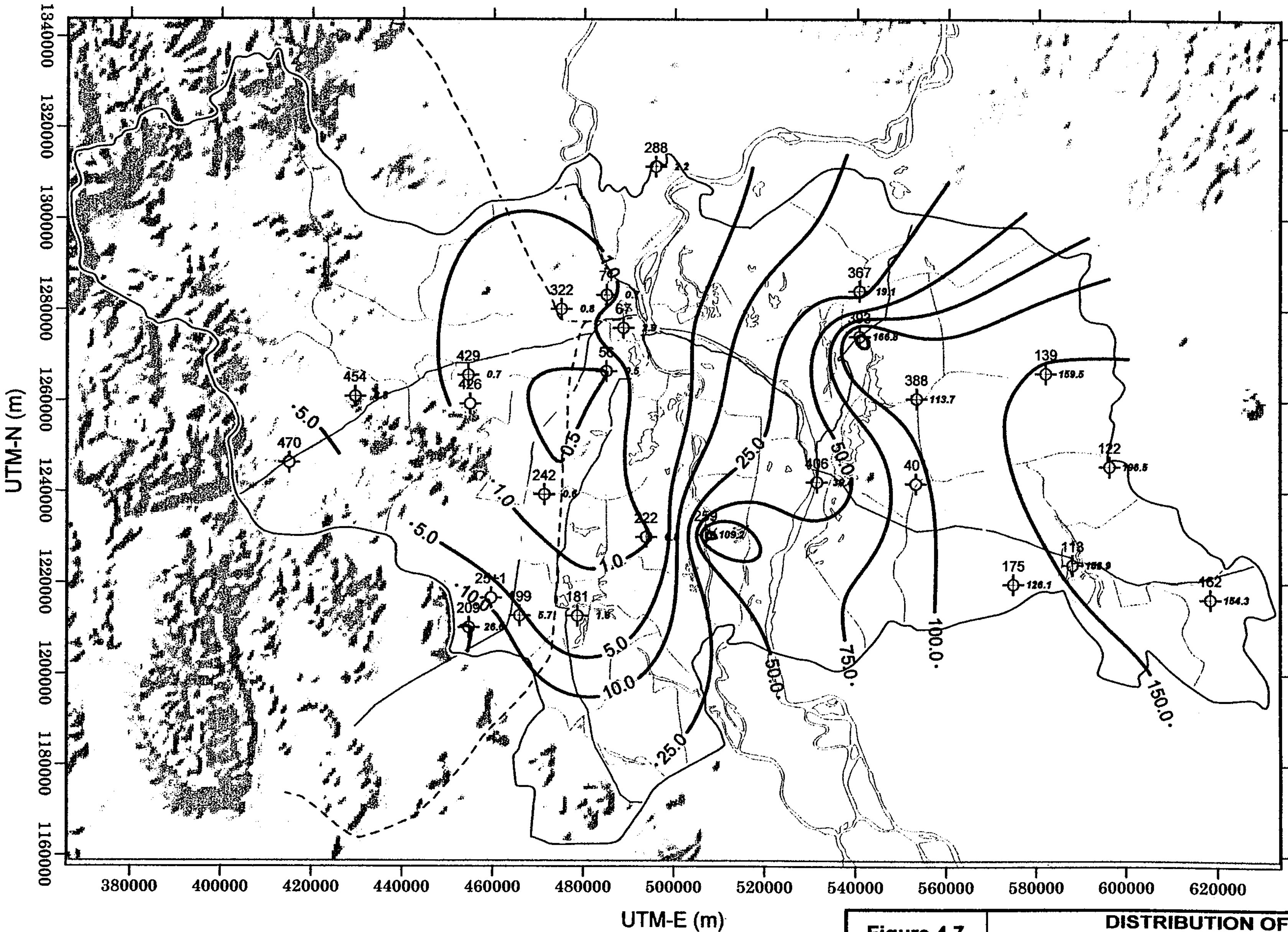


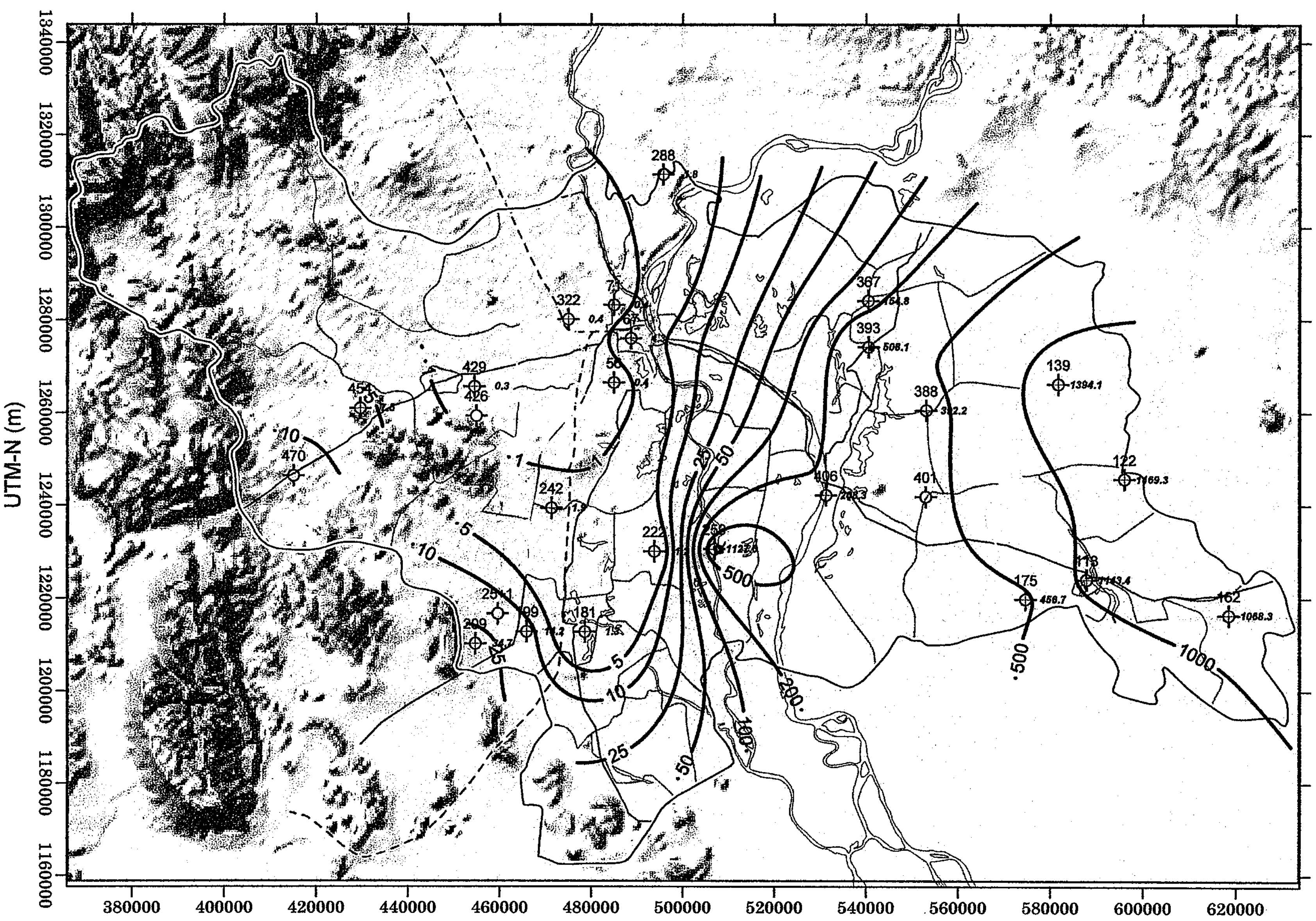
Figure 4.6	STATISTICAL ANALYSIS OF *k* DISTRIBUTION BY GEOLOGY
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



Equal line of specific capacity, Sc (m^2/day)

388 113.7 Test well
[up: Well No., right: specific capacity, Sc (m^2/day)]

Figure 4.7	DISTRIBUTION OF SPECIFIC CAPACITY
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



Equal line of average transmissivity, T (m^2/day)

388 379.0 Test well
[up: Well No., right: average transmissivity, T (m^2/day)]

Figure 4.8	DISTRIBUTION OF AVERAGE TRANSMISSIVITY
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

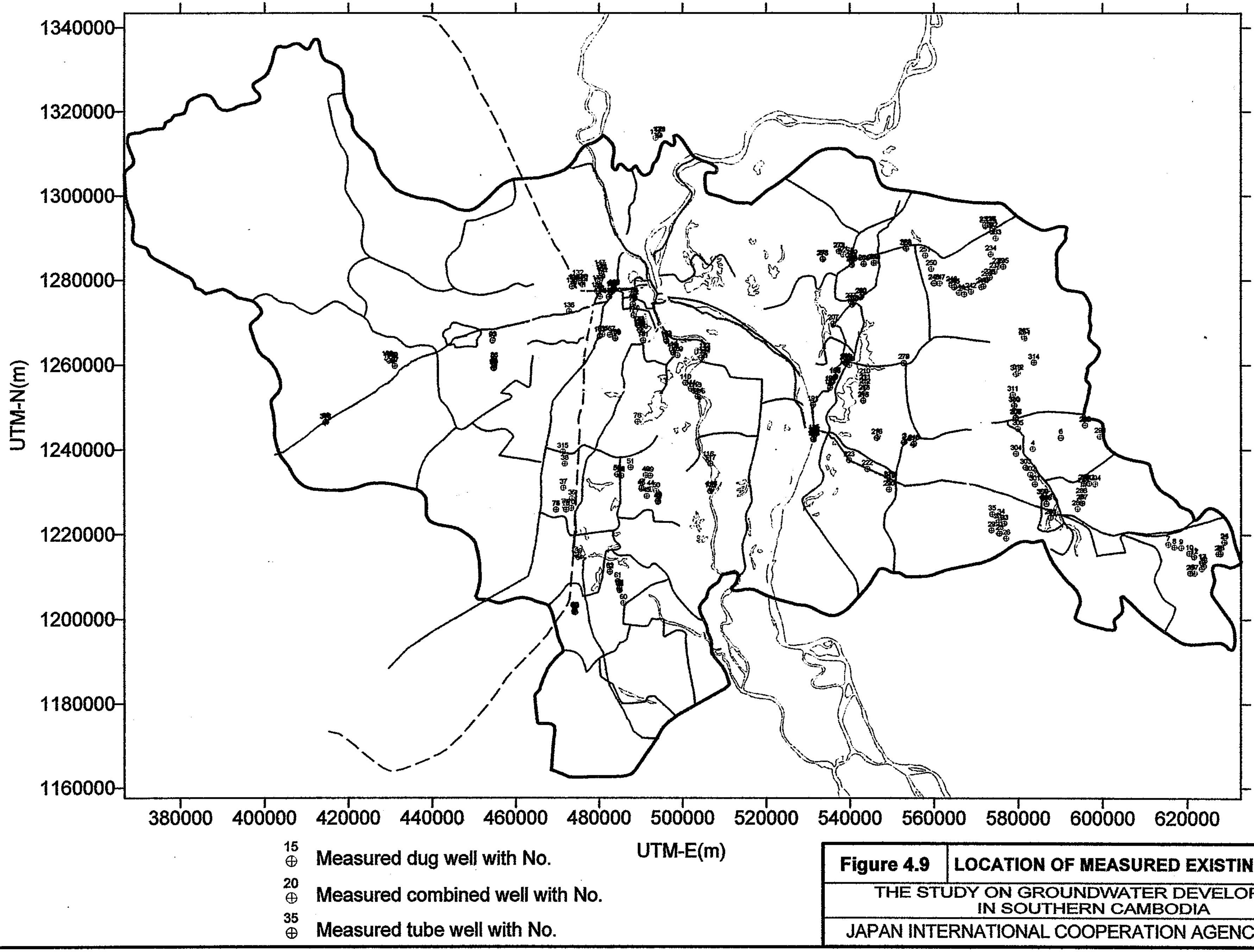
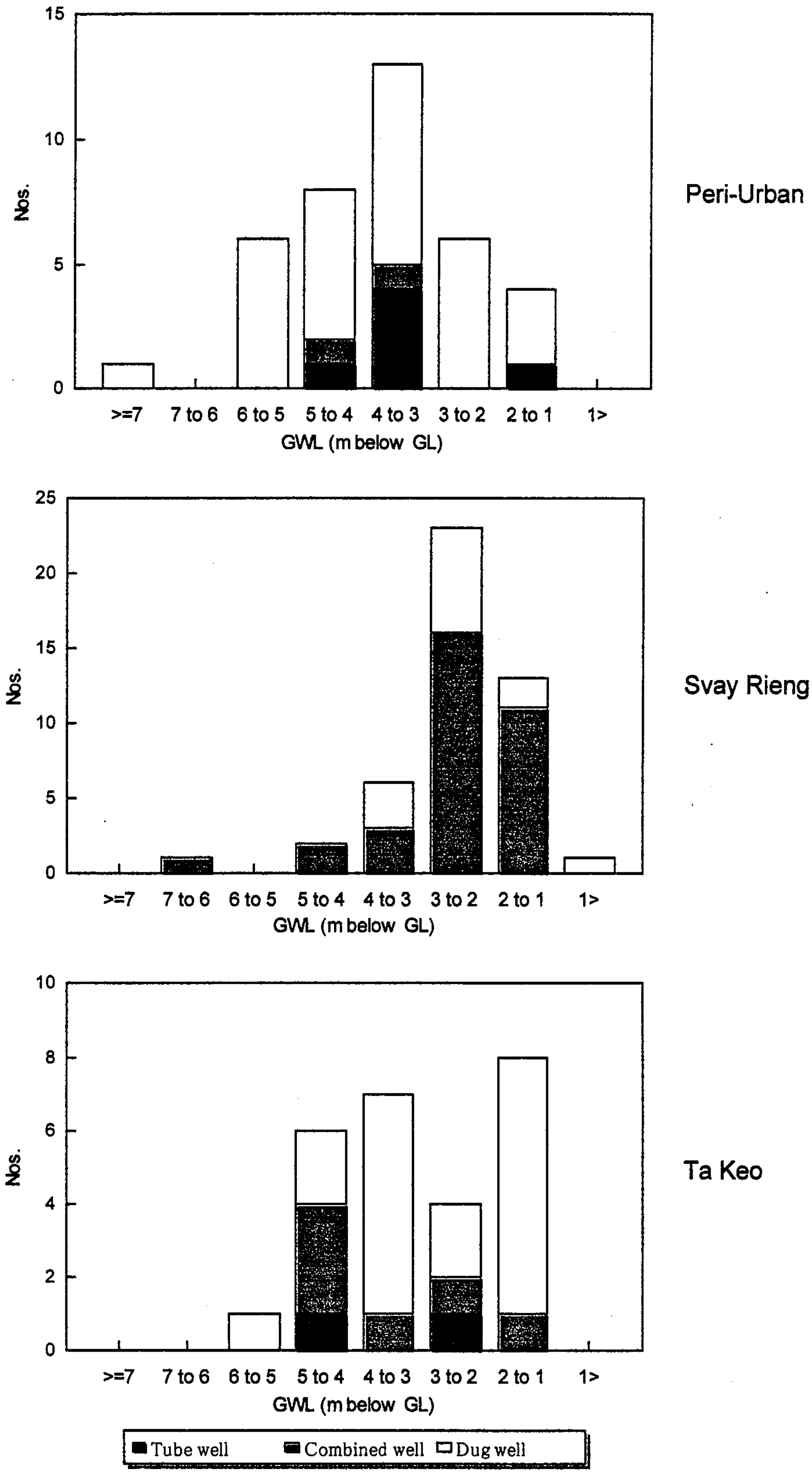
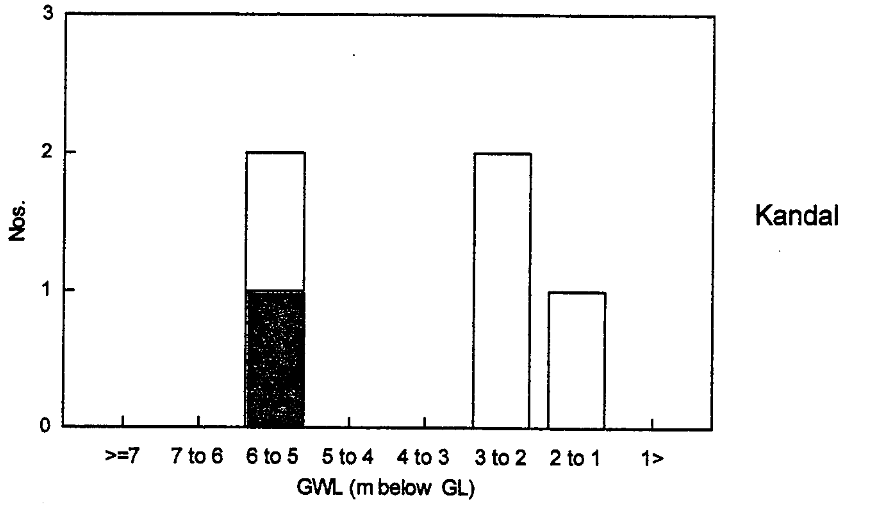


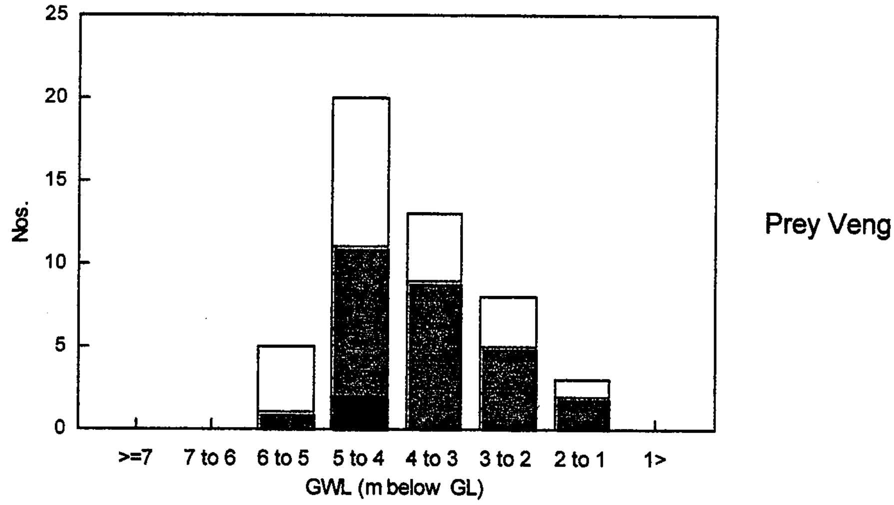
Figure 4.9	LOCATION OF MEASURED EXISTING WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

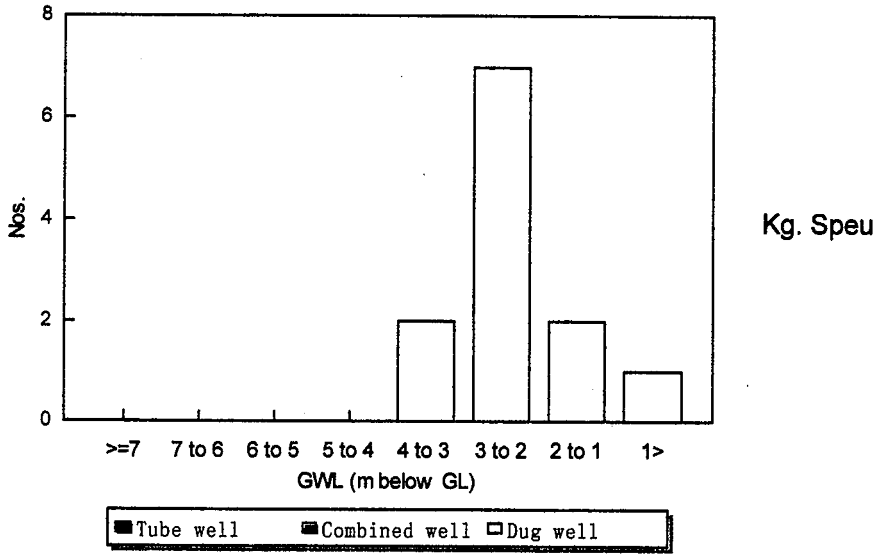


(Groundwater levels were measured during a period from February 1997 to March 1997)

Figure 4.10	DISTRIBUTION OF GROUNDWATER LEVEL BY PROVINCE AND WELL TYPE (1)
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

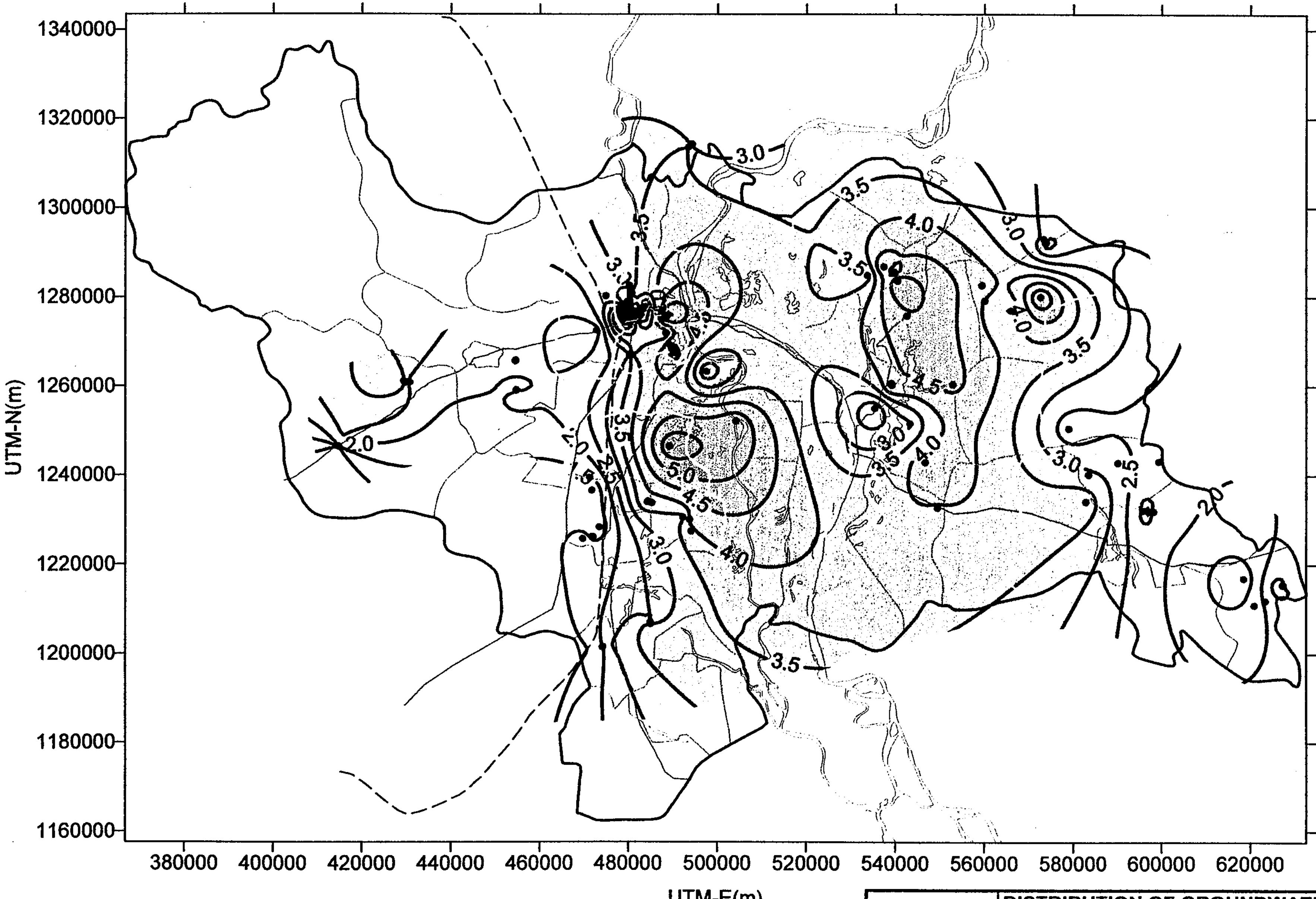






(Groundwater levels were measured during a period from February 1997 to March 1997)

Figure 4.11	DISTRIBUTION OF GROUNDWATER LEVEL BY PROVINCE AND WELL TYPE (2)
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

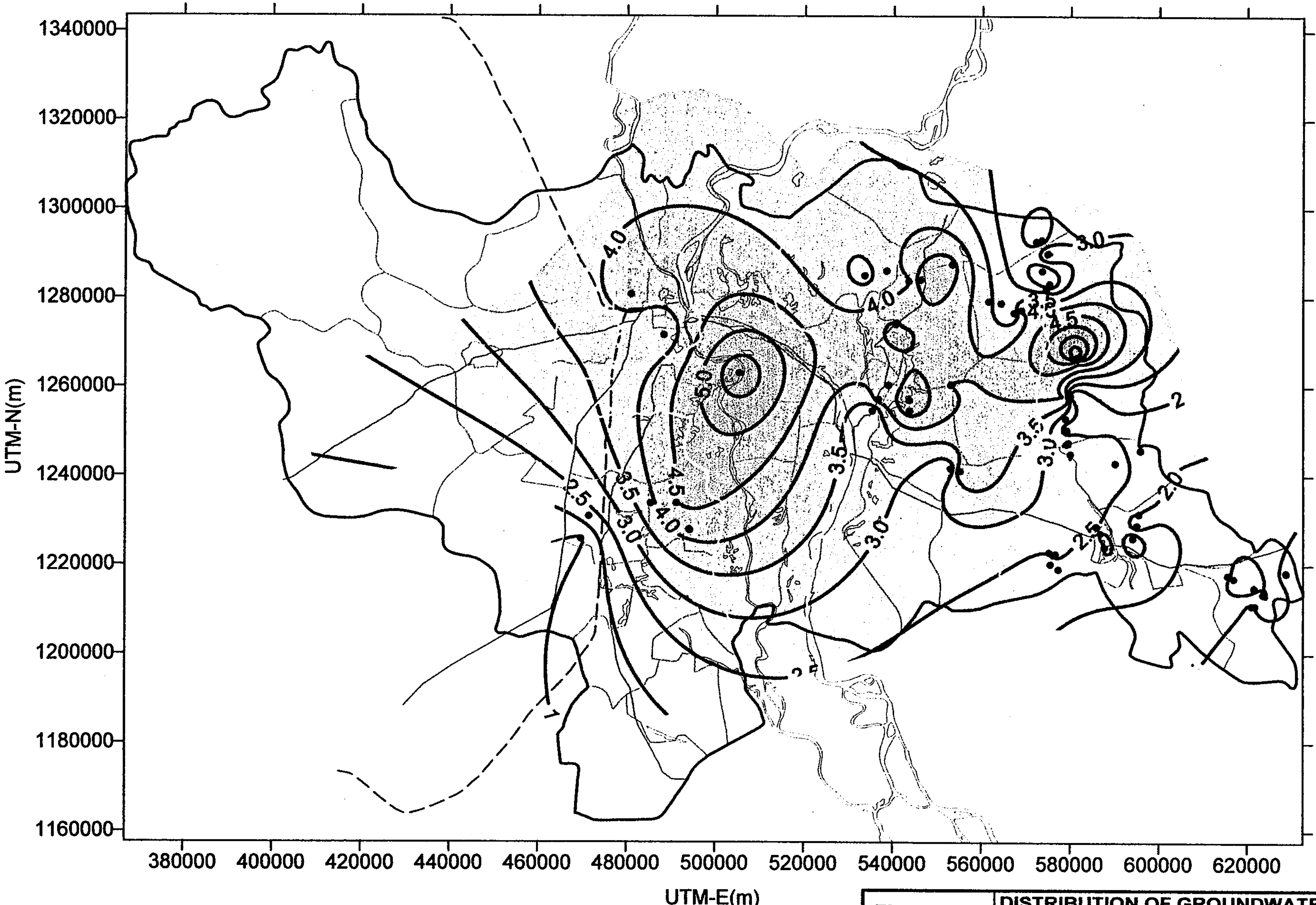


—— 2.0 Equal line of Groundwater Level (m below ground surface)

• Location of measured dug well

(Groundwater levels were measured during a period from February 1997 to March 1997.)

Figure 4.12	DISTRIBUTION OF GROUNDWATER LEVEL MEASURED AT DUG WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



——— 2.0 Equal line of Groundwater Level (m below ground surface)

• Location of measured combined well

(Groundwater levels were measured during a period from February 1997 to March 1997.)

Figure 4.13	DISTRIBUTION OF GROUNDWATER LEVEL MEASURED AT COMBINED WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

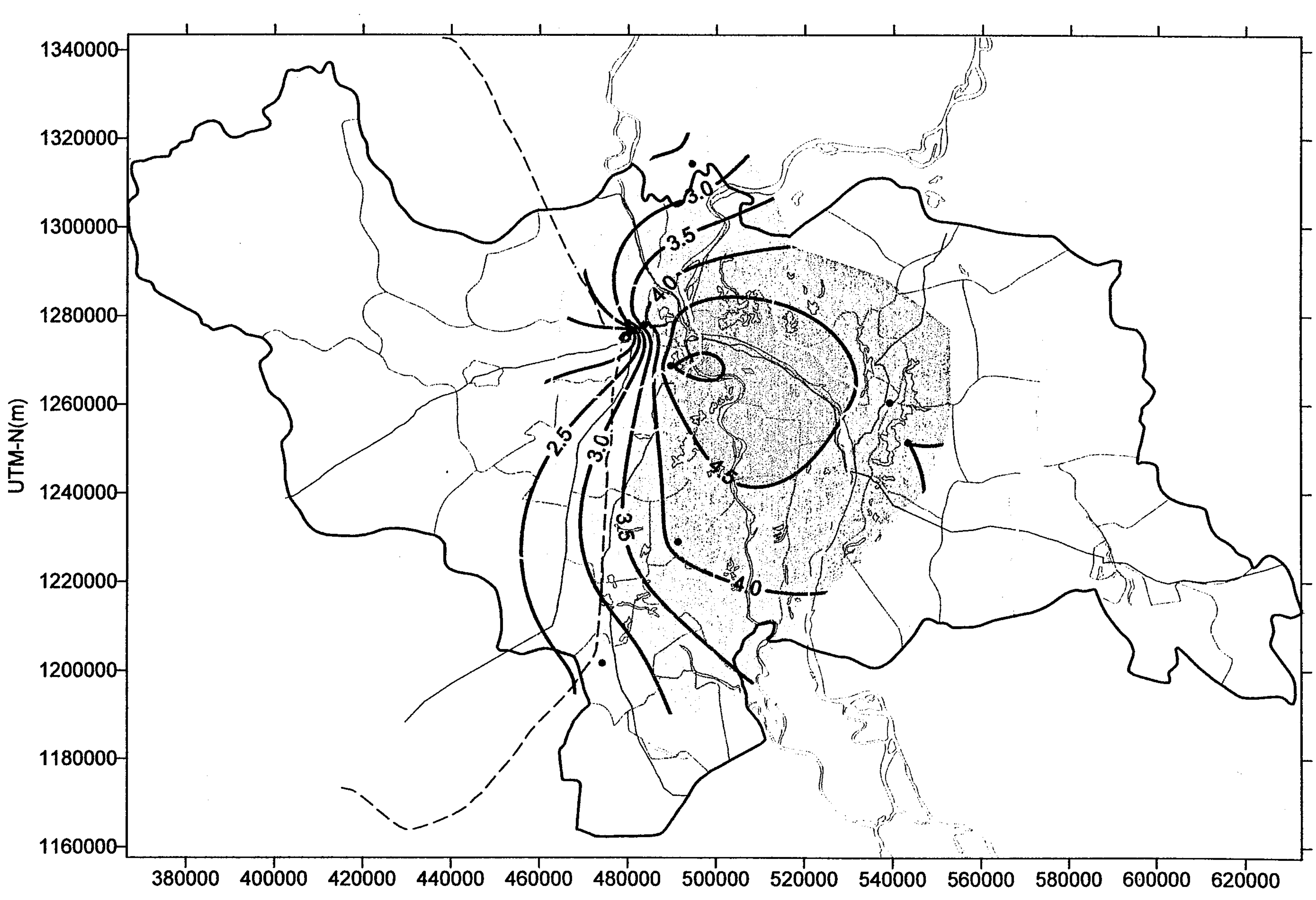


Figure 4.14	DISTRIBUTION OF GROUNDWATER LEVEL MEASURED AT TUBE WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

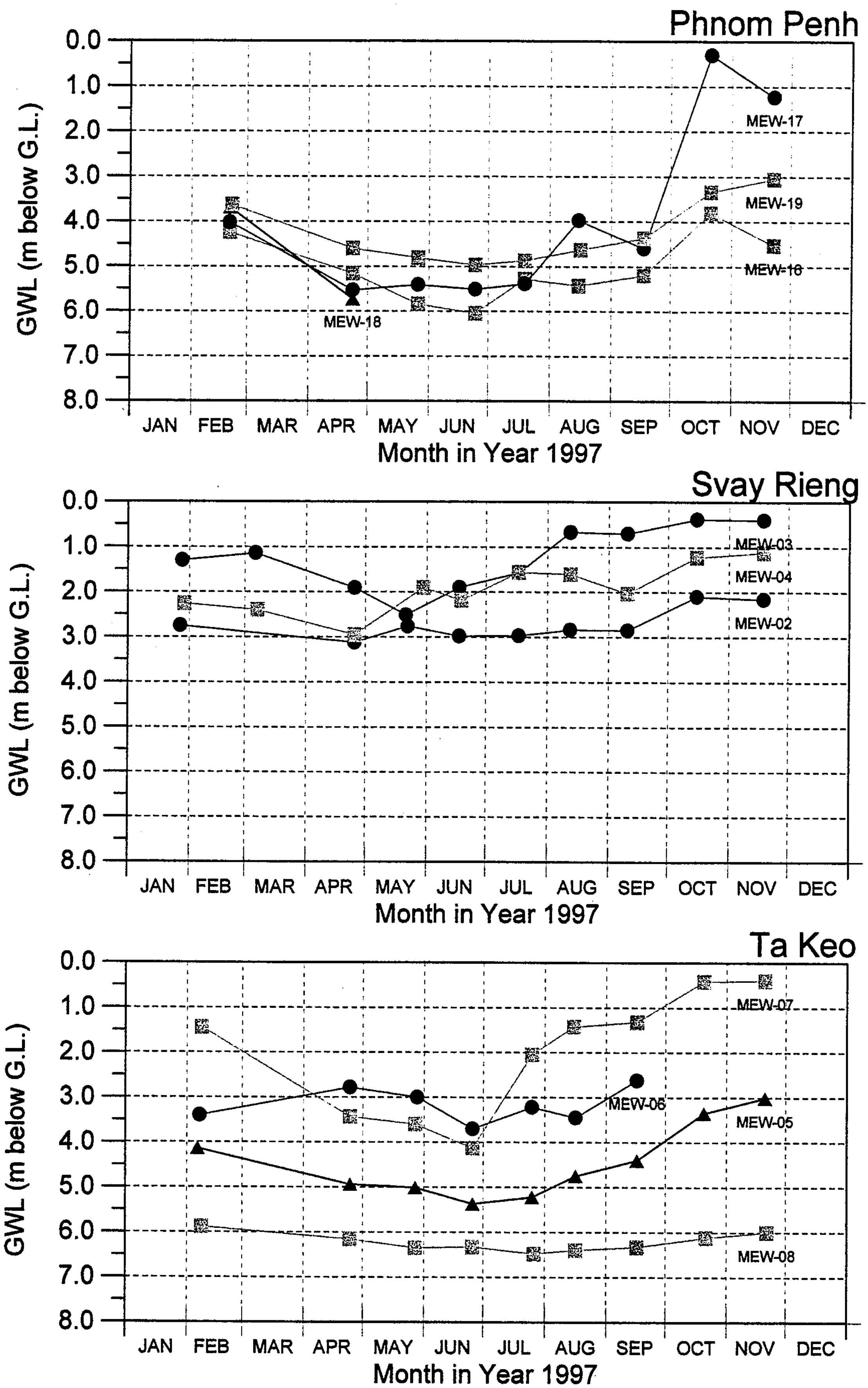


Figure 4.15	**CHANGES IN GROUNDWATER LEVELS IN PHNOM PENH, SVAY RIENG, AND TA KEO**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

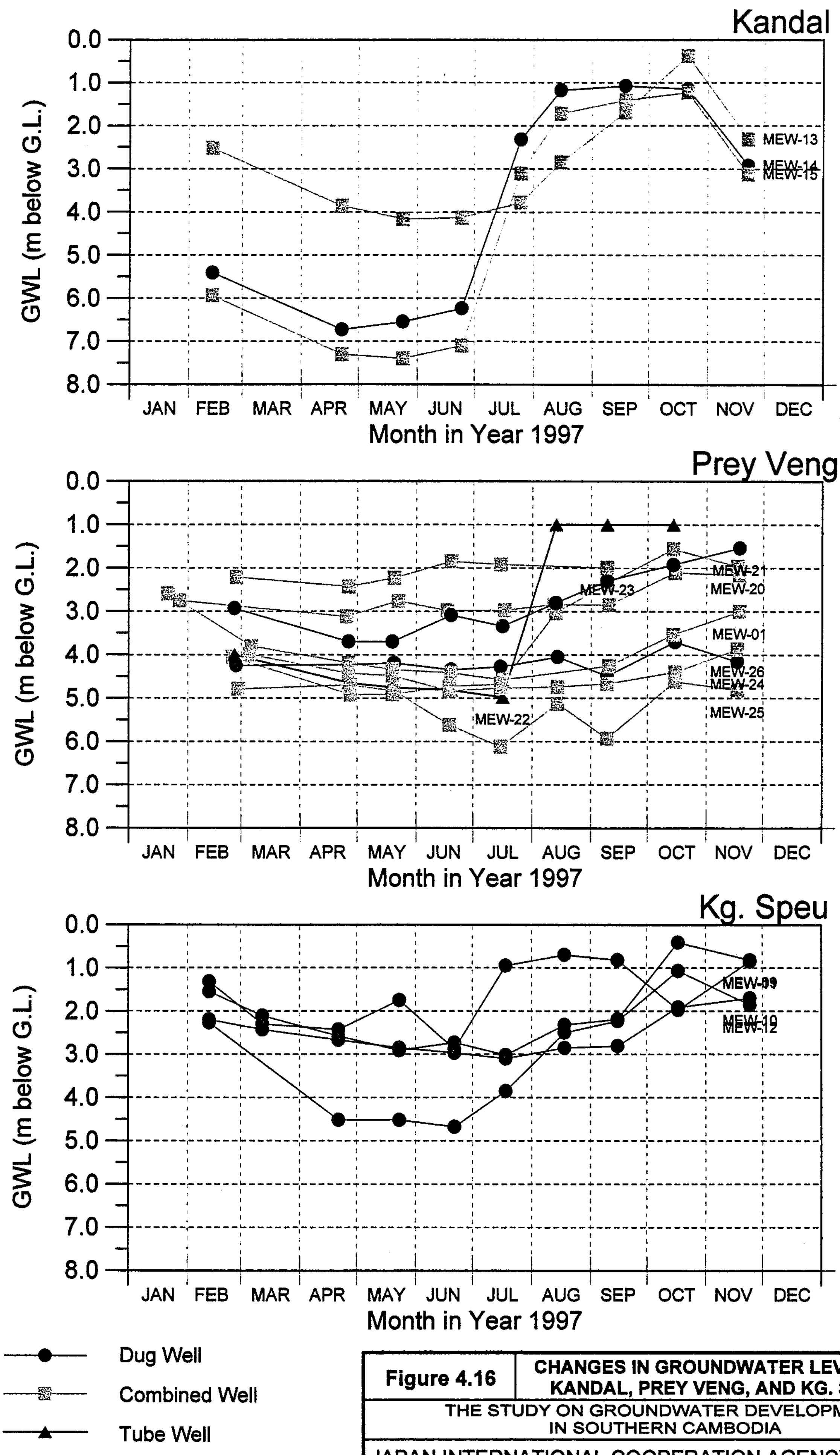
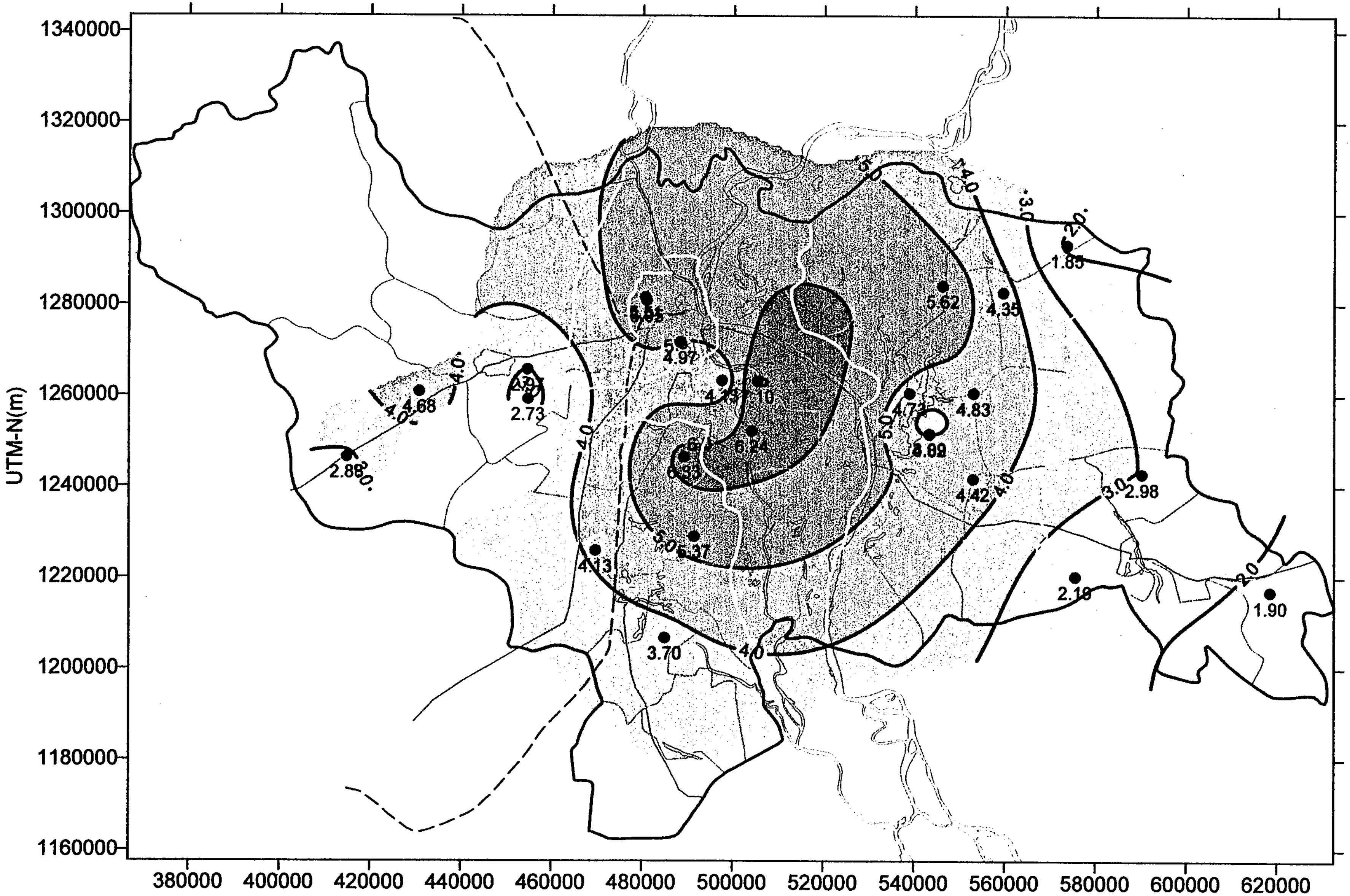


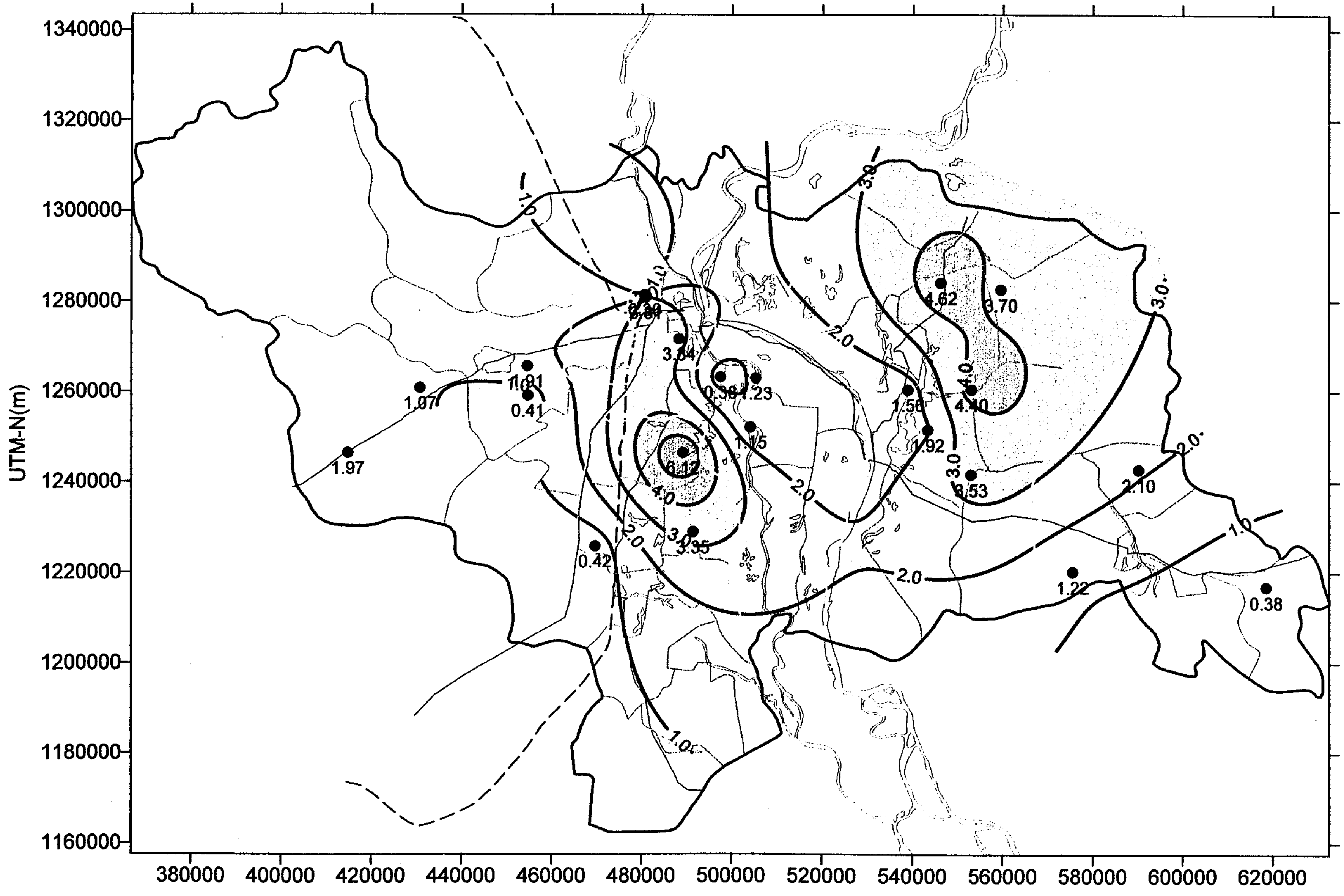
Figure 4.16	CHANGES IN GROUNDWATER LEVELS IN KANDAL, PREY VENG, AND KG. SPEU
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



——— 2.0 Equal Line of Groundwater Level (m below G.L.)

