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THE RECONNAISSANCE SURVEY PROJECT FOR THE ESTABLISHMENT OF AN EMERGENCY REHABILITATION AND RECONSTRUCTION OF THE KINGDOM OF CAMBODIA

FINAL REPORT (SUMMARY)

MARCH 1999

INFRASTRUCTURE DEVELOPMENT INSTITUTE
PASCO INTERNATIONAL Inc.

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Preface

In response to a request from the Government of the Kingdom of Cambodia, the Government of Japan decided to conduct the study on the Reconnaissance Survey for the Establishment of an Emergency Rehabilitation and Reconstruction of the Kingdom of Cambodia and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Dr. Yoshitake Egawa of Infrastructure Development Institute, consisting of Infrastructure Development Institute and Pasco International Inc., to Cambodia, four times between November 1996 to March 1999.

The Team held discussions with the officials concerned of the Government of the Kingdom of Cambodia, and conducted surveys at the study area. Consequently, the present results were prepared based on these surveys.

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

March 1999

Kimio Fujita

President

Japan International Cooperation Agency

Letter of Transmittal

Mr. Kimio Fujita
President
Japan International Cooperation Agency

March 1999

Dear Sir,

It is a great honour for me to submit herewith the final report of the Reconnaissance Survey Project for the Establishment of an Emergency Rehabilitation and Reconstruction of the Kingdom of Cambodia.

A study team, which consists of Infrastructure Development Institute and Pasco International Co., Ltd. headed by myself, conducted surveys and data analysis based on the terms of references instructed by the Japan International Cooperation Agency (JICA), from November 1996 to March 1999.

The study team held thorough discussions and investigations with officials concerned of the Royal Government of Cambodia.

The results were collected in the final report.

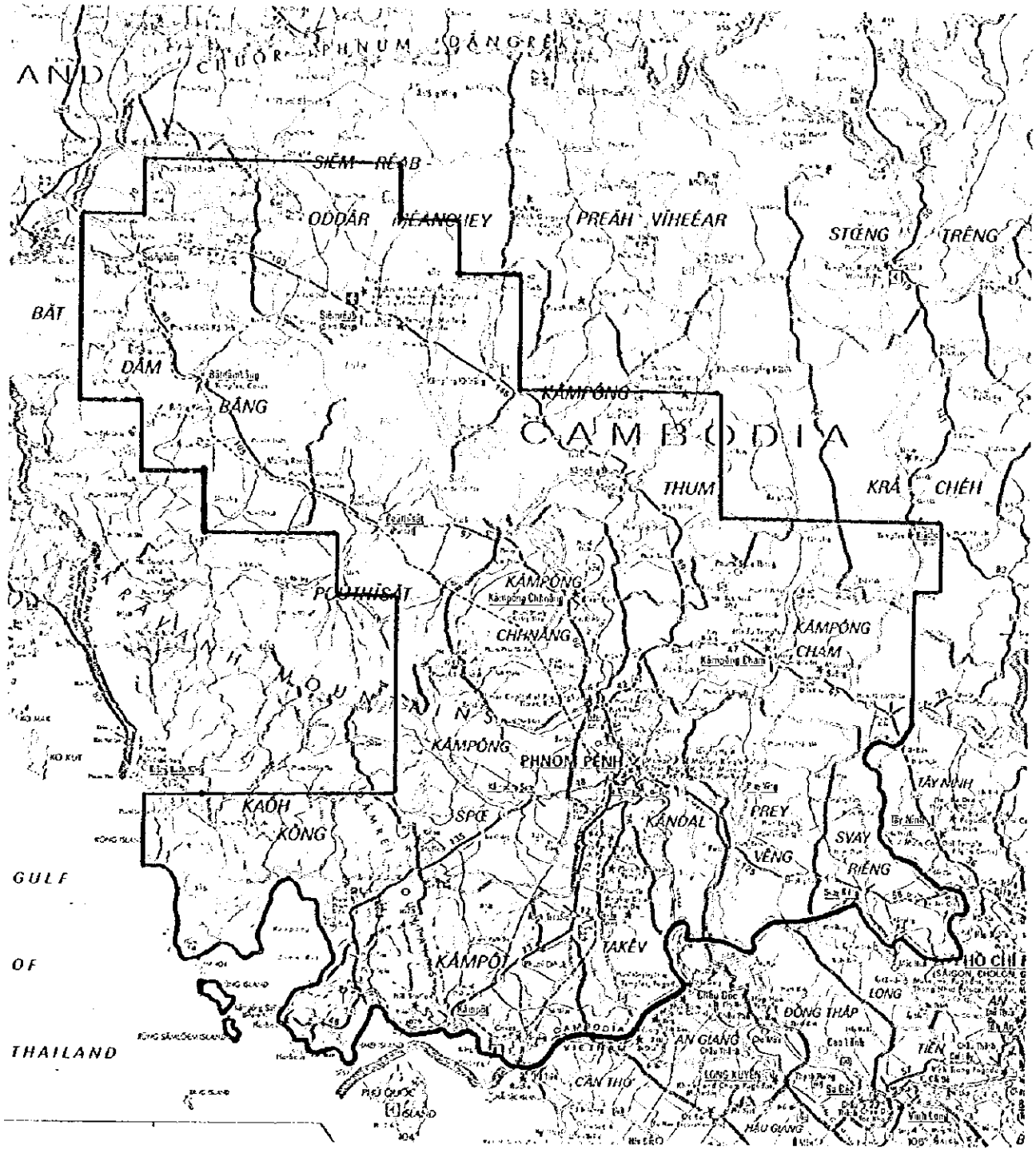
On behalf of the team I wish to express my heartfelt appreciation to the Officials concerned of the Government of the Kingdom of Cambodia for their warm friendship and cooperation extended to us during our stay in Cambodia.