• Location of Monthly Monitoring Well

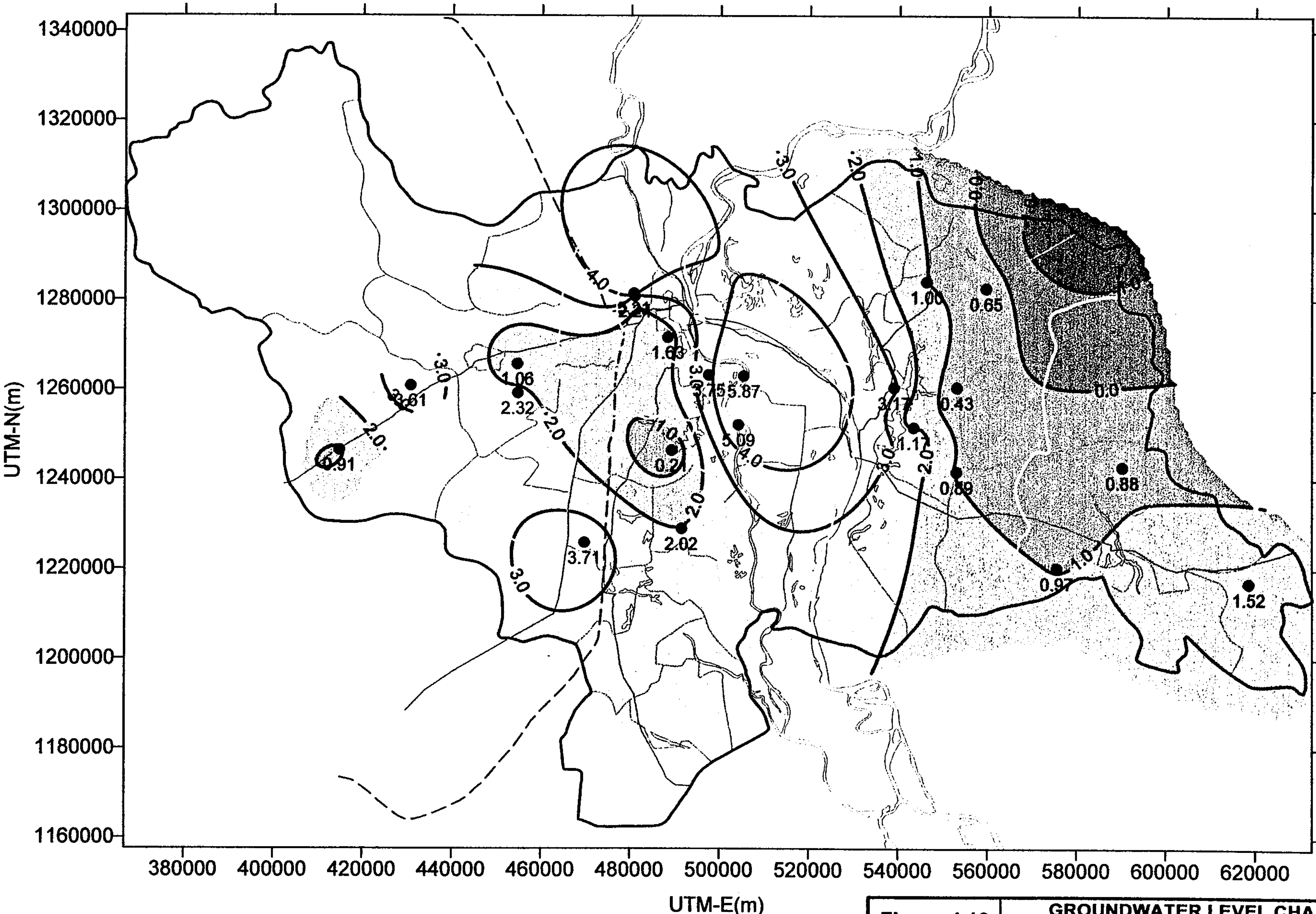
Figure 4.17	DISTRIBUTION OF GROUNDWATER LEVELS IN JUNE 1997 (DRY SEASON)
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



2.0 Equal Line of Groundwater Level (m below G.L.)

• Location of Monthly Monitoring Well

Figure 4.18	DISTRIBUTION OF GROUNDWATER LEVELS IN OCTOBER 1997 (RAINY SEASON)
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



—— 2.0 Equal Line of Groundwater Level Change (in meters, positive: rise)

• Location of Monthly Monitoring Well

Figure 4.19	**GROUNDWATER LEVEL CHANGES BETWEEN JUNE 1997 AND OCTOBER 1997**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

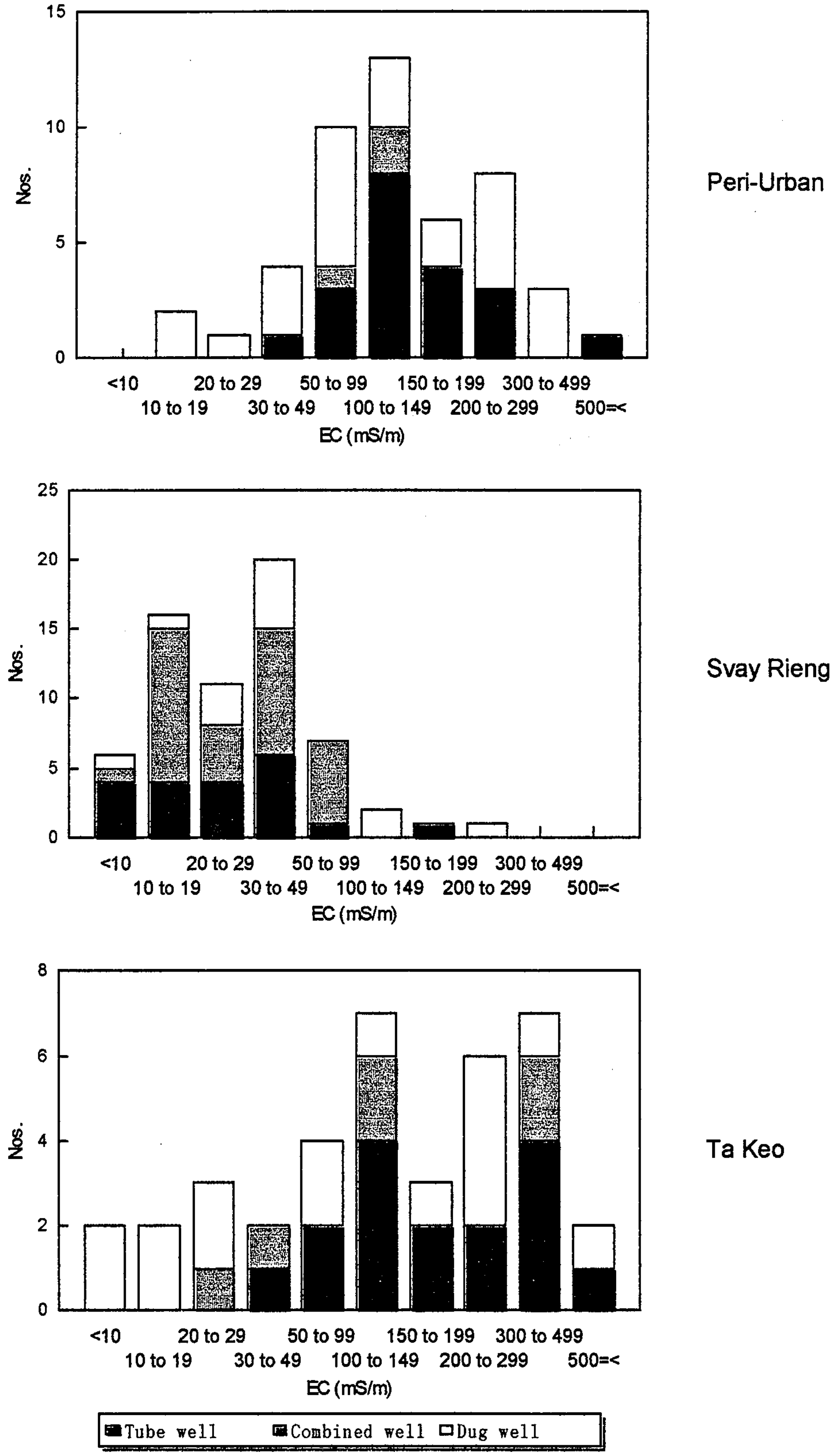


Figure 4.20	DISTRIBUTION OF EC BY PROVINCE AND WELL TYPE (1)
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

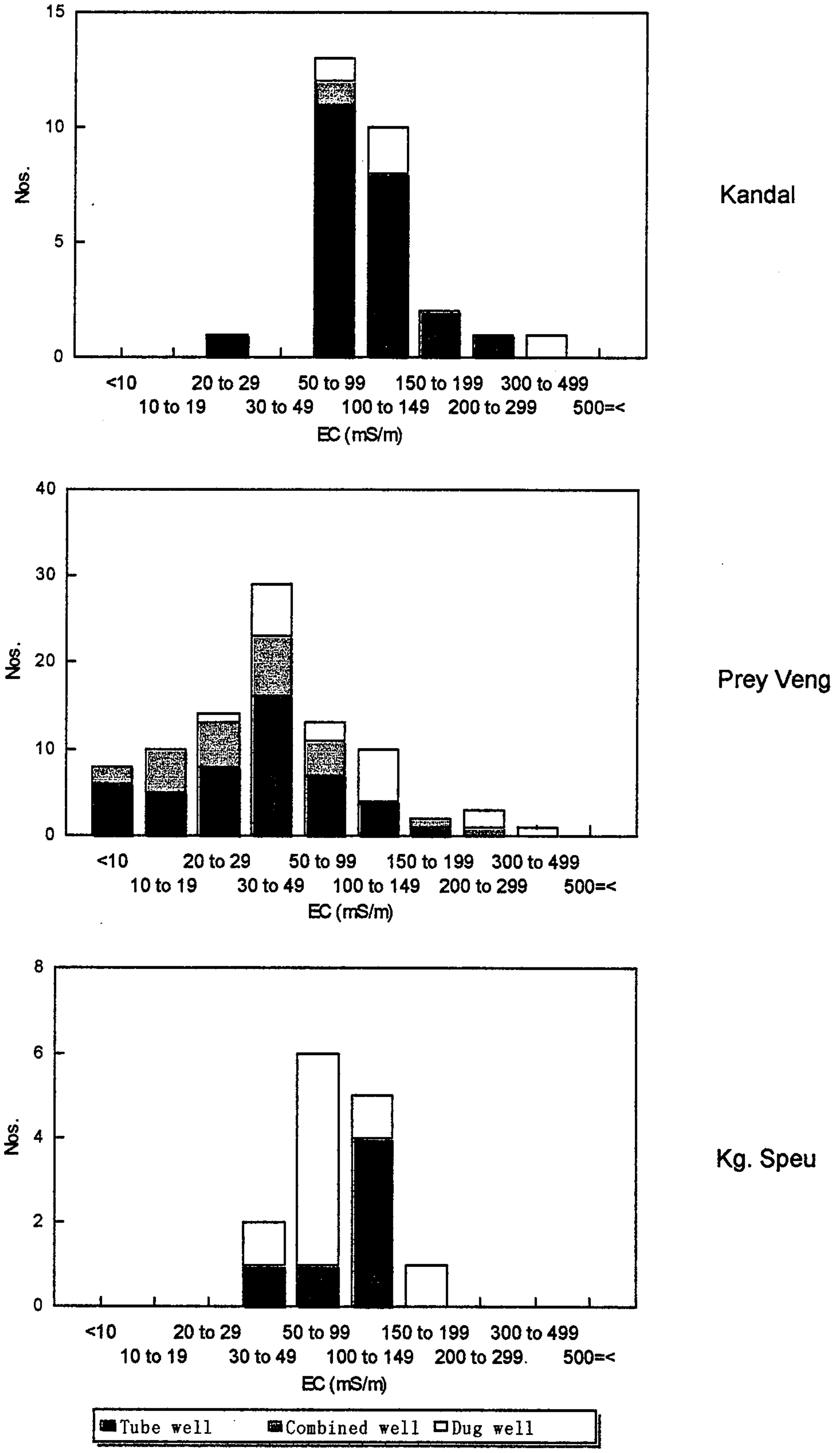
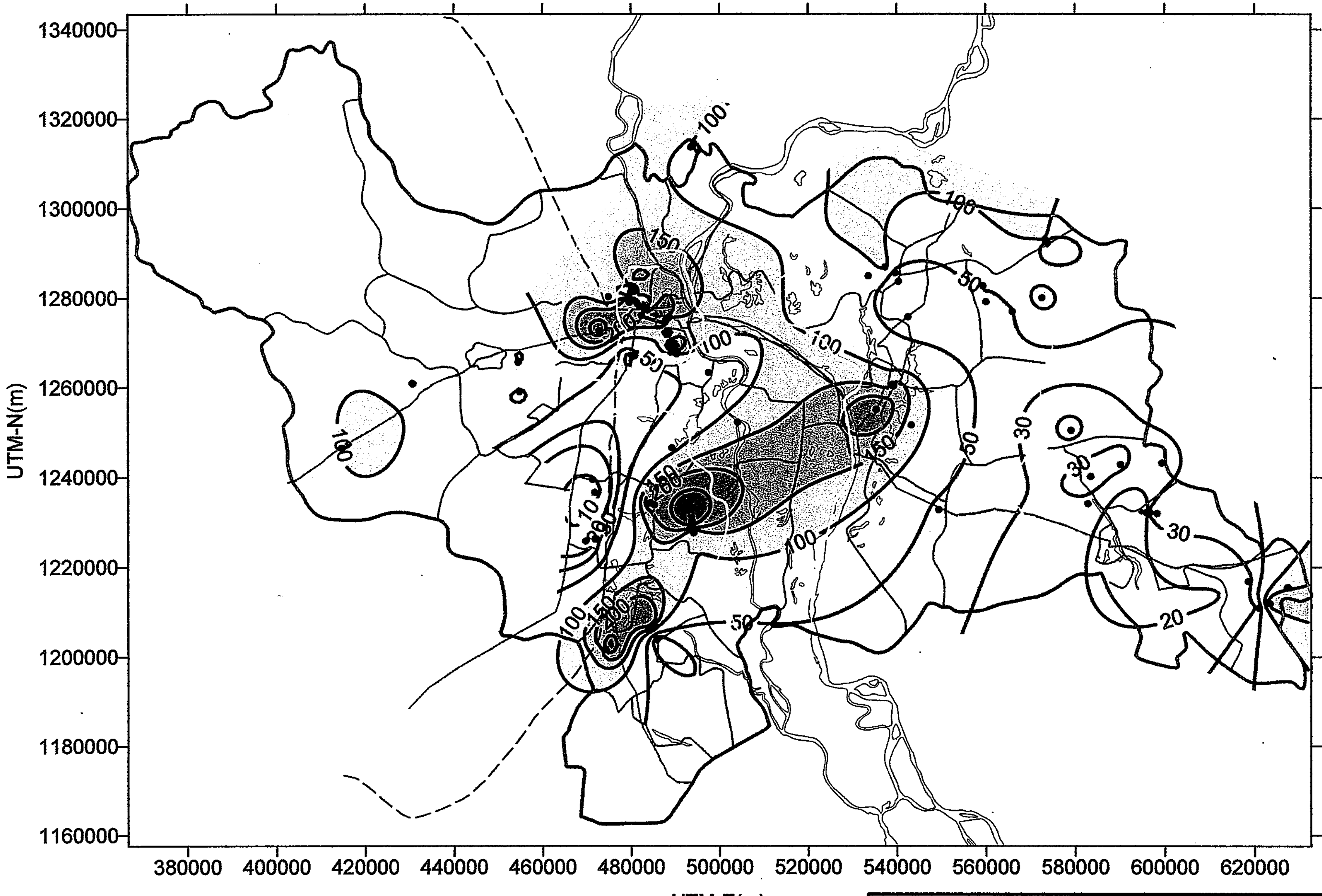


Figure 4.21	DISTRIBUTION OF EC BY PROVINCE AND WELL TYPE (2)
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



100 Equal line of Electric Conductivity, EC (mS/m)

• Location of measured dug well

(EC values were measured during a period from February 1997 to March 1997.)

Figure 4.22	DISTRIBUTION OF EC MEASURED AT EXISTING DUG WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

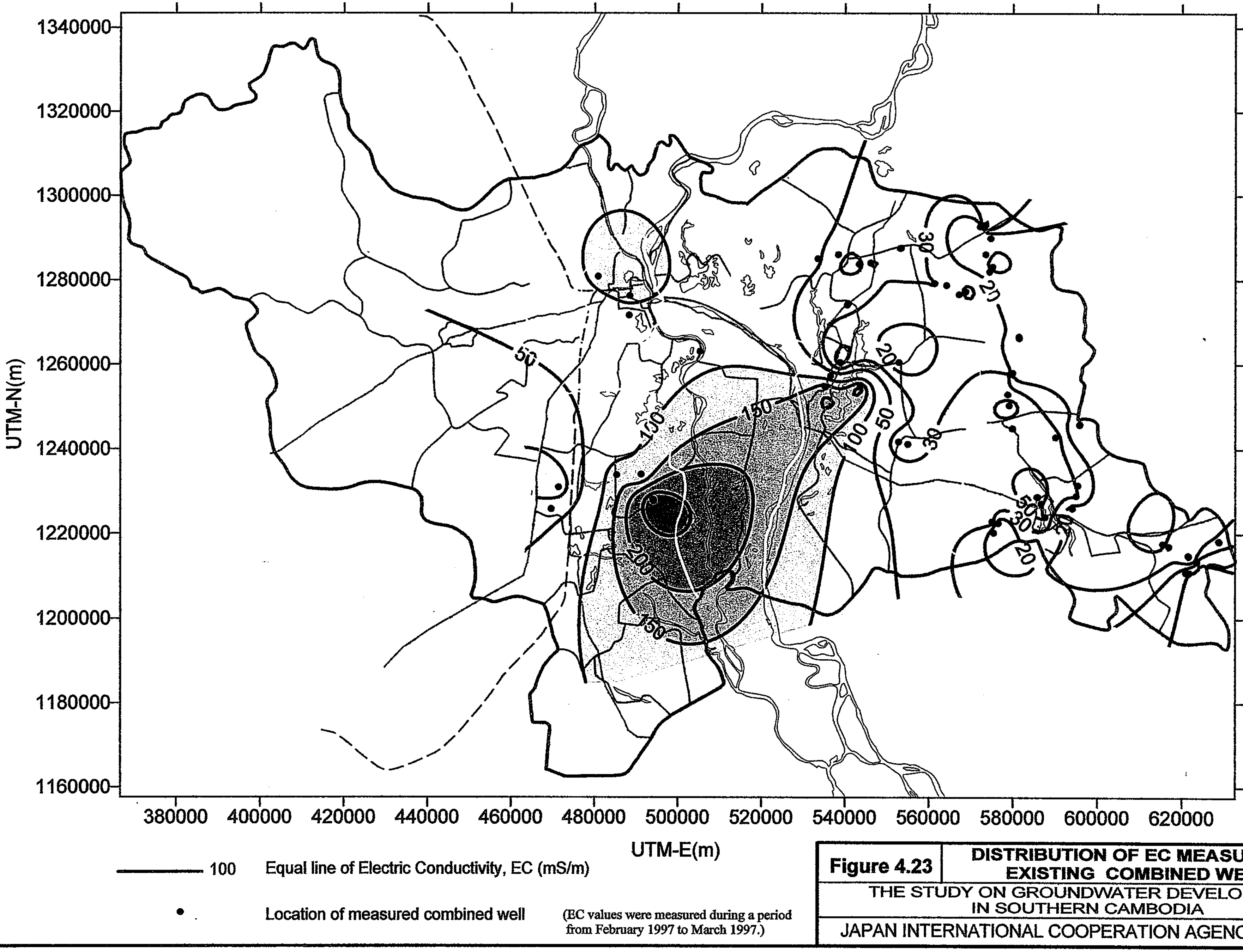
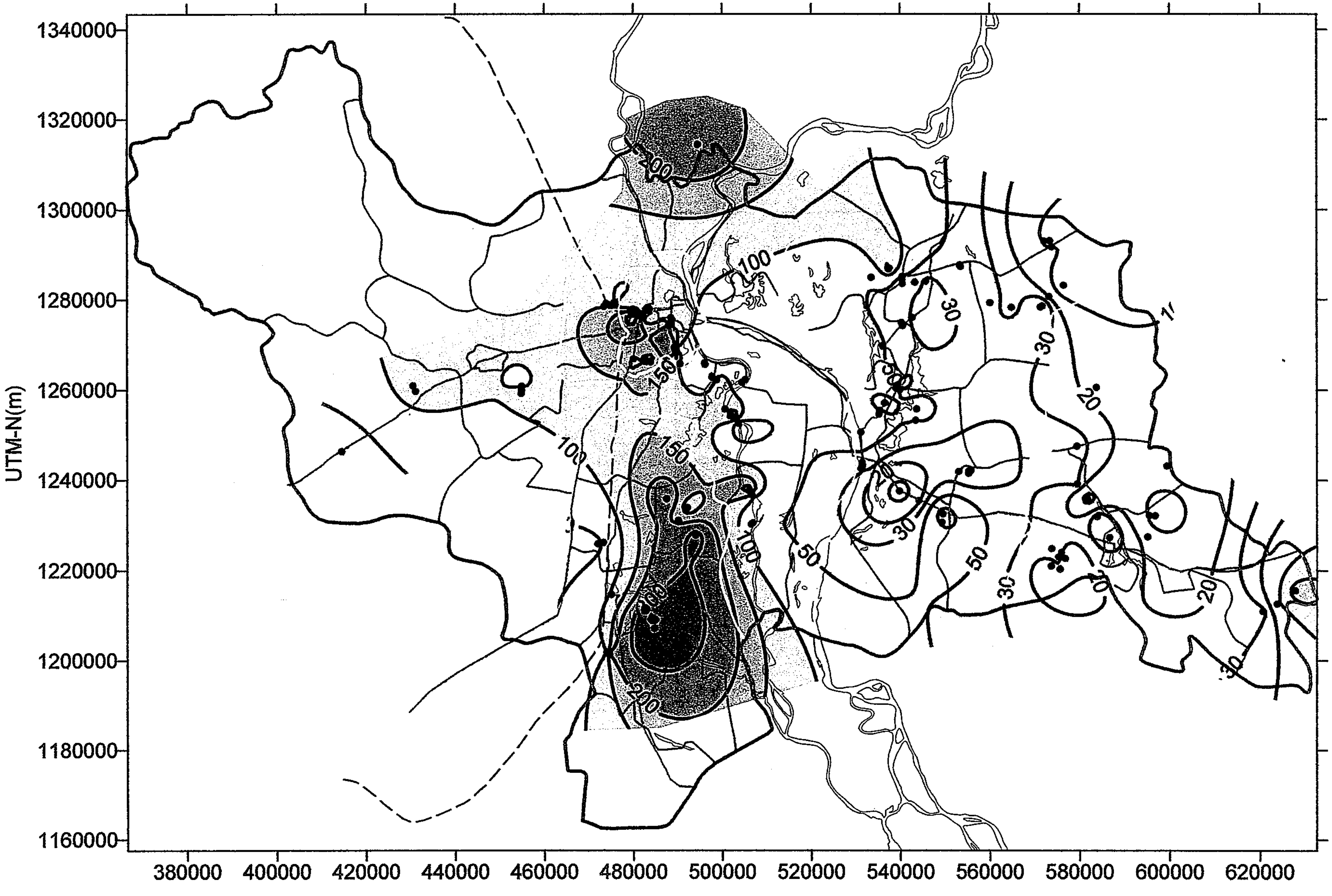


Figure 4.23	**DISTRIBUTION OF EC MEASURED AT EXISTING COMBINED WELLS**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



100 Equal line of Electric Conductivity, EC (mS/m)

• Location of measured tube well

(EC values were measured during a period from February 1997 to March 1997.)

Figure 4.24	DISTRIBUTION OF EC MEASURED AT EXISTING TUBE WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

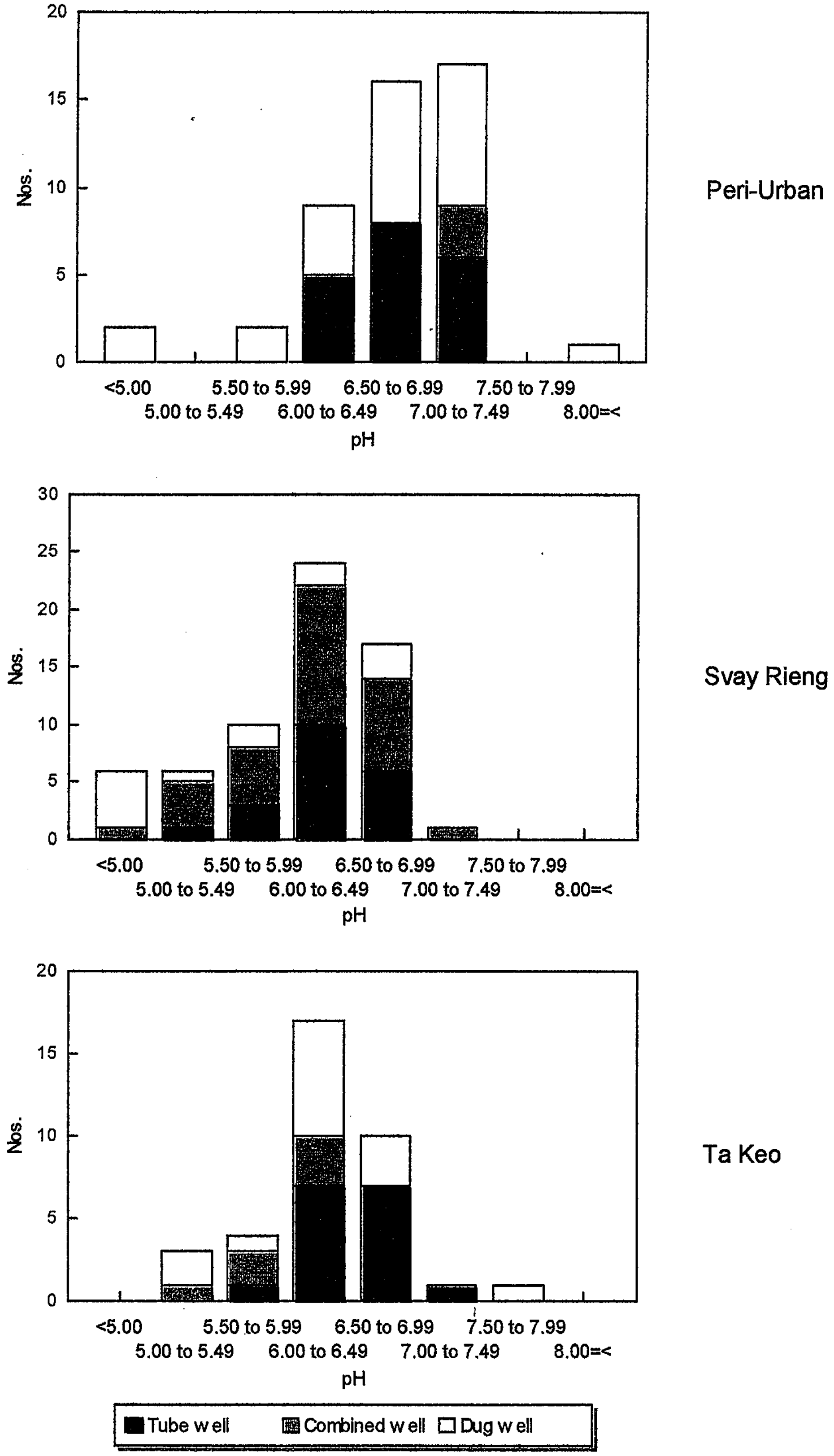


Figure 4.25	DISTRIBUTION OF pH BY PROVINCE AND WELL TYPE (1)
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

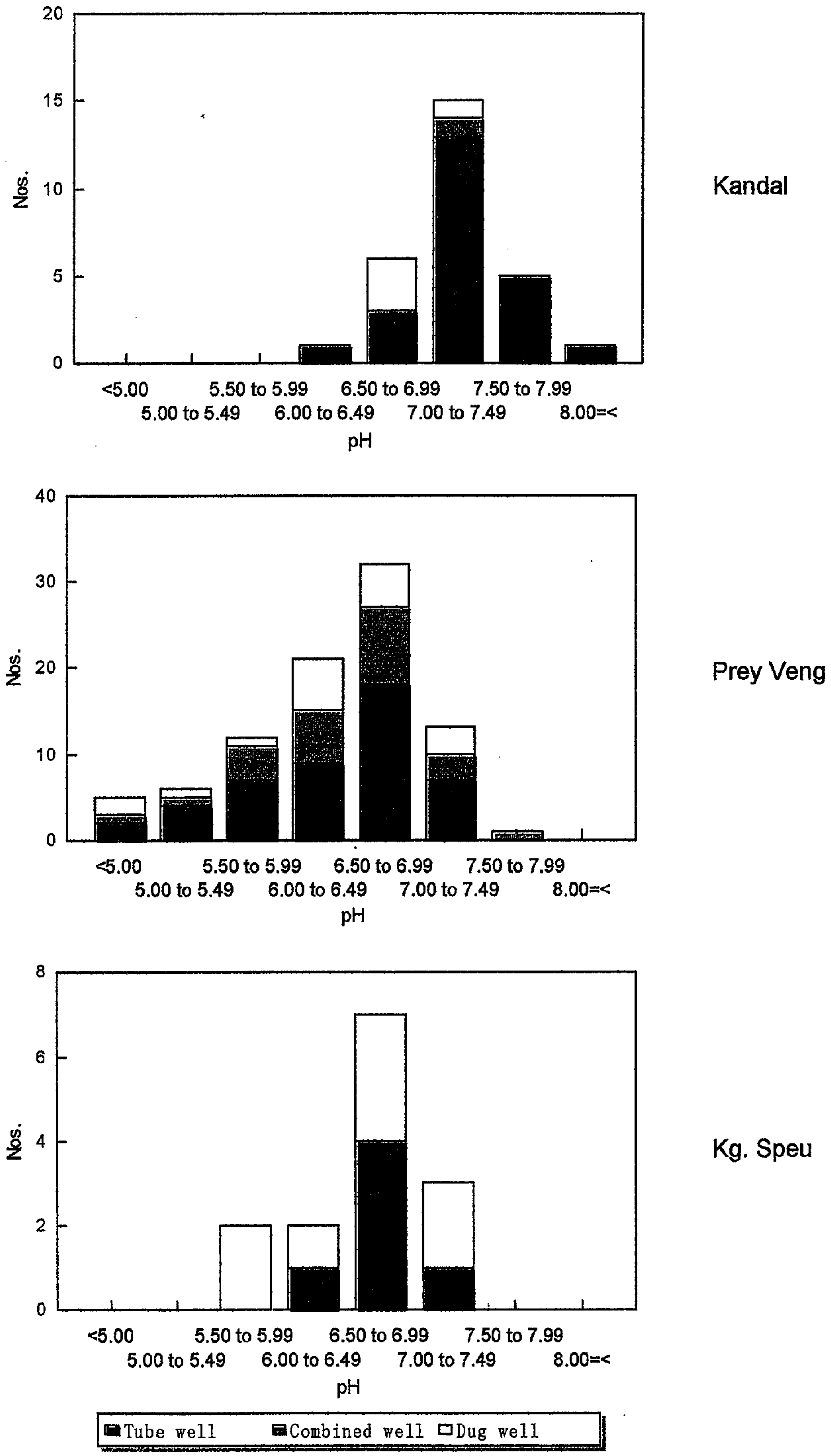
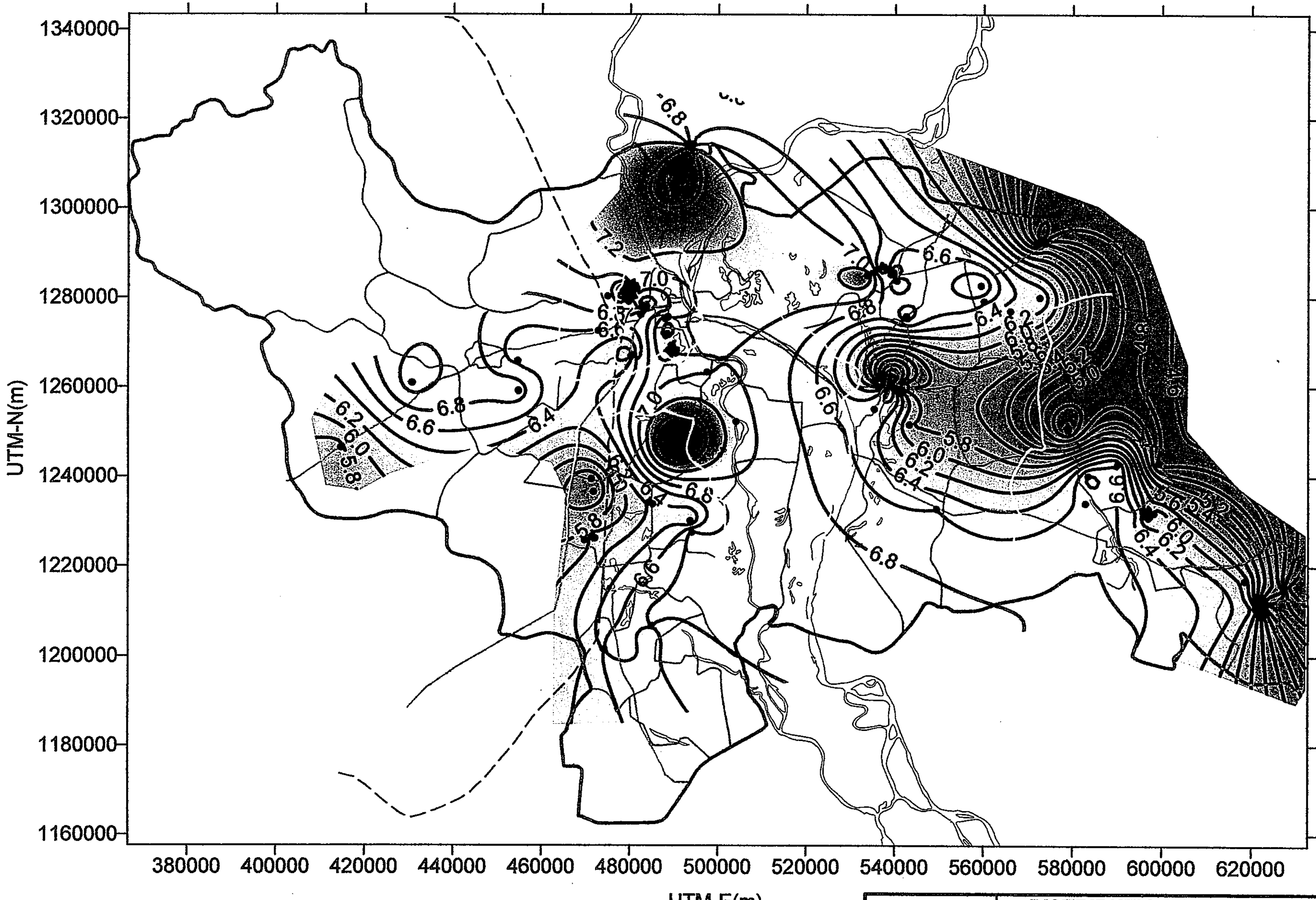


Figure 4.26 DISTRIBUTION OF pH BY PROVINCE AND WELL TYPE (2)

THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

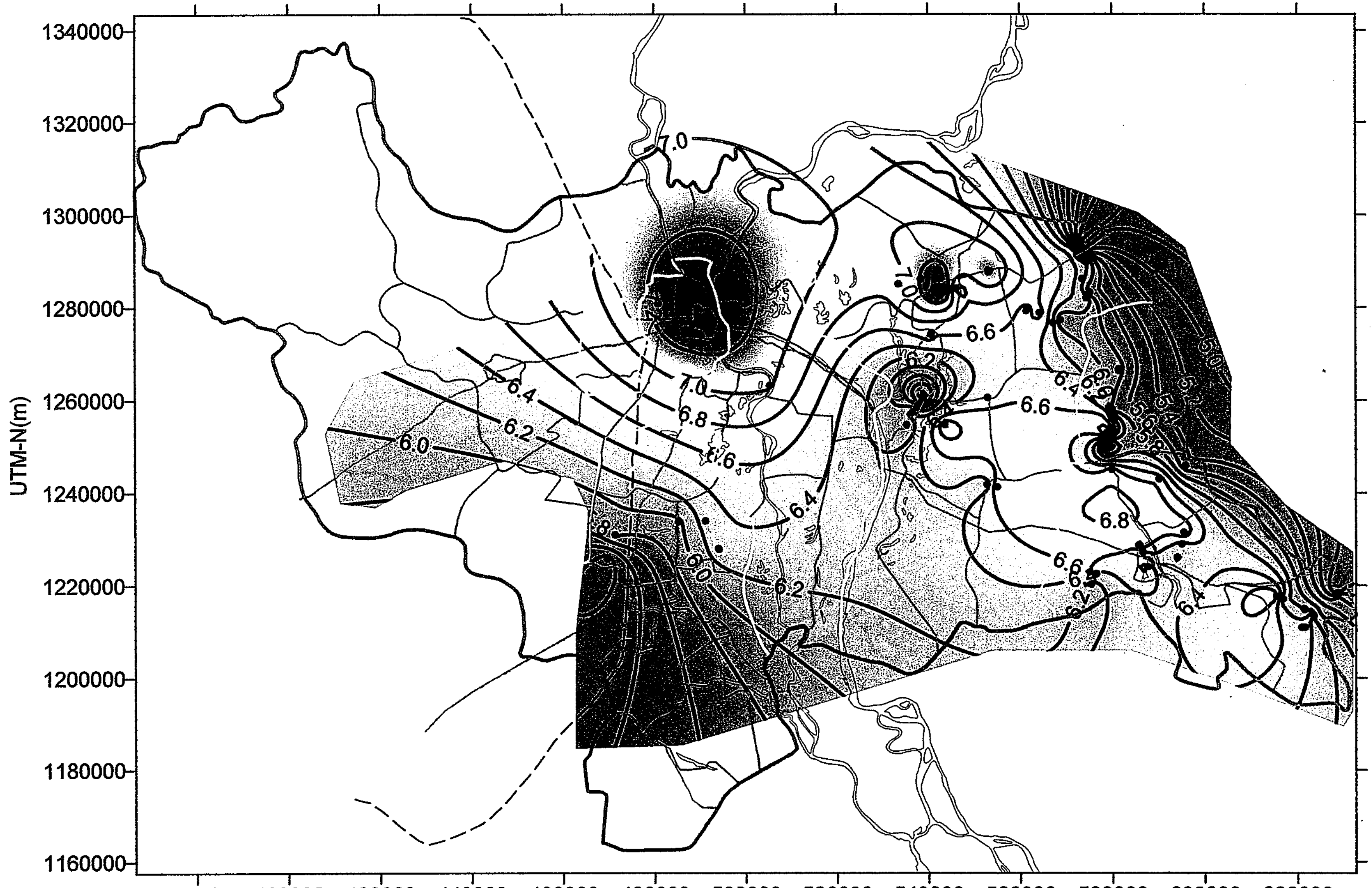


——— 7.0 Equal line of pH

• Location of measured dug well

(pH values were measured during a period from February 1997 to March 1997.)

Figure 4.27	DISTRIBUTION OF pH MEASURED AT EXISTING DUG WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



(pH values were measured during a period from February 1997 to March 1997.)

Figure 4.28	DISTRIBUTION OF pH MEASURED AT EXISTING COMBINED WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

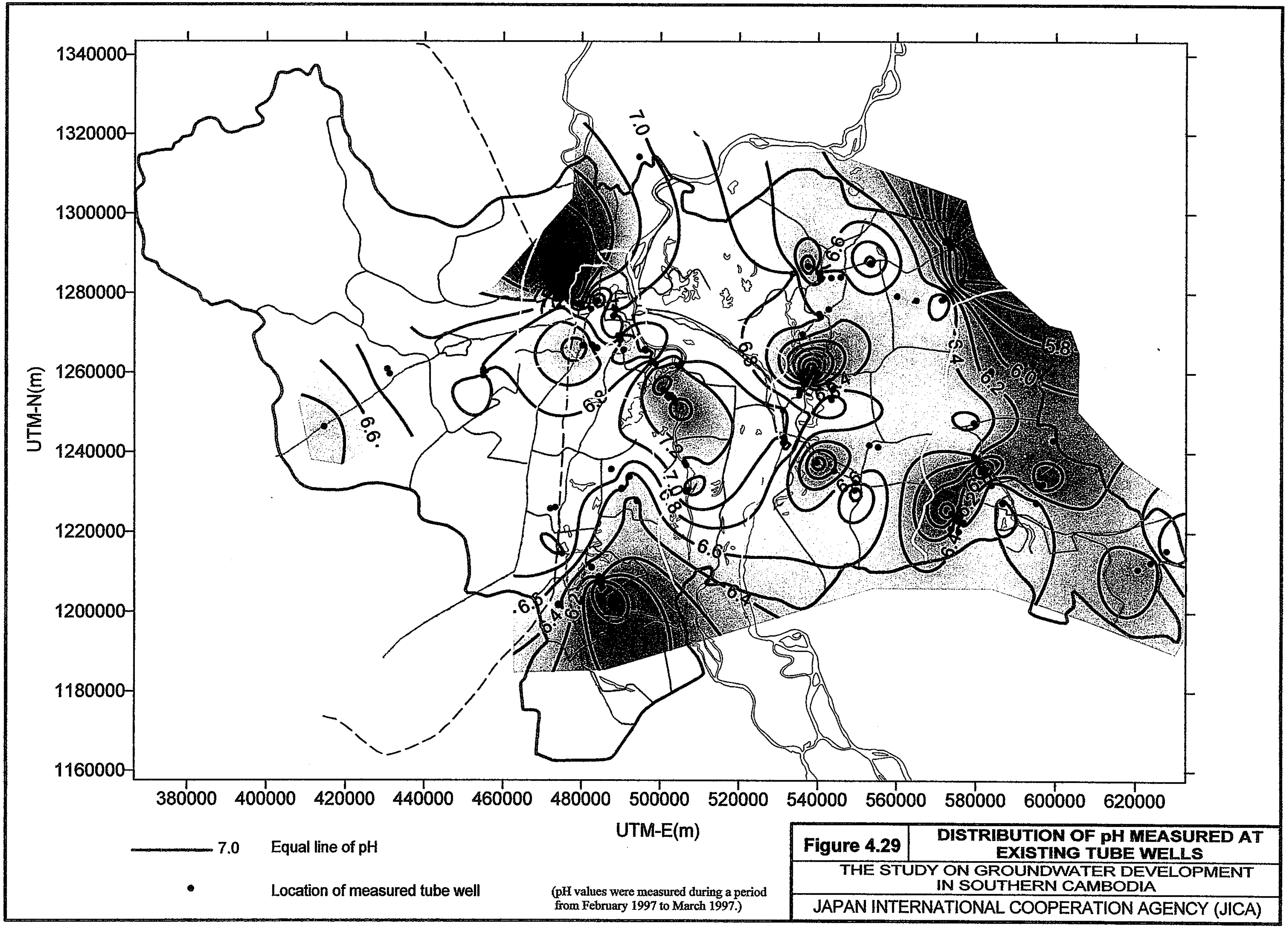


Figure 4.29	DISTRIBUTION OF pH MEASURED AT EXISTING TUBE WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

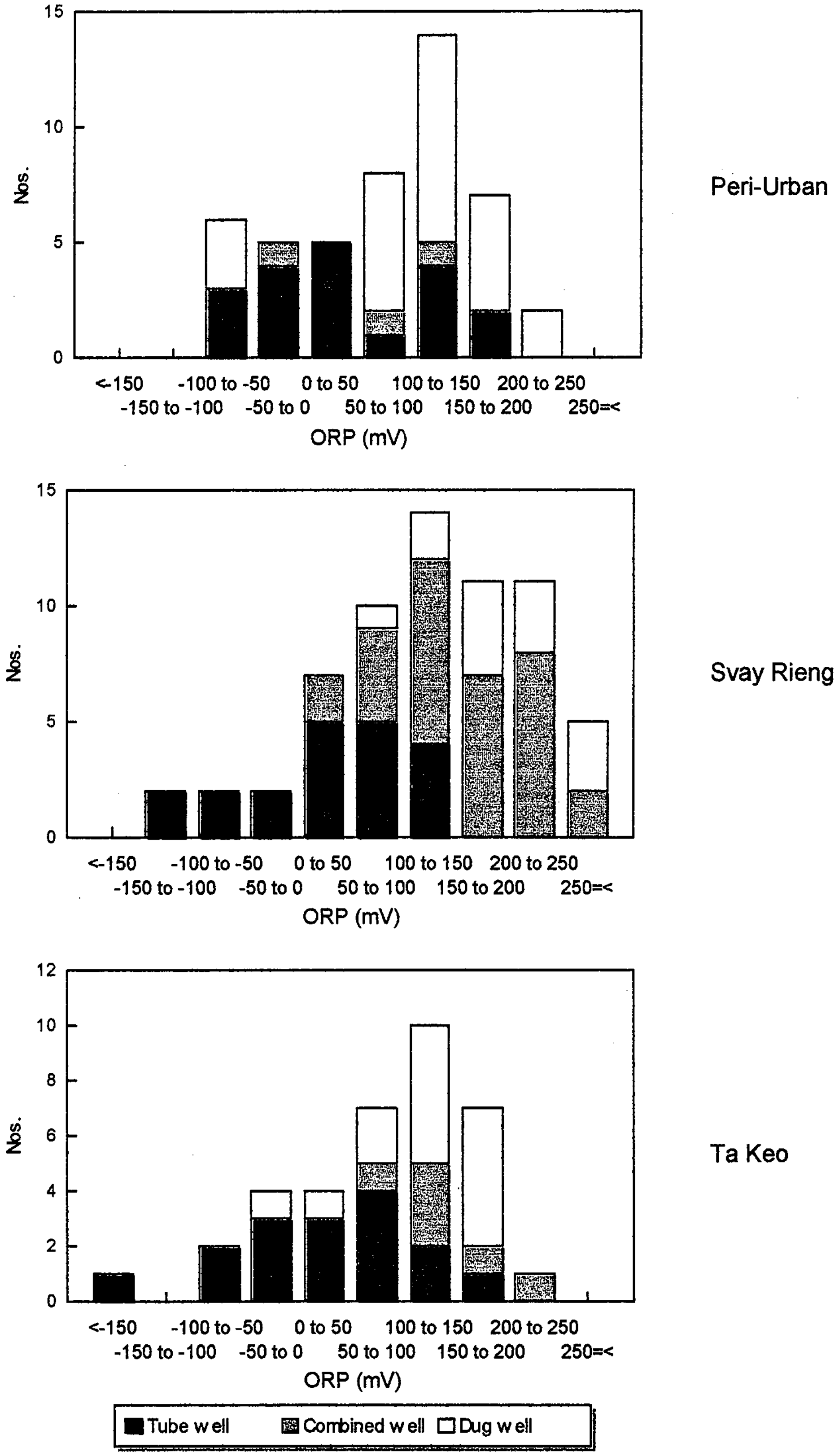


Figure 4.30	**DISTRIBUTION OF ORP BY PROVINCE AND WELL TYPE (1)**

THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

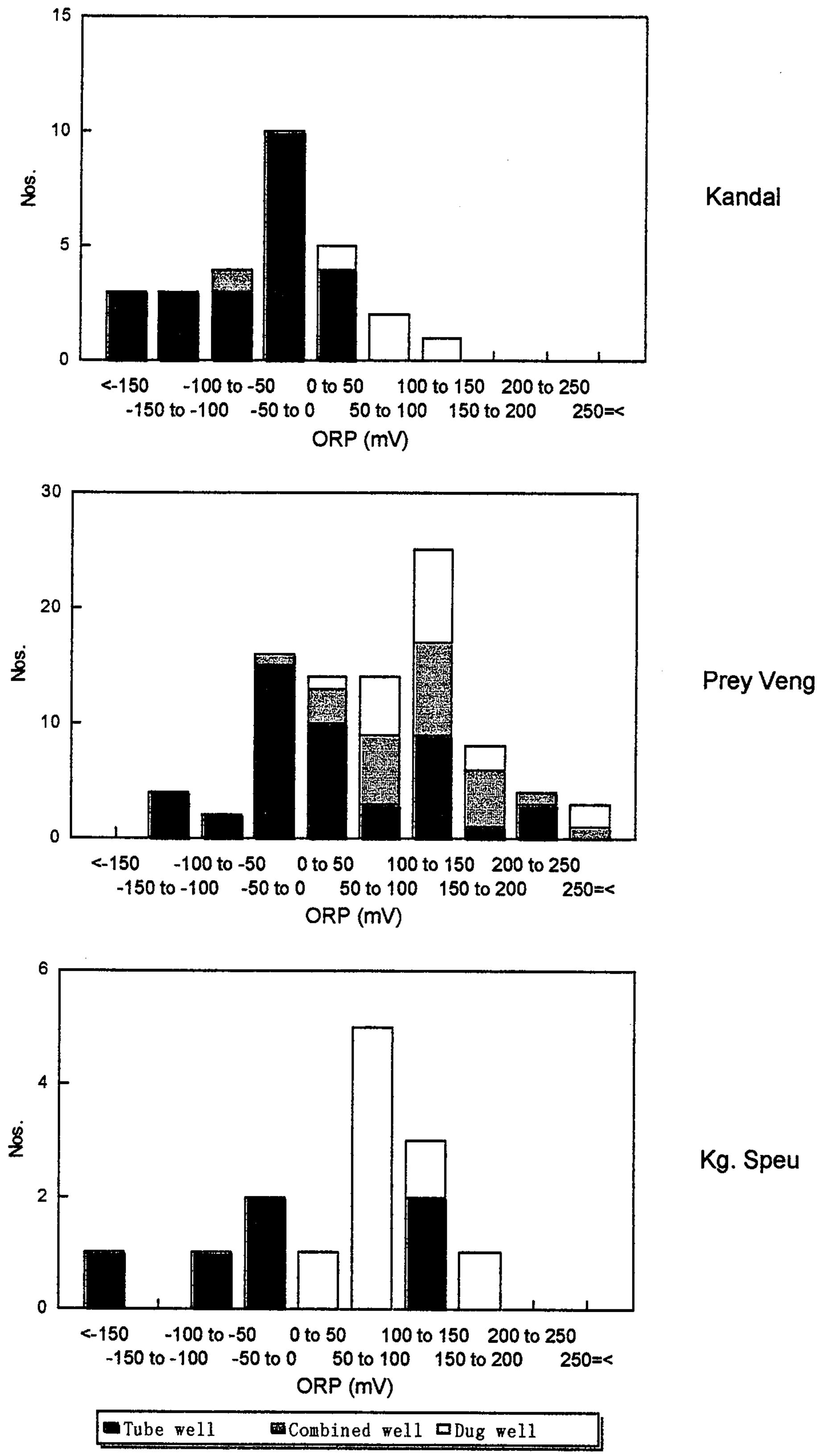
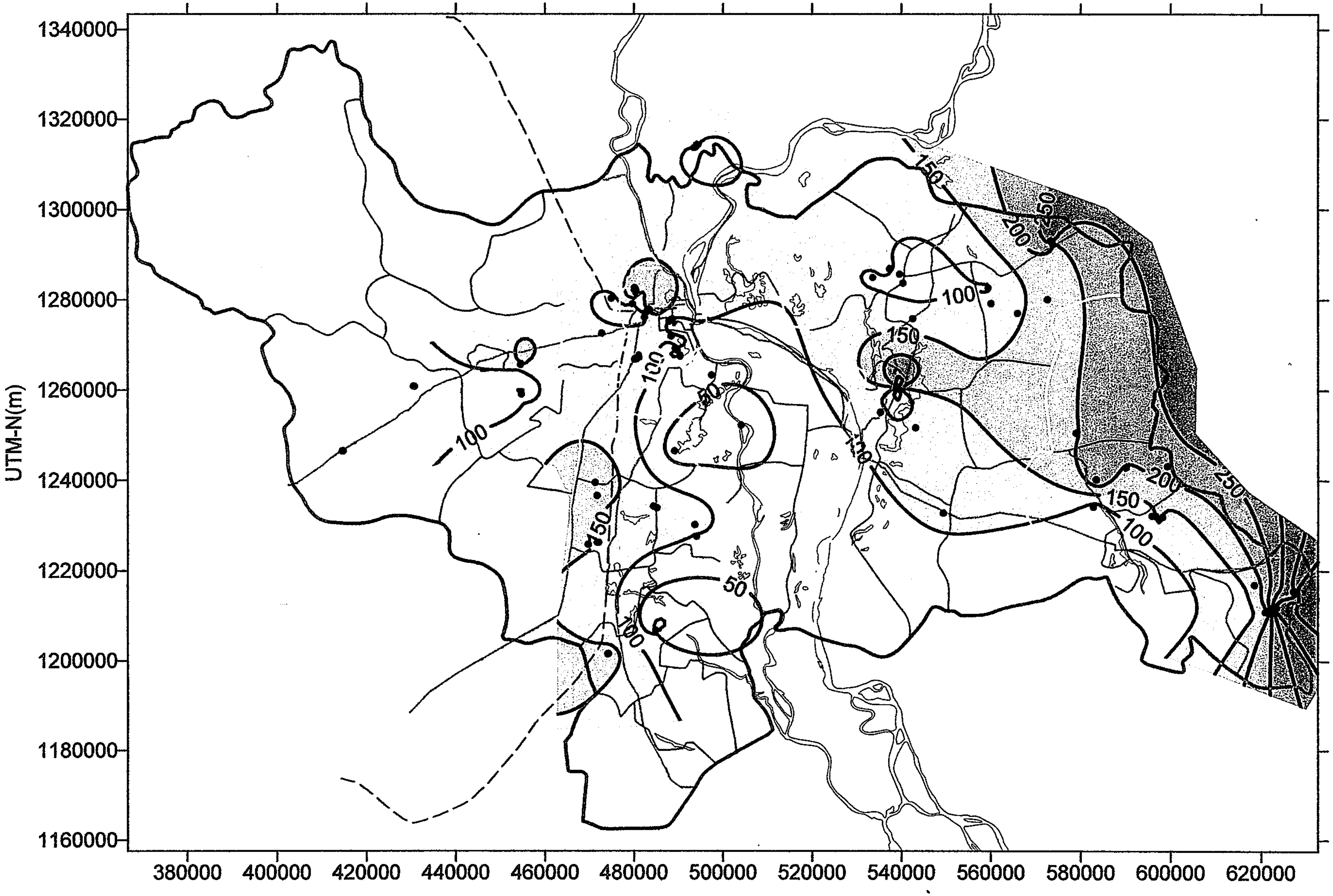


Figure 4.31	DISTRIBUTION OF Eh BY PROVINCE AND WELL TYPE (2)
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

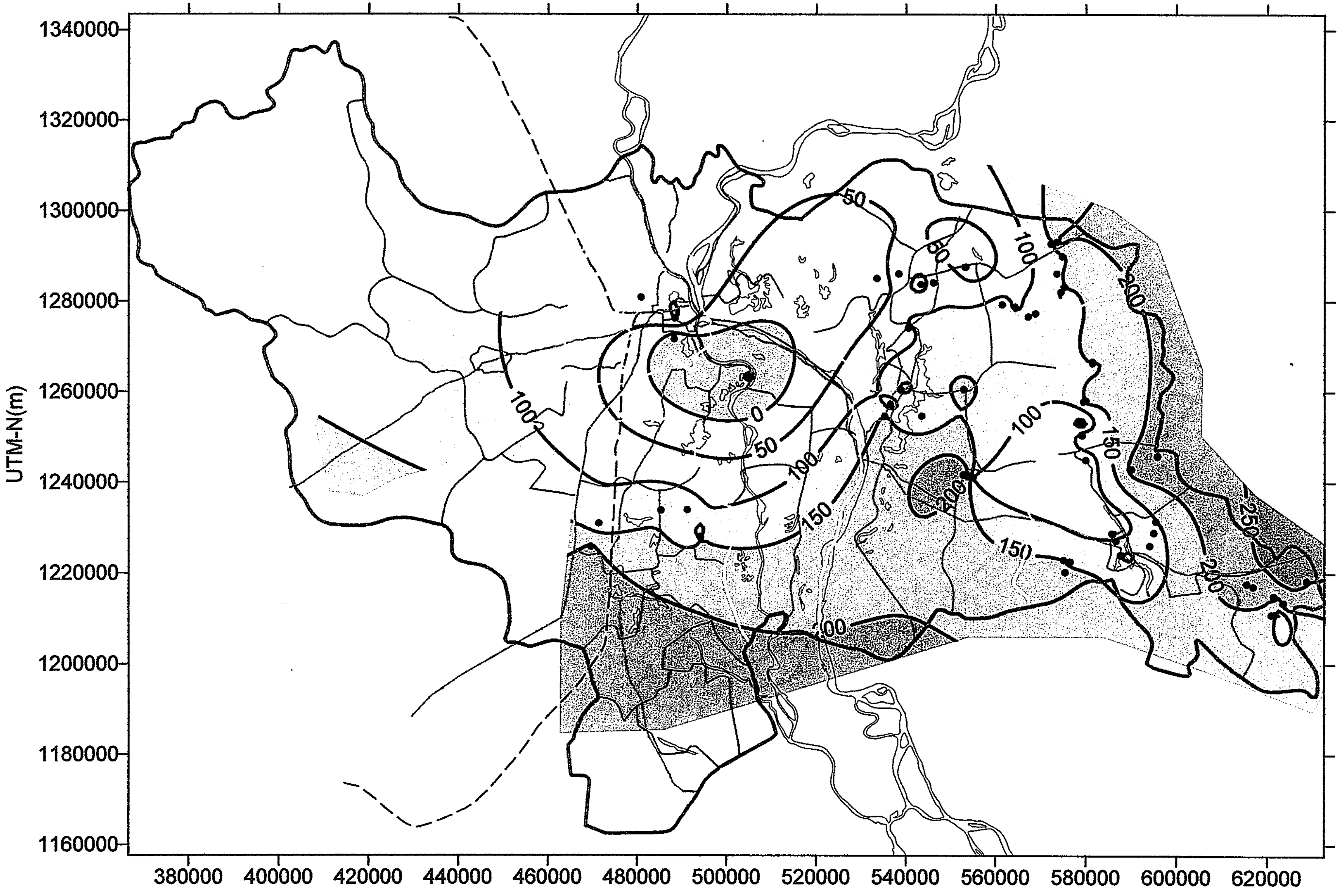


100 Equal line of ORP (mV)

• Location of measured dug well

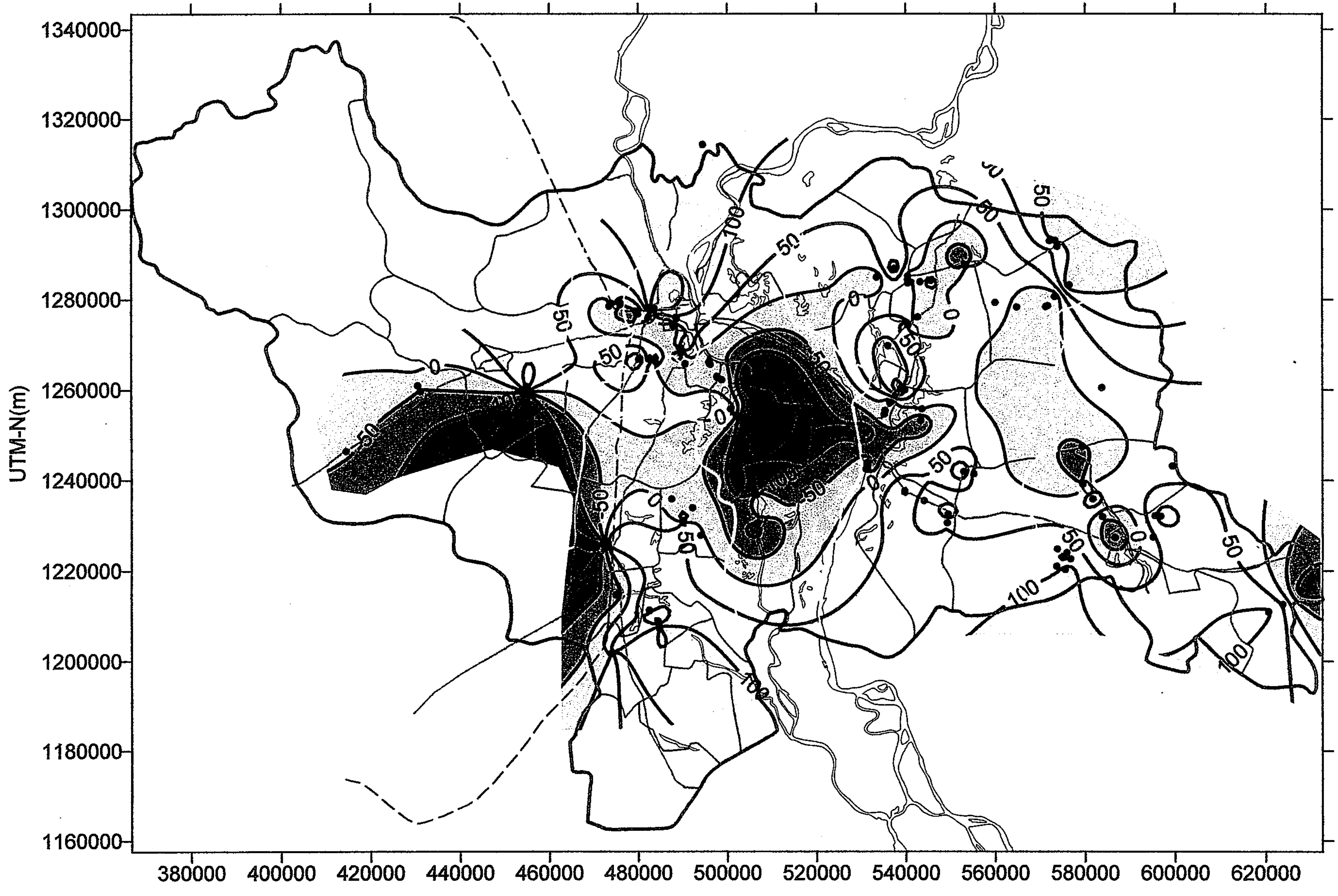
(ORP values were measured during a period from February 1997 to March 1997.)

Figure 4.32	DISTRIBUTION OF ORP VALUES MEASURED AT EXISTING DUG WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



(ORP values were measured during a period from February 1997 to March 1997.)

Figure 4.33	DISTRIBUTION OF ORP VALUES MEASURED AT EXISTING COMBINED WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

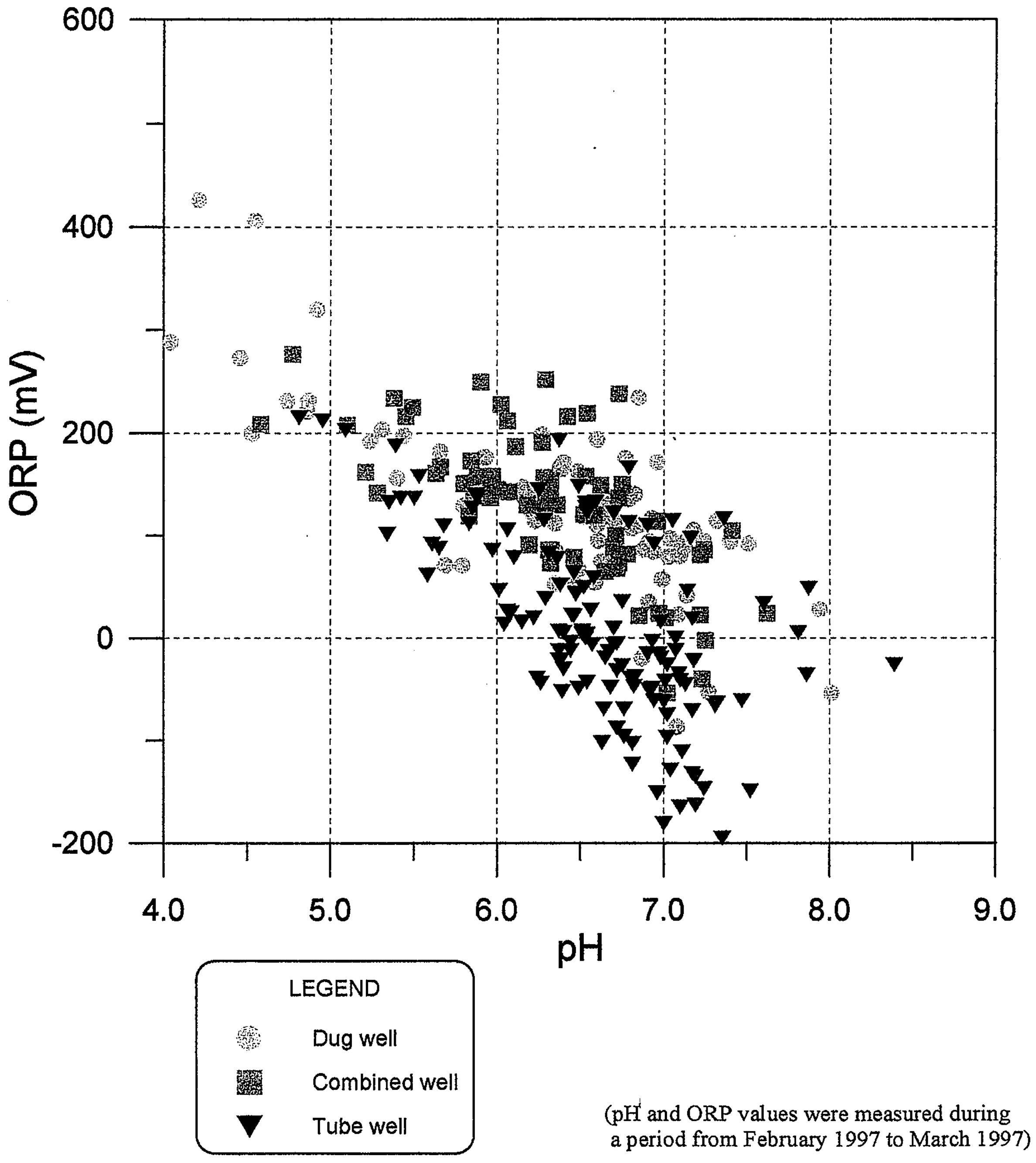


100 Equal line of ORP (mV)

• Location of measured tube well

(ORP values were measured during a period from February 1997 to March 1997.)

Figure 4.34	DISTRIBUTION OF ORP VALUES MEASURED AT EXISTING TUBE WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



(pH and ORP values were measured during a period from February 1997 to March 1997)

Figure 4.35	ORP - pH RELATION OF GROUNDWATER
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

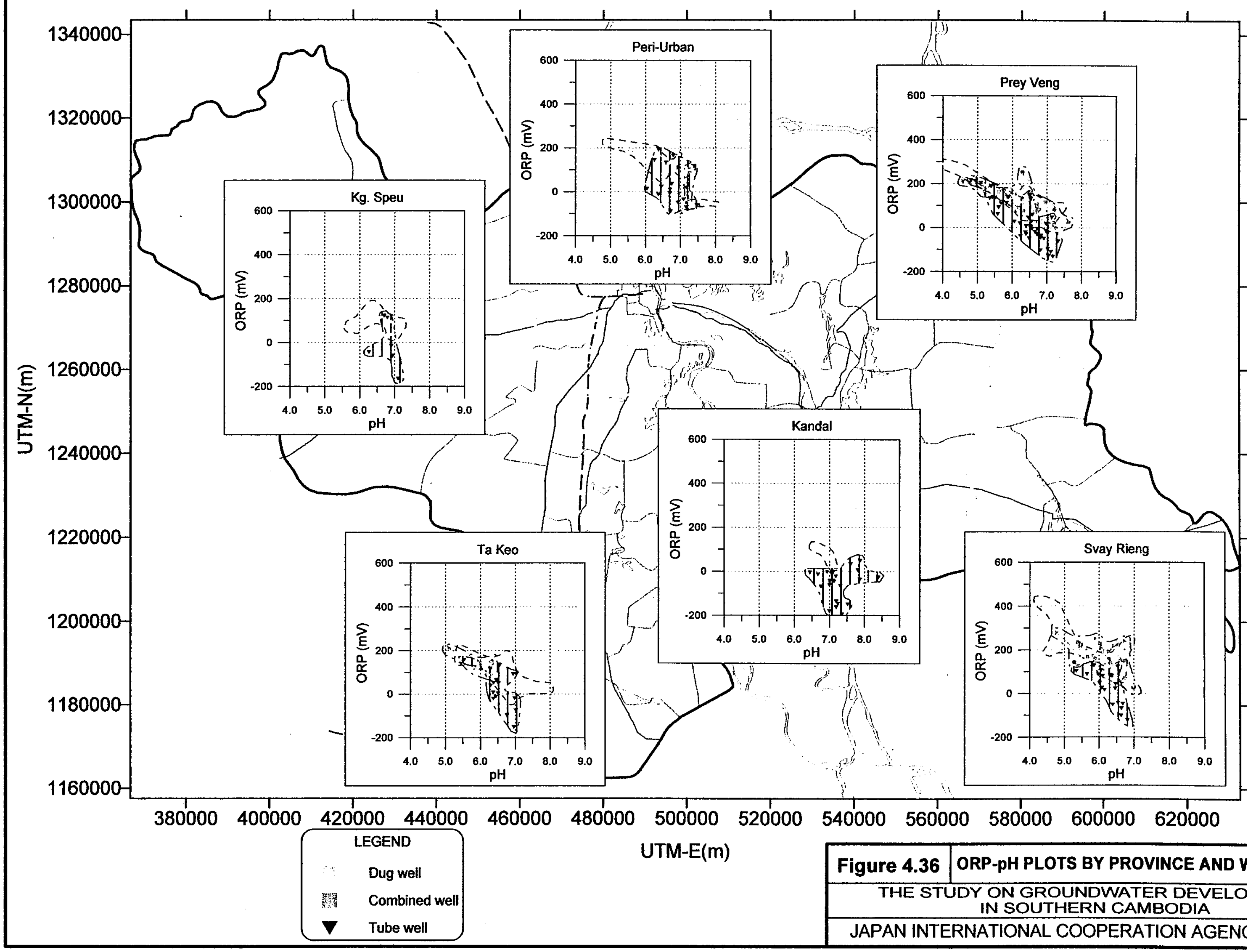


Figure 4.36	**ORP-pH PLOTS BY PROVINCE AND WELL TYPE**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

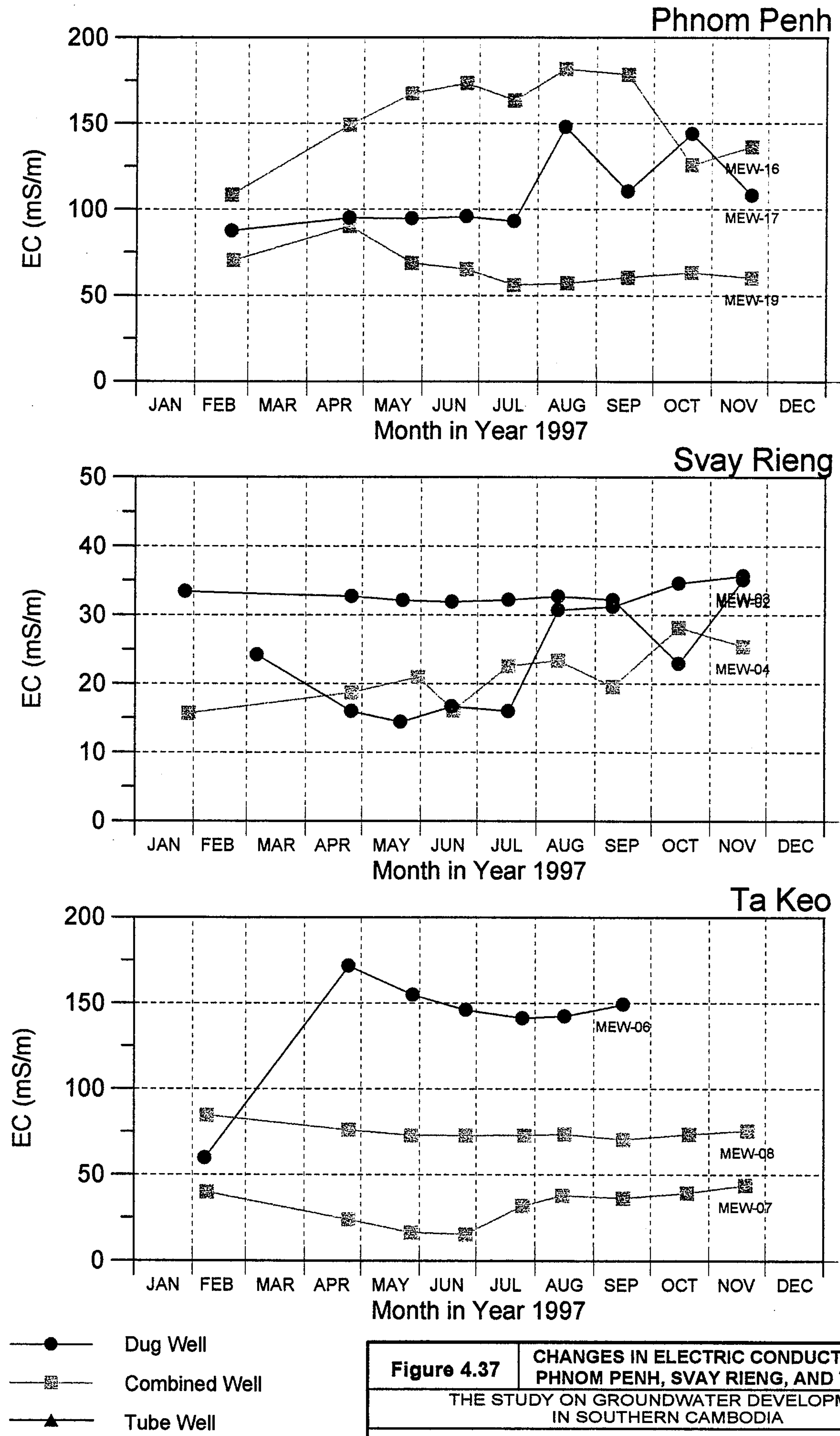
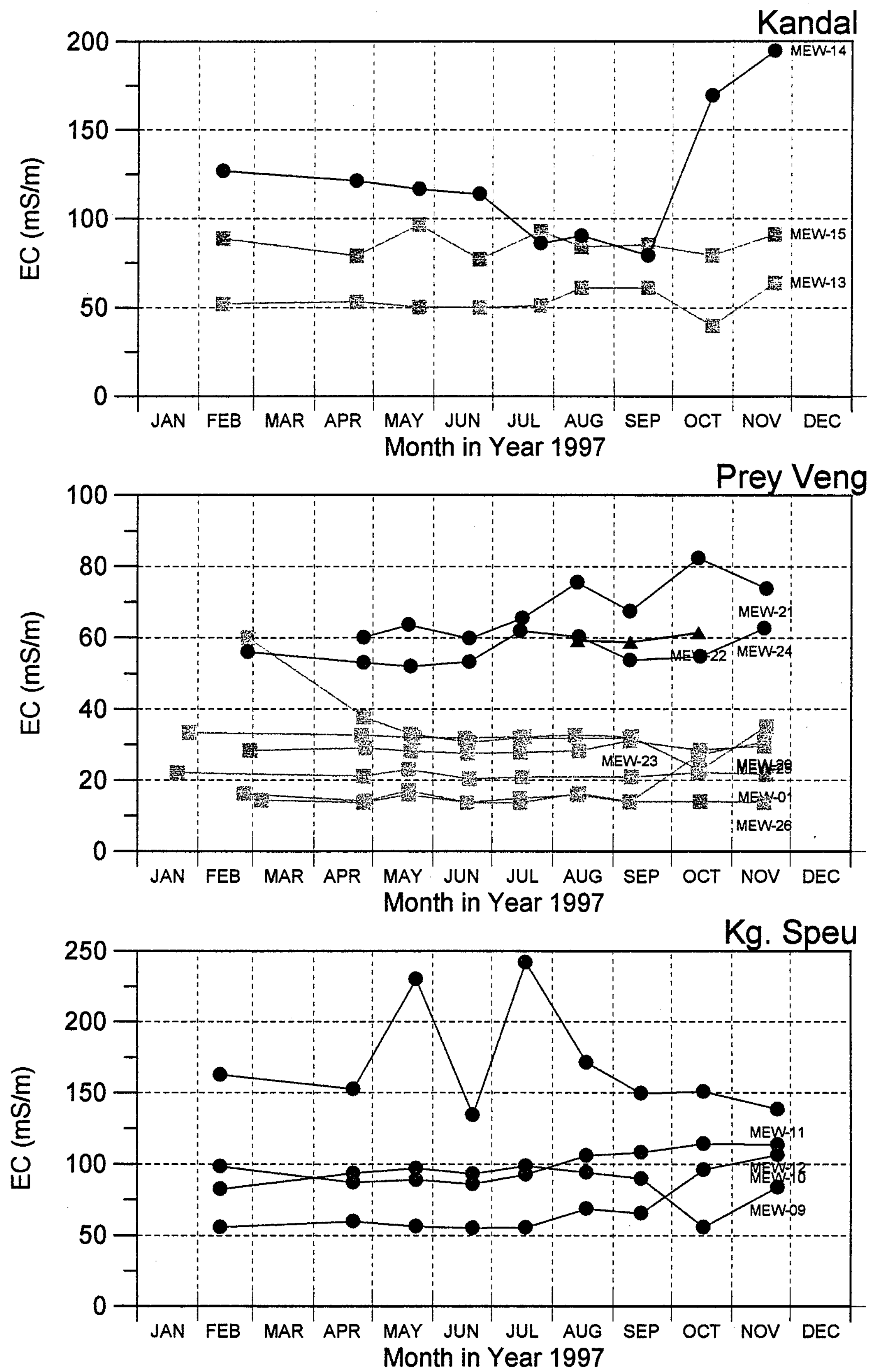


Figure 4.37	**CHANGES IN ELECTRIC CONDUCTIVITY IN PHNOM PENH, SVAY RIENG, AND TA KEO**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



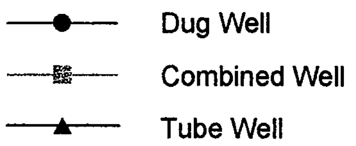


Figure 4.38	**CHANGES IN ELECTRIC CONDUCTIVITY IN KANDAL, PREY VENG, AND KG. SPEU**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

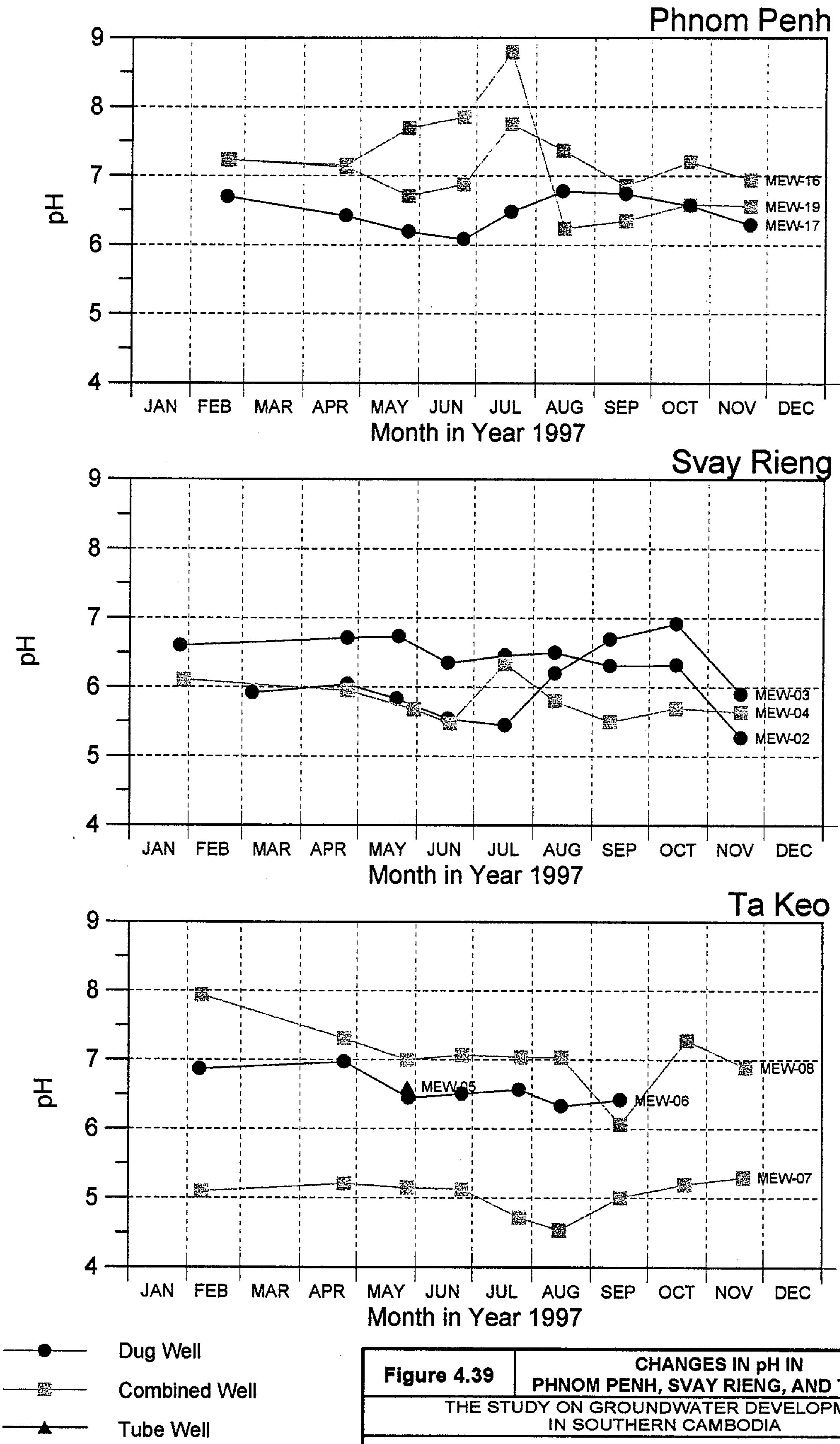


Figure 4.39	CHANGES IN pH IN PHNOM PENH, SVAY RIENG, AND TA KEO

THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

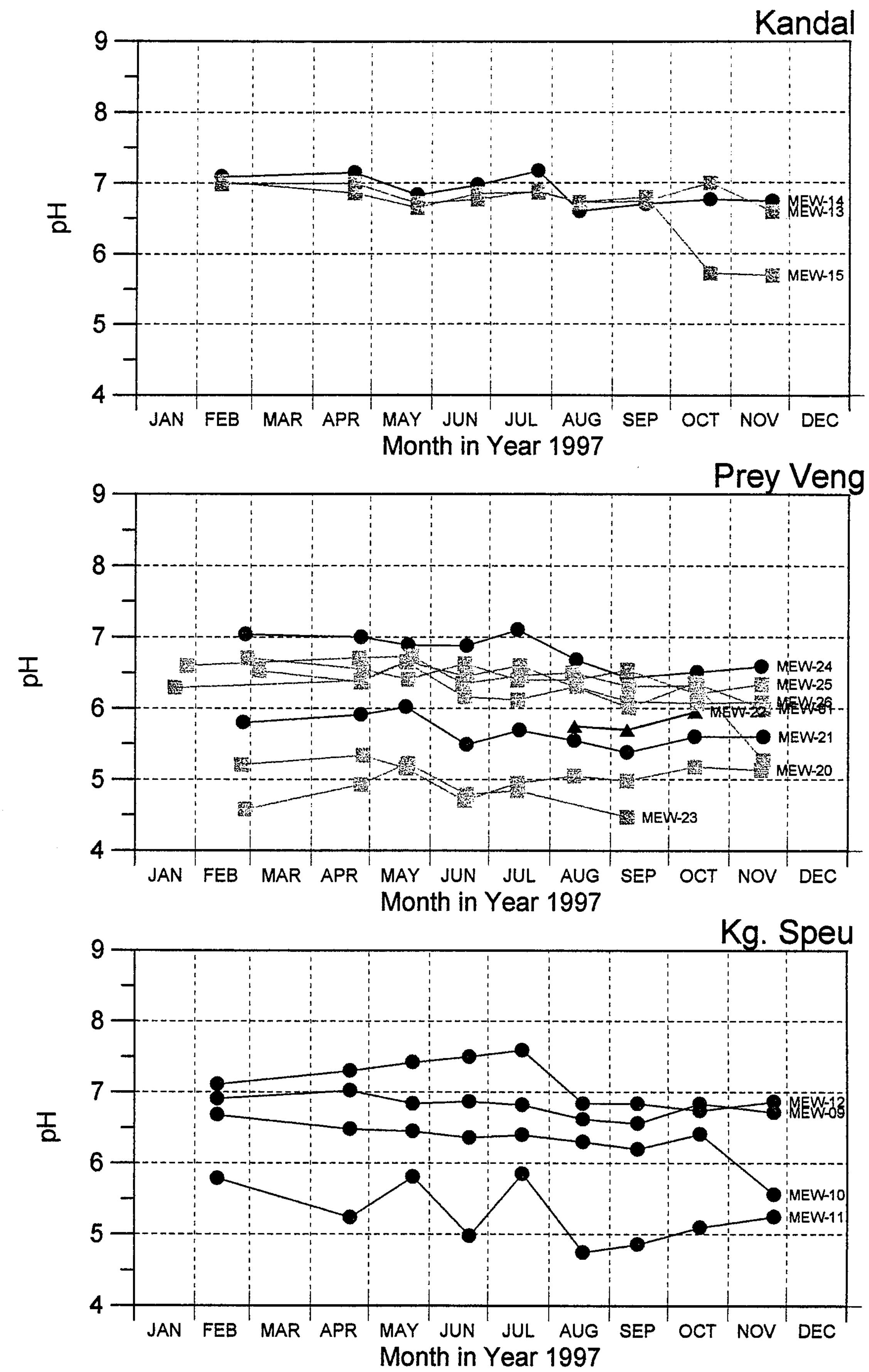


Figure 4.40	**CHANGES IN pH IN KANDAL, PREY VENG, AND KG. SPEU**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

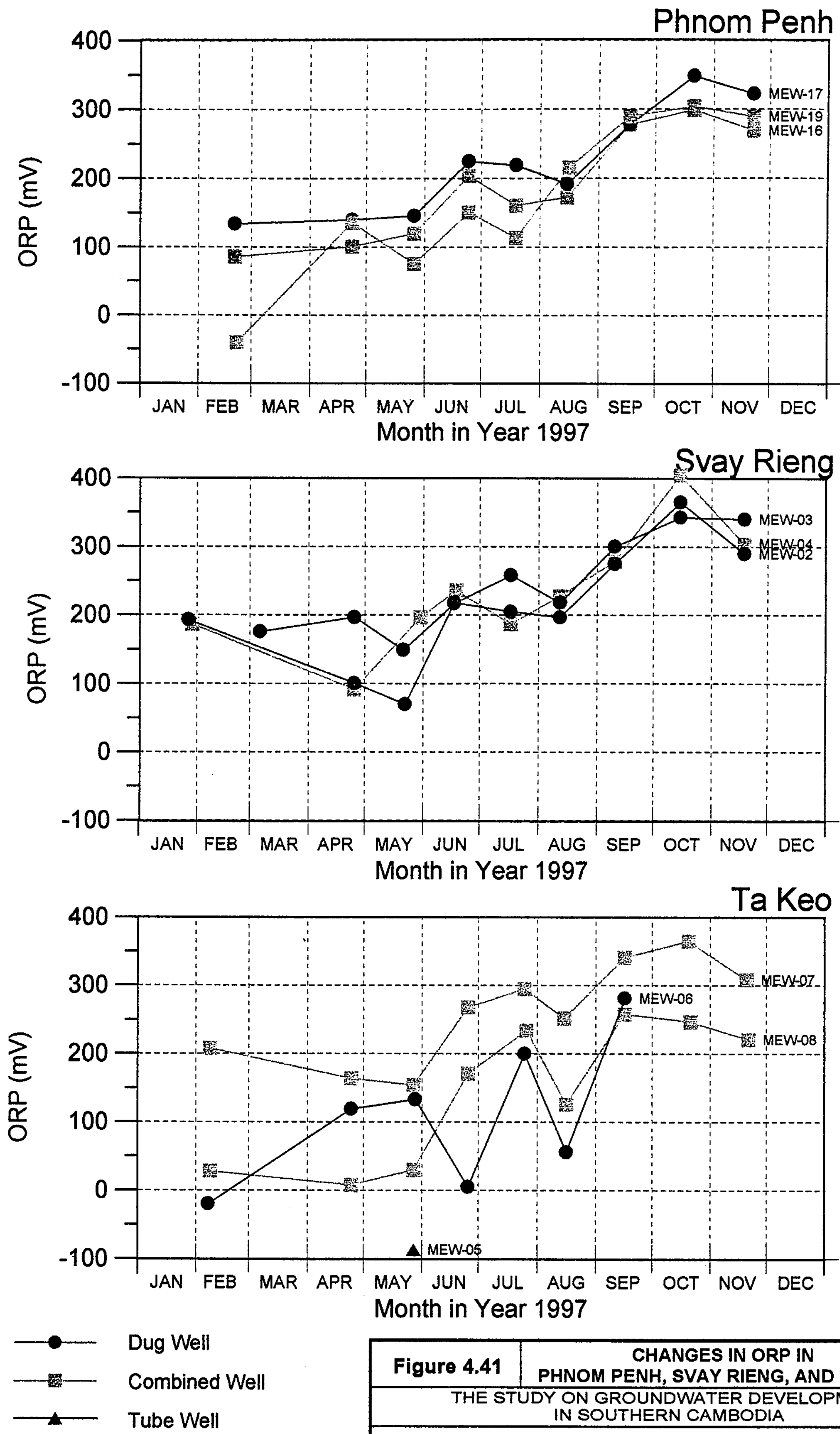


Figure 4.41	**CHANGES IN ORP IN PHNOM PENH, SVAY RIENG, AND TA KEO**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

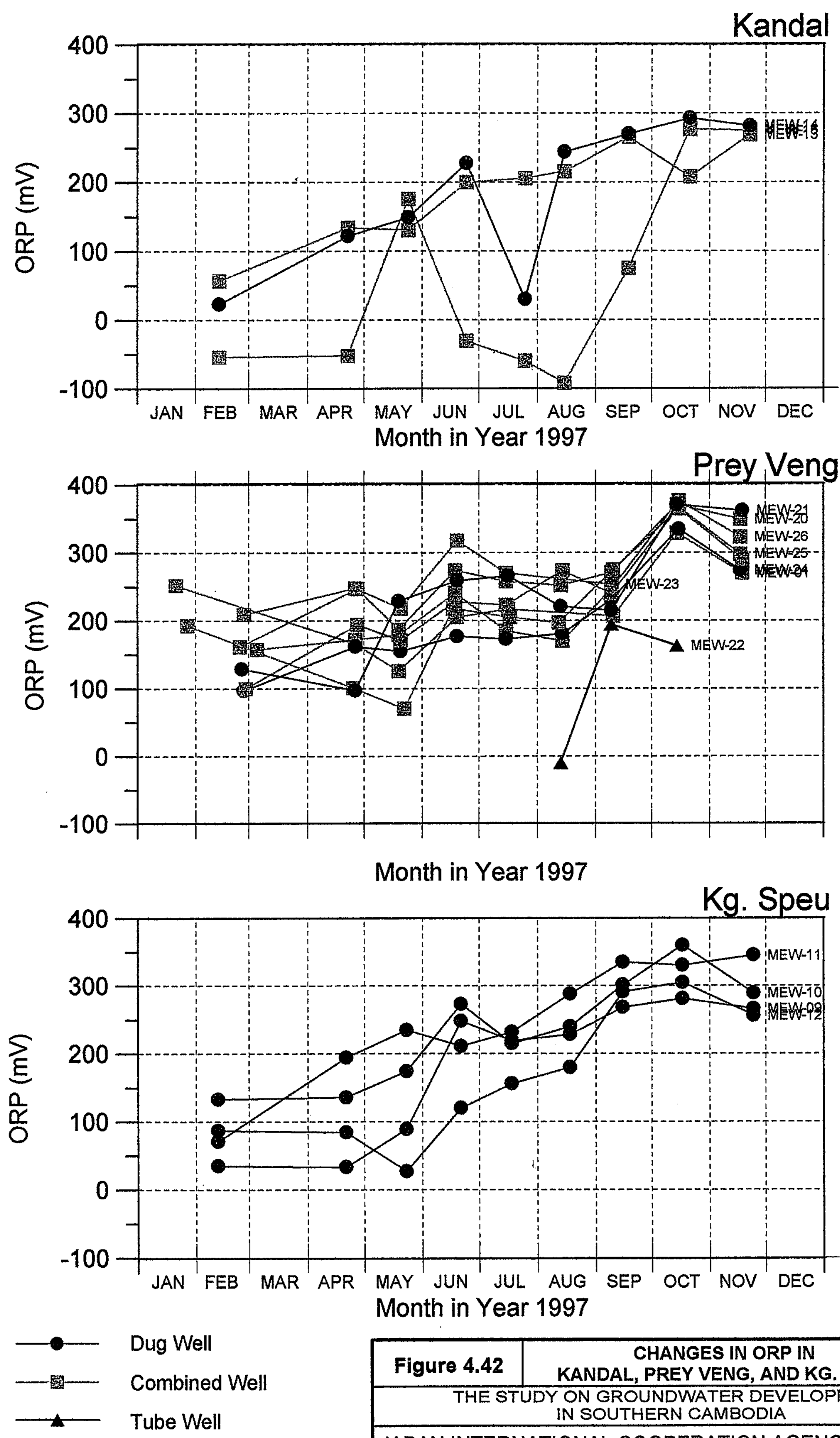
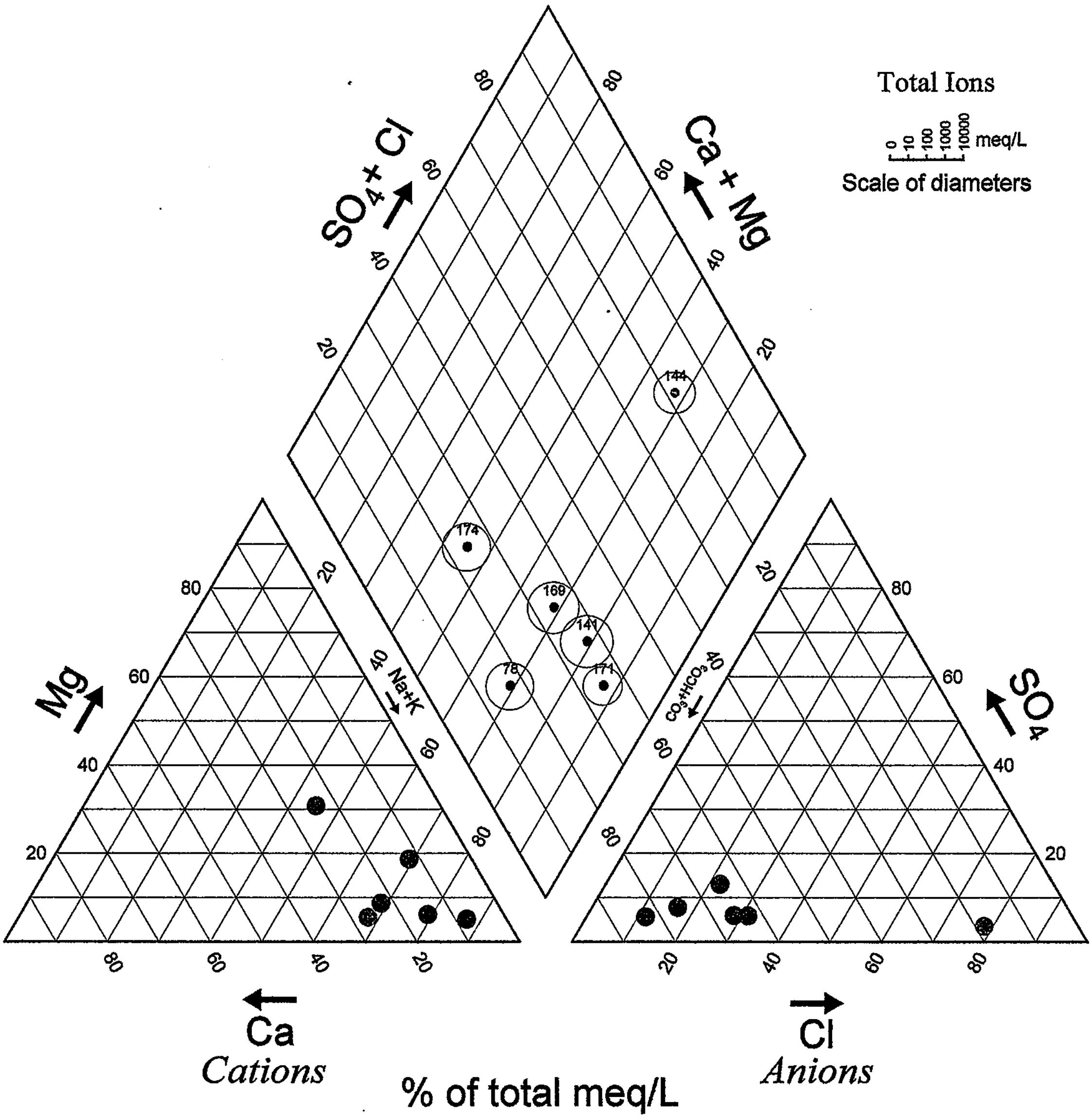
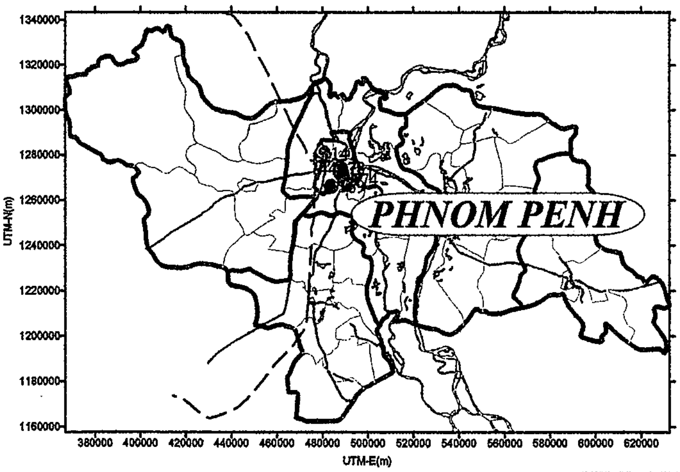