Also, I wish to express my sincere appreciation to JICA, the Ministry of Foreign Affairs, the Ministry of Construction, the Embassy of Japan in Cambodia and other concerned government authorities for their valuable advice and cooperation given to us in the course of the site surveys and preparation of the final report.

Yours Faithfully,

Yoshitake Egawa Y. Egawa
Team Leader
The Reconnaissance Survey Project
for the Establishment of
an Emergency Rehabilitation
and Reconstruction
of the Kingdom of Cambodia

Study Area


SIÉM RÉAB
ODDÂR MÉANCHEY
PREÄH VIHEÉAR
STŒNG TRÉNG
BÂT DÂM BÂNG
KÂMPÔNG
CAMBODIA
THUM
KRÁ CHÉH
KÂMPÔNG CHHNÂNG
KÂMPÔNG CHAM
KÂMPÔNG
PHNOM PÉNH
TÂY NINH
KAÔH KÔNG
SPŒ
KÂNDAL
PREY VÉNG
SVAY RIÉNG
GULF OF THAILAND
TAKÉV
KÂMPÔT
ĐỒNG THÁP
AN GIANG
CẦN THƠ
HẬU GIANG
LONG
TIỀN

Executive Summary

1. Study Background

Recovery and reconstruction from the civil war is the most important national issue in the Kingdom of Cambodia. To successfully implement the reconstruction work, it is essential to prepare up-to-date geographic information with uniform accuracy. However, maps that are available in the country are only at a scale of 1/50,000, initially produced in the 1960s by the United States and adjusted by the Vietnamese about 20 years ago. Their commercial availability is also limited. Even worse, the originals of the maps have been lost, and editing, updating, and re-printing work became impossible.

Necessity of updated topographic maps and thematic maps for the government of Cambodia is apparent; however, the government's its own capability is not sufficient to conduct the work of national importance because of organizational weakness resulted from the civil war and due to reduction in the number of technical staff. The government of Cambodia, therefore, requested, in September 1994, a topographic mapping project for rehabilitation and reconstruction of Cambodian land to the government of Japan.

The government of Japan, responded to the request, and dispatched a preliminary study team to Cambodia in March 1996. The team and the Ministry of Public Works and Transportation (MPWT), the counterpart agency, discussed and negotiated to realize the project. After a thorough discussion, in March 1996, the project's scope was finally agreed, and both parties signed the Scope of Work (S/W).

Infrastructure Development Institute and Pasco International conducted the Reconnaissance Survey Project for the Establishment of an Emergency Rehabilitation and Reconstruction from November 1996 to March 1998, in accordance with the S/W. The schedule, however, was changed and extended due to the political upheaval in July 1997. In March 1999, the Study was finally completed.

2. Contents of the Study

The study area covers some 80,000 km^2, nearly all of the flat alluvial plain area of the country including its peripheral areas. It includes socially and economically active areas of the country and covers approximately 45% of the total land area of Cambodia.

The Study outputs were provided in prints and in digital format stored in CD-ROM. Final products are:

1) Topographic maps (1/100,000)
2) Land Use Data (1/100,000)
3) Geology/Geomorphology Data (1/500,000)

3. The Basic Policies of Study Implementation

The objective of the Study is to produce basic geographic data. Following policies were set forth in conducting the Study:

1) Satellite images, aerial photographs and existing data and information such as existing topographic maps shall be used as much as possible to eliminate field study because of the security conditions in the area. During data and information collection, safety of team members shall be secure tightly.

2) The Study area is large, but the cost of the work and the work period shall be minimized as much as possible.

3) In order to achieve the policies in 1) and 2), a data acquisition method using satellite images, which is first to be employed in the mapping industry, shall be used. The latest computer technology shall also be utilized in data processing.

4) To ensure data quality, existing aerial photographs and existing topographic maps shall be used.

5) To enhance capability of the government in mapping projects, technology transfer shall be undertaken.

6) The Study Team shall maintain close relationship with the counterpart agency, and both sides shall exchange information and resolve issues during the course of the Study.