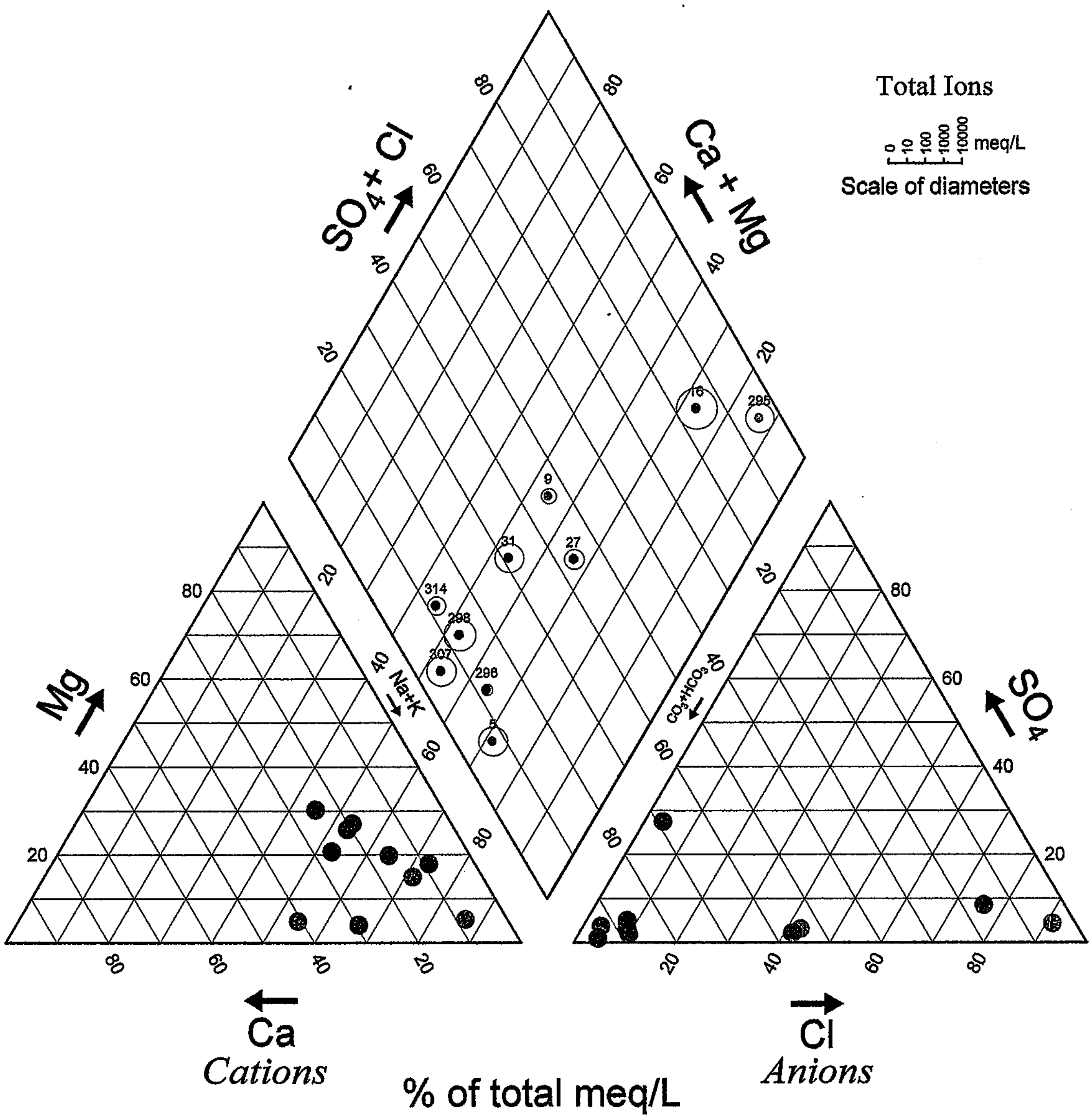
Figure 4.42	CHANGES IN ORP IN KANDAL, PREY VENG, AND KG. SPEU
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

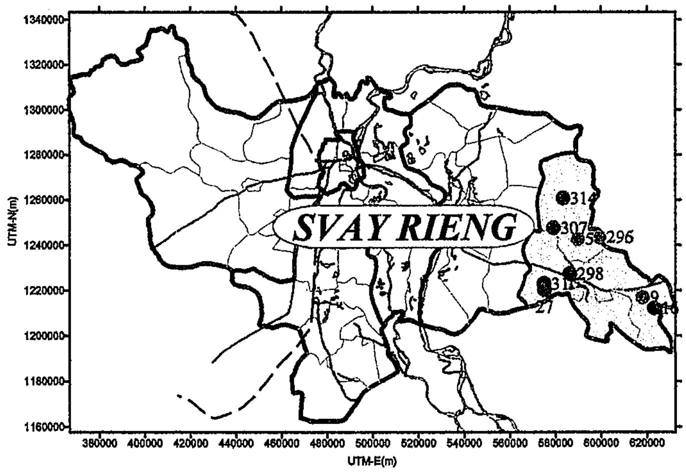




- Existing Dug Well
- Existing Combined Well
- Existing Tube Well

Figure 4.43	TRILINEAR DIAGRAM OF PHNOM PENH GROUNDWATER (EXISTING WELLS)
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	





- Existing Dug Well
- Existing Combined Well
- Existing Tube Well

Figure 4.44	**TRILINEAR DIAGRAM OF SVAY RIENG GROUNDWATER (EXISTING WELLS)**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

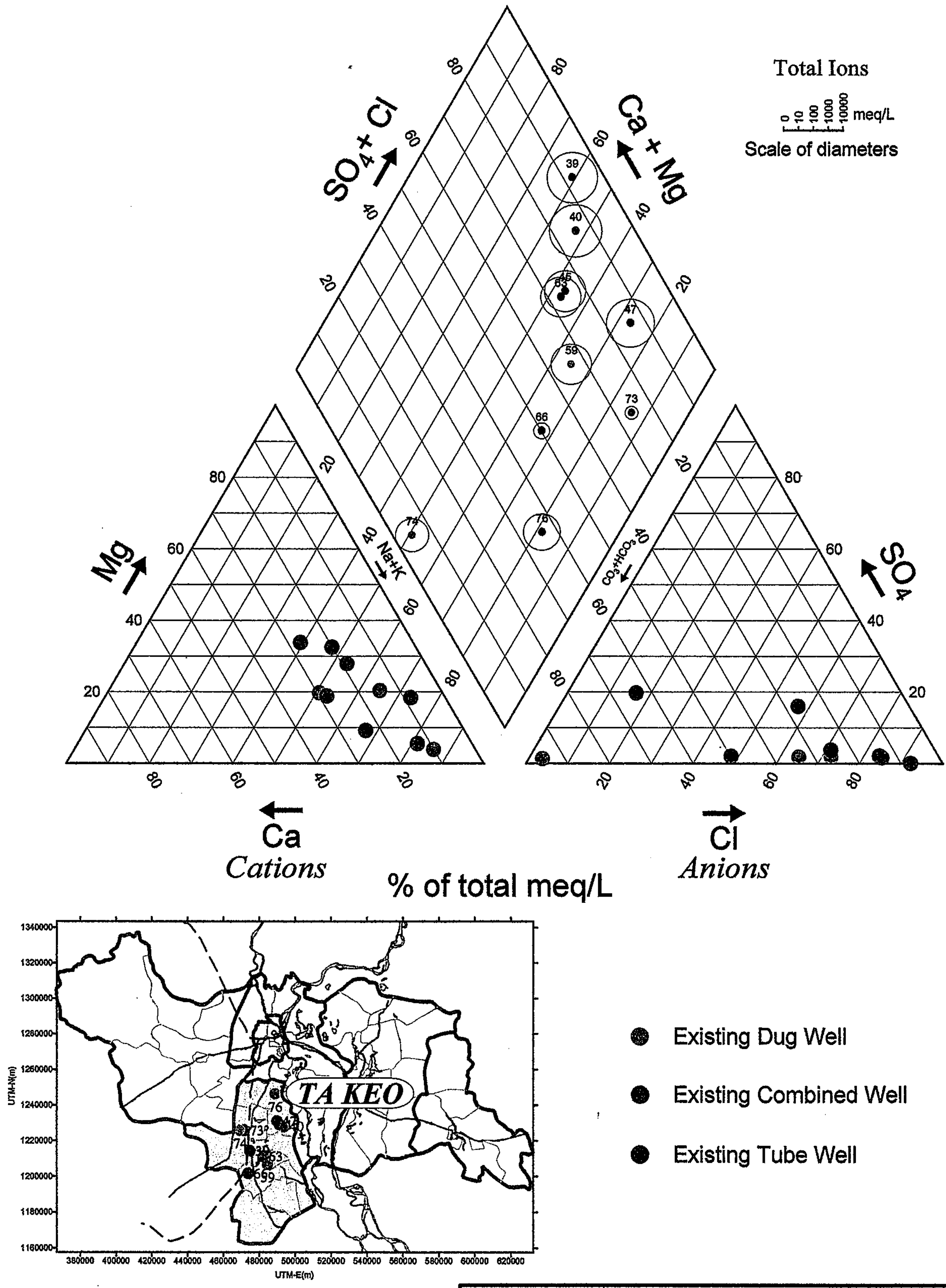


Figure 4.45	**TRILINEAR DIAGRAM OF TA KEO GROUNDWATER (EXISTING WELLS)**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

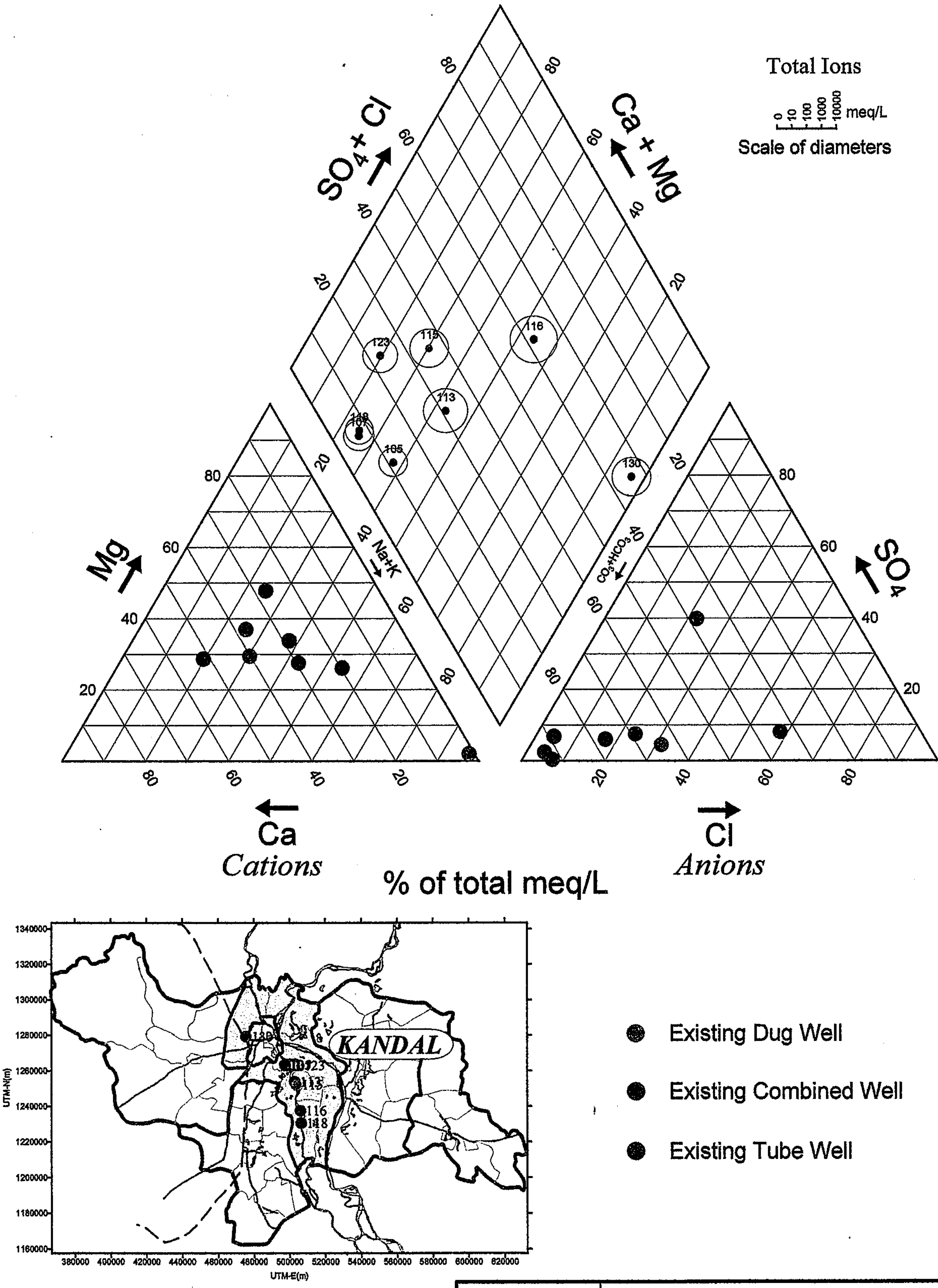


Figure 4.46	TRILINEAR DIAGRAM OF KANDAL GROUNDWATER (EXISTING WELLS)
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

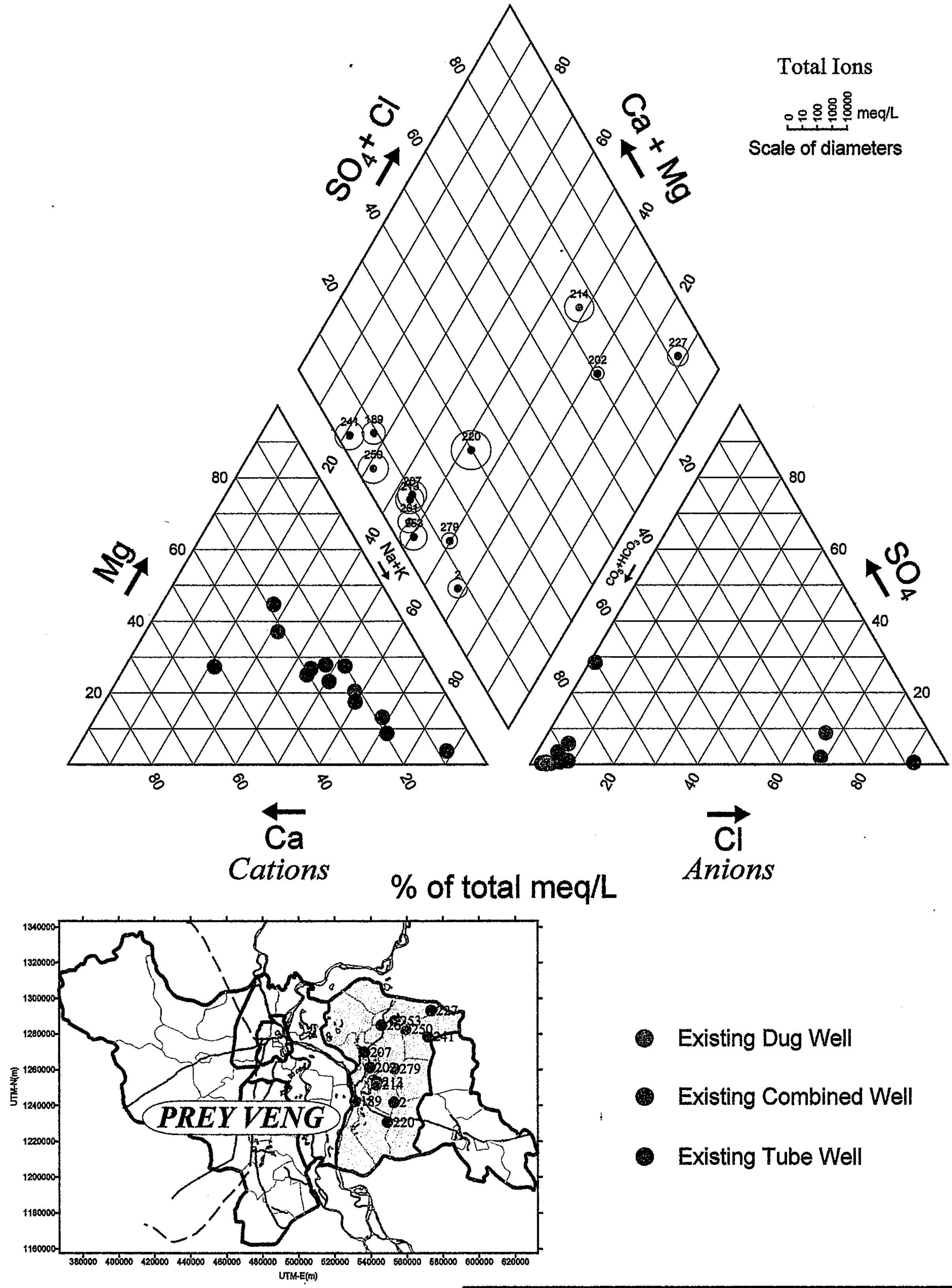


Figure 4.47	TRILINEAR DIAGRAM OF PREY VENG GROUNDWATER (EXISTING WELLS)
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

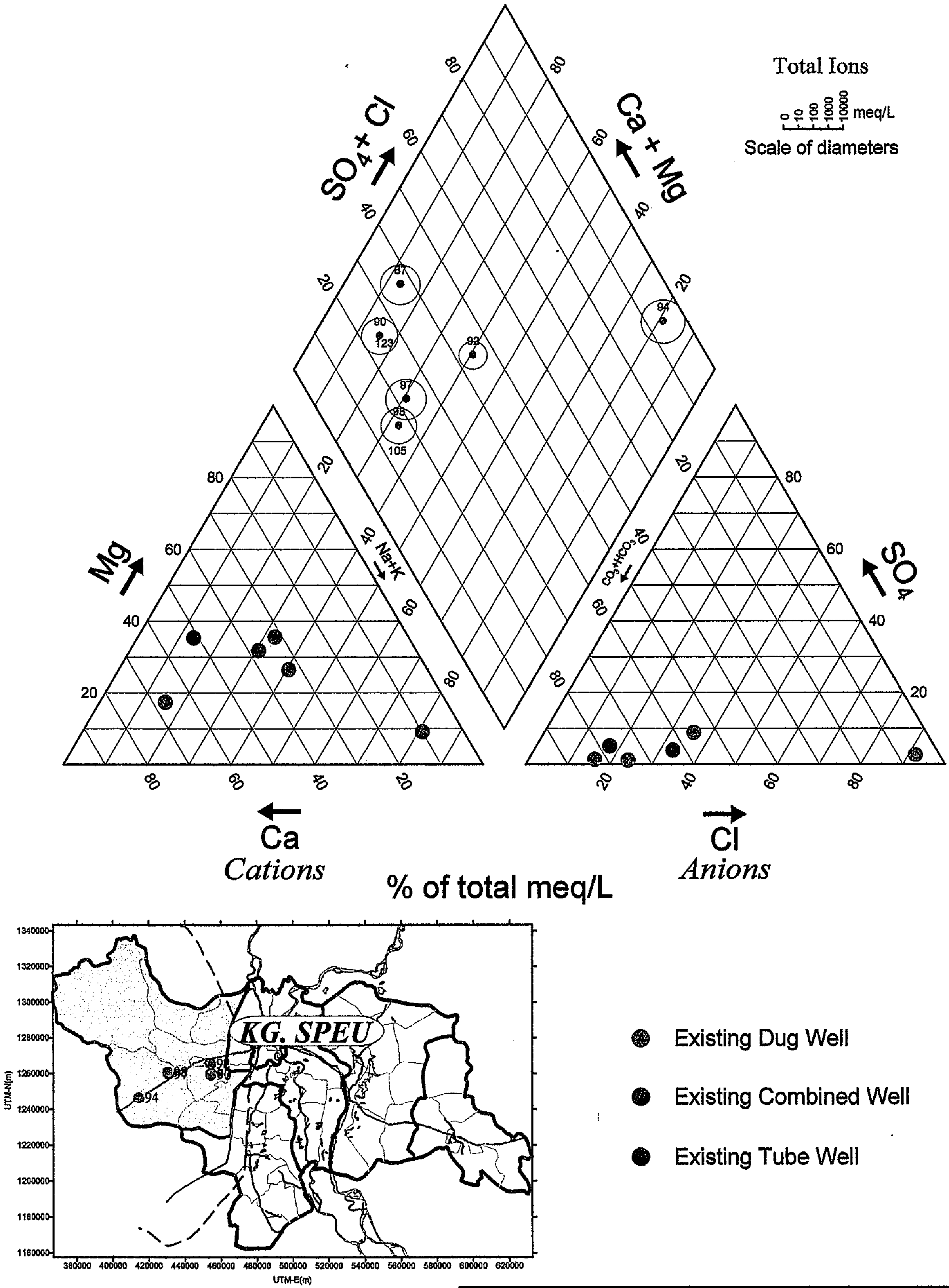


Figure 4.48	TRILINEAR DIAGRAM OF KG. SPEU GROUNDWATER (EXISTING WELLS)
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

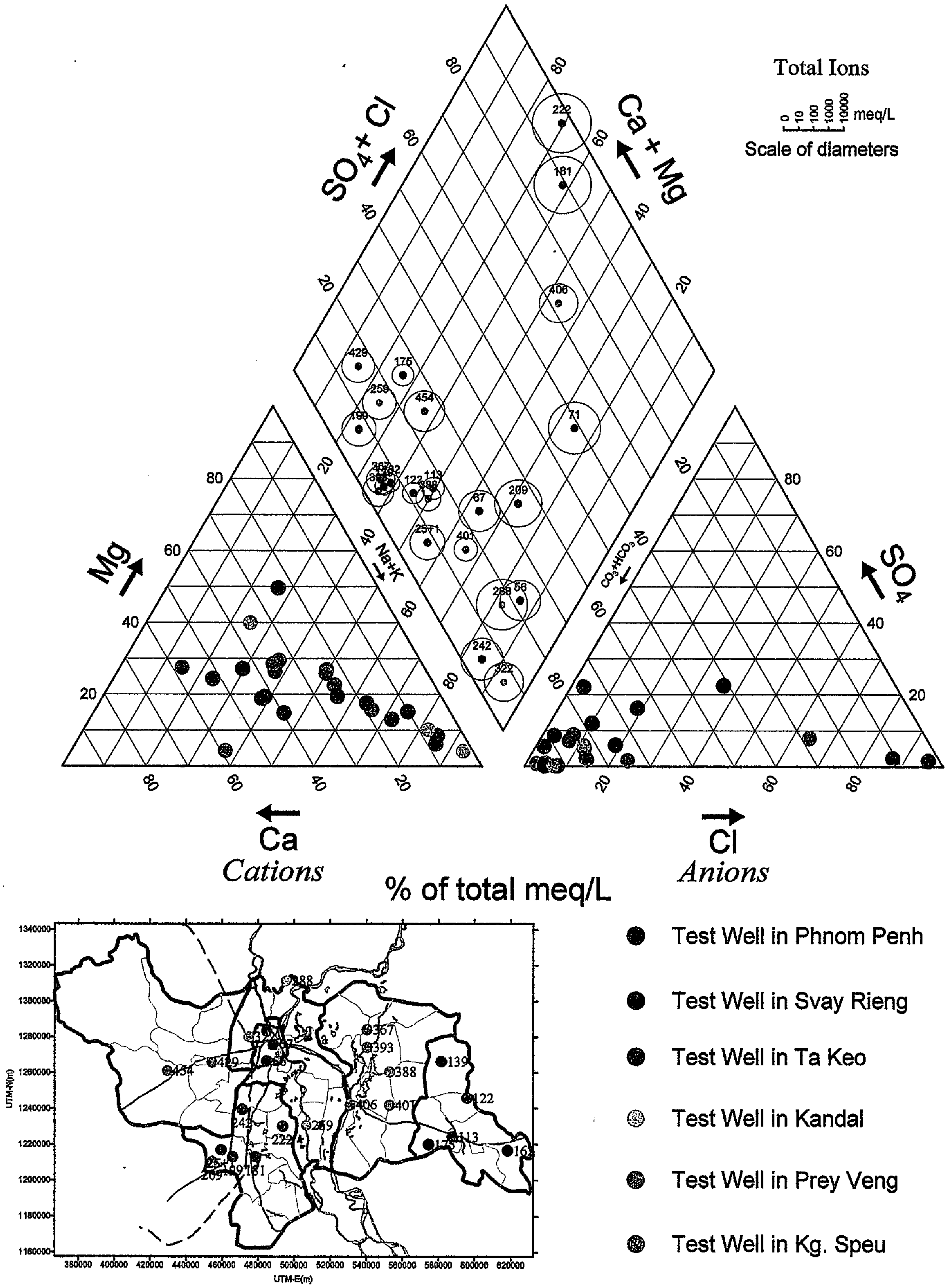
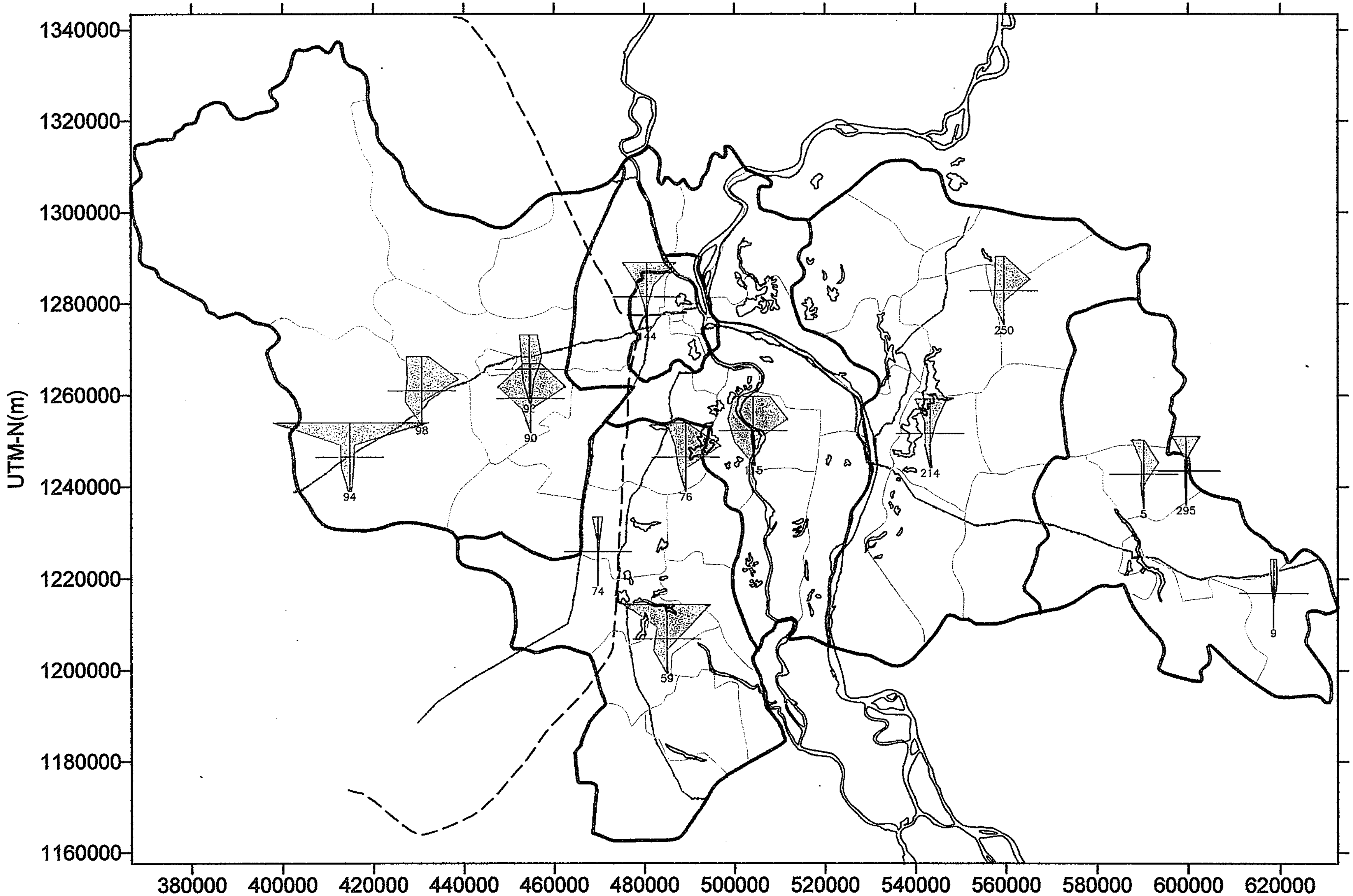


Figure 4.49	**TRILINEAR DIAGRAM OF GROUNDWATER TAKEN FROM THE TEST WELLS**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



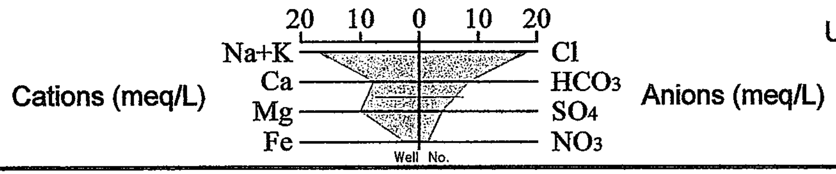


Figure 4.50 STIFF DIAGRAM OF GROUNDWATER TAKEN FROM EXISTING DUG WELLS

THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

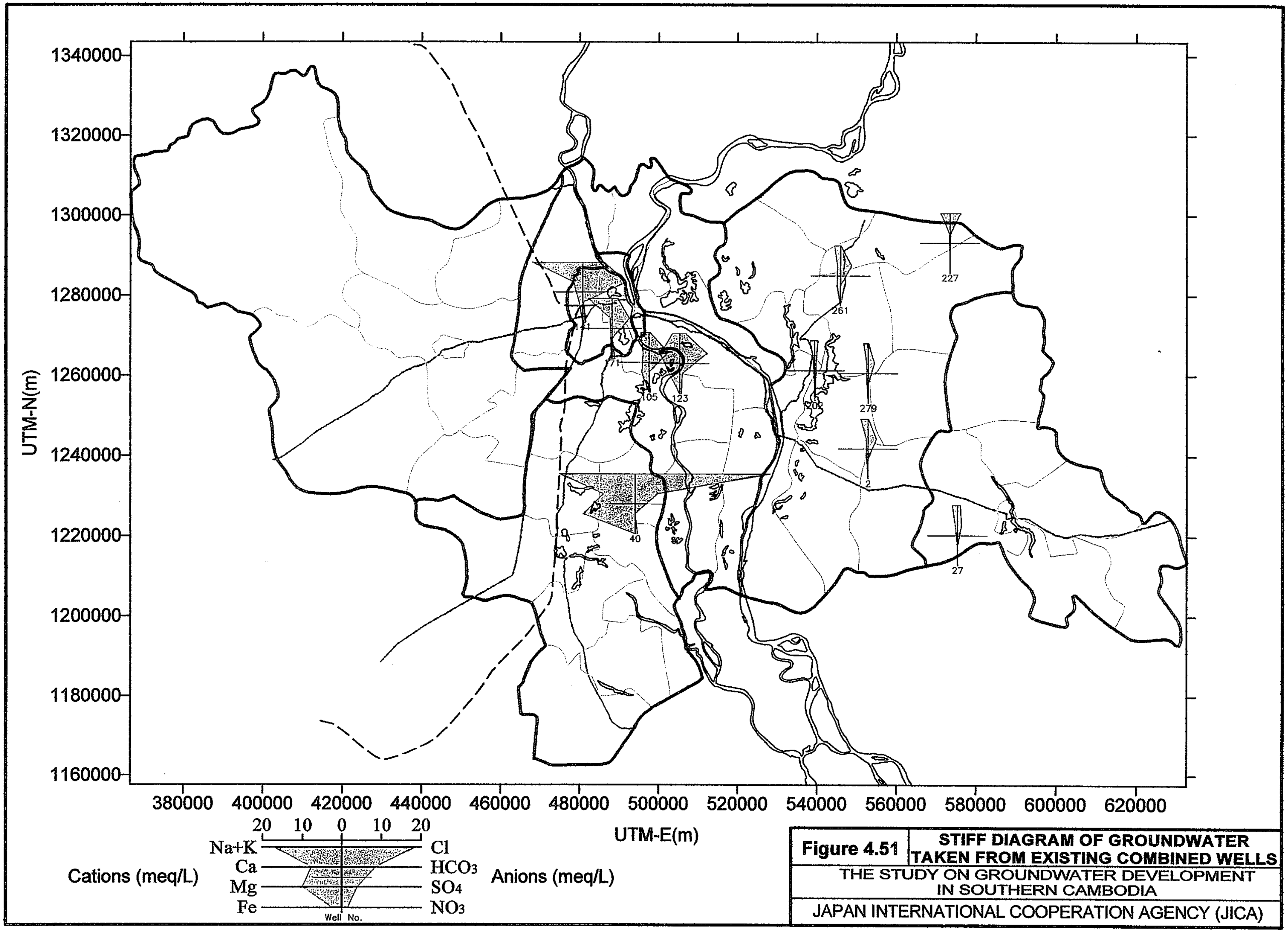


Figure 4.51	STIFF DIAGRAM OF GROUNDWATER TAKEN FROM EXISTING COMBINED WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

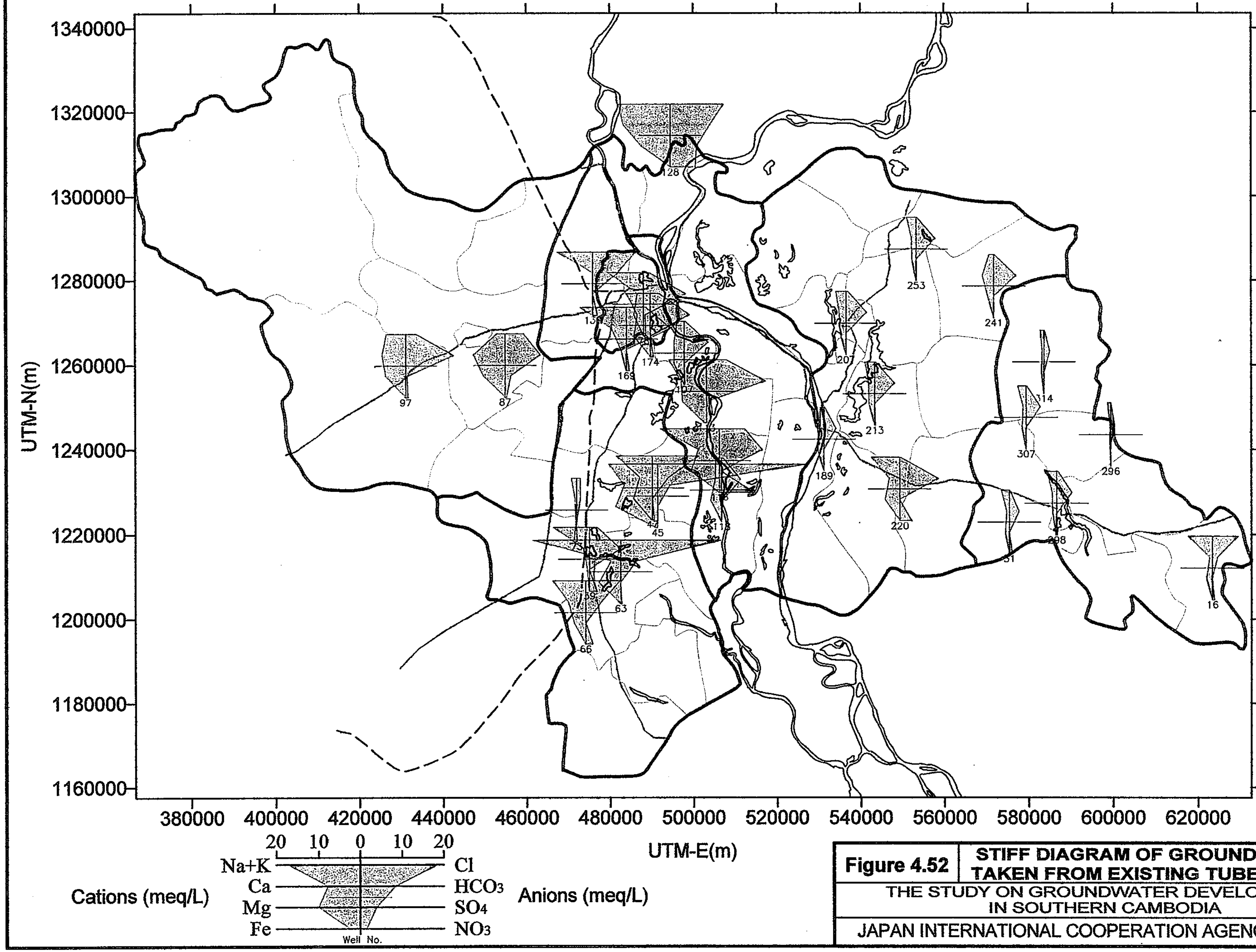


Figure 4.52	**STIFF DIAGRAM OF GROUNDWATER TAKEN FROM EXISTING TUBE WELLS**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

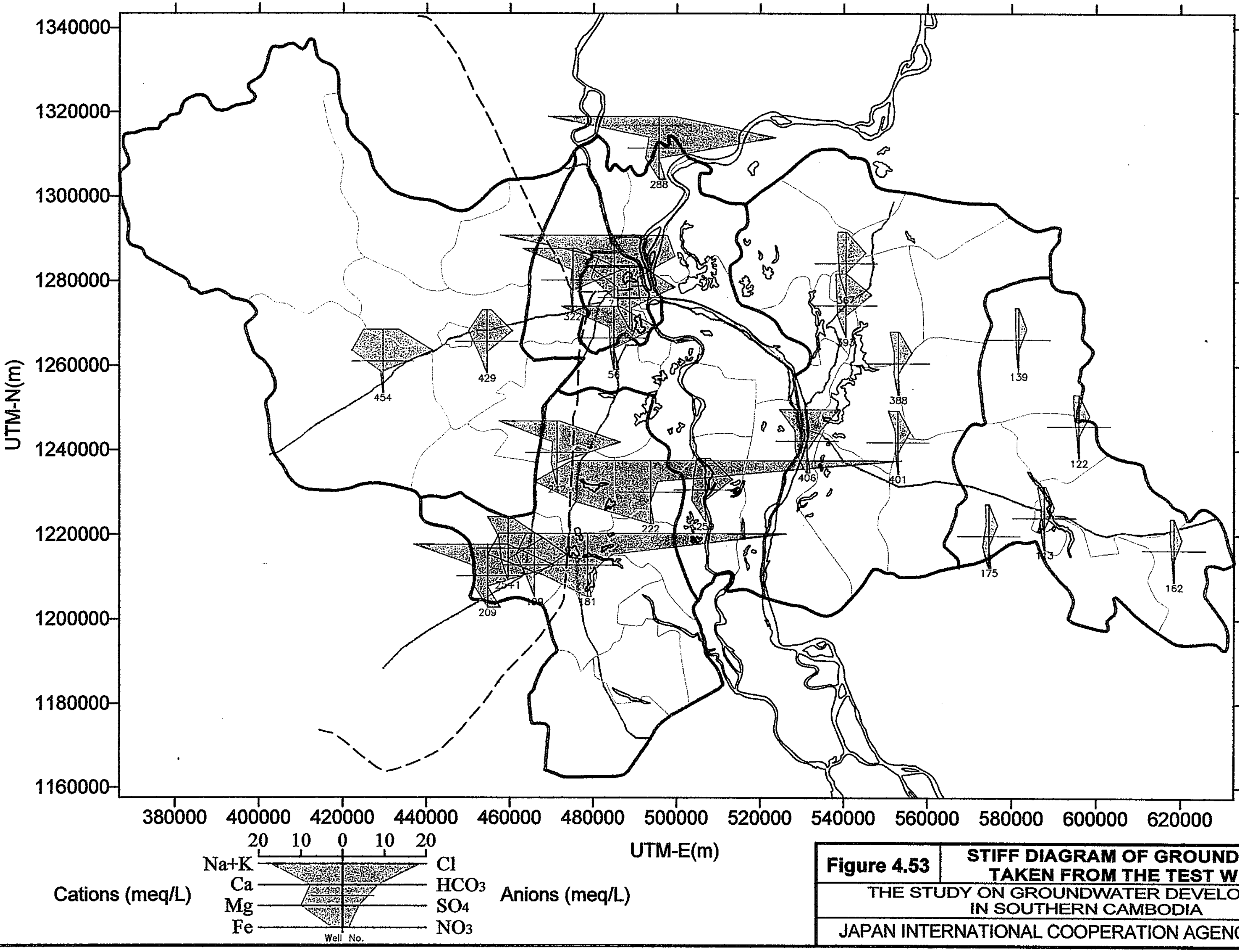
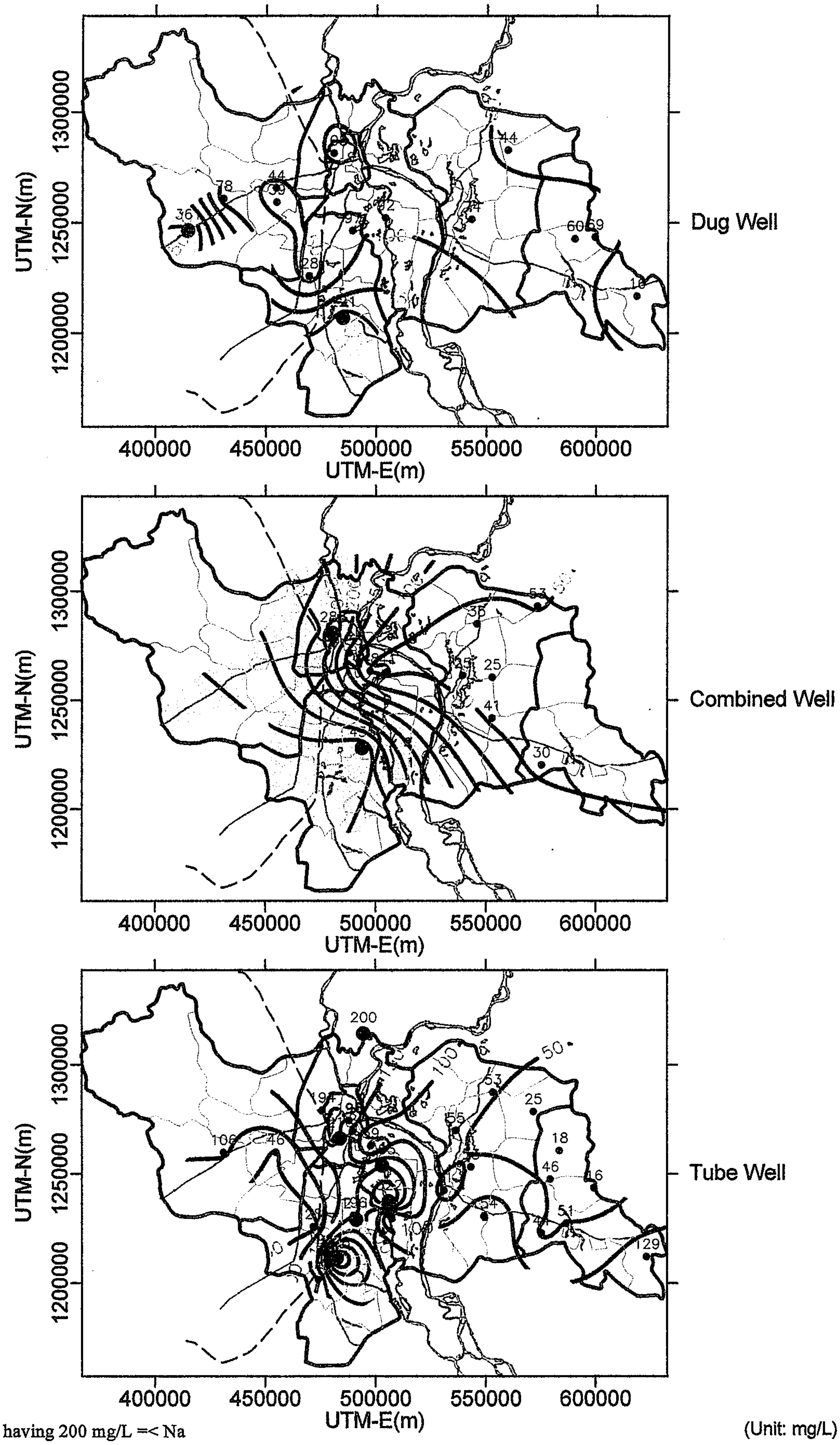


Figure 4.53	STIFF DIAGRAM OF GROUNDWATER TAKEN FROM THE TEST WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



(Unit: mg/L)

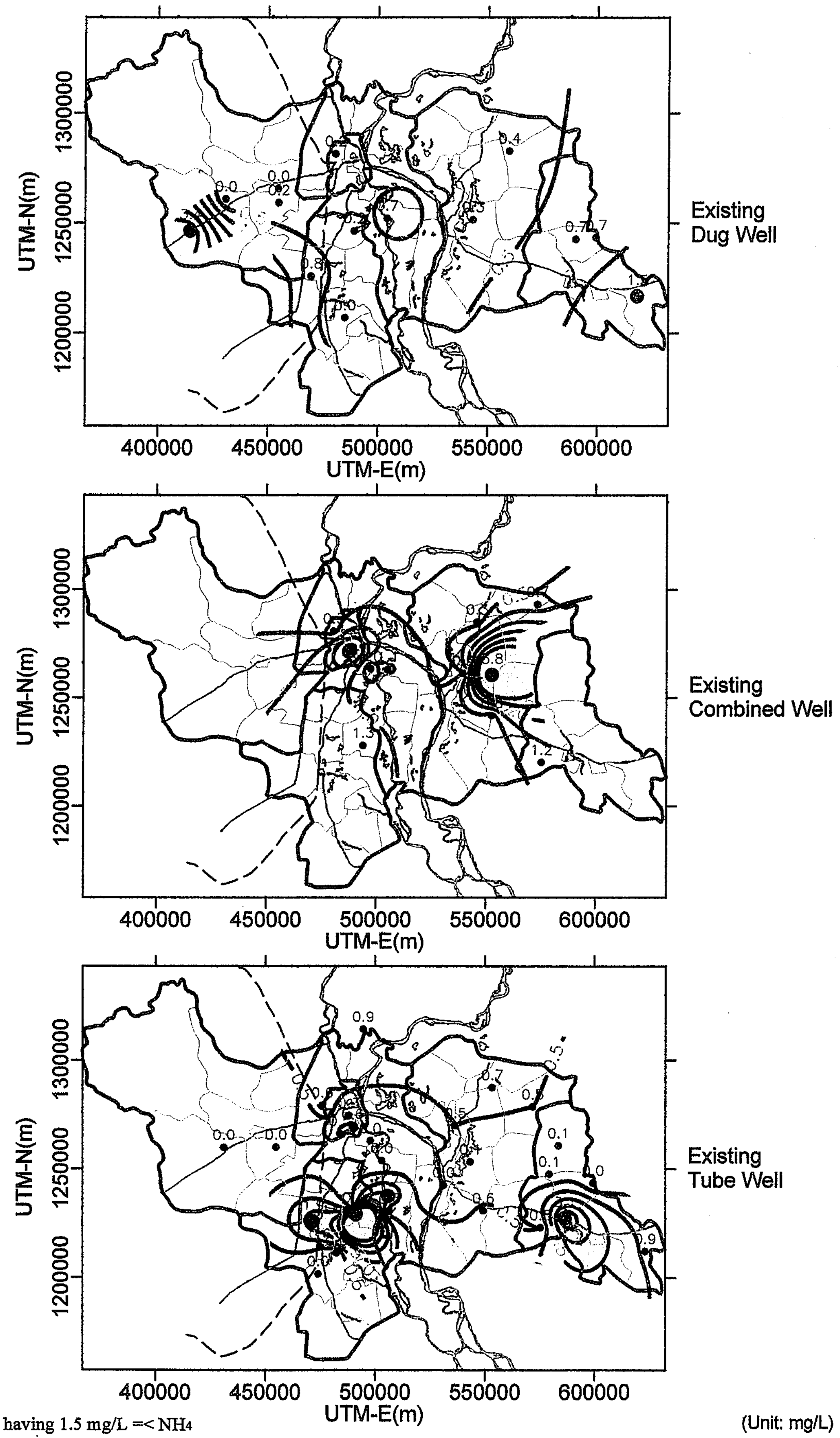
- ● Well having 200 mg/L =< Na
- • Well having Na < 200 mg/L
- ◯ Area having 200 mg/L =< Na
- ━ Equal line of Na concentration

Guidline value of Na for drinking water is 200 mg/L (WHO, 1993)

Figure 4.54 **DISTRIBUTION OF Na CONCENTRATION IN GROUNDWATER BY WELL TYPE**

THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

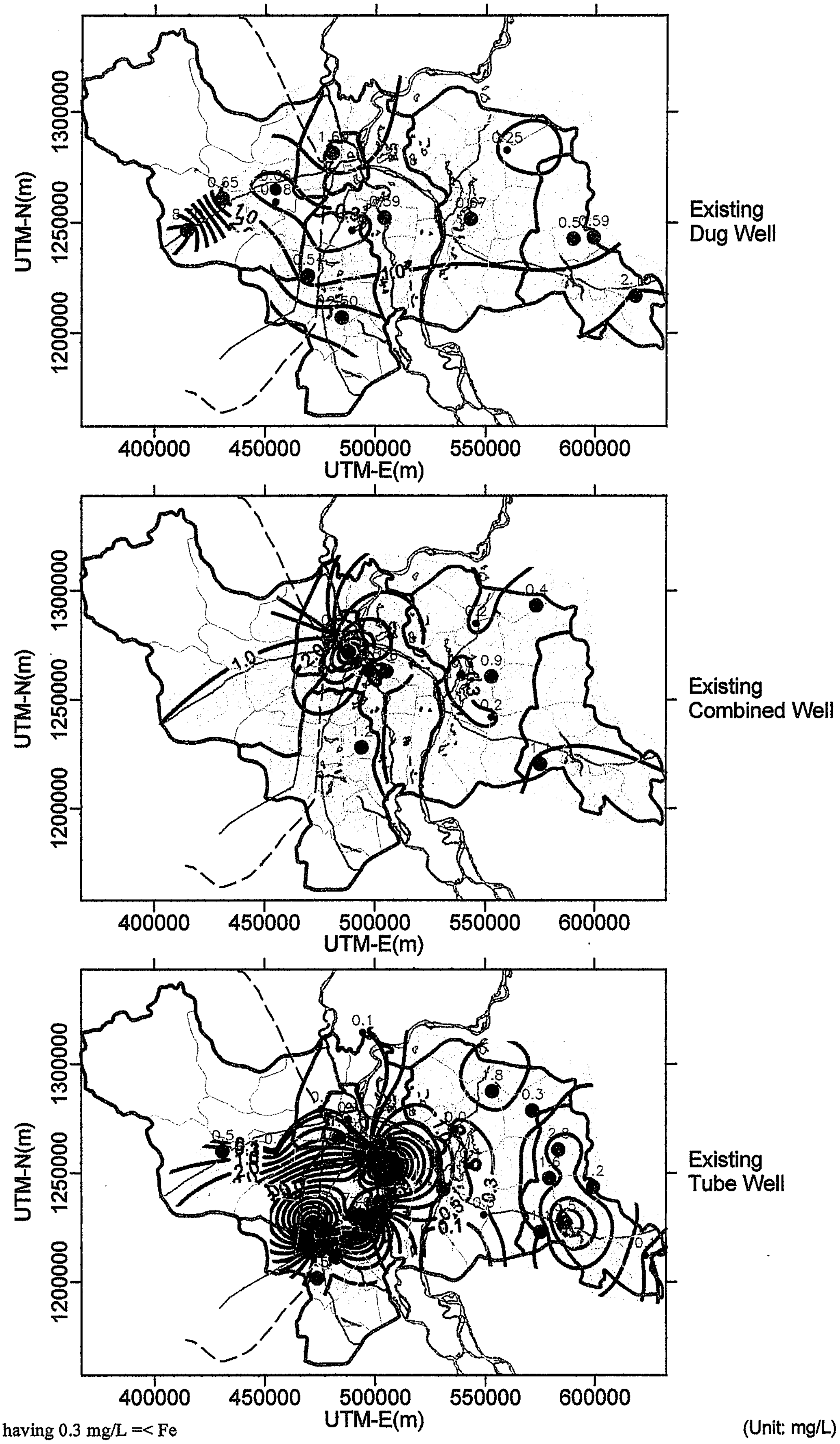


(Unit: mg/L)

● Well having 1.5 mg/L =< NH_4
• Well having NH_4 < 1.5 mg/L
◯ Area having 1.5 mg/L =< NH_4
━ Equal line of NH_4 concentration (0.5 mg/L interval)

Guidline value of NH_4 for drinking water is 1.5 mg/L (WHO, 1993)

Figure 4.55	DISTRIBUTION OF NH_4 CONCENTRATION IN GROUNDWATER BY WELL TYPE
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

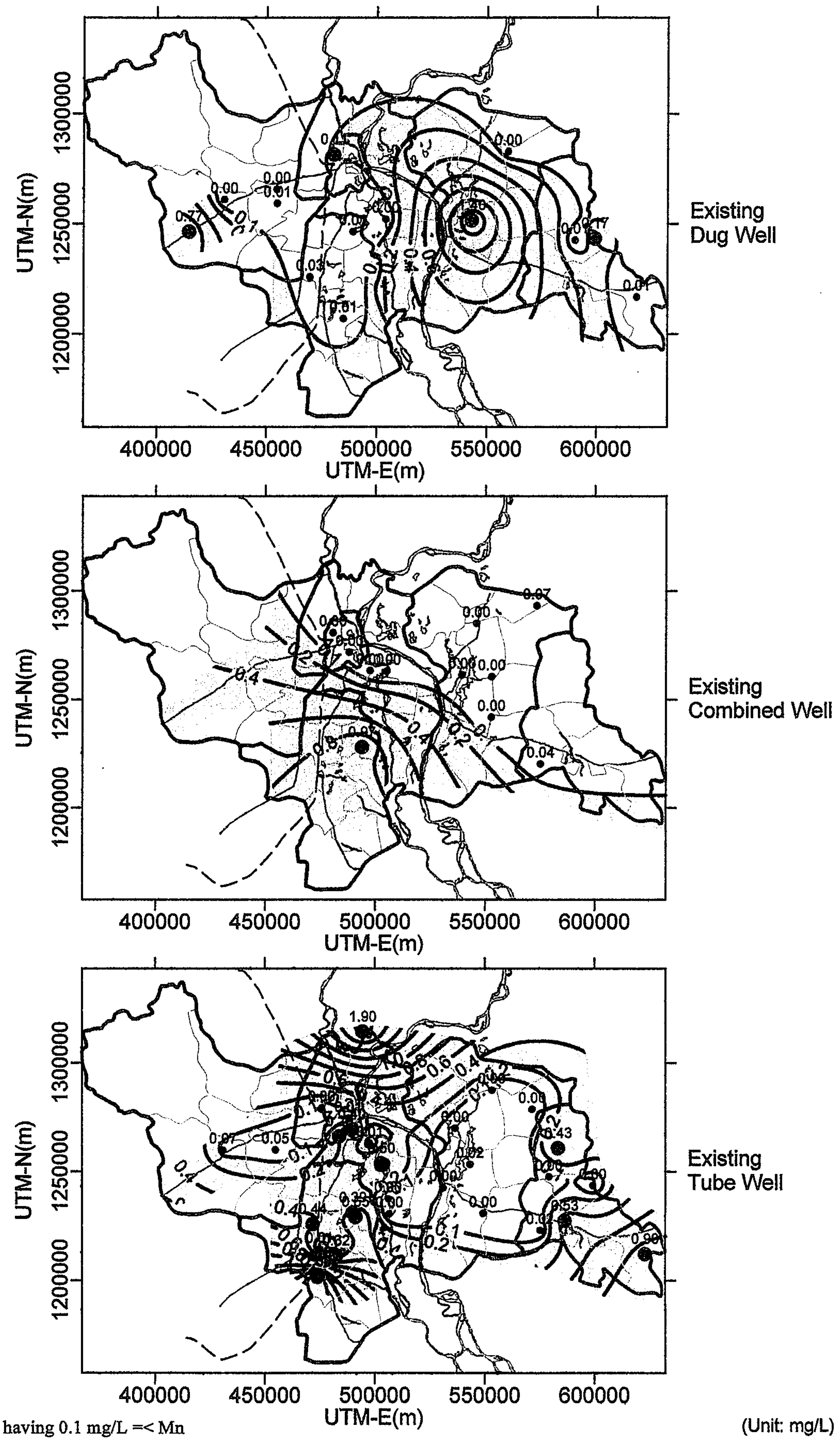


(Unit: mg/L)

- ● Well having 0.3 mg/L =< Fe
- • Well having Fe < 0.3 mg/L
- (ellipse) Area having 0.3 mg/L =< Fe
- ▬ Equal line of Fe concentration (1.0 mg/L interval except 0.3 mg/L)

Guidline value of Fe for drinking water is 0.3 mg/L (WHO, 1993)

Figure 4.56	DISTRIBUTION OF Fe CONCENTRATION IN GROUNDWATER BY WELL TYPE
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

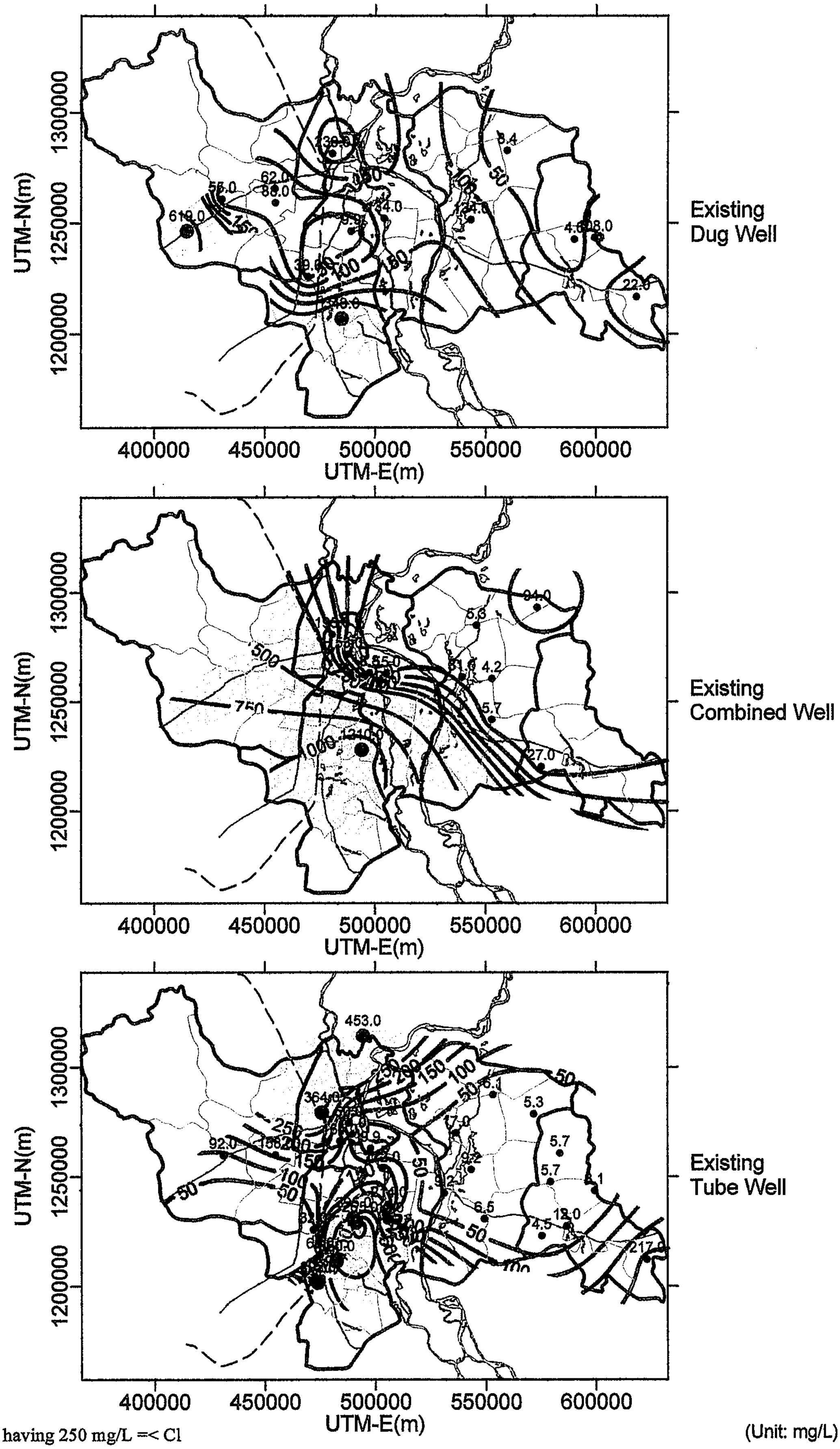


(Unit: mg/L)

- ● Well having 0.1 mg/L =< Mn
- • Well having Mn < 0.1 mg/L
- ◯ Area having 0.1 mg/L =< Mn
- ▬ Equal line of Mn concentration (0.2 mg/L interval except 0.1 mg/L)

Guidline value of Mn for drinking water is 0.1 mg/L (WHO, 1993)

Figure 4.57	DISTRIBUTION OF Mn CONCENTRATION IN GROUNDWATER BY WELL TYPE
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

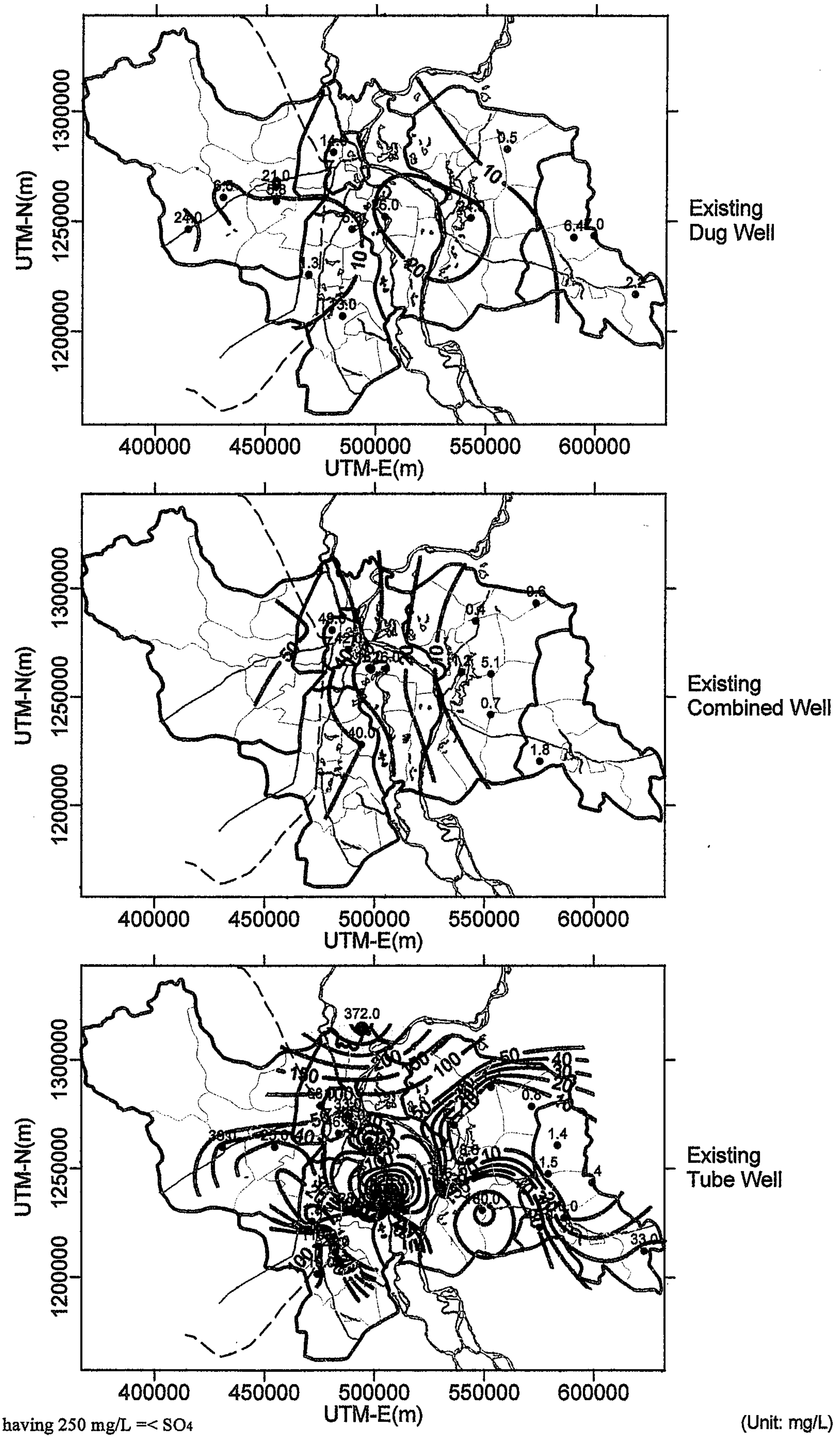


(Unit: mg/L)

- ● Well having 250 mg/L =< Cl
- • Well having Cl < 250 mg/L
- ◯ Area having 250 mg/L =< Cl
- ▬ Equal line of Cl concentration (250 mg/L interval above 250 mg/L)

Guidline value of Cl for drinking water is 250 mg/L (WHO, 1993)

Figure 4.58	**DISTRIBUTION OF Cl CONCENTRATION IN GROUNDWATER BY WELL TYPE**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

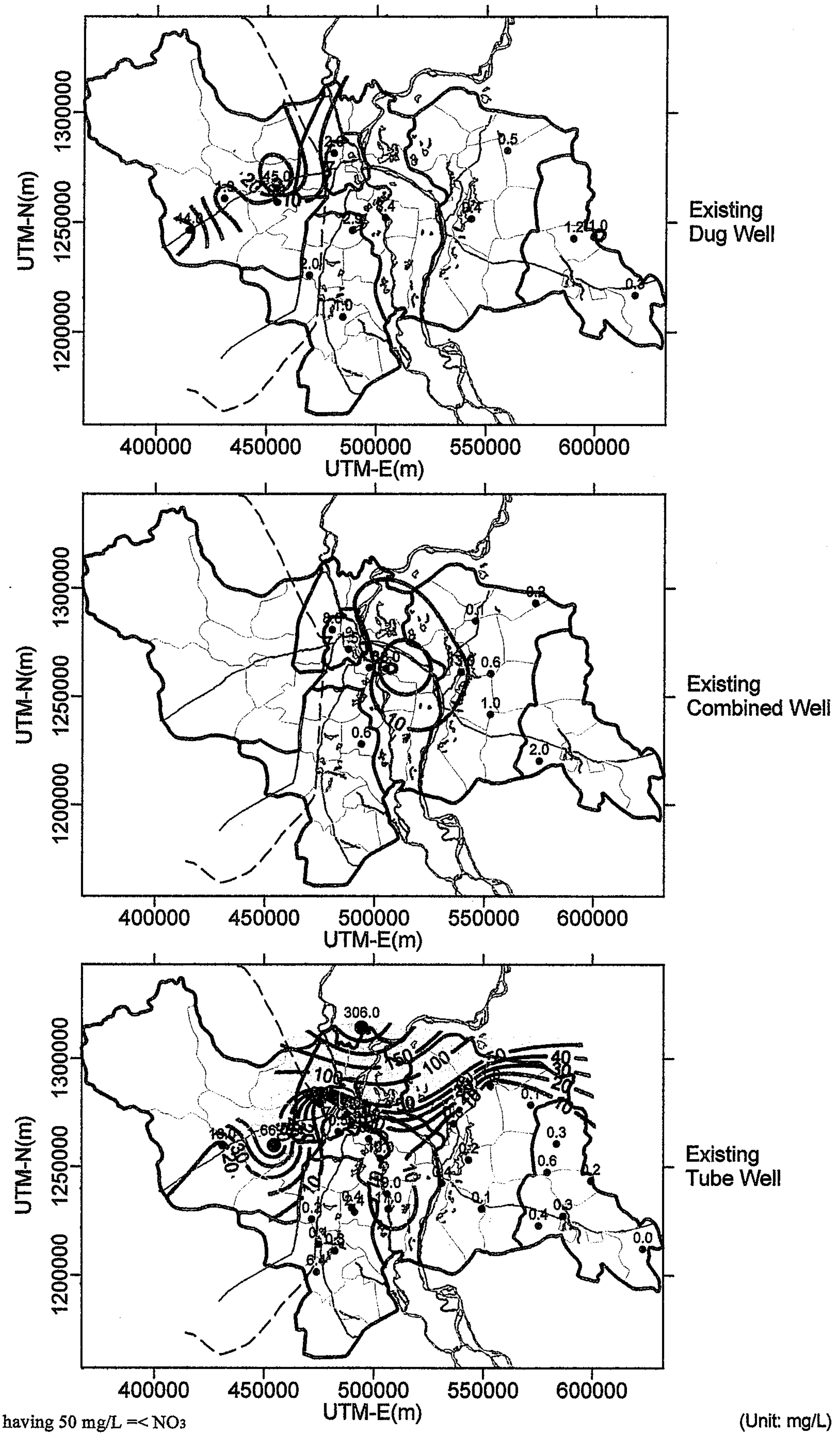


(Unit: mg/L)

- ● Well having 250 mg/L =< SO_4
- • Well having SO_4 < 250 mg/L
- ◯ Area having 250 mg/L =< SO_4
- ▬ Equal line of SO_4 concentration (50 mg/L interval above 50 mg/L)

Guidline value of SO_4 for drinking water is 250 mg/L (WHO, 1993)

Figure 4.59	**DISTRIBUTION OF SO_4 CONCENTRATION IN GROUNDWATER BY WELL TYPE**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

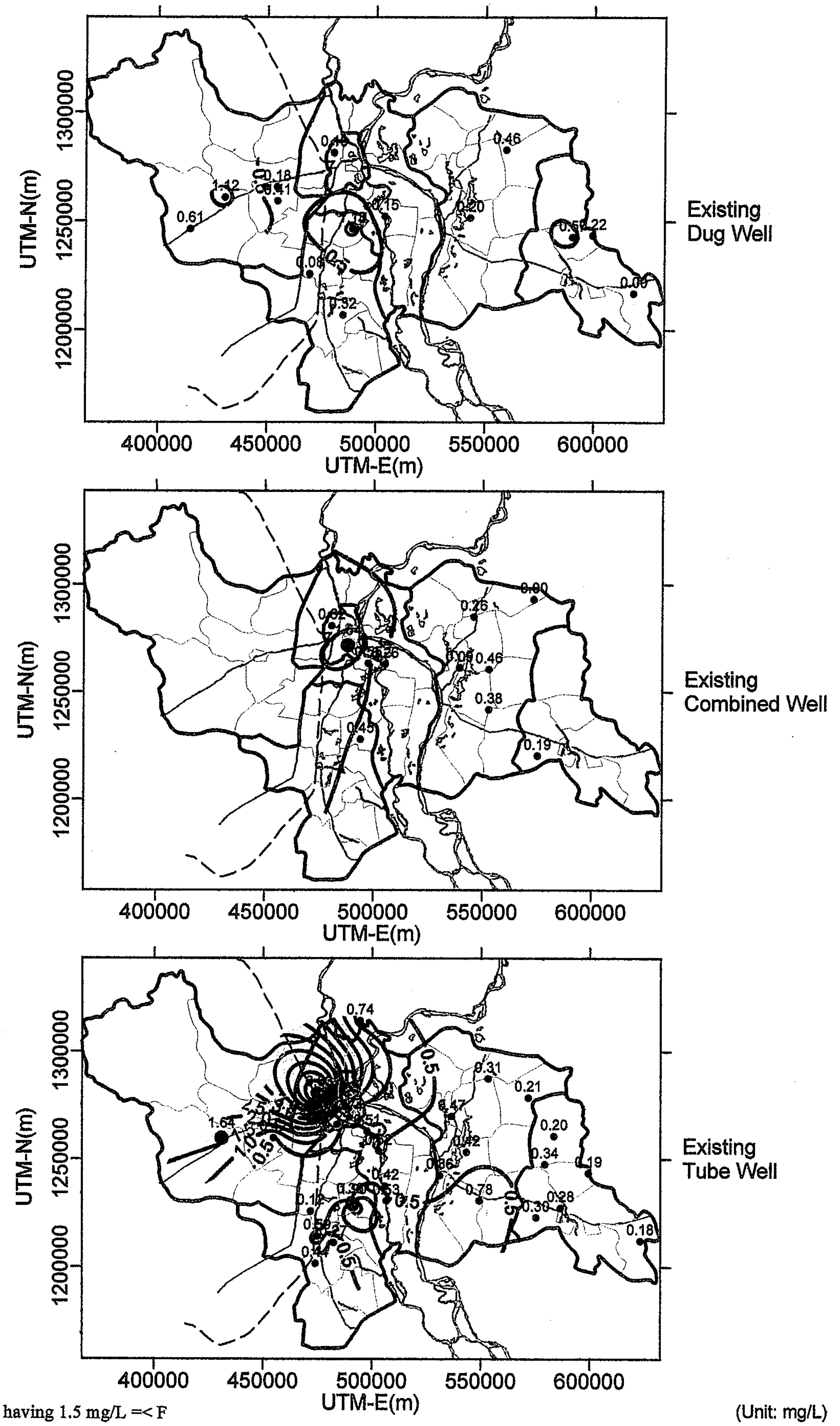


(Unit: mg/L)

- Well having 50 mg/L =< NO3
- Well having NO3 < 50 mg/L
- Area having 50 mg/L =< NO3
- Equal line of NO3 concentration (50 mg/L interval above 50 mg/L)

Guidline value of NO3 for drinking water is 50 mg/L (WHO, 1993)

Figure 4.60	DISTRIBUTION OF NO3 CONCENTRATION IN GROUNDWATER BY WELL TYPE
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

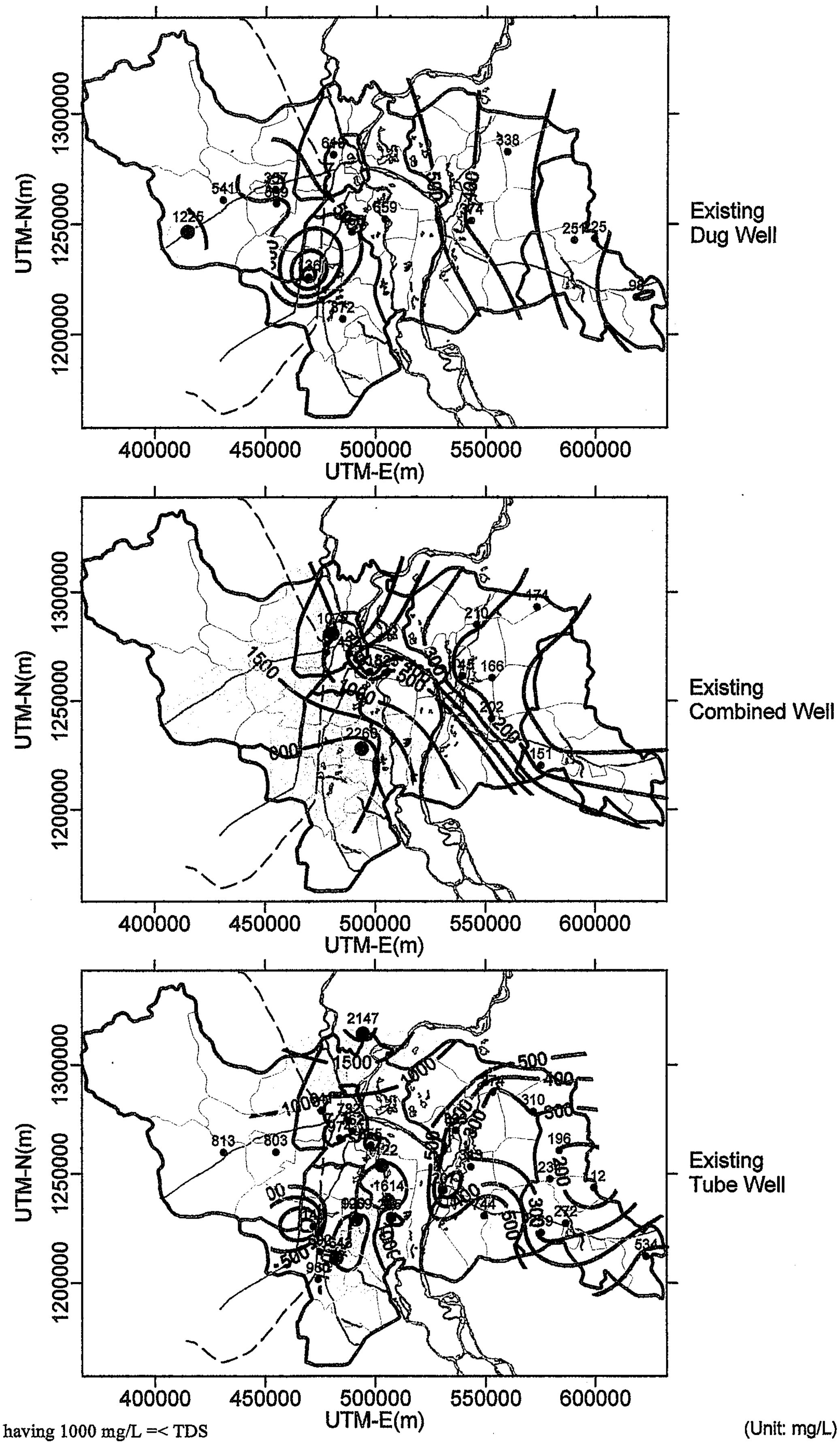


(Unit: mg/L)

- Well having 1.5 mg/L =< F
- Well having F < 1.5 mg/L
- Area having 1.5 mg/L =< F
- Equal line of F concentration (0.5 mg/L interval)

Guidline value of F for drinking water is 1.5 mg/L (WHO, 1993)

Figure 4.61	DISTRIBUTION OF F CONCENTRATION IN GROUNDWATER BY WELL TYPE
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

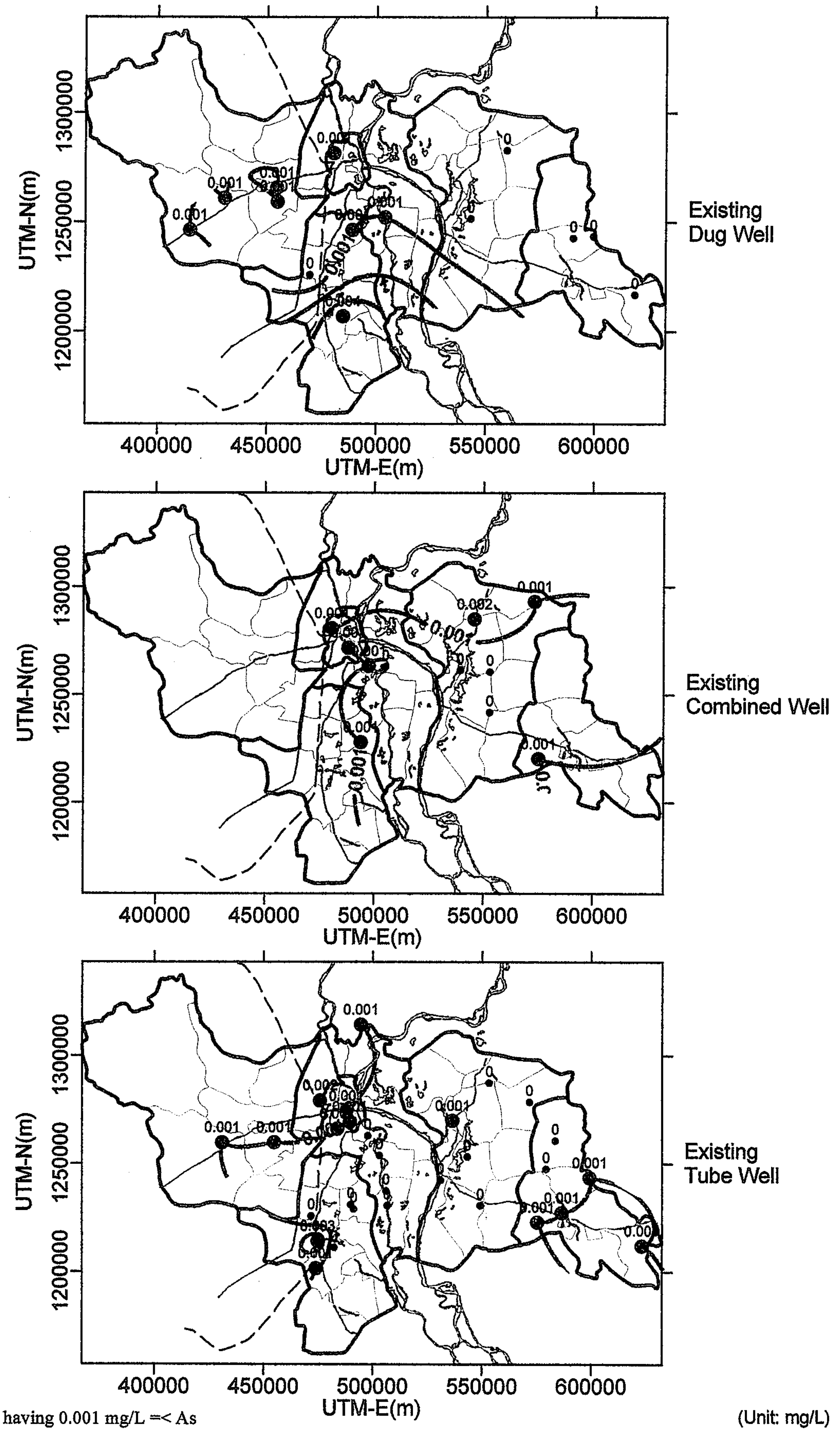


(Unit: mg/L)

- Well having 1000 mg/L =< TDS
- Well having TDS < 1000 mg/L
- Area having 1000 mg/L =< TDS
- Equal line of TDS concentration (500 mg/L interval above 500 mg/L)

Guidline value of TDS for drinking water is 1000 mg/L (WHO, 1993)

Figure 4.62	DISTRIBUTION OF TDS CONCENTRATION IN GROUNDWATER BY WELL TYPE
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



- Well having 0.001 mg/L =< As
- Well having As < 0.001 mg/L
- Area having 0.01 mg/L =< As
- Equal line of As concentration (0.001 mg/L interval)

Guidline value of As for drinking water is 0.01 mg/L (WHO, 1993)

(Unit: mg/L)

Figure 4.63	DISTRIBUTION OF As CONCENTRATION IN GROUNDWATER BY WELL TYPE
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

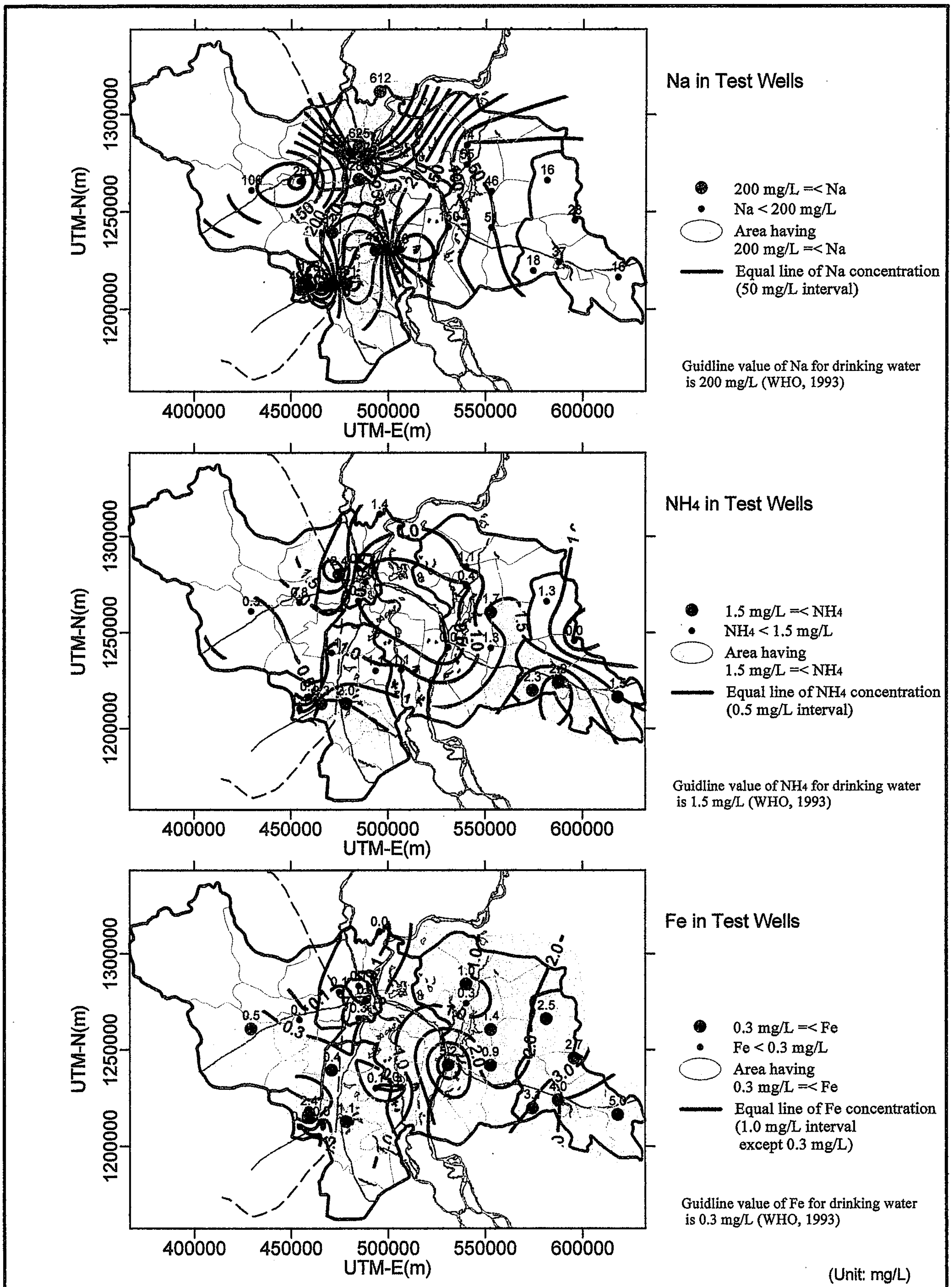
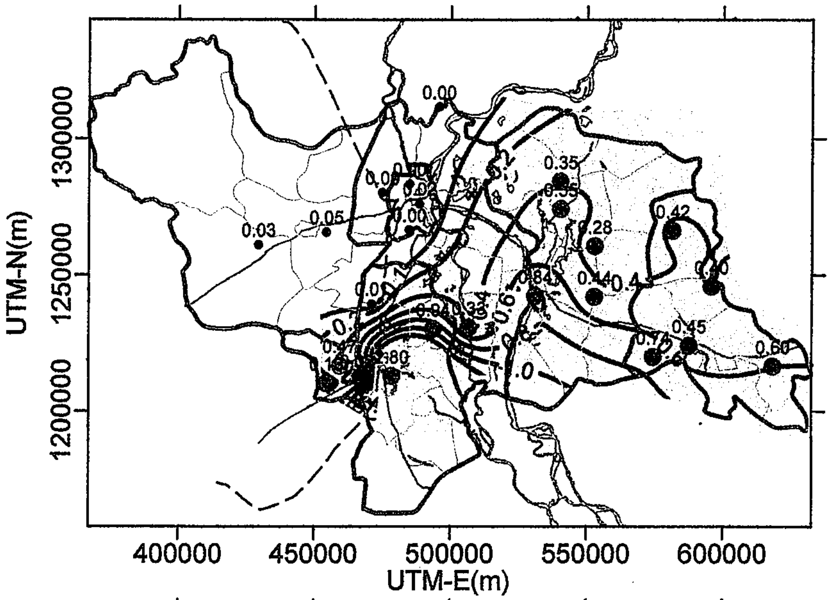


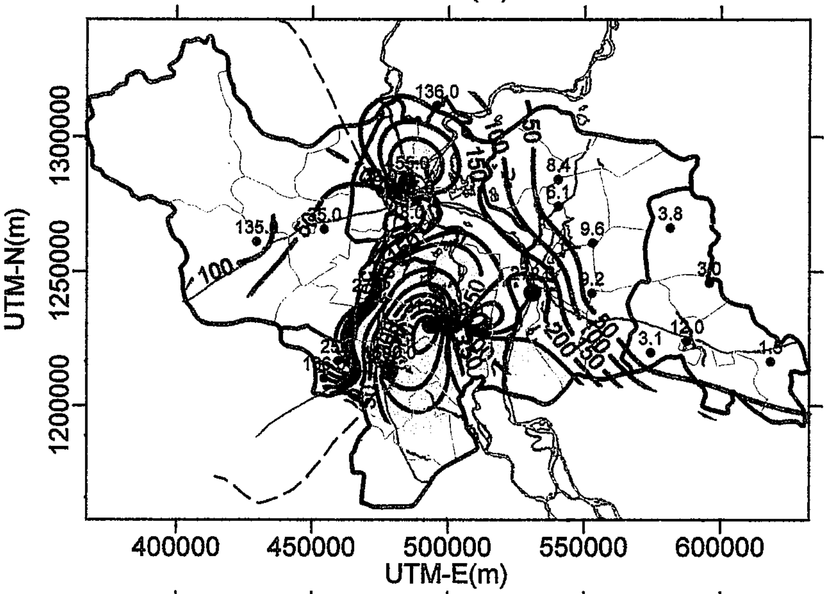
Figure 4.64	Na, NH_4, AND Fe DISTRIBUTIONS IN GROUND-WATER TAKEN FROM THE TEST WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



Mn in Test Wells

- 0.1 mg/L =< Mn
- Mn < 0.1 mg/L
- Area having 0.1 mg/L =< Mn
- Equal line of Mn concentration (0.2 mg/L interval except 0.1 mg/L)

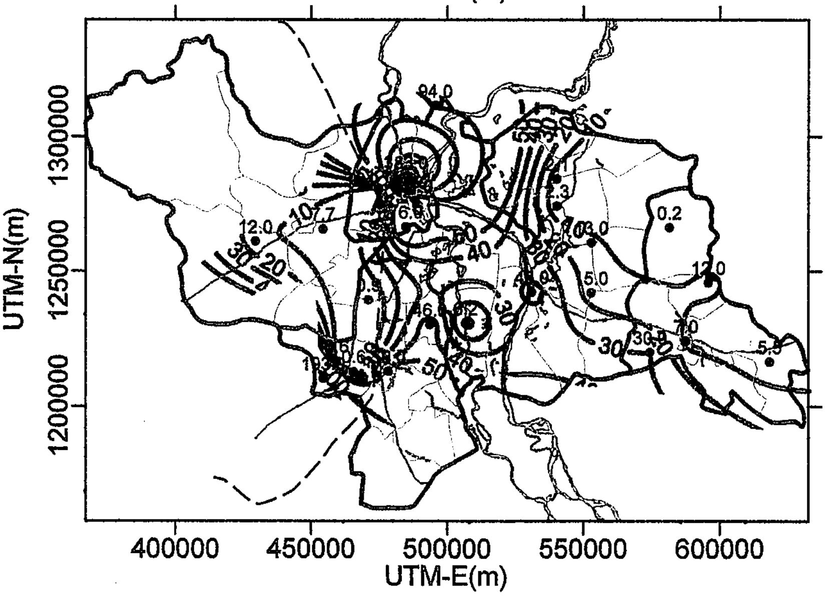
Guidline value of Mn for drinking water is 0.1 mg/L (WHO, 1993)



Cl in Test Wells

- 250 mg/L =< Cl
- Cl < 250 mg/L
- Area having 250 mg/L =< Cl
- Equal line of Cl concentration (250 mg/L interval above 250 mg/L, 50 mg/L interval below 250 mg/L)

Guidline value of Cl for drinking water is 250 mg/L (WHO, 1993)



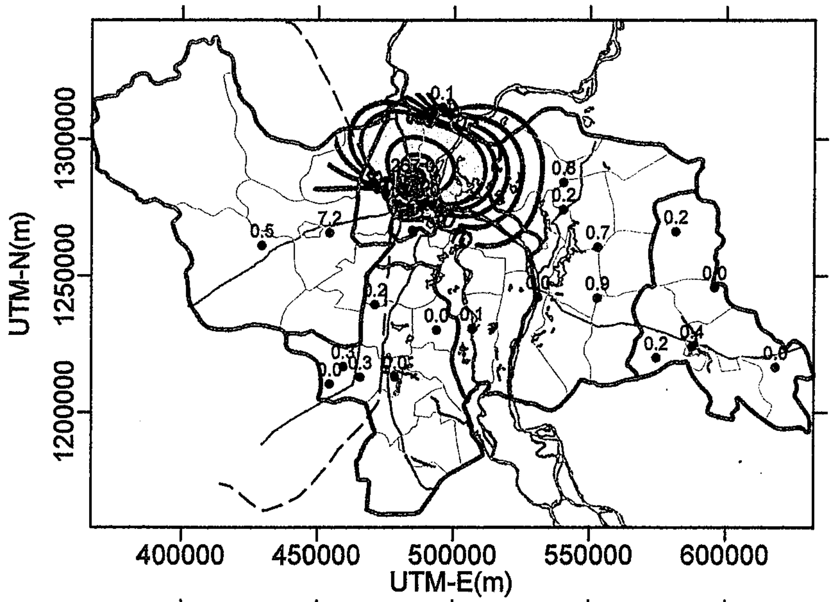
SO_4 in Test Wells

- 250 mg/L =< SO_4
- SO_4 < 250 mg/L
- Area having 250 mg/L =< SO_4
- Equal line of SO_4 concentration (50 mg/L interval above 50 mg/L, 10 mg/L interval below 50 mg/L)

Guidline value of SO_4 for drinking water is 250 mg/L (WHO, 1993)

(Unit: mg/L)

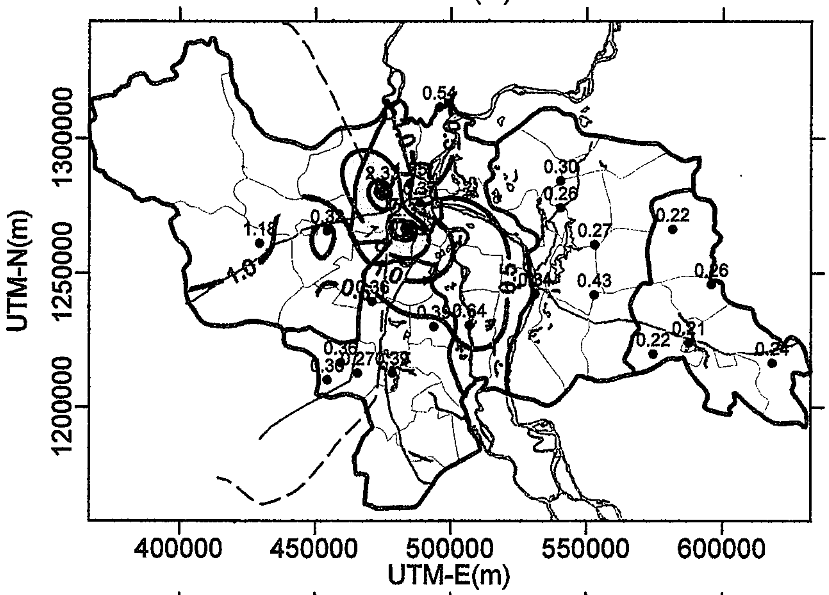
Figure 4.65	Mn, Cl, AND SO_4 DISTRIBUTIONS IN GROUND-WATER TAKEN FROM THE TEST WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



NO3 in Test Wells

- 50 mg/L =< NO3
- NO3 < 50 mg/L
- Area having 50 mg/L =< NO3
- Equal line of NO3 concentration (50 mg/L interval above 50 mg/L, 10 mg/L interval below 50 mg/L)

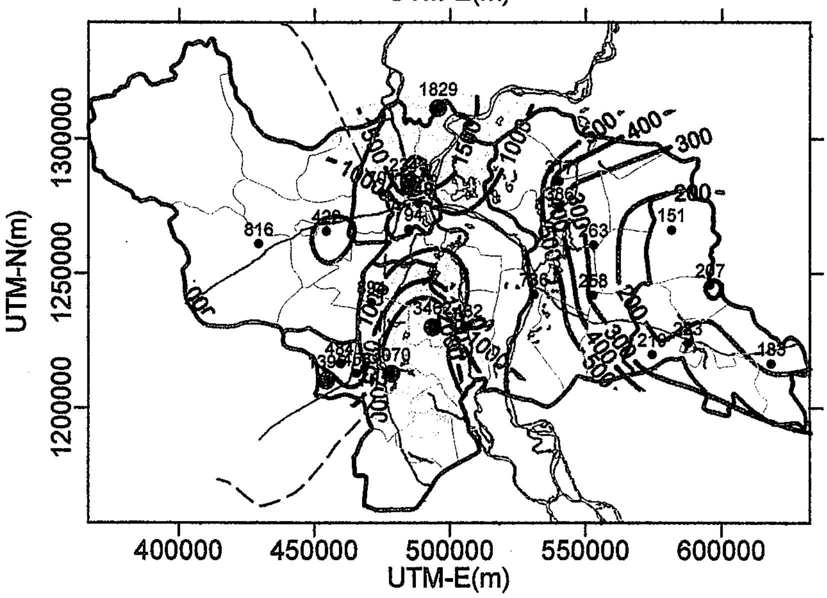
Guidline value of Mn for drinking water is 0.1 mg/L (WHO, 1993)



F in Test Wells

- 1.5 mg/L =< F
- F < 1.5 mg/L
- Area having 1.5 mg/L =< F
- Equal line of F concentration (0.5 mg/L interval)

Guidline value of F for drinking water is 1.5 mg/L (WHO, 1993)



TDS in Test Wells

- 1,000 mg/L =< TDS
- TDS < 1,000 mg/L
- Area having 1,000 mg/L =< TDS
- Equal line of TDS concentration (500 mg/L interval above 500 mg/L, 100 mg/L interval below 500 mg/L)

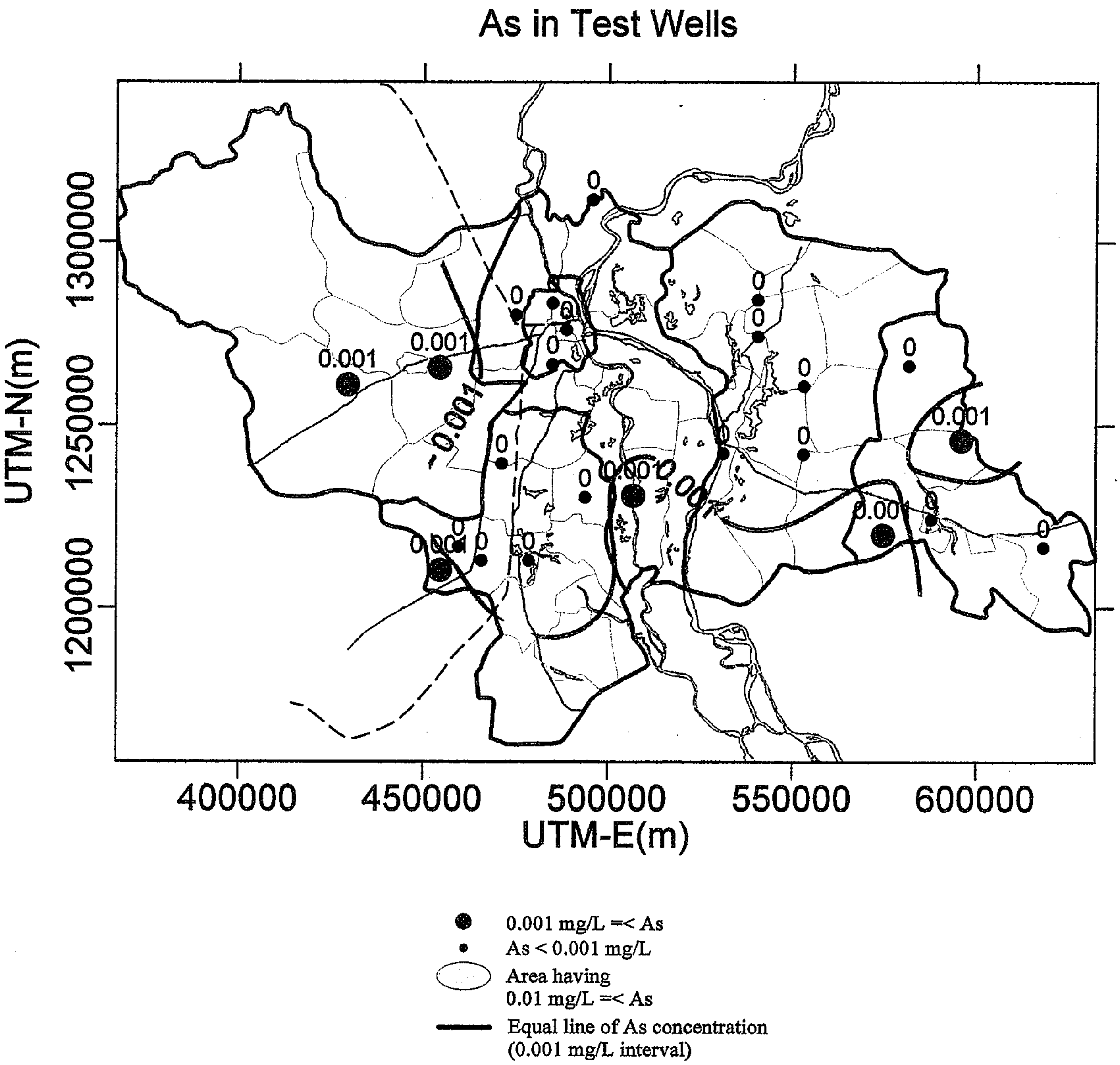
Guidline value of TDS for drinking water is 1,000 mg/L (WHO, 1993)

(Unit: mg/L)

Figure 4.66 NO3, F, AND TDS DISTRIBUTIONS IN GROUND-WATER TAKEN FROM THE TEST WELLS

THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



Guidline value of As for drinking water is 0.01 mg/L (WHO, 1993)

(Unit: mg/L)

Figure 4.67	**As DISTRIBUTION IN GROUNDWATER TAKEN FROM THE TEST WELLS**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

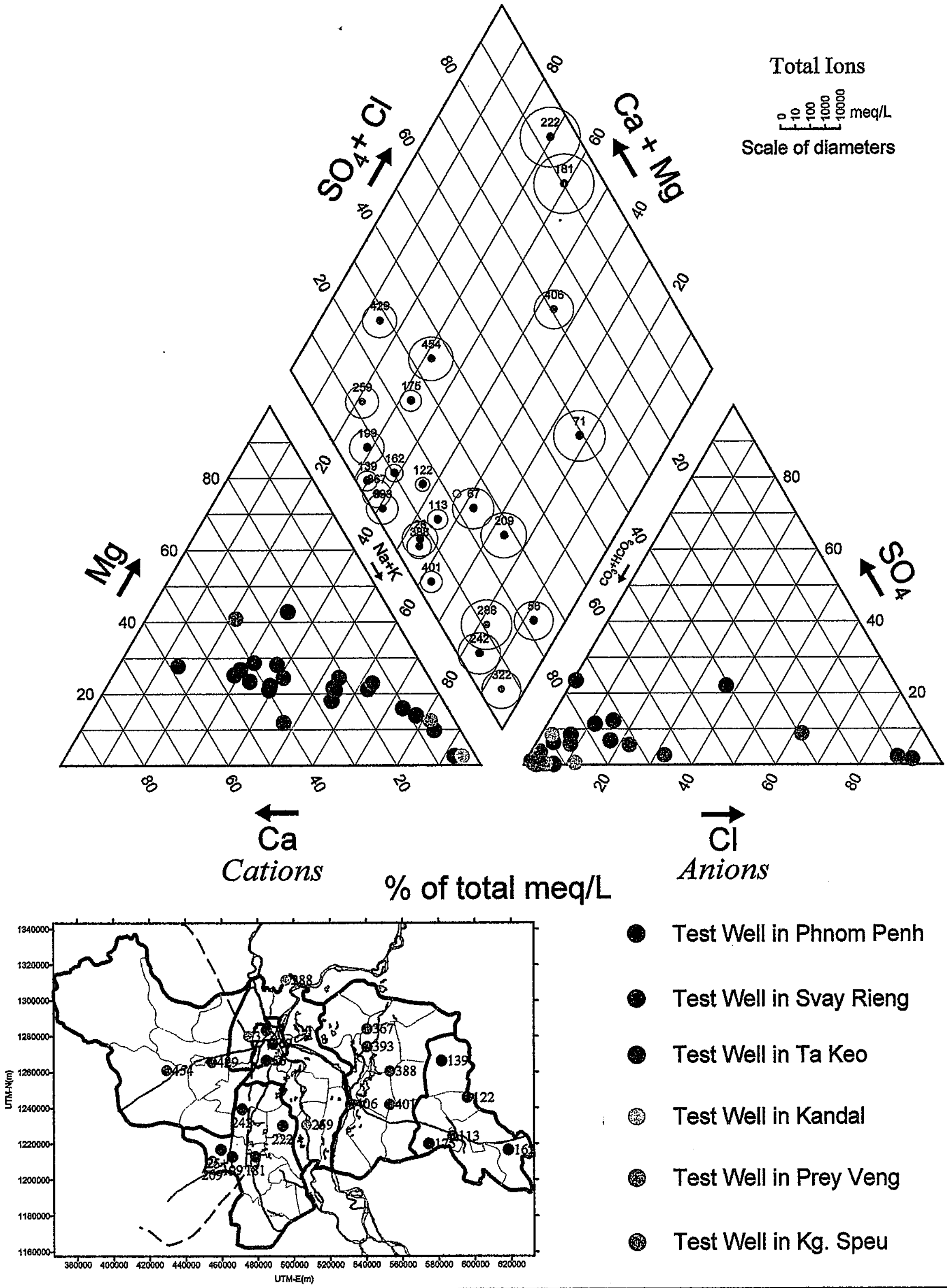


Figure 4.68	**TRILINEAR DIAGRAM OF TEST WELL WATER IN 1999**
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

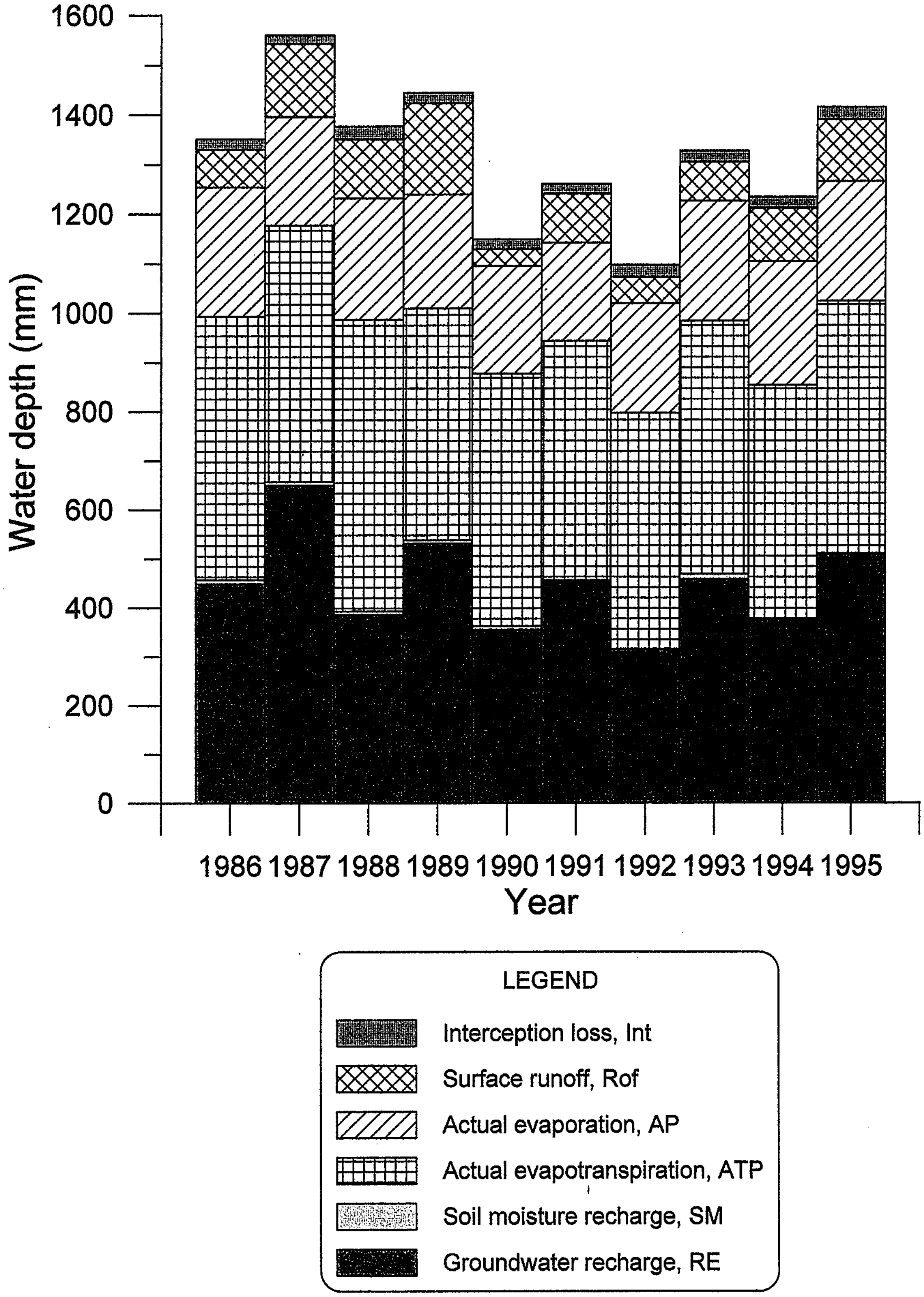


Figure 4.69	ESTIMATED WATER BALANCE IN THE STUDY AREA
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

Table 4.2 List of Test Wells

No.	Province	District Commune Village	V. No.	UTM-E(m)	UTM-N(m)	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Screen Length (m)	Aquifer
1	Phnom Penh	Dangkao Sak Sampov Khvet	56	484926	1266465	55.0	54.0	46.0 - 54.0	8.0	Sandstone
2	Phnom Penh	Mean Chey Stueng Mean Chey Mean Chey	67	488660	1275999	51.0	50.0	34.0 - 46.0	12.0	Weathered sandstone with shale
3	Phnom Penh	Ruessei Keo Khmuonh Somrong	71	484983	1283229	62.0	60.0	26.5 - 30.5 34.5 - 38.5 50.5 - 58.5	16.0	Quaternary and sandstone
4	Svay Rieng	Svay Reing Koy Tra Bek Koy Tra Bek	113	587748	1224037	124.0	120.0	80.0 - 88.0 108.0 - 116.0	16.0	Quaternary
5	Svay Rieng	Rom Doul Thnal Thnong Trapaing Thmor	122	595913	1245674	100.0	96.0	64.0 - 68.0 80.0 - 92.0	16.0	Quaternary
6	Svay Rieng	Ro Meas Hak Chrey Thom Dok Por	139	581674	1266154	130.0	108.0	88.0 - 104.0	16.0	Quaternary
7	Svay Rieng	Chan Trei Prey Koky Cham Kar Leiv	162	618359	1216428	150.0	144.0	104.0 - 108.0 124.0 - 140.0	20.0	Quaternary
8	Svay Rieng	Svay Chrom Cham Bok Toul Khpos	175	574586	1219825	157.0	153.5	136.0 - 148.0	12.0	Quaternary
9	Ta Keo	Doun Keo Roka Krau Preach	181	478603	1212775	59.0	59.0	41.5 - 57.5	16.0	Sandstone
10	Ta Keo	Tram Kak Srae Ro Naong Prey Maok	199	465890	1212780	40.0	40.0	26.5 - 38.5	12.0	Sandstone
11	Ta Keo	Tram Kak Kus Trapaing Thma	209	454635	1210199	52.0	51.5	34.0 - 50.0	16.0	Weathered shale
12	Ta Keo	Prey Kabbas Ban Kam Ta Vong	222	493749	1230039	93.0	93.0	75.0 - 91.0	16.0	Sandstone
13	Ta Keo	Bati Krang Leav Ta Pen	242	471254	1239367	48.0	47.5	22.0 - 34.0 42.0 - 46.0	16.0	Quaternary and sandstone
14	Kandal	Kaoh Thum Prek Thmei Svay Kraom	259	506870	1230577	72.0	60.0	40.0 - 56.0	16.0	Quaternary
15	Kandal	Mukh Kampul Svay Ampear Krang Svay	288	495710	1311424	49.0	49.0	33.0 - 49.0	16.0	Sandstone
16	Kandal	Angsnuol Snao Angkor Chhey	322	475025	1280114	38.0	34.0	14.0 - 30.0	16.0	Quaternary and sandstone
17	Prey Veng	Pea Reang Prey Pnou Ka Kou	367	540495	1284118	127.0	120.0	56.0 - 60.0 68.0 - 76.0 88.0 - 96.0	20.0	Quaternary
18	Prey Veng	Me Sang Prey Khnes Russei Tvear	388	553038	1260510	120.0	120.0	88.0 - 104.0	16.0	Quaternary
19	Prey Veng	Kampong Leav Ta Kao Kok Trom Kha	393	540512	1274163	127.0	126.5	41.0 - 45.0 81.0 - 89.0 121.0 - 125.0	16.0	Quaternary
20	Prey Veng	Ba Phnum Sdau Kaong Prek Phdau	401	552924	1241861	125.0	120.0	92.0 - 104.0	12.0	Quaternary
21	Prey Veng	Peam Ro Neak Loeung Prek Ta Sa	406	531212	1242164	150.0	144.0	72.0 - 80.0 108.0 - 120.0 132.0 - 140.0	28.0	Quaternary
22	Kg. Speu	Samrong Tong Sen Dey Samrong Cheung Phnom	426	454887	1259320	41.0		Abandon		Shale with sandstone
23	Kg. Speu	Samrong Tong Rolaing Chak Sre Kak	429	454500	1265612	34.0	34.0	16.5 - 28.5	12.0	Weathered shale
24	Kg. Speu	Phnom Srouch Taing Sia Kiri Raksmey	454	429542	1260960	24.0	24.0	4.0 - 8.0 12.0 - 24.0	16.0	Sandstone with shale
25	Kg. Speu	Phnom Srouch Treng Trayeung Treng Trayeung II	470	415052	1246371	72.0		Abandon		Quaternary clay with sand
26	Ta Keo	Thamkar Nang Sray		459556	1216675	28.5	28.5	15.0 - 27.0	12.0	Weathered shale

Table 4.3 Result of Step-Drawdown Tests at 25 Test Wells (1/2)

STEP-DRAWDOWN TEST

No.	Province	District / Commune / Village	V. No.	UTM-E(m)	UTM-N(m)	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Screen Length (m)	Date (yy/mm/dd) / Static Water Level (m below G.L.)	Q1(m3/day) / s1(m) / Sc1(m2/day)	Q2(m3/day) / s2(m) / Sc2(m2/day)	Q3(m3/day) / s3(m) / Sc3(m2/day)	Q4(m3/day) / s4(m) / Sc4(m2/day)	Aquifer Loss Coef. B (day/m2)	Well Loss Coef. C (day2/m5)	Well Efficiency, Ew(%) Step-1	Step-2	Step-3	Step-4
		Dangkao									5.98	11.95	33.02	-						
1	Phnom Penh	Sak Sampov	56	484926	1266465	55.0	54.0	46.0 - 54.0	8.0	97/06/09	16.99	26.10	31.55	-	3.13E+000	-6.67E-002	110.2	143.3	327.6	-
		Khvet								7.35	0.35	0.46	1.05	-						
		Mean Chey									11.95	33.0	48.5	67.7						
2	Phnom Penh	Stueng Mean Chey	67	488660	1275999	51.0	50.0	34.0 - 46.0	12.0	97/06/13	3.52	10.87	16.78	16.78	2.94E-001	1.08E-003	99.8	89.3	85.0	118.6
		Mean Chey								9.45	3.39	3.04	2.89	4.03						
		Ruessei Keo						26.5 - 30.5			11.95	33.0	48.5	67.7						
3	Phnom Penh	Khmuonh	71	484983	1283229	62.0	60.0	34.5 - 38.5	16.0	97/05/10	5.12	24.80	30.74	38.53	5.19E-001	1.91E-003	121.1	69.1	81.9	91.2
		Somrong						50.5 - 58.5		9.40	2.33	1.33	1.58	1.76						
		Svay Reing									89.0	118.4	150.1	186.7						
4	Svay Rieng	Koy Tra Bek	113	587748	1224037	124.0	120.0	80.0 - 88.0	16.0	97/06/08	0.41	0.68	0.81	1.03	4.36E-003	7.03E-006	94.4	75.9	80.8	79.0
		Koy Tra Bek						108.0 - 116.0		1.60	216.55	174.12	185.31	181.26						
		Rom Doul									67.7	118.4	150.1	186.7						
5	Svay Rieng	Thnal Thnong	122	595913	1245674	100.0	96.0	60.0 - 64.0	16.0	97/06/14	0.25	0.65	0.83	0.95	3.38E-003	1.20E-005	91.5	61.6	61.1	66.4
		Trapaing Thmor						80.0 - 92.0		3.75	270.80	182.15	180.84	196.53						
		Ro Meas Hak									67.7	118.4	150.1	186.7						
6	Svay Rieng	Chrey Thom	139	581674	1266154	130.0	108.0	80.0 - 104.0	24.0	97/06/16	0.37	1.00	1.19	1.19	5.99E-003	8.12E-006	109.6	70.9	75.6	94.0
		Dok Por								5.90	182.97	118.40	126.13	156.89						
		Chan Trei									67.7	118.4	150.1	186.7						
7	Svay Rieng	Prey Koky	162	618359	1216428	150.0	144.0	104.0 - 108.0	20.0	97/06/10	0.40	0.92	1.23	1.16	4.09E-003	2.86E-005	69.2	52.6	49.9	65.8
		Cham Kar Leiv						124.0 - 140.0		3.60	169.25	128.70	122.03	160.95						
		Svay Chrom									89.0	118.4	150.1	186.7						
8	Svay Rieng	Cham Bok	175	574586	1219825	157.0	153.5	136.0 - 148.0	12.0	97/06/04	0.63	0.81	0.98	1.48	6.08E-003	7.48E-006	85.9	88.9	93.1	76.7
		Toul Khpos								3.10	141.27	146.17	153.16	126.15						
		Doun Keo									14.40	28.80	43.20	57.60						
9	Ta Keo	Roka Krau	181	478603	1212775	59.0	59.0	41.5 - 57.5	16.0	97/08/01	11.19	18.75	20.49	30.11	8.41E-001	-6.53E-003	108.2	129.2	177.3	160.9
		Preach								4.78	1.29	1.54	2.11	1.91						
		Tram Kak									33.0	48.5	67.7	118.4						
10	Ta Keo	Srae Ro Naong	199	465890	1212780	40.0	40.0	26.5 - 38.5	12.0	97/05/22	8.19	16.20	20.35	22.18	3.56E-001	-1.27E-003	143.4	106.6	118.4	190.0
		Prey Maok								3.30	4.03	2.99	3.33	5.34						
		Tram Kak									48.5	67.7	118.4	150.1						
11	Ta Keo	Kus	209	454635	1210199	52.0	51.5	34.0 - 50.0	16.0	97/05/25	0.87	1.15	2.99	4.16	1.13E-002	1.11E-004	63.0	66.5	44.7	40.8
		Trapaing Thma								4.40	55.75	58.87	39.60	36.08						
		Prey Kabbas									7.20	12.00	20.90	-						
12	Ta Keo	Ban Kam	222	493749	1230039	93.0	93.0	75.0 - 91.0	16.0	97/08/07	11.49	15.36	36.30	-	1.33E+000	1.55E-002	83.3	103.9	76.6	-
		Ta Vong								5.25	0.63	0.78	0.58	-						
		Bati									5.98	11.95	20.91	-						
13	Ta Keo	Krang Leav	242	471254	1239367	48.0	47.5	22.0 - 34.0	16.0	97/06/05	15.58	20.91	37.05	-	2.71E+000	-5.12E-002	104.0	154.9	152.9	-
		Ta Pen						42.0 - 46.0		3.79	0.38	0.57	0.56	-						

Table 4.3 Result of Step-Drawdown Tests at 25 Test Wells (2/2)

STEP-DRAWDOWN TEST

No.	Province	District / Commune / Village	V. No.	UTM-E(m)	UTM-N(m)	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Screen Length (m)	Date (yy/mm/dd) / Static Water Level (m below G.L.)	Q1(m3/day) / s1(m) / Sc1(m2/day)	Q2(m3/day) / s2(m) / Sc2(m2/day)	Q3(m3/day) / s3(m) / Sc3(m2/day)	Q4(m3/day) / s4(m) / Sc4(m2/day)	Aquifer Loss Coef. B (day/m2)	Well Loss Coef. C (day2/m5)	Well Efficiency, Ew(%) Step-1	Step-2	Step-3	Step-4
		Kaoh Thum									89.00	118.40	150.10	186.70						
14	Kandal	Prek Thmei	259	506870	1230577	72.0	60.0	40.0 - 56.0	16.0	97/06/25	0.52	1.06	1.34	1.47	5.55E-003	1.73E-005	95.0	62.0	62.2	70.5
		Svay Kraom								5.50	171.15	111.70	112.01	127.01						
		Mukh Kampul									11.95	20.91	33.0	48.5						
15	Kandal	Svay Ampear	288	495710	1311424	49.0	49.0	33.0 - 49.0	16.0	97/05/18	7.35	15.18	24.79	32.68	6.57E-001	1.22E-003	106.8	90.5	87.5	97.5
		Krang Svay								8.70	1.63	1.38	1.33	1.48						
		Angsnuol									5.98	11.95	20.91	33.0						
16	Kandal	Snao	322	475025	1280114	38.0	34.0	14.0 - 30.0	16.0	97/05/25	5.17	9.23	23.70	30.23	8.30E-001	5.09E-003	96.0	107.5	73.2	90.6
		Angkor Chhey								7.40	1.16	1.29	0.88	1.09						
		Pea Reang						56.0 - 60.0			5.98	89.0	118.4	150.1						
17	Prey Veng	Prey Pnou	367	540495	1284118	127.0	120.0	68.0 - 76.0	20.0	97/05/28	3.50	5.31	7.48	8.99	4.87E-002	9.34E-005	8.3	81.6	77.1	81.3
		Ka Kou						88.0 - 96.0		6.87	1.71	16.76	15.83	16.70						
		Me Sang									67.7	89.0	118.4	150.1						
18	Prey Veng	Prey Khnes	388	553038	1260510	120.0	120.0	88.0 - 104.0	16.0	97/06/02	0.59	0.93	1.05	1.29	1.01E-002	-8.71E-006	115.9	96.7	113.9	117.5
		Russei Tvear								4.95	114.75	95.70	112.76	116.36						
		Kampong Leav						41.0 - 45.0			67.7	89.0	118.4	150.1						
19	Prey Veng	Ta Kao	393	540512	1274163	127.0	126.5	81.0 - 89.0	16.0	97/05/30	0.35	0.49	0.72	0.87	4.74E-003	8.45E-006	91.7	86.1	77.9	81.8
		Kok Trom Kha						121.0 - 125.0		5.85	193.43	181.63	164.44	172.53						
		Ba Phnum									33.02	48.51	67.68	118.43						
20	Prey Veng	Sdau Kaong	401	552924	1241861	125.0	120.0	92.0 - 104.0	12.0	97/06/20	1.29	1.35	1.48	2.43	3.97E-002	-1.84E-004	101.6	142.7	181.5	193.5
		Prek Phdau									25.60	35.94	45.73	48.73						
		Peam Ro						72.0 - 80.0			89.00	118.40	150.10	186.70						
21	Prey Veng	Neak Loeung	406	531212	1242164	150.0	144.0	108.0 - 120.0	28.0	97/06/22	3.46	5.59	6.09	6.41	4.93E-002	-6.68E-005	126.8	104.4	121.5	143.6
		Prek Ta Sa						132.0 - 140.0		5.75	25.72	21.18	24.65	29.13						
		Samrong Tong																		
22	Kg. Speu	Sen Dey	426	454887	1259320	41.0	-	Abandon	-	-	-	-	-	-	-	-	-	-	-	-
		Samrong Cheung Phnom																		
		Samrong Tong									5.98	11.95	20.91	-						
23	Kg. Speu	Rolaing Chak	429	454500	1265612	34.0	34.0	16.5 - 28.5	12.0	97/05/27	4.15	15.48	29.60	-	1.14E+000	1.34E-002	164.3	88.0	80.5	-
		Sre Kak								4.00	1.44	0.77	0.71	-						
		Phnom Srouch									11.95	33.00	48.50	67.70						
24	Kg. Speu	Taing Sia	454	429542	1260960	24.0	24.0	4.0 - 8.0	16.0	97/06/16	3.87	14.27	15.90	17.90	3.94E-001	-1.42E-003	121.7	91.1	120.2	149.0
		Kiri Raksmey						12.0 - 24.0		3.53	3.09	2.31	3.05	3.78						
		Phnom Srouch																		
25	Kg. Speu	Treng Trayeung	470	415052	1246371	72.0	-	Abandon	-	-	-	-	-	-	-	-	-	-	-	-
		Treng Trayeung II																		

Table 4.4 Results of Continuous Pumping and Recovery Tests at 25 Test Wells (1/2)

No.	Province	District Commune Village	V. No.	UTM-E(m)	UTM-N(m)	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Screen Length (m)	CONTINUOUS PUMPING TEST Date (yy/mm/dd) Static Water Level (m below G.L.)	Q(m3/day) s(m) Sc(m2/day)	Transmissivity by Cooper-Jacob, T (m2/day)	Storativity by Cooper-Jacob, S (dimensionless)	Transmissivity by Theis T (m2/day)	Storativity by Theis S (dimensionless)	RECOVERY TEST Transmissivity T (m2/day)
1	Phnom Penh	Dangkao Sak Sampov Khvet	56	484926	1266465	55.0	54.0	46.0 - 54.0	8.0	97/06/10 7.74	11.95 24.79 0.48	0.380	2.42E-002	0.326	6.30E-002	0.359
2	Phnom Penh	Mean Chey Stueng Mean Chey Mean Chey	67	488660	1275999	51.0	50.0	34.0 - 46.0	12.0	97/06/14 10.00	48.51 16.72 2.90	5.71	8.69E-008	4.34	1.50E-005	3.17
3	Phnom Penh	Ruessei Keo Khmuonh Somrong	71	484983	1283229	62.0	60.0	26.5 - 30.5 34.5 - 38.5 50.5 - 58.5	16.0	97/05/11 9.55	20.91 29.70 0.70	0.394	2.43E-001	0.375	2.78E-001	0.344
4	Svay Rieng	Svay Reing Koy Tra Bek Koy Tra Bek	113	587748	1224037	124.0	120.0	80.0 - 88.0 108.0 - 116.0	16.0	97/06/09 1.61	186.65 1.19 156.85	1576.8	(Too small)	583.0	5.20E-017	1625.9
5	Svay Rieng	Rom Doul Thnal Thnong Trapaing Thmor	122	595913	1245674	100.0	96.0	60.0 - 64.0 80.0 - 92.0	16.0	97/06/15 3.77	186.65 0.95 196.48	1521.8	(Too small)	831.0	1.07E-019	1264.1
6	Svay Rieng	Ro Meas Hak Chrey Thom Dok Por	139	581674	1266154	130.0	108.0	80.0 - 104.0	24.0	97/06/17 5.91	186.65 1.17 159.53	2065.7	(Too small)	731.0	3.58E-021	1794.4
7	Svay Rieng	Chan Trei Prey Koky Cham Kar Leiv	162	618359	1216428	150.0	144.0	104.0 - 108.0 124.0 - 140.0	20.0	97/06/11 3.60	186.65 1.21 154.26	910.1	(2.08E-26)	422.0	6.29E-011	3174.5
8	Svay Rieng	Svay Chrom Cham Bok Toul Khpos	175	574586	1219825	157.0	153.5	136.0 - 148.0	12.0	97/06/05 3.11	186.65 1.48 126.12	558.5	(4.50E-20)	420.0	3.63E-014	406.0
9	Ta Keo	Doun Keo Roka Krau Preach	181	478603	1212775	59.0	59.0	41.5 - 57.5	16.0	97/08/02 4.83	43.20 24.47 1.77	1.37	5.85E-002	1.38	5.64E-002	1.22
10	Ta Keo	Tram Kak Srae Ro Naong Prey Maok	199	465890	1212780	40.0	40.0	26.5 - 38.5	12.0	97/05/23 4.24	118.43 20.84 5.68	19.14	(4.21E-15)	16.4	4.54E-013	9.04
11	Ta Keo	Tram Kak Kus Trapaing Thma	209	454635	1210199	52.0	51.5	34.0 - 50.0	16.0	97/05/26 4.80	150.09 5.65 26.56	39.43	8.09E-003	33.1	2.45E-002	31.96
12	Ta Keo	Prey Kabbas Ban Kam Ta Vong	222	493749	1230039	93.0	93.0	75.0 - 91.0	16.0	97/08/09 5.23	11.95 15.90 0.75	3.96	(5.23E-26)	1.57	6.96E-010	0.25
13	Ta Keo	Bati Krang Leav Ta Pen	242	471254	1239367	48.0	47.5	22.0 - 34.0 42.0 - 46.0	16.0	97/06/06 4.75	11.95 21.70 0.55	11.95	(6.27E-10)	1.16	8.48E-008	0.527

Table 4.4 Results of Continuous Pumping and Recovery Tests at 25 Test Wells (2/2)

No.	Province	District Commune Village	V. No.	UTM-E(m)	UTM-N(m)	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Screen Length (m)	CONTINUOUS PUMPING TEST Date (yy/mm/dd) Static Water Level (m below G.L.)	Q(m3/day) s(m) Sc(m2/day)	Transmissivity by Cooper-Jacob, T (m2/day)	Storativity by Cooper-Jacob, S (dimensionless)	Transmissivity by Theis T (m2/day)	Storativity by Theis S (dimensionless)	RECOVERY TEST Transmissivity T (m2/day)
14	Kandal	Kaoh Thum Prek Thmei Svay Kraom	259	506870	1230577	72.0	60.0	40.0 - 56.0	16.0	97/06/26 5.49	186.65 1.71 109.15	1763.4	(Too small)	501.0	5.07E-020	1622.8
15	Kandal	Mukh Kampul Svay Ampear Krang Svay	288	495710	1311424	49.0	49.0	33.0 - 49.0	16.0	97/05/19 8.30	48.51 21.80 2.23	2.06	1.56E-002	1.74	5.70E-002	1.68
16	Kandal	Angsnuol Snao Angkor Chhey	322	475025	1280114	38.0	34.0	14.0 - 30.0	16.0	97/05/25 8.15	11.95 15.07 0.79	0.526	2.68E-001	0.491	3.64E-001	0.338
17	Prey Veng	Pea Reang Prey Pnou Ka Kou	367	540495	1284118	127.0	120.0	56.0 - 60.0 68.0 - 76.0 88.0 - 96.0	20.0	97/05/29 6.87	150.09 7.86 19.10	243.2	(Too small)	41.1	4.07E-010	371.3
18	Prey Veng	Me Sang Prey Khnes Russei Tvear	388	553038	1260510	120.0	120.0	88.0 - 104.0	16.0	97/06/03 4.95	150.09 1.32 113.71	511.3	(2.40E-19)	419.0	1.02E-015	281.5
19	Prey Veng	Kampong Leav Ta Kao Kok Trom Kha	393	540512	1274163	127.0	126.5	41.0 - 45.0 81.0 - 89.0 121.0 - 125.0	16.0	97/05/31 5.85	150.09 0.90 166.77	439.3	5.68E-010	446.0	1.30E-010	669.6
20	Prey Veng	Ba Phnum Sdau Kaong Prek Phdau	401	552924	1241861	125.0	120.0	92.0 - 104.0	12.0	-	-	-	-	-	-	-
21	Prey Veng	Peam Ro Neak Loeung Prek Ta Sa	406	531212	1242164	150.0	144.0	72.0 - 80.0 108.0 - 120.0 132.0 - 140.0	28.0	97/06/23 5.75	186.65 6.15 30.35	141.7	(3.04E-21)	93.8	2.30E-013	679.6
22	Kg. Speu	Samrong Tong Sen Dey Samrong Cheung Phnom	426	454887	1259320	41.0	-	Abandon	-	-	-	-	-	-	-	-
23	Kg. Speu	Samrong Tong Rolaing Chak Sre Kak	429	454500	1265612	34.0	34.0	16.5 - 28.5	12.0	97/05/28 4.10	11.95 17.96 0.67	0.512	3.77E-002	0.492	4.39E-002	0.169
24	Kg. Speu	Phnom Srouch Taing Sia Kiri Raksmey	454	429542	1260960	24.0	24.0	4.0 - 8.0 12.0 - 24.0	16.0	97/06/17 6.60	67.68 17.86 3.79	3.507	2.84E-002	3.14	5.27E-002	38.66
25	Kg. Speu	Phnom Srouch Treng Trayeung Treng Trayeung II	470	415052	1246371	72.0	-	Abandon	-	-	-	-	-	-	-	-

Table 4.5 Results of Laboratory Chemical Analysis of Groundwater (1/2)

No.	Well No.	LAB No.	Province	District	Village No	Village Name	UTM-E (m)	UTM-N (m)	Date YY/MM/DD	Well Type	pH	EC (mS/cm)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	NH4 (mg/L)	Fe (mg/L)	Mn (mg/L)	SiO2 (mg/L)	As (mg/L)	CO3 (mg/L)	HCO3 (mg/L)	CO2 (mg/L)	Cl (mg/L)	SO4 (mg/L)	NO3 (mg/L)	F (mg/L)	T-Hard (mg/L)	N-hard (mg/L)	TDS (mg/L)	Remark
WHO Guideline Values for Drinking Water (mg/L)															200		1.5	0.3	0.1		0.01				250	250	50	1.5			1000	
1	123	40258	Kandal	Saang		Kompong Pring	505360	1262924	97/05/24	combined well	6.93	883	98	33	41	3.2	1.1	1.6	0.00	23	0.000	0	425	80	55	26	33	0.26	381	33	523	
2	105	40252	Kandal	Saang		Toul Krasaing	497608	1263249	97/05/24	combined well	7.53	510	32	23	48	0.9	0.0	0.50	0.00	38	0.001	0	298	14	8.8	18	1.8	0.55	177	0	318	
3	115	40255	Kandal	Saang		Prek Thmei	504113	1252133	97/05/24	dug well	7.26	1,170	112	50	92	9.4	0.7	0.39	0.00	24	0.001	0	472	42	134	26	8.4	0.15	486	100	659	
4	130	40260	Kandal	Ang Snoul	313	Snao Keut	475970	1279177	97/05/24	tub well	8.34	903	2.4	2.1	194	4.0	0.6	0.09	0.00	20	0.002	0	364	3	364	68	0.1	6.63	15	0	841	
5	118	40257	Kandal	Koh Thom		Svay Kraom	506709	1230451	97/05/24	tub well	7.12	488	30	32	30	3.1	0.6	0.23	0.00	30	0.000	0	281	34	13	0.8	17	0.53	206	0	295	
6	116	40256	Kandal	Koh Thom		Prek Takei	506248	1237343	97/05/24	tub well	7.24	2,390	103	83	322	5.7	1.7	2.2	0.00	34	0.000	0	631	58	214	520	19	0.42	598	81	1,614	
7	113	40254	Kandal	Saang		Svay Tany	503166	1253664	97/05/24	tub well	7.72	1,820	123	70	205	3.2	0.0	15	0.50	25	0.000	0	863	26	172	73	10	0.52	596	0	1,122	
8	107	40253	Kandal	Saang		Toul Krasaing	497869	1262763	97/05/24	tub well	7.67	553	50	30	39	1.0	0.0	0.03	0.01	43	0.000	0	353	12	9.9	7.0	0.2	0.51	248	0	355	
9	98	40251	Kg. Speu	Phnom Srouch	453	Prum Rolok	430752	1260843	97/05/23	dug well	7.95	886	66	45	78	0.5	0.0	0.65	0.00	42	0.001	0	496	9	55	6.5	1.9	1.12	348	0	541	
10	94	40249	Kg. Speu	Phnom Srouch	470	Treng Trayeng II	414798	1246437	97/05/23	dug well	5.91	2,330	41	23	361	45	3.4	8.3	0.77	26	0.001	0	66	130	619	24	44	0.61	196	142	1,225	
11	92	40248	Kg. Speu	Samraong	429	Sre Kok	454608	1265572	97/05/23	dug well	7.01	561	37	18	44	14	0.0	0.06	0.00	34	0.001	0	166	26	62	21	45	0.18	166	30	357	
12	90	40247	Kg. Speu	Samraong	426	Samraong	454838	1259196	97/05/23	dug well	7.49	968	146	23	39	0.7	0.2	0.18	0.01	31	0.001	0	476	25	88	5.8	0.1	0.41	436	45	569	
13	97	40250	Kg. Speu	Phnom Srouch		Mort Say	431128	1259721	97/05/23	tub well	7.46	1,330	115	59	106	3.6	0.0	0.46	0.07	38	0.001	0	700	39	92	36	16	1.64	530	0	813	
14	87	40246	Kg. Speu	Samraong		Mohalam Paing I	454891	1259853	97/05/23	tub well	7.34	1,350	153	64	46	0.5	0.0	0.06	0.05	35	0.001	0	517	38	158	25	66	0.42	646	424	803	
15	128	40259	Kg.Cham	Ba Theay		Taing Kraing	494590	1314255	97/05/29	tub well	7.76	3,430	228	86	200	148	0.9	0.09	1.90	66	0.001	0	579	16	453	372	306	0.74	922	447	2,147	
16	171	40264	Phnom Penh	Dang Kao		Thmei	488246	1271696	97/05/26	combined well	7.37	693	11	4.3	133	13	2.5	7.4	0.00	34	0.001	0	267	18	53	42	1.5	1.54	44	0	432	
17	141	40261	Phnom Penh	Dang Kao	23	Thlok	480780	1280730	97/05/26	combined well	7.36	1,670	48	12	288	8.9	0.3	0.04	0.00	128	0.001	0	677	47	195	49	8.6	0.62	171	0	1,072	
18	144	40262	Phnom Penh	Dang Kao		Khmer Leu	480646	1281370	97/05/26	dug well	6.63	942	42	5.3	108	25	0.2	1.6	0.11	139	0.001	0	92	35	230	14	2.0	0.19	127	0	613	
19	174	40265	Phnom Penh	Dang Kao		Cheung Ek	489742	1269276	97/05/26	tub well	7.20	1,130	62	48	127	10	0.6	0.08	0.40	107	0.001	0	577	58	74	46	2.5	0.74	351	0	762	
20	169	40263	Phnom Penh	Dang Kao	54	Kom Reng	484005	1266061	97/05/26	tub well	7.34	1,510	73	17	216	66	0.5	1.6	0.20	68	0.001	0	651	48	164	46	0.5	0.63	250	0	974	
21	78	40245	Phnom Penh	Mean chey	64	Russei	488118	1274269	97/05/26	tub well	7.75	1,100	30	28	196	0.4	0.3	0.07	0.01	71	0.001	0	620	18	50	33	17	1.12	192	0	732	
22	279	40277	Prey Veng	Me Sang	388	Russei Tvear	552939	1260562	97/05/19	combined well	7.04	165	8.6	4.0	25	1.6	5.8	0.90	0.00	67	0.000	0	99	14	4.2	5.1	0.6	0.46	38	0	166	
23	261	40276	Prey Veng	Prey Veng		Prey Kla	545935	1284922	97/05/20	combined well	7.02	283	16	11	35	0.9	0.3	0.28	0.00	55	0.002	0	175	27	5.3	0.4	0.1	0.26	85	0	210	
24	227	40272	Prey Veng	Komchay Mear	380	Don Daok(east)	573483	1293128	97/05/20	combined well	5.97	329	4.2	1.2	53	2.2	0.7	0.41	0.07	11	0.001	0	14	24	94	0.6	0.2	0.00	15	3	174	
25	2	40230	Prey Veng	Ba Phnum	401	Prey Phdau	552861	1241760	97/05/19	combined well	6.90	215	9.9	4.3	41	2.0	0.8	0.22	0.00	72	0.000	0	132	27	5.7	0.7	1.0	0.38	42	0	202	
26	202	40267	Prey Veng	Peam Ro		Prey Kompenh	539455	1261241	97/05/19	combined well	5.79	179	6.7	1.8	25	5.3	0.5	0.03	0.00	50	0.000	0	23	60	31	1.2	13	0.09	24	5	145	
27	250	40274	Prey Veng	Kam chay Mear		Tra Bek	559602	1282725	97/05/20	dug well	7.39	522	39	28	44	1.8	0.4	0.25	0.00	41	0.000	0	353	23	8.4	0.5	0.5	0.46	213	0	338	
28	214	40270	Prey Veng	Ba Phnom		Kok Sandek	543258	1251563	97/05/19	dug well	6.53	622	24	14	74	2.0	0.3	0.67	1.4	57	0.000	0	86	41	134	24	0.4	0.20	121	50	374	
29	253	40275	Prey Veng	Kamchay Mear		Sang ke	553359	1287324	97/05/20	tub well	7.34	419	24	13	53	1.2	0.7	1.8	0.00	36	0.000	0	275	20	6.1	1.2	1.6	0.31	116	0	274	
30	241	40273	Prey Veng	Kamchay Mear		Thnal Keng	571800	1278519	97/05/20	tub well	7.33	478	56	18	25	2.9	0.5	0.3	0.00	42	0.000	0	324	24	5.3	0.8	0.1	0.21	214	0	310	
31	220	40271	Prey Veng	Preah Sdech	409	Kok Sampouv	549334	1230625	97/05/21	tub well	7.69	1,140	52	43	154	1.4	0.6	0.26	0.00	29	0.000	0	563	18	6.5	180	0.1	0.78	306	0	744	
32	207	40268	Prey Veng	Kampong leav		Hydrology office	536612	1269799	97/05/20	tub well	7.12	503	34	17	55	3.6	0.5	0.00	0.00	55	0.001	0	301	37	17	2.4	0.3	0.47	154	0	333	
33	189	40266	Prey Veng	Peam Ro	406	Prek Tasar	531272	1242386	97/05/21	tub well	7.35	293	20	19	21	0.9	0.0	1.1	0.00	46	0.000	0	178	13	9.2	1.6	0.4	0.36	127	0	207	
34	213	40269	Prey Veng	Ba Phnom		Chroul Thmei	543418	1253120	97/05/19	tub well	7.43	452	30	17	53	1.2	0.1	0.06	0.02	50	0.000	0	290	17	9.2	8.6	0.2	0.42	144	0	313	
35	27	40234	Svay Rieng	Svay Chrom	175	Toul Khpos	575350	1220253	97/05/30	combined well	6.39	188	12	1.0	30	1.9	1.2	1.1	0.04	43	0.001	0	63	41	27	1.8	2.0	0.19	35	0	151	
36	295	40278	Svay Rieng	Svay Teap		Veal	599438	1243464	97/05/21	dug well	4.98	435	5.8	2.3	69	4.0	0.7	0.59	0.17	13	0.000	0	9	144	108	7.0	11	0.22	24	0	225	
37	9	40232	Svay Rieng	Cham Trea	162	Chamkar Leiv	618501	1216837	97/05/21	dug well	6.00	143	11	0.8	16	1.5	1.5	2.1	0.01	18	0.000	0	48	77	22	2.2	0.3	0.00	31	0	98	
38	5	40231	Svay Rieng	Rom Duol	120	Trapaing Kret	590174	1242688	97/05/22	dug well	7.04	324	10	6.7	60	1.1	0.7	0.52	0.01	60	0.000	0	202	29	4.6	6.4	1.2	0.57	52	0	251	
39	314	40282	Svay Rieng	Romeas Hek		Chheu Phleung	583644	1260627	97/05/22	tub well	6.37	149	9.3	6.9	18	2.6	0.1	2.8	0.43	106	0.000	0	87	59	5.7	1.4	0.3	0.20	52	0	196	

Table 4.5 Results of Laboratory Chemical Analysis of Groundwater (2/2)

No.	Well	LAB	Province	District	Village		UTM-E	UTM-N	Date	Well Type	pH	EC	Ca	Mg	Na	K	NH4	Fe	Mn	SiO2	As	CO3	HCO3	CO2	Cl	SO4	NO3	F	T-Hard	N-hard	TDS	Remark
	No.	No.			No	Name	(m)	(m)	YY/MM/DD			(mS/cm)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
											LABORATORY TEST				WHO Guideline Values for Drinking Water (mg/L): 200		1.5	0.3	0.1		0.01				250	250	50	1.5			1000	
40	307	40281	Svay Rieng	Romeas Hek		Chan Trei	579422	1247514	97/05/22	tub well	7.05	334	16	12	46	2.2	0.1	1.6	0.00	45	0.000	0	209	30	5.7	1.5	0.6	0.34	91	0	234	
41	298	40280	Svay Rieng	Svay Rieng		Andong Tasei	586634	1227283	97/05/22	tub well	7.14	386	23	11	51	3.7	3.1	5.5	0.53	44	0.001	0	224	26	12	10	0.3	0.28	103	0	272	
42	296	40279	Svay Rieng	Svay Teap		Veal	599438	1243464	97/05/21	tub well	6.36	86	3.8	2.9	16	3.2	0.0	1.2	0.00	54	0.001	0	52	36	3.1	1.4	0.2	0.19	22	0	112	
43	31	40235	Svay Rieng	Svay Chrom	179	Toul Tres	575396	1222860	97/05/21	tub well	6.67	329	14	12	44	2.0	0.5	1.1	0.02	65	0.001	0	143	49	4.5	45	0.4	0.30	85	0	259	
44	16	40233	Svay Rieng	Cham Trea	159	Ta Deiv	623360	1212062	97/ 05 /21	tub well	6.17	892	14	17	129	4.8	0.9	0.13	0.90	67	0.001	0	77	83	217	33	0.0	0.18	105	42	534	
45	40	40237	Ta Keo	Prey Kabbas	219	Pech Changva	494064	1227952	97/ 05/ 27	combined well	6.87	4,280	163	160	435	9.9	1.3	1.2	0.97	67	0.001	0	353	76	1,210	40	0.6	0.45	1,070	777	2,260	
46	59	40239	Ta Keo	Treang	234	Trapaing Slar	484970	1206797	97/ 05/ 28	dug well	7.31	1,560	44	37	221	3.3	0.0	2.5	0.01	56	0.004	0	307	24	343	13	1.0	0.32	264	12	872	
47	76	40244	Ta Keo	Bati	255	Prey Moul	489181	1246368	97/ 05/ 27	dug well	7.70	730	49	20	97	0.5	0.2	0.13	0.01	45	0.001	0	476	15	9.9	5.3	2.9	1.13	206	0	465	
48	74	40243	Ta Keo	Samraong	191	Srei Chey	469680	1225837	97/ 05/ 27	dug well	5.87	172	3	0.7	28	2.5	0.8	0.54	0.03	47	0.000	0	24	52	39	1.3	2.0	0.08	10	0	136	
49	73	40242	Ta Keo	Samraong	193	Boeng Tranh	471978	1225745	97/ 05/ 27	tub well	6.13	198	9.4	2.2	28	4.4	1.9	17	0.44	25	0.000	0	57	68	32	1.8	0.2	0.12	32	0	140	
50	66	40241	Ta Keo	Treang	231	Samraong	474101	1201558	97/ 05/ 28	tub well	6.79	1,540	84	34	147	59	0.0	1.5	2.0	108	0.001	0	235	61	292	110	6.4	0.44	348	155	960	
51	63	40240	Ta Keo	Treang		Prey Tube	482545	1211150	97/ 05/ 28	tub well	6.78	3,080	48	64	478	9.9	0.0	1.9	0.32	52	0.000	0	238	63	850	21	0.3	0.27	384	189	1,643	
52	47	40238	Ta Keo	Prey Kabbas	223	Dang Het	490157	1230917	97/ 05/ 27	tub well	7.06	1,690	61	55	196	4.0	0.4	7.2	0.39	55	0.000	0	238	33	395	28	0.4	0.35	377	182	920	
53	45	40283	Ta Keo	Prey Kabbas		Kok Kanhchab	491414	1228984	97/ 05/ 27	tub well	6.63	2,930	162	123	221	83	7.1	13	0.65	7.4	0.000	0	181	68	1,265	0.0	2.4	1.90	908	760	1,969	
54	39	40236	Ta Keo	Doun Keo		PDRD Office	475035	1214127	97/ 05/ 28	tub well	7.48	1,040	28	7.1	198	2.6	0.6	1.2	0.01	53	0.003	0	453	24	68	110	0.1	0.59	99	0	692	
55	BH-056	40303	Phnom Penh	Dangkao	56	Khvet	484926	1266465	97/06/10	Test Well	7.88	1,200	23	11	288	2.1	0.5	0.28	0.00	32	0.000	0	631	13	48	76	0.2	2.33	104	0	794	
56	BH-067	40336	Phnom Penh	Mean Chey	67	Mean Chey	488660	1275999	97/06/15	Test Well	7.10	1,420	58	33	225	2.9	0.0	0.05	0.02	38	0.000	0	668	85	97	41	25	0.37	280	0	849	
57	BH-071	40284	Phnom Penh	Ruessei Keo	71	Somrong	484983	1283229	97/05/12	Test Well	7.15	3,700	74	67	625	4.2	0.7	0.09	0.00	27	0.000	0	892	101	455	383	267	1.05	468	0	2343	
58	BH-113	40302	Svay Rieng	Svay Reing	113	Koy Tra Bek	587748	1224037	97/06/09	Test Well	6.36	266	16	11	37	2.6	2.9	4.0	0.45	60	0.000	0	146	102	12	7.0	0.4	0.21	83	0	223	
59	BH-122	40337	Svay Rieng	Rom Doul	122	Trapaing Thmor	595913	1245674	97/06/16	Test Well	6.33	275	23	5.2	28	3.9	0.0	2.7	0.40	50	0.001	0	158	118	3.0	12	0.0	0.26	78	0	207	
60	BH-139	40332	Svay Rieng	Ro Meas Hak	139	Dok Por	581674	1266154		Test Well	6.42	195	16	7.1	16	5.3	1.3	2.5	0.42	40	0.000	0	120	73	3.8	0.2	0.2	0.22	68	0	151	
61	BH-162	40335	Svay Rieng	Chan Trei	162	Cham Kar Leiv	618359	1216428	97/06/12	Test Well	6.44	198	19	5.3	16	7.1	1.5	6.0	0.60	65	0.000	0	118	69	1.5	5.5	0.0	0.24	69	0	183	
62	BH-175	40301	Svay Rieng	Svay Chrom	175	Toul Khpos	574586	1219825	97/06/06	Test Well	6.13	265	15	19	18	2.2	2.3	3.1	0.74	55	0.001	0	129	153	3.1	30	0.2	0.22	120	13	210	
63	BH-181	40334	Ta Keo	Doun Keo	181	Preach	478603	1212775		Test Well	6.93	5,650	480	127	481	13	2.0	1.1	2.8	37	0.000	0	363	68	1,690	59	0.0	0.39	1,720	1,423	3070	
64	BH-199	40285	Ta Keo	Tram Kak	199	Prey Maok	465890	1212780	97/05/24	Test Well	7.25	731	88	25	46	0.0	2.3	0.02	0.02	46	0.000	0	468	42	21	0.6	0.3	0.27	324	0	458	
65	BH-209	40286	Ta Keo	Tram Kak	209	Trapaing Thma	454635	1210199	97/05/24	Test Well	7.22	2,130	74	39	405	2.5	1.4	0.04	0.13	29	0.001	0	987	95	166	193	0.0	0.36	344	0	1395	
66	BH-222	40339	Ta Keo	Prey Kabbas	222	Ta Vong	493749	1230039	97/06/19	Test Well	6.84	6,650	561	212	432	5.7	1.1	0.10	0.94	22	0.000	0	104	24	2,130	46	0.0	0.39	2,270	2,180	3462	
67	BH-242	40290	Ta Keo	Bati	242	Ta Pen	471254	1239367	97/05/21	Test Well	7.40	1,350	21	17	317	6.1	1.1	0.44	0.01	45	0.000	0	932	59	27	0.9	0.2	0.36	122	0	894	
68	BH-259	40287	Kandal	Kaoh Thum	259	Svay Kraom	506870	1230577	97/05/27	Test Well	7.08	713	58	40	46	1.7	1.1	0.07	0.33	43	0.001	0	399	53	39	6.2	0.1	0.64	308	0	432	
69	BH-288	40288	Kandal	Mukh Kampul	288	Krang Svay	495710	1311424	97/05/19	Test Well	7.09	2,550	50	40	612	2.4	1.4	0.02	0.00	52	0.000	0	1,710	222	136	94	0.1	0.54	288	0	1829	
70	BH-322	40289	Kandal	Angsnuol	322	Angkor Chhey	475025	1280114	97/05/26	Test Well	8.18	1,100	6.1	6.5	274	2.4	2.4	0.13	0.00	27	0.000	0	714	8	30	1.1	0.1	2.33	42	0	701	
71	BH-367	40291	Prey Veng	Pea Reang	367	Ka Kou	540495	1284118	97/05/30	Test Well	6.79	445	39	19	44	2.2	1.1	1.0	0.35	55	0.000	0	293	76	8.4	2.1	0.8	0.30	177	0	317	
72	BH-388	40292	Prey Veng	Me Sang	388	Russei Tvear	553038	1260510	97/06/03	Test Well	6.62	325	20	13	46	2.2	1.7	1.4	0.28	59	0.000	0	198	76	9.6	13	0.7	0.27	102	0	263	
73	BH-393	40293	Prey Veng	Kampong Leav	393	Kok Trom Kha	540512	1274163	97/05/30	Test Well	6.75	560	45	24	55	3.1	0.4	0.25	0.55	63	0.000	0	379	108	6.1	2.3	0.2	0.26	210	0	386	
74	BH-401	40333	Prey Veng	Ba Phnum	401	Prek Phdau	552924	1241861		Test Well	7.01	310	13	6.7	51	3.8	1.3	0.88	0.44	68	0.000	0	181	28	9.2	15	0.9	0.43	60	0	258	
75	BH-406	40340	Prey Veng	Peam Ro	406	Prek Ta Sa	531212	1242164	97/06/23	Test Well	6.43	1,280	59	34	150	4.2	0.0	5.2	0.84	65	0.000	0	204	121	272	45	0.0	0.34	289	122	736	
76	BH-429	40294	Kg. Speu	Samrong Tong	429	Sre Kak	454500	1265612	97/05/28	Test Well	6.97	675	90	26	25	2.3	0.8	0.12	0.05	45	0.001	0	373	64	35	7.7	7.2	0.32	330	24	422	
77	BH-454	40338	Kg. Speu	Phnom Srouch	454	Kiri Raksmey	429542	1260960	97/06/17	Test Well	6.81	1,450	150	6.6	106	2.1	0.3	0.49	0.03	43	0.001	0	729	181	135	12	0.5	1.18	644	47	816	
78	BH-25/1	40331	Ta Keo	Thamkar	25/1	Nang Sray	459556	1216675		Test Well	7.49	806	44	21	113	1.2	0.1	2.4	0.47	27	0.000	0	505	26	25	0.6	0.3	0.36	197	0	484	

Table 4.6 Groundwater Quality of Test Wells in 1999

No.	Lab No.	Well No	Location	Temp. C	Eh (mV)	pH	EC (mS/m)	Unit : milligrams/Litre Ca	Mg	Na	K	NH_4	Fe	Mn	SiO_2	CO_3	HCO_3	Cl	SO_4	NO_2	NO_3	F	T-Hard	N-Hard	TDS
2	42071	56	Khvet	29.2	98	8.06	120.0	12	3.7	255	1.6	0.11	0.05	0.00	27	0	619	53	72	0.00	0.0	2.20	44	0	733
3	42072	67	Mean Chey	29.2	115	7.32	138.0	49	39	216	2.1	0.46	0.26	0.00	38	0	685	91	48	0.00	33	0.35	282	0	856
4	42073	71	Somrong	28.8	105	7.37	359.0	61	61	644	4.5	0.98	0.18	0.00	29	0	834	444	355	0.03	323	0.87	404	0	2335
15	42084	93	River	26.9	146	6.20	8.9	5.6	2.0	12	2.3	0.65	0.98	0.00	4.9	0	43	5.7	2	0.12	2.9	0.26	22	0	59
22	42091	113	Koy Trabek	26.5	150	6.32	26.2	14	5.8	32	3.2	0.45	9.6	0.53	47	0	143	8.0	7.7	0.01	0.1	0.21	60	0	189
23	42092	122	Trapaing Thmor	25.8	165	6.11	15.0	13	2.3	15	3.8	0.00	5.4	0.24	54	0	86	4.2	6.7	0.01	0.0	0.13	43	0	142
24	42093	139	Dok por	26.4	153	6.46	24.5	24	7.9	18	5.8	0.12	10.0	0.12	39	0	154	1.9	0.9	0.01	0.0	0.11	93	0	173
25	42094	162	Chamkarleav	27.1	165	6.15	19.6	17	5.9	16	6.0	0.34	7.8	0.62	58	0	117	3.1	6.4	0.02	0.0	0.13	67	0	171
16	42085	175	Toul Khpos	27.6	155	6.11	25.6	15	16	21	3.7	0.47	2.5	0.70	44	0	131	0.8	32	0.00	0.1	0.37	102	0	198
5	42074	181	Prich	28.6	138	6.75	676.0	551	177	621	5.8	4.3	0.11	0.10	45	0	400	2132	73	0.00	0.0	0.30	2102	1774	3804
6	42075	199	Prey Maok	29.2	125	7.17	75.2	81	27	58	0.7	0.51	0.01	0.18	41	0	488	22	0.7	0.00	0.0	0.24	312	0	472
7	42076	209	Trapaing Thmor	29.3	107	7.24	189.0	44	40	350	1.4	0.76	0.11	0.16	26	0	948	116	127	0.00	0.5	0.33	275	0	1174
8	42077	222	Ta Vong	28.6	118	6.81	683.0	615	227	472	7.2	6.2	1.0	1.6	39	0	271	2245	51	0.01	0.0	0.43	2468	2246	3791
9	42078	242	Ta Pen	28.7	115	7.55	139.0	20	19	310	1.5	0.31	0.20	0.01	40	0	940	29	2.6	0.00	0.0	0.35	126	0	887
10	42079	259	Svay Krom	28.8	130	7.31	66.5	59	39	37	2.5	0.67	0.05	0.30	39	0	391	31	2.3	3.90	0.1	0.45	304	0	407
11	42080	288	Krang Svay	28.8	93	7.36	253.0	37	49	607	4.0	0.57	0.02	0.00	46	0	1665	29	124	0.00	0.0	0.53	292	0	1720
12	42081	322	Angkor Chey	28.9	75	8.18	110.0	8.0	3.9	274	1.6	0.26	0.51	0.00	24	0	688	22	2.0	0.02	0.0	2.1	36	0	679
17	42086	367	Ka Kou	27.8	130	6.70	44.2	36	18	44	2.2	0.27	0.09	0.36	46	0	289	5.4	0.4	0.00	0.0	0.39	165	0	295
18	42087	388	Russei Trear	27.3	136	6.46	32.0	19	10	48	3.0	0.18	0.27	0.28	53	0	200	2.7	6.4	0.01	0.0	0.35	90	0	242
19	42088	393	Kok Thom Kha	26.3	135	6.78	57.6	49	21	64	4.5	0.35	0.07	0.57	59	0	380	3.1	3.6	0.01	0.0	0.34	207	0	392
20	42089	401	Prey Phdon	26.6	170	6.38	25.0	9.4	9.1	46	2.1	0.18	7.6	0.35	57	0	163	3.1	1.1	0.03	0.0	0.43	61	0	209
21	42090	406	Prek Ta Sa	26.5	135	6.32	124.0	56	39	161	3.6	0.60	4.5	1.8	59	0	212	261	50	0.03	0.0	0.42	301	127	736
13	42082	429	Sre Kak	28.1	110	7.23	79.0	100	29	28	0.5	0.65	0.02	0.04	39	0	360	65	22	0.02	20	0.33	369	74	482
14	42083	454	Kiri Raksmey	28.0	118	6.93	176.0	145	64	133	1.7	0.84	0.03	0.03	38	0	774	222	25	0.01	2.9	1.1	625	0	1016
1	42070	25+1	JICE	28.9	148	7.40	79.5	46	25	117	2.0	0.37	0.03	0.10	29	0	506	22	1.3	0.00	0.1	0.22	216	0	493

Table 4.7 Changes of Fe Concentration in Test Wells

Well No.	Province	Village Name	Fe in 1997 (A) (mg/L)*	Fe in 1999 (B) (mg/L)*	(B)-(A) (mg/L)
BH-056	Phnom Penh	Khvet	0.28	0.05	-0.23
BH-067	Phnom Penh	Mean Chey	0.05	0.26	0.21
BH-071	Phnom Penh	Somrong	0.09	0.18	0.09
BH-113	Svay Rieng	Koy Tra Bek	**4.00**	**9.60**	5.60
BH-122	Svay Rieng	Trapaing Thmor	**2.70**	**5.40**	2.70
BH-139	Svay Rieng	Dok Por	**2.50**	**10.00**	7.50
BH-162	Svay Rieng	Cham Kar Leiv	**5.00**	**7.80**	2.80
BH-175	Svay Rieng	Toul Khpos	**3.10**	**2.50**	-0.60
BH-181	Ta Keo	Preach	**1.10**	0.11	-0.99
BH-199	Ta Keo	Prey Maok	0.02	0.01	-0.01
BH-209	Ta Keo	Trapaing Thma	0.04	0.11	0.07
BH-222	Ta Keo	Ta Vong	0.10	**1.00**	0.90
BH-242	Ta Keo	Ta Pen	**0.44**	0.20	-0.24
BH-259	Kandal	Svay Kraom	0.07	0.05	-0.02
BH-288	Kandal	Krang Svay	0.02	0.02	0.00
BH-322	Kandal	Angkor Chhey	0.13	**2.50**	2.37
BH-367	Prey Veng	Ka Kou	**1.00**	0.09	-0.91
BH-388	Prey Veng	Russei Tvear	**1.40**	0.27	-1.13
BH-393	Prey Veng	Kok Trom Kha	0.25	0.07	-0.18
BH-401	Prey Veng	Prek Phdau	**0.88**	**7.60**	6.72
BH-406	Prey Veng	Prek Ta Sa	**5.20**	**4.50**	-0.70
BH-429	Kg. Speu	Sre Kak	0.12	0.02	-0.10
BH-454	Kg. Speu	Kiri Raksmey	**0.49**	0.03	-0.46
BH-25/1	Ta Keo	Nang Sray	**2.40**	0.03	-2.37

*Bold number: more than WHO Guideline value (=0.3 mg/L)

Table 4.8 Changes of Cl Concentration in Test Wells

Well No.	Province	Village Name	Cl in 1997 (A) (mg/L)*	Cl in 1999 (B) (mg/L)*	(B)-(A) (mg/L)
BH-056	Phnom Penh	Khvet	48.0	53.0	5.0
BH-067	Phnom Penh	Mean Chey	97.0	91.0	-6.0
BH-071	Phnom Penh	Somrong	**455.0**	**444.0**	-11.0
BH-113	Svay Rieng	Koy Tra Bek	12.0	8.0	-4.0
BH-122	Svay Rieng	Trapaing Thmor	3.0	4.2	1.2
BH-139	Svay Rieng	Dok Por	3.8	1.9	-1.9
BH-162	Svay Rieng	Cham Kar Leiv	1.5	3.1	1.6
BH-175	Svay Rieng	Toul Khpos	3.1	0.8	-2.3
BH-181	Ta Keo	Preach	**1690.0**	**2132.0**	442.0
BH-199	Ta Keo	Prey Maok	21.0	22.0	1.0
BH-209	Ta Keo	Trapaing Thma	166.0	116.0	-50.0
BH-222	Ta Keo	Ta Vong	**2130.0**	**2245.0**	115.0
BH-242	Ta Keo	Ta Pen	27.0	29.0	2.0
BH-259	Kandal	Svay Kraom	39.0	31.0	-8.0
BH-288	Kandal	Krang Svay	136.0	29.0	-107.0
BH-322	Kandal	Angkor Chhey	30.0	22.0	-8.0
BH-367	Prey Veng	Ka Kou	8.4	5.4	-3.0
BH-388	Prey Veng	Russei Tvear	9.6	2.7	-6.9
BH-393	Prey Veng	Kok Trom Kha	6.1	3.1	-3.0
BH-401	Prey Veng	Prek Phdau	9.2	3.1	-6.1
BH-406	Prey Veng	Prek Ta Sa	**272.0**	**261.0**	-11.0
BH-429	Kg. Speu	Sre Kak	35.0	65.0	30.0
BH-454	Kg. Speu	Kiri Raksmey	135.0	222.0	87.0
BH-25/1	Ta Keo	Nang Sray	25.0	22.0	-3.0

*Bold number: more than WHO Guideline value (=250 mg/L)

Table 4.9 Estimated Water Balance in the Study Area

Year	Rainfall *P* (mm)	Evaporation *PE* (mm)	Interception loss *Int* (mm)	Surface runoff *Rof* (mm)	Actual evaporation *AP* (mm)	Actual transpiration *ATP* (mm)	Soil moisture recharge *SM* (mm)	Groundwater recharge *RE* (mm)	Recharge ratio *RE/P* (%)
1986	1351.3	1348.3	21.0	75.8	260.7	536.3	8.6	448.9	33.2
1987	1551.8	1348.3	17.1	147.0	218.6	520.1	8.0	649.6	41.9
1988	1369.0	1353.0	26.1	118.9	245.1	593.9	7.0	386.1	28.2
1989	1437.7	1348.3	21.5	183.2	230.3	471.3	7.0	531.5	37.0
1990	1142.1	1348.3	19.8	34.1	217.8	514.7	7.8	354.9	31.1
1991	1253.6	1348.3	20.2	98.7	199.3	487.1	2.9	453.2	36.1
1992	1094.8	1353.0	25.0	53.1	222.5	481.3	0.4	315.4	28.8
1993	1327.3	1348.3	22.6	77.9	243.1	515.0	11.3	457.8	34.5
1994	1223.6	1348.3	23.0	107.0	251.4	476.2	1.8	375.5	30.7
1995	1413.3	1348.3	24.5	124.3	241.4	513.4	1.5	510.0	36.1
Average	1316.5	1349.2	22.1	102.0	233.0	510.9	5.6	448.3	34.1

CHAPTER 5

EXISTING WATER SOURCE IN THE VILLAGES

CHAPTER 5 EXISTING WATER SOURCE IN THE VILLAGES

Existing water sources in candidate target villages were surveyed from December 1996 to July 1997. The number of villages MRD requested the Study to be implemented for with the agreement of the Study team (December 1996) totals 474. As of July 1997, the Study team visited 413 of the villages. Of the unvisited villages, 59 were inaccessible by 4WD vehicles even in the dry season and 2 did not exist.

5.1 Village Location and Demography

5.1.1 Population and Village Size

The 474 candidate target villages are located in the five (5) southern provinces, i.e., Kandal, Kompong Speu, Ta Keo, Prey Veng, Svay Rieng, and the three (3) Peri-Urban Areas of Phnom Penh (refer to Table 5.5). However, two (2) of the villages in Kompong Speu included in the request list did not exist, reducing the total number of candidate target villages to 472, and the total population to 405,773. The location of these villages and the population by province are presented in Figure 5.1 and Table 5.1, respectively.

Table 5.1 Number and Population of Candidate Villages by Province

Province	Number of Village	Population	Average Size
Peri-Urban Area	99	128,775	1,300.8
Svay Rieng	80	53,667	670.8
Ta Keo	77	47,941	622.6
Kandal	85	82,476	970.3
Prey Veng	75	68,299	910.7
Kompong Speu	56	24,615	439.6
Total	472	405,773	859.7

Of the 472 candidate target villages, 117 are populated with more than 1,000, while the remaining 355 have less than 1,000 (average number of persons per village: 855.6). Villages in Peri-Urban Areas are the largest, from 62 to 8,931, averaging 1,296.8 persons per village. Out of the 40 villages in the Peri-Urban Areas having a population of more than 1,000, 25 have over 2,000. In other provinces, the village size ranges from: 117 to 5,412 in Kandal, 184 to 4,422 in Kompong Speu, 256 to 1,262 in Ta Keo, 314 to 1,968 in Prey Veng, and 133 to

2,810 in Svay Rieng.

5.1.2 Village Environment

The villages in the Study area are located in the alluvial plain along Mekong River, Bassac River and their tributaries, and surrounded by rice fields. Some villages in Ta Keo and Kompong Speu are located near western mountains. The main economic activities in these areas are lowland rice cultivation, livestock raising, and fishing.

Houses are raised on piles, constructed of bamboo or wood, and covered with thatch, tiles or iron sheets. The space underneath the house is used for storing tools and securing livestock and farm animals at night.

The village structure can be classified into the following three (3) types:

I	Closely built villages:	a distance of 10 to 50 m between houses
II	Medium built villages:	somewhere between I and III
III	Dispersed villages:	a distance of 100 to 500 m between houses

Closely built villages are situated in the vicinity of the provincial capital, and each household only owns a small farming area. The community in these villages is close, and community activities have a direct impact on the residents' daily life. Rice planting and harvesting are usually carried out collectively.

Medium built villages are located along trunk roads and rivers. Some farmers are also engaged in manufacturing and other business endeavors. Some of the villages extend 1 to 2 km along the road. Communication between households is not as close as in closely built villages.

Dispersed villages are located remotely from the provincial capital, each household covering huge farmlands. These villages are deemed to be self sufficient, and because of the distance between households, the feeling of belonging to a community is not fostered.

Apart from the above classification, houses in villages within the Mean Chey Peri-Urban Area next to Phnom Penh City are closely structured. Each of these villages is also densely populated, from 1,843 to 8,931, and are almost as urbanized as the city itself. Several villages located along Tonle Sap River in Russey Keo District also have the same environment.

There are no different ethnic groups in the Study area.

5.2 Existing Water Source

5.2.1 General Situation

Although there is no definite data on the coverage of clean water supply in the Study area, it is estimated that tube wells with hand pumps have a supply rate of 34 %, assuming that each well services 180 persons (refer to Table 5.2). However, this figure is questionable considering that more than 30 % of the existing hand pumps are broken or not utilized because water produced is high in salinity or iron. As a result, many rely on nearby surface water sources, e.g. ponds, rivers and groundwater from hand-dug wells, despite the fact that some of these water sources get depleted in the dry season.

Table 5.2 Estimated Coverage Ratio of Drilled/Deep Wells in 5 Provinces

(as of 1995)

Province	UNICEF/MRD Wells	Other Wells	Total	Population Served	Population	Coverage
Svay Rieng	382	170	552	99,360	391,127	25 %
Ta Keo	1,360	30	1,390	250,200	710,961	35 %
Kandal	1,896	171	2,067	372,060	904,103	41 %
Prey Veng	903	199	1,102	198,360	890,586	22 %
Kompong Speu	1,090	30	1,120	201,600	445,759	45 %
Total	5,131	600	6,231	1,121,580	3,342,536	34 %

* Population estimate as of 1993
** "Other Wells": including those constructed by NGOs, although they only number a few.

Although water can be secured in the rainy season, the sources, i.e. ponds and dug wells, are exposed to human and livestock wastes as most are located near rice fields or ground depressions to facilitate intake. Not properly maintained dug wells are common sources of water borne diseases.

5.2.2 Types of Water Source

Most of the villagers in the Study area (472 villages) obtain water from traditional sources such as ponds, rivers, and shallow dug wells, which are often unreliable and polluted. In the rainy season, villagers generally use rainwater for drinking and cooking. Aside from these traditional water sources, there are also deep wells and combined wells constructed by

UNICEF, MRD, and NGOs since the 1980s. Of the 472 candidate target villages, 177 have deep wells with hand pumps. Many of these wells are not used, however, due to hand pump breakdown and poor water quality (refer to Table 5.3). There are also many private deep wells in Prey Veng and Svay Rieng, which have been manually dug by local companies using very simple methods.

The villagers use ponds as their main water source in addition to rivers, dug wells and hand pump deep wells. Two (2) types of ponds exist in the candidate target villages: the public pond which is constructed by the villagers themselves, and the family pond which is constructed with the assistance of the Ministry of Agriculture, Forestry and Fisheries (MAFF).

Many villages use surface water (pond water) and groundwater (shallow or deep wells) at the same time. The former is used for drinking, while the latter is used for laundry and bathing. Some villages also use water from nearby rivers and canals.

Groundwater is being utilized by the construction of dug and deep wells. Dug wells are generally less than 10 m deep, from 0.5 to 2.0 m in diameter, and are built manually. They are either lined with a casing of wood staves, brick or concrete, and are generally without hand pumps.

Deep wells are constructed by UNICEF and MRD, and are generally 30 to 50 m deep with 100 mm PVC pipe casing. The deep well drilling operation is usually stopped after the first aquifer has been encountered. Because water quality is not analyzed, many produce inferior water quality, i.e. high in salinity or iron. Many of these tube wells were also constructed by NGOs. In many villages, tube wells producing water of poor quality are not being used or if they are, the usage is limited to laundry, gardening, and livestock raising.

Combined wells were initially constructed by the Groupe de Recherche et d'Enchanges Technologique (GRET) followed by other NGOs. This well type is a combination of a shallow dug well and a deep well, and is constructed as follows: a deep well is drilled, after which a hole is manually dug all the way to a depth deemed suitable. The tube is cut at the bottom of the excavated hole, then the water is made to flow into the hole from the tube well. The hole is lined with concrete ring and covered by concrete slab (platform). Usually, the well is capped and equipped with a suction hand pump such as No.6. However, most combined wells found in the Study area are uncovered, the hand pump removed, or abandoned.

As various kinds of hand pumps were used in rural water supply projects in this country, UNICEF and MRD are recommending the standardization of hand pumps according to lift capacity, availability of spare parts, and ease in maintenance.

(1) No.6 Suction Pump: 0 to 6 meters
(2) Tara Direct Action Pump: 6 to 12 meters
(3) Afridev Deep Lift Pump: 12 to 45 meters

5.2.3 Distance, Water Quality and Water Use

(1) Distance

The average distance to main water source is 150 m. A water source can be located as far as approximately 400 m. Sources located farther than this are not used daily, except in April and May, the dry season, when nearby water sources dry up, consequently forcing the villagers to collect water from villages about 1 to 3 km away. Sometimes, the journey takes 30 to 40 days.

(2) Water Quality

Not all villagers are particularly fond of drinking rainwater. Water produced by tube wells and combined wells is not fully utilized if high in salinity and iron. The use of nearly 70 % of the hand pumps is based on this premise. On the other hand, ponds, rivers, and shallow dug wells are fully utilized, since water produced from these sources tastes like rainwater. Actually, the field Electric Conductivity (EC) values of these water sources are generally lower than the tube well.

Every family has 5 to 6 jars, each of which has a capacity of about 200 liters. The villagers not only store rainwater, but also water from other sources. Water is left in the jar overnight to let sand, silt and oxidized iron settle at the bottom and make water drinkable and useful for cooking. Based on the bacteriological tests conducted at existing water sources, almost all water sources have problems in water quality. Considering the present state of the water sources, contamination by human and animal excrement is highly likely.

(3) Water Use

According to interviews concerning existing water sources and the amount of water consumed estimated based on the number of jars, the Study assumes that one household (about 5.3 persons/household) consumes about 200 liters of water every day. This calculation, however, does not include the amount of water used for bathing and laundry.

5.2.4 Maintenance of Existing Hand Pumps

About 60 % of the candidate target villages have tube wells, shallow dug wells or combined wells. However, only less than 40 (about 9 % of candidate target villages) are established with the Village Water Committee (VWC) or similar organizations. The awareness of the importance of public hand pumps diminishes in villages far from the main town. However, in areas where hand pump well is the only water source, the villagers are seen to be eager to establish VWC.

Table 5.3 presents the condition of the hand pumps in the candidate target villages surveyed as of March 1997. There are 269 public hand pumps in 177 villages; 221 are operative, while 48 (18 %) are out of order. The number of inoperative hand pumps is lower than anticipated. However, even operative hand pumps are not always functioning well or not utilized at present.

According to interviews with the villagers, hand pump operation and maintenance training was not provided prior to use. The pumps were repaired once or twice in the past and the villagers collected money from the users to cover the expenses. However, these hand pumps are abandoned at present due to poor water quality and in consideration of the repair expenses, availability of spare parts, and lack of skills to carry out repair.

Spare parts for deep well hand pumps, such as India Mark II, III and Afridev, installed by UNICEF, MRD, and NGOs are not available in the provincial capital. Local drillers repaired about 60 % of the hand pumps, disassembling the pumps without proper technical skills and spare parts. Consequently, the pumps become unfit for further use and the villagers get nothing for the money they spend for the repair.

The most commonly used hand pump is the No.6 suction pump, which is cheap and easy to handle. It is also easy to obtain the pump and its spare parts from local hardware shops. Nonetheless, the pump lift is only 0 to 6 m and breaks easily.

5.3 Target Village Selection

5.3.1 Needs for New Water Supply

All candidate target villages visited were classified according to the criteria and procedure presented in Figure 5.2, for categorization and prioritization.

Village accessibility is classified according to road conditions, as shown below.

(1) Accessibility

1) Superior:
   Asphalt roads that facilitate the access of drilling rigs
2) Excellent:
   Gravel or laterite roads that facilitate the access of drilling rigs
3) Favorable:
   Unpaved roads; access of drilling rigs is possible in the dry season
4) Impassable:
   Inaccessible to drilling rigs

Villages inaccessible to drilling rigs are excluded from the Project.

(2) Condition of Hand Pumps

Existing water supply system is evaluated in terms of hand pump operation. If a village has no hand pump or the hand pump is broken, this village is ranked under “A”, in which a new water supply is most urgently needed.

If all or some of the hand pumps are still operating, the village water needs are evaluated in terms of water quality.

(3) Water Quality

The quality of water produced by existing hand pump wells was evaluated based on the following criteria:

1) Unsuitable for drinking due to high iron and salinity levels.
2) Can be used for domestic purposes other than drinking due to high iron and salinity levels
3) Good water quality and therefore suitable for drinking

Villages with wells not used because they produce bad water quality or used for purposes other than drinking are ranked under “A”.

According to the EC survey, an EC of approximately 150 mS/m is the permissible limit for groundwater as a drinking water source. If iron is high, the villagers put water in the jar and leave it overnight to make the water drinkable.

Villages with wells producing bad water quality but used for drinking or producing good water quality and used for drinking were categorized according to water volume.

(4) Water Quantity

Quantity of water produced by a well with hand pump depends on the groundwater level, aquifer yield, and pump capacity. Water quantity is evaluated simply as "Sufficient" or "Insufficient", considering the number of households utilizing the well.

Villages with wells producing water that is drinkable but of bad quality and insufficient quantity are ranked under "B". A new water supply is needed in these villages, following those ranked in "A". Villages with wells producing bad water quality but sufficient quantity are ranked under "C", with wells producing drinkable water but insufficient quantity are ranked under "D", and those with wells producing drinkable water and sufficient quantity are ranked under "E". Villages ranked under "E" are not considered for the plan.

5.3.2 Classification of Candidate Target Villages

All candidate villages were classified according to the above criteria. Table 5.4 presents the results of the classification: 182 villages out of 472 villages are ranked under "A", 59 under "B", 38 under "C", 21 under "D", and 46 under "E". Due to inaccessibility, however, 126 villages were excluded as candidate villages. Further, 19 villages were not included in the classification as they were not surveyed. Some villages excluded from the Study did not want or declined the construction of a new water supply system based on land unavailability, the existence of private wells, among others. Figure 5.3 presents village prioritization by province.

All villages ranked from "A" to "D" were assessed based on the villagers willingness to organize a VWC and independently maintain the water supply system. After these were assessed, the villages were categorized taking hydro-geologic and socio-economic conditions into account. Prioritization was carried out to determine which village will be covered by the project first. The water supply system will be designed considering the aforementioned issues (refer to Chapter 8).

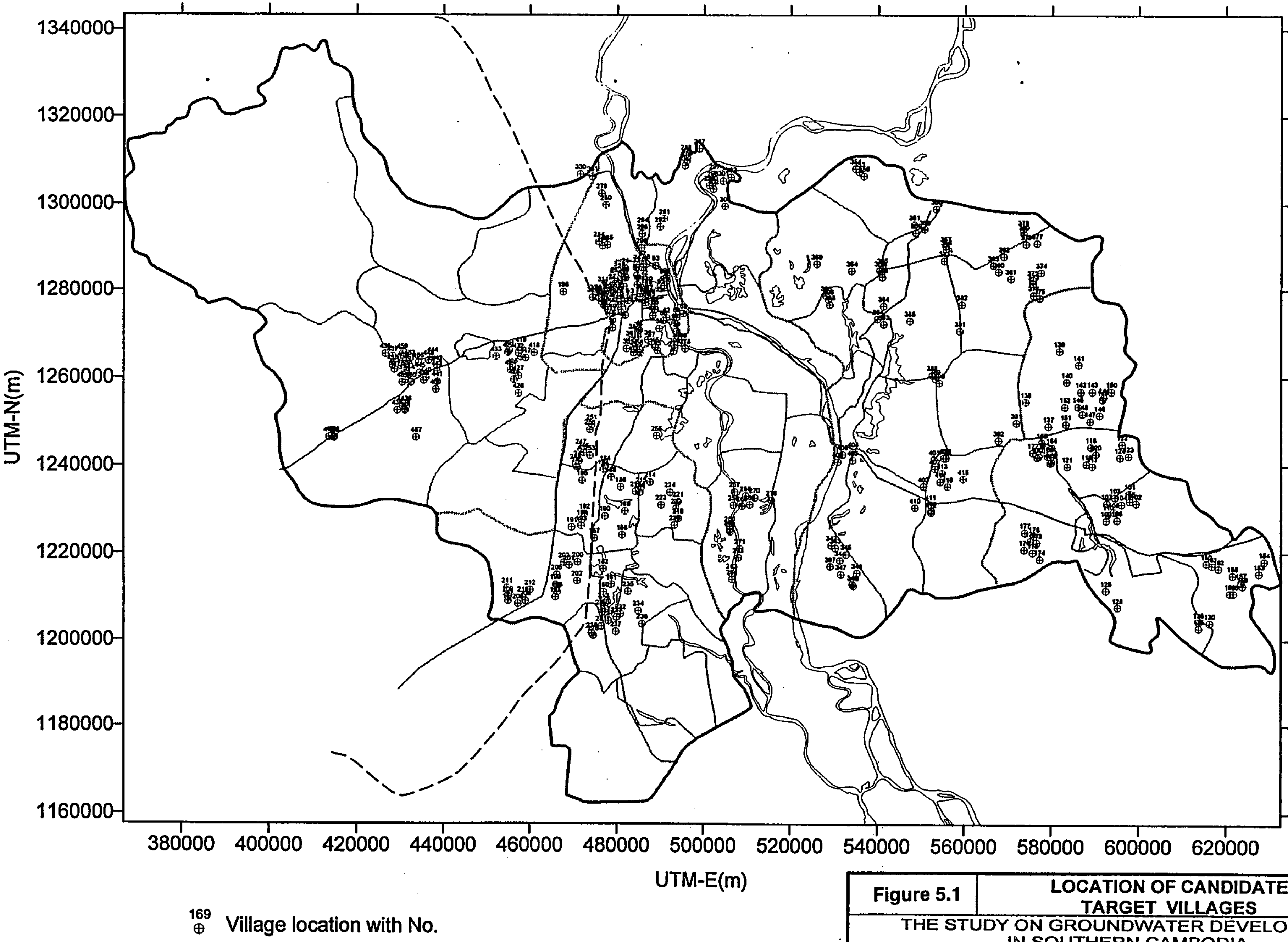


Figure 5.1	LOCATION OF CANDIDATE TARGET VILLAGES
THE STUDY ON GROUNDWATER DEVELOPMENT IN SOUTHERN CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

Figure 5.2 FLOW CHART OF VILLAGE CLASSIFICATION

NEEDS FOR NEW WATER SUPPLY SYSTEM

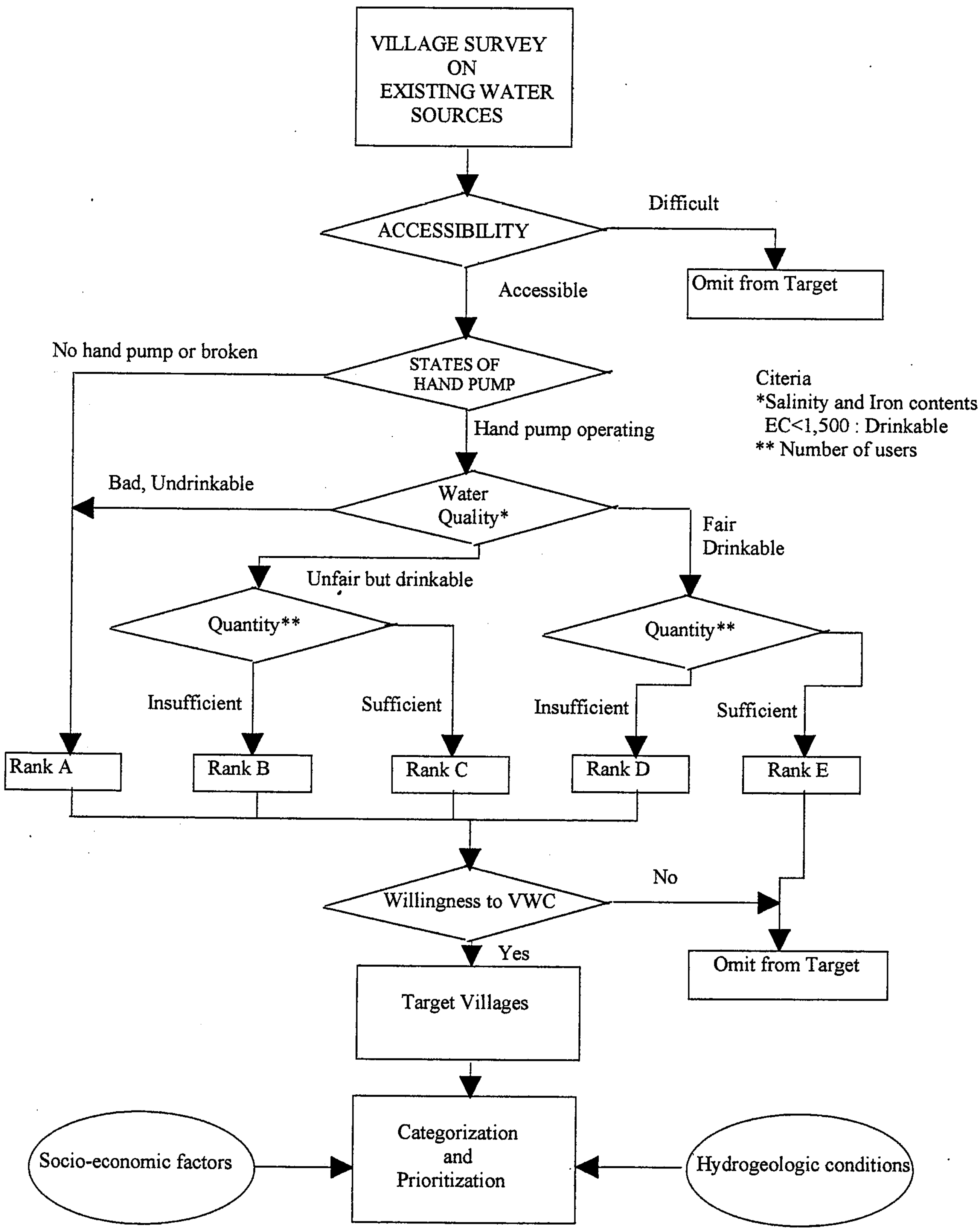


Figure 5.3 Classification of Candidate Villages by Basic Field Survey

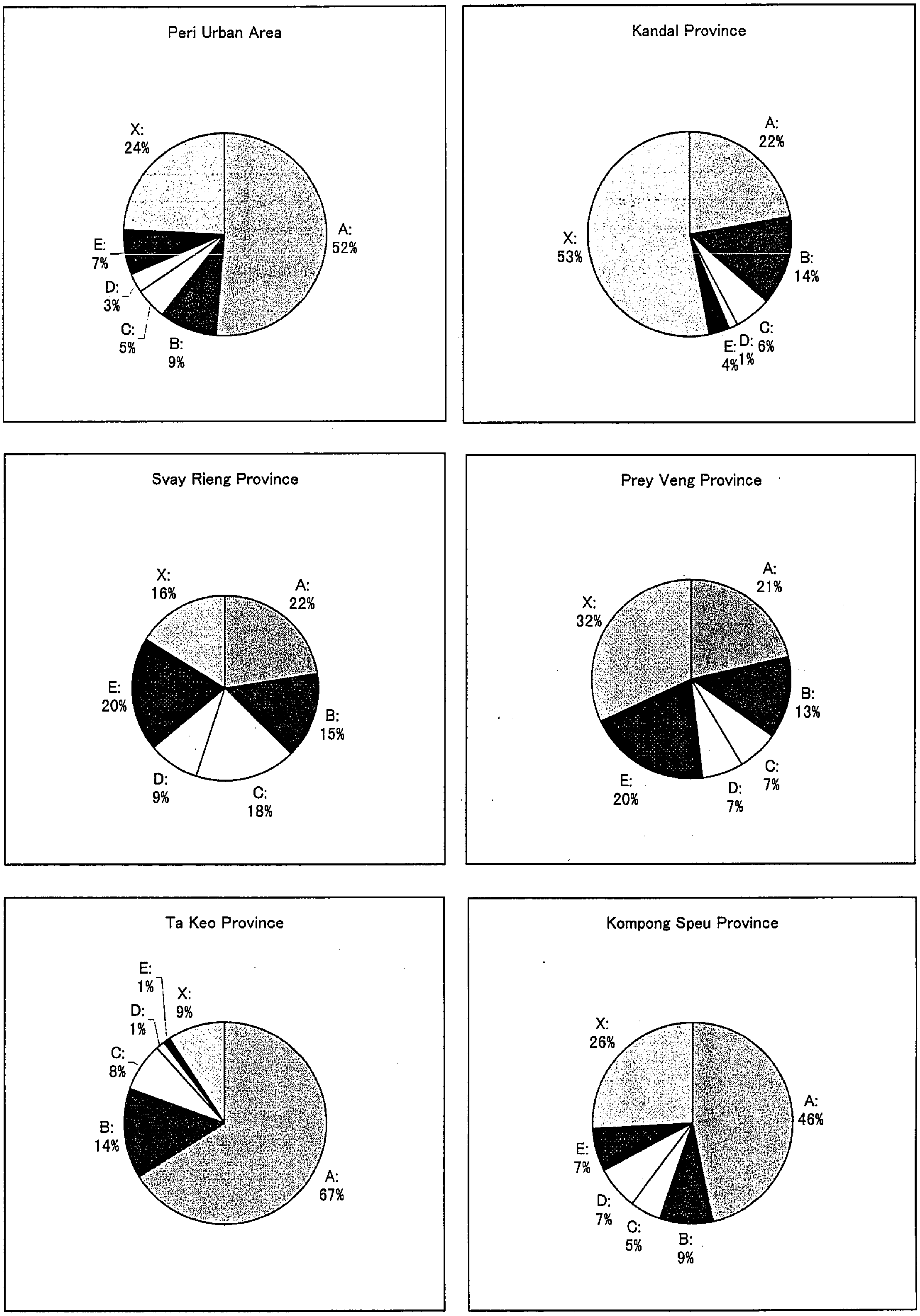


Table 5.3 Condition of Existing Hand Pumps in Candidate Villages

(Unit: set)

	Province	Village	Hand Pump	Working	Broken	Ope. %
1	Peri Urban Area	19/99	30	27	3	90.0%
2	Svay Rieng	20/80	38	28	10	73.7%
3	Ta Keo	21/77	50	40	10	80.0%
4	Kandal	58/85	50	45	5	90.0%
5	Prey Veng	24/75	60	50	10	83.3%
6	Kg. Speu	35/56	41	31	10	75.6%
	Total	177/472	269	221	48	82.2%

Note: 177/472 Upper Figure: No. of Villages which has Hand Pump
Lower Figure: Total No. of Villages

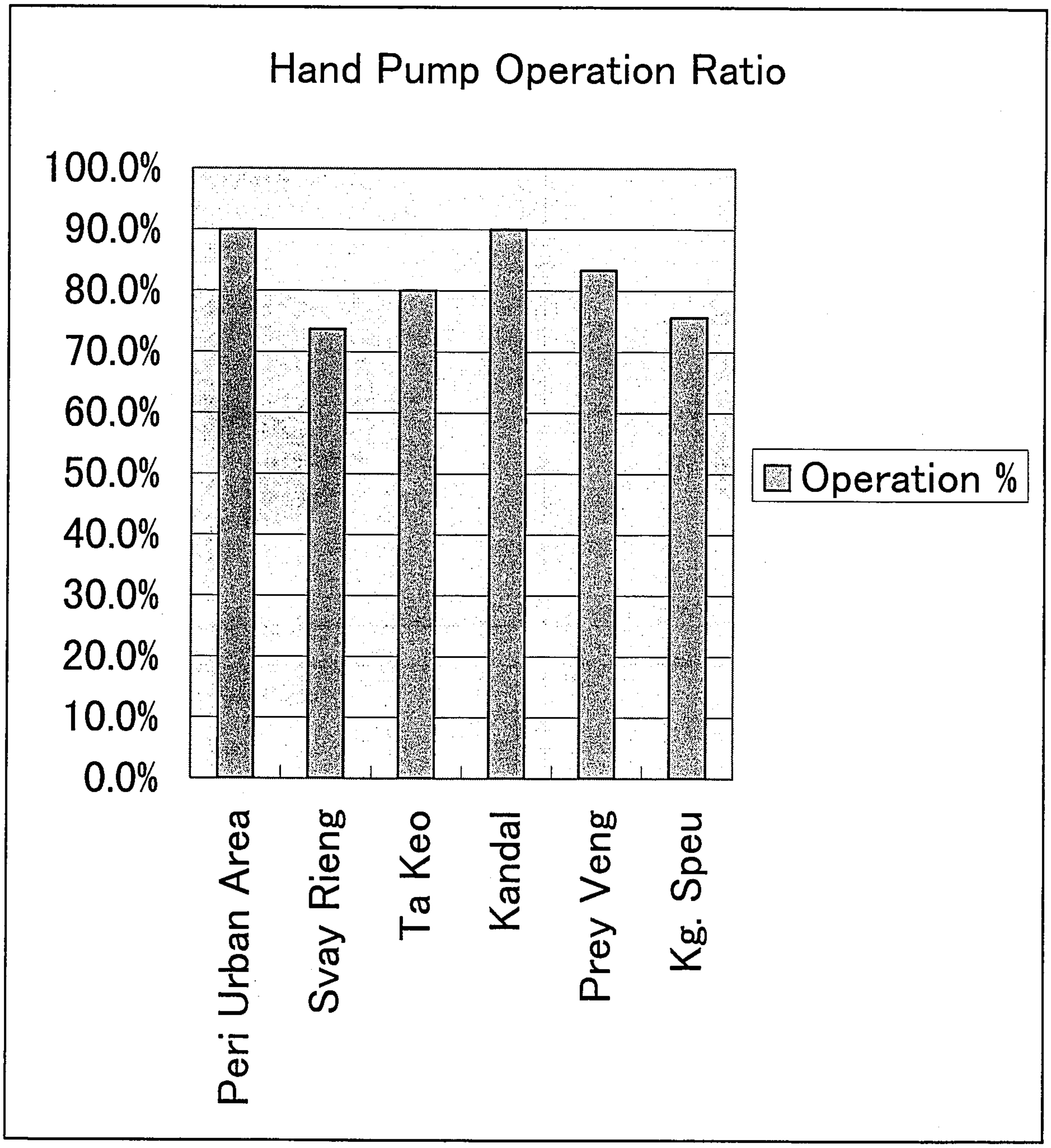


Table 5.4 Classification of the Candidate Target Village

Province		Rank						Total
		A	B	C	D	E	Others	
1	Peri Urban Area	51	9	5	3	7	24	99
2	Svay Rieng	18	12	14	7	16	13	80
3	Ta Keo	51	11	6	1	1	7	77
4	Kandal	19	12	5	1	3	45	85
5	Prey Veng	16	10	5	5	15	24	75
6	Kg. Speu	27	5	3	4	4	13	56
	Total	182	59	38	21	46	126	472
	Accumulative Tota	182	241	279	300	346	472	

Table 5.5 Summary of Village Survey - Water Source Data

Province	Village No.		Nos. of Villages	Population	Nos. of Family
	From	To			
Peri-Urban Area	1	99	99	128,775	25,350
Svay Rieng	100	179	80	53,667	12,030
Ta Keo	180	256	77	47,941	9,141
Kandal	257	341	85	82,476	17,087
Prey Veng	342	416	75	68,299	14,134
Kg. Speu	417	474	58	24,615	5,358
Total			474	405,773	83,100

Rank	No. of Village
A:	182
B:	59
C:	38
D:	21
E:	46
X:	128
Total	474

ABBREVIATION	
Pri.HPW	private hand pump well
PHPW	public hand pump well
Pri.HDW	private hand dug well
PHDW	public hand dug well
Pri.P	private pond
PP	public pond
FP	family pond

* Village No. 468 Sala Khum and No. 474 Trapaing Trpuk of Kompong Speu Province do not exist.

Table 5.6 Village Survey -Water Source Data

Sheet No 1/17

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Phnom Penh	Dangkao	1	Chaom Chau	Thnal Bamback	223	51		Good					Omitted	X
		2	Kakab	Prey Pring Cheung	1,111	168		Better	1				1(PHP)	A
		3		Chamkar Ovloek	921	196		Better	5	Chloride		Washing		D
		4		Kakab	415	99		Better					2(PP)	A
		5		Trapaing Chrey	271	61		Good					2(PP)	A
		6		Prey Sala	377	75		Good	1	Chloride		Drinking	1(PP)	B
		7		Kbal Damrei	844	153		Better	4(-1)			Drinking	6(Pri.HPW)	D
		8	Samaraong Kraom	Cham kar Sbaeng	210	42		Better					1(PP)	A
		9		Trapaing Thnung	541	106		Better					1(PP)	A
		10		Kouk Prich	277	54		Better					3(PP)	A
		11		Tekhabpanhao	252	62		Better					1(PP)	A
		12		Samraong Kraom	370	70		Better					1(Pri.HDW),1(PP)	A
		13		Chak Chruk	276	50		Better	1	Chloride		Washing	1(Pri.HDW),1(PP)	B
		14		Ak Rumduol	157	33	Gathered	Better					3(Pri.HDW)	A
		15		Srae Rochcheak	394	75	Gathered	Better	1	Chloride		Washing	1(PP)	A
		16		Andoung Ta An	359	68	Gathered	Better					3(PHDW)	A
		17	Kouk Rokar	Baek Bak	224	49	Gathered	Better	1	Chloride		Drinking	2(PP)	C
		18		Kab Srov Touch	485	99	Gathered	Better	1	Chloride		Drinking	1(PP)	B
		19		Kab Srov Thom	695	139		Good	2(-1)	Iron		Drinking	1(PP)	B
		20		Prey Thom	171	51	Gathered	Better			(+)		1(PP)	A
		21		Toul Sampov	132	25	Gathered	Bad			(+)		2(PHDW)	A
		22		Chumrov	264	51		Better	1				1(PDW),1(Pri.HDW)	A
		23		Thlok	173	31	Gathered	Better					1(PP)	A
		24		Phlu Phaem	298	51	Gathered	Better					2(PP)	A
		25		Putrea	232	50	Gathered	Better	1			Broken	3(Pri.HDW),1(PP)	A
		26		Svay Chek	508	103	Gathered	Better	1	Iron		Drinking	2(PriHDW),3(PP)	B
		27		Kouk Rokar	213	48	Gathered	Better					1(PHDW),2(PP)	A
		28		Angk Ta Kov	169	38	Gathered	Better					2(PP)	A
		29		Trapaing Tounpal	143	35	Gathered	Better					1(PHDW),1(PP)	A
		30	Ohkenung Chheh Rotch	Kab Phluk	245	50		Good					2(PriHDW)	A
		31	Dang Kao	Baku	722	167		Better	7	Good		Drinking	4(PHDW)	X
		32		Thmei	1,256	260	Scattered	Better	5	Good		Drinking	Many(Pri.HDW)	X
		33		Khva	2,157	499		Better	25	Good		Drinking	25(Pri.HPW),20(Pri.HDW)	X
		34	Prey Veng	Kamrieng	396	85	Gathered	Better	1	Chloride		Washing	1(Pri.HDW),3(PP)	E
		35		Prey Veng Keat	433	89		Better					1(Pri.HDW),2(PHDW)	A
		36		Trapaing Svay	297	33	Gathered	Better	1	Chloride		Washing	1(Pri.HPW),1(PriHDW)	A

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Table 5.6 Village Survey -Water Source Data

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Phnom Penh	Dangkao	37	Prey Sar	Peam	270	58	Gathered	Better					1(PHDW),1(river)	A
		38		Thommeak Trai	215	41	Scattered	Best					1(PP)	A
		39		Anlong Kong	443	98	Scattered	Better					1(river)	A
		40		Prey Sar Keat	358	80	Scattered	Better					2(Pri.HDW),1(PP)	A
		41		Prey Thom	248	57	Gathered	Better	1	Good		Drinking	1(Pri.HDW),1(PHDW)	B
		42		Prey Tituy	295	67	Gathered	Better/Narrow					1(PHDW),1(PP)	A
		43		Kouk Banteay	180	44	Scattered	Better	1			Broken	2(Pri.HDW),1(PHDW),1(PP)	C
		44		Mphey Boun	207	43	Gathered	Better					3(PP)	A
		45	Cheung Aek	Prek Tloeng	540	136	Gathered	No access	1	Good		Drinking	1(river)	X
		46		Prek Pranak	217	55		Good/Narrow	1					A
		47	Trapaing Krasang	Trapaing Tea	228	42		Better			(+)		2(PP)	A
		48		Trapaing Andoung	262	61	Gathered	Better					2(PP)	A
		49		Trapaing Karasang	362	74	Gathered	Better					1(PP)	A
		50		Khvaeng	172	33	Gathered	Better					3(PHDW),1(PP)	A
		51		Veal	296	65	Gathered	Best			(+)		1(PP)	A
		52		Prey Doun Sok	62	23	Gathered	Better					1(PP)	A
		53	Sak Sampov	Sambour	153	29	Scattered	Bad					1(river)	A
		54		Kamreng	231	46		Bad/Narrow	3(-2)			Drinking	1(PHDW)	C
		55		Krang Ta Phou	258	40	Gathered	Better					1(river)	A
		56		Khvet	562	119		Good/Narrow			(+)		1(river)	A
		57		Pou Rolum	174	35		Good/Narrow	1				1(river)	A
		58	Chak Angrae Kraom	Toul Rola	8,931	1,129		Best					City Water Supply Area	X
		59		Prek Ta Long	5,641	1,026		Best					City Water Supply Area	X
		60		Sansam Kosal I	3,720	676		Best					City Water Supply Area	X
		61		Sansam Kosal II	4,122	749		Best					City Water Supply Area	X
		62		Kbal Tumnob	4,579	833		Best					City Water Supply Area	X
		63		Thnaot Chrum	4,558	829		Best					City Water Supply Area	X
	Meanchey	64	Stueng Mean Chey	Ruessei	2,565	579		Better	5	Chloride		Washing	16(PriHPW),47(PriHDW),3(PP)	B
		65		Damnak Thom	2,914	453		Better					30(Pri.HPW),10(PriHDW)	E
		66		Trea	3,767	918		Better	1	Good		Drinking	49(Pri.HPW),10(Pri.HDW)	E
		67		Mean Chey	3,868	569		Better	2	Chloride		Washing	3(Pri.HDW)	B
		68	Prek Pra	Chrouy Basask	1,843	47		Good/Narrow	2				1(Pri.HPW),2(PP) No Public Contro	X
		69	Nirouth	Boeng Chhuk	1,892	380		Better	5				3(Pri.HDW)	X
	Ruessei Keo	70	Khmuonh	Khmuonh	1,051	210		Better			(+)		3(PP)	A
		71		Samraong	642	125		Good			(+)		3(PP)	A
		72		Banla Set	979	195		Good			(+)		3(PP)	A

Table 5.6 Village Survey -Water Source Data

Sheet No 3/17

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Phnom Penh	Ruessei	73	Khmuonh	Anlong Kngan	1,618	313		Good	3	Good		Drinking	24(-2)Pri.HDW,1(PP)	E
		74		Trapaing Reang	1,857	371		Better	1	Good		Washing	7(PP)	C
		75	Phnom Penh Thmei	Phnom Penh Thmei	2,857	408		Better					2(Pri.HPW),2(Pri.HDW)	A
		76		Poung Peay	1,327	265		Good	2	Good		Drinking	2(Pri.HPW),2(ri.HDW),2(PP)	B
		77		Chres	726	145		Better	1	Good	(-)	Drinking	1(Pri.HPW),1(PP)	D
		78		Dei Thmei	1,425	285		Good					3(PP)	A
		79		Roung Chak	1,425	258		Better					2(Pri.HPW)	A
		80		Bayab	1,822	364		Better					2(Pri.HPW)	A
		81		Tumnob	2,240	509		Better					No Public Compound	X
		82		Kouk Kleang	716	143		Better					4(Pri.HDW),6(FP)	A
		83		Krang Svay	445	89		Good	1(-1)	Chloride		Washing	2(PP)	A
		84	Toek Thla	Ou Beak Kam	1,516	345		Better					No Public Compound	X
		85		Trapaing Chhuk	5,101	729		Better					No Public Compound	X
		86		Slaeng Roleung	2,144	428		Good	1	Little Chloride		Drinking	3(PP)	A
		87		Bourei 100 Khnang	2,054	467		Good					1(Pri.HPW)	X
		88		See Pee See	1,473	335		Good					No Public Compound	X
		89		Chong Thnal Keaut	1,456	331		Better					No Public Compound	X
		90		Chong Thnal Lech	1,998	454		Better					No Public Compound	X
		91	Toul Sangkeo	Toul Sangkeo	3,699	1,330		Best	4				3(Pri.HPW),35(Pri.HDW)	E
		92		Toul Kouk	2,783	1,008		Better	9				4(Pri.HPW),35(Pri.HDW)	E
		93	Chrang Chamreh II	Ohum Kha II	1,648	375		Best					Private Water Supply	E
		94	Russei Keo	Boeng Salang	3,007	526		Better	12	Iron		Washing	12(Pri.HDW)	C
		95		Sameaki	3,432	780							Omitted	X
		96		Khleang Sang	2,532	422		Better						X
		97	Svay Pak	Lor Kambao	2,848	588		Better	1				2(Pri.HPW),1(Pri.HDW)	A
		98		Svay Pak	2,595	590		Better					Omitted	X
		99	Chrang Chamreh	Ohum Tei IV	1,015	212		Better	6				13(Pri.HPW),1(Pri.HDW)	X
Phnom Penh	Total	99			128,775	25,350								

Rank	No. of Village
A:	51
B:	9
C:	5
D:	3
E:	7
X:	24
Total	99

Table 5.6 Village Survey -Water Source Data

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Svay Rieng	Svay Teap	100	Svay Rompea	Ang Krurng	729	134		Better					30Pri.HPW),11(Pri.HDW),50(FP)	C
		101		Kon Chhet	486	99		Better					25(Pri.HPW),18(Pri.HDW),8(FP)	C
		102		Kok	845	106		Bad					58(Pri.HW),50(Pri.HDW),2(P.P)	E
		103		Toul Ampil	422	77		Bad					8(Pri.HPW),19(Pri.HDW)	C
		104		Sra Mor	407	84		Bad	1	Chloride		Washing	11(Pri.HPW),20(Pri.HDW)	D
		105		Svay Thom	735	134		Bad					10(Pri.HPW),10(Pri.HDW)	B
		106	Ro Maing Thkol	Prey Thnong	430	92	Scattered	Better					60(Pri.HPW),8(Pri.HDW),1(PP)	X
		107		Bek Chan	753	156	Scattered	No access	1	Good		Drinking	17(Pri.HPW),9(PHDW)	X
		108		Kra Nhoung	1,155	144		Bad	1			Broken	3(Pri.HDW),5(P.P),M(Pri.HP)	E
		109		Choung Rouk	535	121	Scattered	No access					36(Pri.HPW),40(Pri.HDW)	E
		110		Ro Maing Thkol	345	70	Scattered	No access					28(Pri.HPW),6(Pri.HDW),2(PHDW)	X
	Svay Rieng	111	Svay Rieng	Choung Prek	1,570	523	Crowded	Better	1				7(Pri.HPW),94(Pri.HDW)	C
		112	Prey Chlak	Andaugn Taleu	509	106	Scattered	Better			(+)		1(Pri.HPW),24(Pri.HDW)	E
		113	Koy Tra Bek	Koy Tra Bek	1,374	172		Good	1			Broken	18(FP),7(Pri.HP),5(Pri.HDW)	D
		114		Tarang Bal	1,383	299		Better					2(Pri.HPW),14(Pri.HDW)	C
	Rom Doul	115	Sang Ke	Taneng Kheut	911	190		Better	1	Iron		Drinking	15(Pri.HPW),20(FP)	X
		116	Kouk Rokar	Taneng Lech	911	190		Better	1	Iron		Drinking	15(Pri.HPW),20(FP)	X
		117		Tachhou	504	105		Bad					2(Pri.HPW),12(FP)	A
		118	Chroul Popel	Pras Ang Keo	625	78		Better	1			Bad Operation	1(PHDW),1(PP)	B
		119		Toul Sala	908	179		Better					3(Pri.HDW), 3(PHDW)	C
		120		Trapaing Krek	862	147		Bad					15(Pri.HP),15(Pri.HDW)	E
		121	Moeun Chey	Ang Pok	676	127		Good					10(Pri.HP),3(PHDW)	E
		122	Thnal Thnong	Trapaing Thmor	604	76		Good	1			Broken	1(Pri.HP),2(Pri.HDW),3(FP)	A
		123	Boss Mon	Thmey	865	167		Better					3(Pri.HPW),2(Pri.HDW),9(FP)	X
		124		Boss phlaing	685	145		Better					25(PRi.HPW),9(Pri.HDW),4(PHDW	X
	Kampong Ro	125	Sam Young	Sam Yooung	854	188		Better	3	Chloride + Iron		Drinking	5(Pri.HPW),11(Pri.HDW),3(PHDW)	E
		126		Svay Kamtrai	236	60		Good					5(Pri.HPW),1(PHDW),1(Pri.HDW)	E
		127		Roeussey Leip	795	195		Good					9(Pri.HPW),2(Pri.HDW),1(PHDW)	E
		128	Banteay Kraing	Brochan Trea	360	79		Good	2	Iron		Drinking	6(Pri.HPW),10(Pri.HDW)	X
		129	Thnot	Bon	347	81		Good	1			Broken	3(Pri.HPW),3(Pri.HDW),1(PHDW)	E
		130	Dang Kao	Thom	555	138		Better					3(Pri.HPW),13(Pri.HDW)	D
		131		Thlok Thmey	368	68		Good					2(Pri.HPW)	E
		132		Kbal Thnol	875	222		Good					10(Pri.HPW),3(Pri.HDW),1(PHDW)	C
		133		Po Mo Orm	584	133		Better					10(Pri.HPW),6(Pri.HDW),15(FP)	E
		134	Thnot	Poth	435	106		Good					6(Pri.HPW),3(Pri.HDW),2(PP)	E
		135		Prey Robes	676	146		Good	1			Broken	15(Pri.HPW),8(Pri.HDW),1(PHDW)	E

Table 5.6 Village Survey -Water Source Data

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Svay Rieng	Kampong Ro	136	Thnot	Kandal	779	145		Better					11(Pri.HPW),12(Pri.HDW)	D
	Ro Meas Hak	137	Chan Try	Krahom Kor	234	121	Scattered	Better	1			Broken	3(Pri.HDW),1(PHDW)	B
		138	Mreim	Mreim Thbong	353	119		No Access	1			Broken	2(PHDW),5(FP)	X
		139	Chrey Thom	Dok Por	228	92	Scattered	Bad			(+)		3(PHDW),1(Pri.HDW)1 River	A
		140	Kampong Trach	Pra Mat Praim	235	162		Better					3(Pri.HP),5(PHDW),11(Pri.HDW)	D
		141		Cheu Ploeung	256	187		Better					7(Pri.HP),8(Pri.HDW)	C
		142		Ta Homg	253	119		Bad					6(Pri.HP),2(Pri.HDW)	D
		143	Andoung Porth	Arak Svay	245	86	Scattered	Good	3	Good		Drinking	3(Pri.HPW),5(shallow wells)	E
		144		Thmey	263	133		Good					3(Pri.HP),4(Pri.HDW)	A
		145		Rong Snor	375	133	Scattered	Good			(+)		6(Pri.HDW)	A
		146	Ang Prasre	Trapaing Thom	237	50		Good			(+)		2(PP)	A
		147		Trapaing Ro Denh	234	50		Bad	4	Iron		Drinking	4(Pri.HP),1(Pri.HDW),1(PP)	C
		148		Trapaing Raing	253	140	Scattered	Bad					3(Pri.HP),12(Pri.HDW)	B
		149	Daung	Thmey	261	115		Better					3(PriHP),2(PHDW)	B
		150		Svay Pok	215	111		Better						A
		151	Trapaing Sdao	Mras Prov	235	74	Scattered	Bad					4(Pri.HPW),2(Pri.HDW),1(PHDW)	B
		152	Sak Sampov	rapaing Skounthme	248	73	Scattered	Better			(+)		3(Pri.HDW)	A
	Chan Trei	153	Pras Sat	Kandal	1,380	290		Best	2			Broken	14(Pri.HDW)	A
		154		Prasat	346	86		No Access					5(shallow Wells)	X
		155	Mes Thkok	Baray	666	120		Bad					33(Pri.HDW)	A
		156		Svay Kuy	509	99		Bad					2(Pri.HP),40(Pri.HDW)	A
		157		Porth	1,293	273		Better					8(Pri.HP),16(Pri.HDW)	B
		158		Boss	678	151		Better					6(Pri.HP),4(PHDW)	B
		159		Ta Deiv	321	60		Bad					2(Pri.HP),20(Pri.HDW)	A
		160	Prey Koky	Prey Koky	796	160		Better					7(Pri.HP),9(Pri.HDW)	D
		161		Ang Khdorch	991	161		Better					2(Pri.HP),7(PHDW)	A
		162		Cham Kar Leiv	809	174		Better					11(Pri.HDW),20(FP)	A
	Svay Chrom	163	Doun Sor	Chan Sa	554	126		Better					17(Pri.HDW),1(PP)	A
		164		Au Sra Ngam	342	125		No Access					9(Pri.HP),9(Pri.HDW)	X
		165		Beng Kek	285	503		No Access					2(Pri.HP),2(Pri.HDW)	X
		166		Trach	133	81		Bad					3(Pri.HP),7(Pri.HDW)	C
		167		Kouy	361	115		Better					10(Pri.HDW),1(PP)	A
		168		Don Sor	267	135		Better	2			Broken	19(HDW)	B
		169		Prey Po	208	115		Good	3	Chloride		Washing	11(Pri.HDW),1(PP)	C
		170		Rom Pout Chrok	176	100		No Access	1			Broken	1(PHDW),6(Pri.HDW)	X
		171		Dong Pras	277	114		Good					7(Pri.HDW),2(Pri.HP)	C

Table 5.6 Village Survey -Water Source Data

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Svay Rieng	Svay Chrom	172	Doun Sor	Prey Rokar	1,618	152		Good/Narrow					1(Pri.HP),14(Pri.HDW)	B
		173	Cham Bok	Thmey	1,857	479		Good/Narrow					12(Pri.HP),2(PHDW),20(Pri.HDW)	E
		174		Ta Nu	2,857	427		Good/Narrow					10(Pri.HDW),1(PP)	A
		175		Toul Khpos	1,327	180		Good/Narrow					1(Pri.HP),6(Pri.HDW)	A
		176		Ampov Prey	726	112		Good/Narrow	2	Iron + Chloride		Drinking	10(Pri.HDW)	C
		177		Prey Tapov	1,425	130		Good/Narrow					4(Pri.HP),3(Pri.HDW)	B
		178		Ang Sala	1,425	285		Bad	4	Chloride		Drinking		C
		179		Toul Chres	1,822	230		Better					9(Pri.HDW),27(FP)	B
Svay Rieng	Total	80			53,667	12,030								

Rank	No. of Village
A:	18
B:	12
C:	14
D:	7
E:	16
X:	13
Total	80

Table 5.6 Village Survey -Water Source Data

Sheet No 7/17

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Ta Keo	Doun Keo	180	Roka Krau	Trapaing Sala	930	186		Good					1(HDW),2(PP)	A
		181	Roka Krau	Preach	1,049	210		Good	1	Chloride		Broken	2(PP)	A
		182	Ba Ray	Chong Thnal	1,031	206		Good	1			Broken	1(lake)	A
	Sam Raong	183	Ro Vieng	Kok Tara	347	82		Good					1(HDW),45(shallow well)	A
		184	Ro Vieng	Trapaing Khnar	344	66		Better					1(PP),52(FP)	A
		185	Ro Vieng	Trapaing Storng	470	87		Better	2	Iron		Drinking	60(FP)	C
		186	Sla	Trapaing Sraong	535	114		Best					1(PP)	A
		187	Lumchang	Lumchang	344	76		Good					1(River),1(PP)	A
		188	Trea	Ressei Chum	1,247	198		Good	2	Chloride + Iron		Washing	2(PP),20(FP)	A
		189	Cheung Kuon	Cheung Kuon	942	184		Good	5	Little Iron		Drinking	1(Pri.HDW),12(FP),2(PP)	C
		190	Soengh	Trapaing Kei	492	100		Good			(+)		25(FP)	A
		191	Boeng Trach Tbong	Srei Cheay	1,224	236		Better	1			Broken	13(HDW),30(FP)	A
		192	Boeng Trach Cheung	Pech Entrea	959	179		Good	1		(+)	Broken	1(HDW),8(FP),1(PP)	D
		193	Boeng Trach Tbong	Boeng Trach	959	187		Better	5	Chloride		Drinking	5(HDW)	E
		194	Boeng Trach Cheung	Koun Romeas	1,142	228		Good	1			Broken	1(PHDW),1(PP)	A
		195	Chumreah Peen	Boeng	673	100		Better					2(HDW),3(PP)	A
	Tram Kak	196	Srae Ro Naong	Phum Thmei	427	64		Better					2(PP)	A
		197	Srae Ro Naong	Kraing Svay	437	82		Better	1	Good		Drinking	1(PP),3(FP)	C
		198	Chroul Popel	Brothum	644	129		Good					1(PP)	A
		199	Chroul Popel	Prey Maok	689	128		Better	1			Broken	4(FP),1(PP)	A
		200	Leay Bour	Prasat	420	81		Good					5(FP), 10(PP)	A
		201	Leay Bour	Trapaing Kur	450	90		No access					No Information	X
		202	Leay Bour	Saen Ban	1,262	271		Good					1(PP),1(Damp)	A
		203	Leay Bour	Trey Theat	922	170		Good	3	Chloride + Iron		Drinking	4(PP),14(FP),4(shallow wells	B
		204	Leay Bour	Khnar	810	163		Good					1(PP),2(FP)	A
		205	Leay Bour	Trapaing Chhuk	680			No access					No Information	X
		206	Kus	Chheu Teal Thkoul	263	49		No access					25(FP)	X
		207	Kus	Andoung Thma	595	103		No access					31(FP)	X
		208	Kus	Chamkar Sieng	319	63		No access			(+)		35(FP)	X
		209	Kus	Trapaing Thma	750	152		Very Good					10(FP)	A
		210	Kus	ong Tuek Khang Chheu	256	50		Good			(+)		2(HDW),47(FP)	A
		211	Kus	Trapaing Pring	820	92		Good					2(PP),1(Stream)	A
		212	Kus	Chamkar Andoung	461	86		No access					No Information	X
		213	Angk Ta Saom	Chamkar Dieb	406	86		Best					2(PHDW),20(FP)	B
	Prey Kabbas	214	Kdanh	Krang Vich	536	115		Better					1(HDW),100(FP),2(PP)	A
		215	Tang Yap	Chum Rou	367	73		Good					1(PP),2(FP)	A

Table 5.6 Village Survey -Water Source Data

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Ta Keo	Prey Kabbas	216	Prey Phdao	Dong	735	149		Better	1	Chloride		Broken	5(HDW),1(PP)	A
		217	Prey Phdao	Chheu Teal	480	95		Better					2(HDW),5(FP),1(Lake)	A
		218	Rou Rumchak	Angk Samke	502	97		Good					3(Pri.HP),3(HDW)	A
		219	Prey Kabbas	Pech Changva	593	118		Better	1	Chloride + Iron		Drinking	1(Pri.HP),2(HDW)	B
		220	Prey Kabbas	Prey Prum	625	124		Good	1			Broken	3(HDW)	A
		221	Ban Lam	Thok Dong Tum	984	198		Good					1(Pri.HDW),1(PP)	A
		222	Ban Lam	Ta Vong	1,219	237		Good	3	Chloride		Drinking	4(Pri.HDW),4(PP)	A
		223	Champa	Danghet	708	128		Better	2	Chloride		Washing	2(PP)	B
		224	Champa	Ponsang	653	139		Better					2(PHDW),1(Pri.HDW),3(Pri.HP)	C
	Treang	225	Prey Sloek	Kouk Nhor	458	85		Better					15(FP)	A
		226	Prey Sloek	Baray	1,143	270		Good					1(Lake),1(PP)	A
		227	Prey Sloek	Svay Rumdeng	386	80		Good					70(FP)	A
		228	Prey Sloek	So Chann	348	69		Good	1	Chloride		Cooking	2(PP)	A
		229	Prey Sloek	Niel	477	95		No access					1(PP),5(FP)	X
		230	Prey Sloek	Trapaing Veng	781	133		Bad	2	Chloride		Drinking	2(PP)	C
		231	Prey Sloek	anraong Meam Chea	407	80		Better	1	Chloride		Cooking	3(Pri.HDW),8(PP)	B
		232	Thlok	Kdei Thaot	448	91		Good					2(PP),3(FP)	A
		233	Thlok	Samna Khmau	394	89		Good					1(PP)	A
		234	Thlok	Trapaing Slar	915	181		Better					2(PHDW),2(PP)	A
		235	Thlok	Rovieng	1,128	220		Better	1	Chloride		Washing	10(FP)	A
		236	Angkanh	Doek Mai	772	154		Good					1(PHDW),30(FP)	A
		237	Angkanh	Ang Roka	678	170		Better	1	Chloride		Broken	20(FP),1(PHDW)	A
		238	Angk Kev	Angk Kev	334	63		Good					7(FP),1(PP)	A
		239	Angk Kev	Russey Duch	366	92		Good					3(Pri.P)	A
		240	Khvav	Preus Leu	536	99		Good	1	Good			1(PHDW),2(PP)	A
	Bati	241	Krang Leav	Siem Dek	341	68		Good	1	Iron	(+)	Drinking		A
		242	Krang Leav	Ta Pen	350	67		Better			(+)		1(Pri.HDW),7(Shallow Well)	A
		243	Krang Leav	Prohut	479	97		Better	1			Broken	1(PHDW),14(FP)	A
		244	Krang Leav	Mean Chouk	393	78		Better						A
		245	Krang Leav	Doeum Svay	457	91		Better	1	Fine Sand		Drinking	1(PHDW)	B
		246	Krang Leav	Prey Chonluonh	540	54		Good					1(Pri.HP),8(FP)	A
		247	Komar Reachea	Tramung Chrum	546	94		Better					3(PHDW),1(Dam),1(PP)	A
		248	Komar Reachea	Kanchom	500	92		Good					3(PHDW),3(PP)	A
		249	Komar Reachea	Serei Mean Chouk	625	100		Better	3	Chloride + Iron		Drinking	2(Pri.HDW),2(PP)	B
		250	Trapaing Krasaing	Yeam Khav	440	74		Better					1(PP)	A
		251	Trapaing Krasaing	Boeung Ponhea Kuk	350	55		Good					4(PHDW),20(FP),1(PP)	C

Table 5.6 Village Survey -Water Source Data

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Ta Keo	Bati	252	Trapaing Krasaing	Thlok	317	51		Better	1	Chloride		Washing	3(Pri.HDW),5(FP),1(PP)	B
		253	Trapaing Krasaing	Roka Pok	340	65		Better	1	Iron		Washing	4(PP),2(Pri.HD)	B
		254	Cham Pei	Moeang Prachen	715	159		Good	1	Chloride		Washing	4(FP)	B
		255	Cham Pei	Prey Mul	716	151		Good			(+)		2(HDW),2(PP),1(Lake)	A
		256	Lum Pong	Thma Sa	560	103		Better	2	Chloride + Iron		Drinking		B
Ta Keo	Total	77			47,941	9,141								

Rank	No. of Village
A:	51
B:	11
C:	6
D:	1
E:	1
X:	7
Total	77

Table 5.6 Village Survey -Water Source Data

Sheet No 10/17

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Kandal	Kaoh Thum	257	Prek Thmei	Prek Ta Duong	2,124	337		Best	4			Washing	2(small river)	X
		258		Svay Kandal	1,519	189		Better	5	Iron		Drinking	16(Pri.HPW),1(river)	B
		259		Svay Kraom	1,508	335		Better	3			Drinking	10(Pri.HPW)	B
		260	Prek Sdei	Prek Louk	2,028	376		No access	1	Iron, Chloride		Washing	1 (river)	X
		261		Chung Prek	2,005	370		Bad	3	Iron		Washing	1 (river)	B
		262		Prek Ta Mem	2,612	451		Bad	5	Iron		Drinking	1(PHDW),2(small river)	A
		263	San Pou Pun	Khpob	2,908	661		No access					No Information	X
		264		Kampong Thkol	1,646	374		No access					No Information	X
		265		Prek Sbov	216	49		No access					No Information	X
		266	Kampong Kong	Prek Phav	822	187		No access					No Information	X
		267		Trabek Pok	585	133		No access					No Information	X
		268		Prek Ressei	1,655	376		No access					No Information	X
		269		Tuol Don Koam	582	132		No access					No Information	X
		270		Lvea Toung	1,147	261		No access					No Information	X
		271	Chheu Khmau	Kbal Kaoh	876	199		No access					No Information	X
		272		Kaoh Toch	554	126		No access					No Information	X
		273		Trapaing Chrey	1,747	397		No access					No Information	X
		274	Leuk Dek	Chmakar Dong	566	129		No access					No Information	X
		275		Anlong Slat	863	196		No access					No Information	X
		276		Sam Raong	727	165		No access					No Information	X
	Ta Khmau	277	Prek Hor	Prek Hor Lich	1,926	337		Better	6(-1)	Iron + Chloride		Washing	2(PHDW),30(Pri.HPW),1(river	B
		278	Ta Khmau	Prek Sam Raong	5,412	900		Best	6(-1)			Drinking	16(Pri.HPW),1(PHDW)	X
		279	Phnom Bat	Daeum Pou	320	89		Better	3(-1)	Iron		Washing	2(PP)	C
		280		Thma Sa	902	182		Better	3(-1)			Drinking	1(PP)	B
		281		Pou Ral	835	165		Better	3	Iron + Chloride		Washing	1(PHDW),1(PP)	B
		282	Chrey Leas	Ta Chey	439	90		Good	2				4(Pri.HDW),1(PP)	B
		283		Tbong Vat	494	97		Good	1				3(PHDW),1(PP),2(FP)	E
		284	Chhvaing	Prey Phchek	425	85		Better	3(-1)			Drinking	1(PP)	C
		285		Svay	787	140		Better	3(-2)	Iron		Washing	3(PHDW),1(PP),2(FP)	C
		286		Chhvaing	364	64		Better	2(-1)	Iron		Drinking	1(PHDW),2(PP)	A
	Mukh Kampul	287	Poka Kaong I	Kouhe	1,259	236		No access	1	Iron		Drinking	1(river)	X
		288	Svay Ampear	Krang Svay	1,376	296		Best					1(river),70(FP)	A
		289		Kampong Prasat	665	136		Better	1	Too much Chloride		Washing	1(river)	A
		290		Chheu Teal Phloah	951	224		Good					1(PHDW),1(river)	A
		291	Sambuor Meas	Chrey Muoy Roy	800	182		No access					No Information	X

Table 5.6 Village Survey -Water Source Data

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Kandal	Mukh Kampul	292	Sambuor Meas	Ampil Toek	727	165		No access					No Information	X
		293		Pou Po	675	153		No access					No Information	X
		294		Prek Bos	889	202		No access					No Information	X
		295		Kraol Kou	730	166		No access					No Information	X
		296		Peam	574	130		No access					No Information	X
	Khsach Kandal	297	Kaoh Choram	Leu	942	214		No access					No Information	X
		298		Kandal	1,096	249		No access					No Information	X
		299		Tbong	1,687	383		No access					No Information	X
		300		Kraom	1,420	323		No access					No Information	X
		301	Svay Romiet	Chheu Teal	744	169		No access					No Information	X
		302		Kandal	856	195		No access					No Information	X
		303		Svay Damnak	933	212		No access					No Information	X
		304	Preah Prasab	Tep Montrei	535	122		No access					No Information	X
		305	Prek Ta Meak	Boeng Krachab Tboung	1,038	236		No access					No Information	X
		306		Thmei	3,680	836		No access					No Information	X
	Ta Khmau	307	Prek Ressei	Prek Ressei	1,607	335		Best	4(-2)	Iron		Drinking	13(Pri.HPW)	C
		308	Ta Kdul	Ta Kdul	2,240	448		Better						E
		309	Kampong Samnan	Kampong Samnanh	2,390	436		Better	5	Little Iron		Drinking	7(Pri.HPW)	B
	Angsnuol	310	Snao	Sre Ampil	215	44		Good					2(PP)	A
		311		Svay	117	20		Good					2(PHDW)	A
		312		Prasat	126	17		Good					1(PP)	A
		313		Snao Keut	236	44		Good	1	Little bit Chloride		Cooking	1(PP)	B
		314		Snao Lich	280	56		Good	1	Little bit Chloride		Drinking	1(PP)	D
		315		Ta En	202	40		Good					1(PHDW),2(PP)	A
		316		Rumduol Chheung	178	31		Good			(+)		2(PHDW),2(PP)	A
		317		Rumduul Tbong	158	28		Good						A
		318		Prey Roeng	146	32		Good					1(PP)	A
		319		Pongro	137	29		Good					2(PP)	A
		320		Phlang	126	24		Good						A
		321		Kul Krasna	281	60		Good	1		(+)	Drinking	2(PP)	B
		322		Angkor Chhey	120	24		Good			(-)		5(PHDW),4(PP)	A
		323		Toul Leab	344	68		Good	3			Drinking		E
		324		Sakd Prayutt	163	30		Good			(+)		2(PHDW)	B
		325		Ta Pung	177	38		Good	1			Drinking	2(PP)	B
		326	Ponsang	Chong Thnal	347	60		Good					2(PHDW),1(PP)	A

Table 5.6 Village Survey -Water Source Data

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Kandal	Angsnuol	327	Ponsang	Boeng Khnam	291	66		Good					1(PP)	A
		328		Kanleng Kul	350	55		Good					1(PHDW),3(PP)	A
		329		Chambak Thum	270	44		Good					2(PP)	A
	Ponhea Loe	330	Vihear Luong	Vat Vihear Luong	550	125		Better					Pagoda	X
		331		Ampil Phem	212	45		Good/Narrow	1	Chloride	·		Old 2(PHDW)	C
	Khsach Kandal	332		Boeng Krachab Cheung	1,075	244		No access					No Information	X
		333		Anlung	1,161	264		No access					No Information	X
		334	Sanlong	Sanlong	1,468	334		No access					No Information	X
		335		Chhuk	1,554	353		No access					No Information	X
		336		Thmei	963	219		No access					No Information	X
		337		Kandal	696	158		No access					No Information	X
		338		Prek Thum	566	129		No access					No Information	X
		339		Dol	1,545	351		No access					No Information	X
		340	Prah Vihear Sour	Prey Chass	1,594	362		No access					No Information	X
		341	Prah Vihe	Prey Thum	420	53		No access					No Information	X
Kandal	Total	85			82,476	17,087								

Rank	No. of Village
A:	19
B:	12
C:	5
D:	1
E:	3
X:	45
Total	85

Table 5.6 Village Survey -Water Source Data

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Prey Veng	Peam Chor	342	Krang Ta Yang	Chrey Oddam	1,490	339		No access					No Information	X
		343		Krang Chin	1,224	278		No access					No Information	X
		344		Krang Ta Yang	1,236	281		No access					No Information	X
		345		Pong Tuek	621	141		No access					No Information	X
		346	Russei Srok	Russei Srok	597	136		No access					No Information	X
		347		Chheu Teal	1,353	308		No access					No Information	X
		348		Prey Meas	1,040	236		No access					No Information	X
		349		Ta poung	936	213		No access					No Information	X
	Ampil Krau	350	Ampil Krau	Ampil Krau	1,690	376		Best					2(Pri.HP),32(Pri.HDW),6(PP)	B
		351		Svay Teab	1,776	392		Good					6(Pri.HP),8(Pri.HDW)	D
		352		Peanea	1,328	320		Best					10(Pri.HP),Many (HDW)	D
		353	Pnou I	Ta Keab	917	150		Good					4(Pri.HP),8(HDW)	E
		354		Kam Prov	1,776	320		Good					20(Pri.HP),(Pri.HDW)	C
		355		Pnou	1,513	502		Good					10(Pri.HP),12(Pri.HDW)	C
	Kanh Chreach	356	Kdoeung Raey	Don Veal	560	115		Better	1	Iron		Drinking	1(Pri.HP),15(Pri.HDW)	B
		357		Kdoeung Reay	708	140		Better					4(Pri.HP),8(Pri.HDW),1(PP)	B
		358		Peanea Phas	690	146		Best					8(Pri.HP),8(Pri.HDW),20(FP)	E
		359		Sar Long	894	167		Best					27(Pri.HP),5(HDW),3(FP)	E
		360	Preal	Trapaing Ses	314	62		No access					2(HDW)	X
		361		Andong Sala	721	104		Better					11(Pri.HDW)	A
		362		Lhaeuy	955	161		Better	1			Broken	1(Pri.HP),10(Pri.HDW)	A
		363		Kouk Roka	1,060	183		Good	1			Broken	1(Pri.HP),8(Pri.HDW)	A
	Pea Reang	364	Prey Pnou	Angkeas Dei	1,062	200		No access					6(HDW)	X
		365		Krours	838	158		Good	2	Iron		Drinking	10(Pri.HP),Many (HDW)	E
		366		Srama	1,022	200		Good	3	Iron		Drinking	50(Pri.HP)	E
		367		Ka Kou	638	115		Good			(-)		12(Pri.HP),8(Pri.HDW)	C
		368		Samrab	674	107		Good	2			Drinking	30(Pri.HP)	D
		369	Prey Sralet	Pray Sralet	1,000	227		No access					No Information	X
		370		rey Samlanh Cheur	665	151		No access					No Information	X
		371		Prey Samlanh Tbon	1,117	254		No access					No Information	X
	Kamchay Mear	372	Kranhung	Angkrong I	335	63		Better					3(Pri.HP),2(Pri.HDW),1(PP),1(Rive	A
		373		Angkrong II	393	70		Better					5(Pri.HDW)	A
		374		Samokki	600	120		Better					Many Shallow Wells	A
		375		Pongro	504	112		Better	1	Iron		Washing	1(PHDW),2(Pri.HDW)	A
		376		Kravan	675	127		Better	3	Iron		Washing	5(Pri.HDW)	B
		377	Cheach	Neak Ta chen	267	59		Good			(+)		1(Chanal),3(Shallow Wells)	A

Table 5.6 Village Survey -Water Source Data

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Prey Veng	Kamchay Mear	378	Cheach	Trach Chhrum	224	43		Good			(+)		4(Pri.HDW)	A
		379		Trapaing Romeas	574	112		Good					2(Pri.HDW),10(Shallow Wells)	A
		380		Don Daok	517	97		Good					19(Pri.HDW)	A
	Prey Vang	381	Pean Roung	Prey Chreang	1,715	387	Scattered	Good					20(Pri.HPW),7(Pri.HDW),1(Lake)	E
		382		Prey Rung	462	102		Better	5	Iron		Drinking	1(HDW)	E
		383		Prey Nokor Knong	470	89		Better	1	Iron		Drinking	1(HDW)1(PP)	B
		384	Me Bon	Ha Bor	1,381	300	Crowded	Better	10	Chloride		Drinking	0(Pri. HPW),6(Pri. HDW),5(PHDW	E
		385		Thkov	409	90		Best	12	Iron		Drinking	12(Pri.HP)	E
		386		Chachak I	1,198	245		Best					77(Pri.HP),8(HDW)	E
		387		Chachak II	834	166		Best					Many (Pri.HPW)	E
	Me Sang	388	Prey Khnes	Sussei Tvear	718	104		Good/Narrow	1	Iron		Drinking	5(Pri.HP)2(HDW)	B
		389		Robas Phchet	652	121		Better					1(Pri.HP),3(HDW)	A
		390		Thmei	530	99		Better					5(HDW),17(FP)	A
		391	Ankor Sar	Srah Ta Oem	925	179	Scattered	Very Bad	1			Drinking	3(Pri.HDW),1(PP)	X
		392		Ponley	1,577	370	Scattered	Good	2			Drinking	1(Pri.HPW),2(PHDW)	B
	Kampong Leav	393	Ta Kao	Kok Trom Kha	504	99		Best	1	Iron		Drinking	4(Pri.HP),3(HDW)	C
		394		Khnay	525	103		Better					11(Pri.HP),1(HDW)	E
		395	Pou Rieng	Pou Rieng Cheng	1,778	404		No access					No Information	X
		396		Pou Rieng Tbong	1,828	415		No access					No Information	X
		397		Veal Prou	1,338	304		No access					No Information	X
		398		Yeay Sal	392	89		No access					No Information	X
	Ba Phnum	399	Sdau Kaong	Chrak Svay	806	166	Scattered	Good					4(Pri.HPW),3(PHDW)	D
		400		Dun Mea	985	187	Scattered	Good					3(Pri.HPW), 4(PHDW)	X
		401		Prek Phdau	609	110		Better					5(Pri.HP),1(HDW),1(PP)	C
		402		Trapaing Svay	449	93	Scattered	Good					4(Pri.HPW),2(PHDW)	X
		403		Thmit	361	57		Good					5(Pri.HPW), 1(River)	X
	Peam R6	404	Neak Loeung	Stoeng Slot	1,838	356		Good					River	A
		405		Stoeng Santephng	828	145		Better					River	A
		406		Prek Ta Sa	833	141		Good	2	Iron		Drinking	River	B
		407		Prek Thum	1,130	217		Good	1			Broken	1(Pri.HP),River	A
		408		Neak Loeung	1,968	356		Better					2(HDW),River	B
	Preah Sdech	409	Kok Sampou	Kok Sampou	377	86		Good/Narrow	1	Salty			2(PP)	B
		410		Pou Thum	1,136	208		Bad	5			Drinking		E
		411	Ponsang	Srah Koe	329	68		Bad	6			Drinking	1(HDW)	E
		412		Toul Mean kun	973	198		Better					12(HDW),46(FP)	E
	Kg. Trabek	413	Kraing Svay	Chhruol	1,055	219		No access					17(Pri.HPW),3(Pri.HDW)	X

Table 5.6 Village Survey -Water Source Data

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Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Prey Veng	Kg. Trabek	414	Kraing Svay	Kroch	1,515	315		Good					7(Pri.HPW),2(PHDW),1(PP)	X
		415		Pre Andoung	635	141		No access					6(Pri.HPW),2(Pri.HDW)	X
		416		Prey Khmau	732	120		Good					10(Pri.HP),5(Pri.HDW)	D
Prey Veng	Total	75			68,299	14,134								

Rank	No. of Village
A:	16
B:	10
C:	5
D:	5
E:	15
X:	24
Total	75

Table 5.6 Village Survey -Water Source Data

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Kg. Speu	Peam Chor	417	Rolaing	Ang Metrey	441	88		Better	2			Broken	1(PP)	E
		418		Chambak Phaem	184	38		Better					1(River)	E
		419		Chamkar Bos	352	70		Better	2	Good		Drinking	1(PP)	E
		420		Trapaing Ek	246	49		Better	1	Iron		Drinking	1(PP)	B
		421		Srateal Krom	480	109		No access					No Information	X
		422	Seb Dey	Trapaing Damrey	550	110		Better	1	Iron		Drinking	1(PP)	D
		423		Srah Srang	617	121		Better					2(PP)	A
		424		Prey Chreav	334	66		Good/Narrow	1			Drinking	1(PP)	A
		425		O Rumchek	575	113		Better	2	Good		Drinking	1(PHDW),1(PP)	D
		426		Samrong Cheung Phnom	366	72		Good	3	Iron		Drinking	1(PP)	A
		427		Thlok Andas	384	75		Better	2	Iron		Washing	1(Pri.HDW),2(PP)	C
		428		Tum Nup	285	57		Better	1			Broken	1(PP)	A
		429	Rolaing Chak	Sre Kak	358	70		Good					7(Pri.HDW),1(River)	A
		430		Prey Kdey	406	82		Better	2	Good		Drinking	3(PP)	D
		431		Sre Cheng	408	82		Better			(+)		13(Pri.HDW)	A
		432		Andaung Preng	253	50		Bad			(+)		1(River),4(PP)	A
		433		Phum Pring	539	102		Better	2	Good		Drinking	1(River),1(Pri.HDW)	D
	Phnom Srouch	434	Khum Au	Am Pov	506	115		No access					No Information	X
		435		Prey Toteung	307	61		No access						X
		436		Ro Lous	388	88		No access					1(Stream)	X
		437		Ta Va	258	59		No access					No Information	X
		438		Chraing Choine	219	50		No access					No Information	X
		439	Mohar Saing	Kraing Chor Chart	434	99		No access					No Information	X
		440		Kraing Thnol	312	56		No access					1(PHDW)	X
		441		Trapaing Oip	299	85		Better					8(PP)	A
		442		Sleng	378	76		Better	1		(+)	Drinking		A
		443		Sam Bour	446	89		Better	1		(-)	Drinking		B
		444		Taing Rongeang	356	82		Good/Narrow					River	A
		445		Serey Voine	588	114		Better	1		(-)	Drinking	1(PP)	B
		446		Laring Lahong	578	115		Better					1(PP)	A
		447		Kraing Ta Minh	344	62		Better	2				2(PHDW),5(PP)	C
		448		Toul	436	87		Better	2		(+)	Drinking		C
		449		Trapaing Ampil	8			Good					(pagoda)	X
		450		Prasath	646	125		Good	1		(-)	Drinking	Lake	B
		451	Taing Sia	Kraing Khcheay	422	84		Better	1			Drinking		B
		452		Moit Say	613	122		Better	3					X

Table 5.6 Village Survey -Water Source Data

Province	District	No	Commune	Village	Population	Family	Village Style	Accessibility	HP* No.	Water quality Iron, Chloride	Bacteria and Typhoid	Handpump utilized for	Other Water source	Rank
Kg. Speu	Phnom Srouch	453	Taing Sia	Prum Rolok	362	82		No access					No Information	X
		454		Kiri Raksmey	480	96		Bad			(-)		1(HDW),3(PP)	A
		455		Dey Dos	253	45		Better						A
		456		Kraing Takorn	421	84		Good	1			Broken	5(shallow wells)	A
		457		Thnot Prek	561	112		Better					1(PP)	A
		458		Chheuneang Khpous	258	59		No access					No Information	X
		459		Chrak Khla	388	81		Better	1			Broken		A
		460		Chrey	502	114		Good	3				Didn't meet village leader	E
		461		Kandoil Kaong	262	52		Better	1			Broken	1(Stream)	A
		462		Taing Sia	359	82		No access					No Information	X
		463		Pong Ror	438	89		Better	1			Broken	1(Dam)	A
		464		Sambour	428	85		Good					10(Pri.HDW)	A
		465		Taing Sralao	628	110		Better					1(Pri.HDW)	A
		466		Keak Porng	540	116		Better					1(Pri.HDW),1(PHDW),1(PP)	A
		467		Kraing Sleng	412	80		No access					1(PP)	X
		468?	Treng Trayeung	Sala Khum	8			Commune Office					1(PP)	X
		469		Treng Trayeung I	625	105		Better					1(Lake)	A
		470		Treng Trayeung II	482	92		Best					2(Pri.HDW)	A
		471		Treng Trayeung III	481	96		Better	1	Good		Drinking	1(PP)	A
		472		Treng Trayeung IV	931	465		Better	2				1(spring),1(PP)	A
		473		Treng Trayeung V	730	140		Better			(+)		1(PHDW)	A
	Srok Thporng	474	Khum Prambey Mum	Trapaing Trouk	750	250		Good						A
Kg. Speu	Total	58			24,615	5,358								

Rank	No. of Village
A:	27
B:	5
C:	3
D:	4
E:	4
X:	15
Total	58