4. Study Implementation

The study period was extended for one year, because of the political upheaval. Besides the extension, the Study was conducted in accordance with the policies set forth. The policy of no-field study usually affects the quality of work negatively; however, with assistance from the local technical staff, who was familiar with the field conditions, the quality was ensured. And at the same time, the objective of technology transfer was achieved as the staff was exposed more to opportunities of conducting the work.

5. Utilization of the Output

The output of the Study could be utilized as base data in using Geographical Information Systems (GIS). MPWT has already started using the output in applying GIS for "Agricultural Land Allocation to Former Pol Pot Soldiers" and "Analysis of Road Alignment Study of Route 5". These trials have proved potential of future development of GIS using the output.

6. Information Dissemination

A seminar titled "Exhibition on the Fist Full-Scale GIS Database in Cambodia" was held to facilitate technology transfer and information dissemination. To ensure that the results of the study be fully utilized, they should be widely disseminated to the relevant agencies in Cambodia.

Table of Contents

1. Introduction

In accordance with the Paris Peace Accord of 1991, general elections were held in Cambodia in 1991 under the supervision of the United Nations Transitional Authority in Cambodia to mark the birth of the new Kingdom of Cambodia. The present priorities of the Cambodian Government's policy are reconstruction of economy, the rebuilding of social and economic infrastructure, such as for transportation, power supply, agriculture, and so on, which were destroyed in the prolonged instability, and providing stable livelihood for 370,000 refugees who have returned home.

To successfully implement the reconstruction work, it is essential to prepare up-to-date geographic information with uniform accuracy. But such geographic information is not available now in Cambodia since topographic, land use, geology/geomorphology maps and other necessary geographic data have never been updated or generated to date. Because of this reason, the government of Cambodian decided to acquire the latest geographic data with the assistance from the Japanese Government.

In response to the request of the Royal Government of Cambodia, the Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programs of Japan, undertook the preliminary study to identify conditions and discussed realization of a technical cooperation study with concerned agencies of the Cambodian government. The Government of Japan decided to conduct the Reconnaissance Survey Project for the Establishment of an Emergency Rehabilitation and Reconstruction (hereinafter referred to as "the Study") as a Japan's Overseas Technical Cooperation Program.

The Ministry of Public Works and Transportation (hereinafter referred to as "MPWT") has served as a counterpart agency and appointed the Cambodia National Mekong Committee (CMNC) as the coordinating body for smooth implementation of the Study.

The objective of the Study is to create topographic maps and land use maps at a scale of 1:100,000 and geology/geomorphology maps at a scale of 1:500,000 along with digital database for establishing a geographic information system. The study area covers some 80,000 km^2, nearly all of the flat alluvial plain area of the country including Phnom Penh. The geographical information generated under the Study covers approximately 45% of the total land area of Cambodia (181,000 km^2).

The Study was commenced in November 1996 and was scheduled to be completed in two years. However, because of the political upheaval in 1997, the Study period was extended for one year, and completed in March 1999.

2. Outline of the Study

2.1 Specifications of the Study

The specifications of the Study is shown on Table 1.

Table 1 Basic Specifications

Item	Description
Products Topographic mapping	Scale - 1:100,000 Area - Approx.80,000 km² Printed maps:36 map sheets in 4 colors 2,000 copies each map sheet (English 1,500 and Khmer 500) Topographic digital data files (CD-ROM) 1 Master File 100 copies
Landuse mapping:	Scale - 1:100,000 Area - Approx. 80,000 km² Printed maps: Multi-colors; about 36 map sheets 20 copies each map sheet Land use digital data files (CD-ROM) 1 Master File 100 copies
Surface geology/geomorphology mapping:	Scale - 1:500,000 Area - Approx. 80,000 km² Printed maps: Multi-colors; about 4 map sheets 20 copies each map sheet Surface geology/geomorphology digital data files: 1 Master File 100 copies
Map symbols	To be agreed with Cambodia
Mapping standards	Reference ellipsoid : Everest 1830 Projection: UTM Neat lines: 30'x30' Contour lines: 40m principal contour lines;
Inspection	The final results to be inspected by JICA.
Special	The following notations to be printed notations in the margin of each map sheet. "This map was prepared by the Japan International Cooperation Agency (JICA) under the Japanese Government Technical Cooperation Program and the Government of Cambodia." "This map was compiled to meet the urgent need for recovery of Cambodia based SPOT imagery without field survey."

2.2 Outline of the Study

The flow of the Study is shown in Figure 1.

2.2.1 Topographic Mapping

New satellite imagery, which covered large areas, was used. The digital photogrammetry method using analytical plotters was also used instead of the conventional analogue method. The production process followed: auto-spatial triangulation, preparation of digital terrain model, auto-extraction of topographic contour lines, production of ortho-imagery, and editing ground features. For security reasons, the aerial photograph interpretation replaced the general process of field verification.

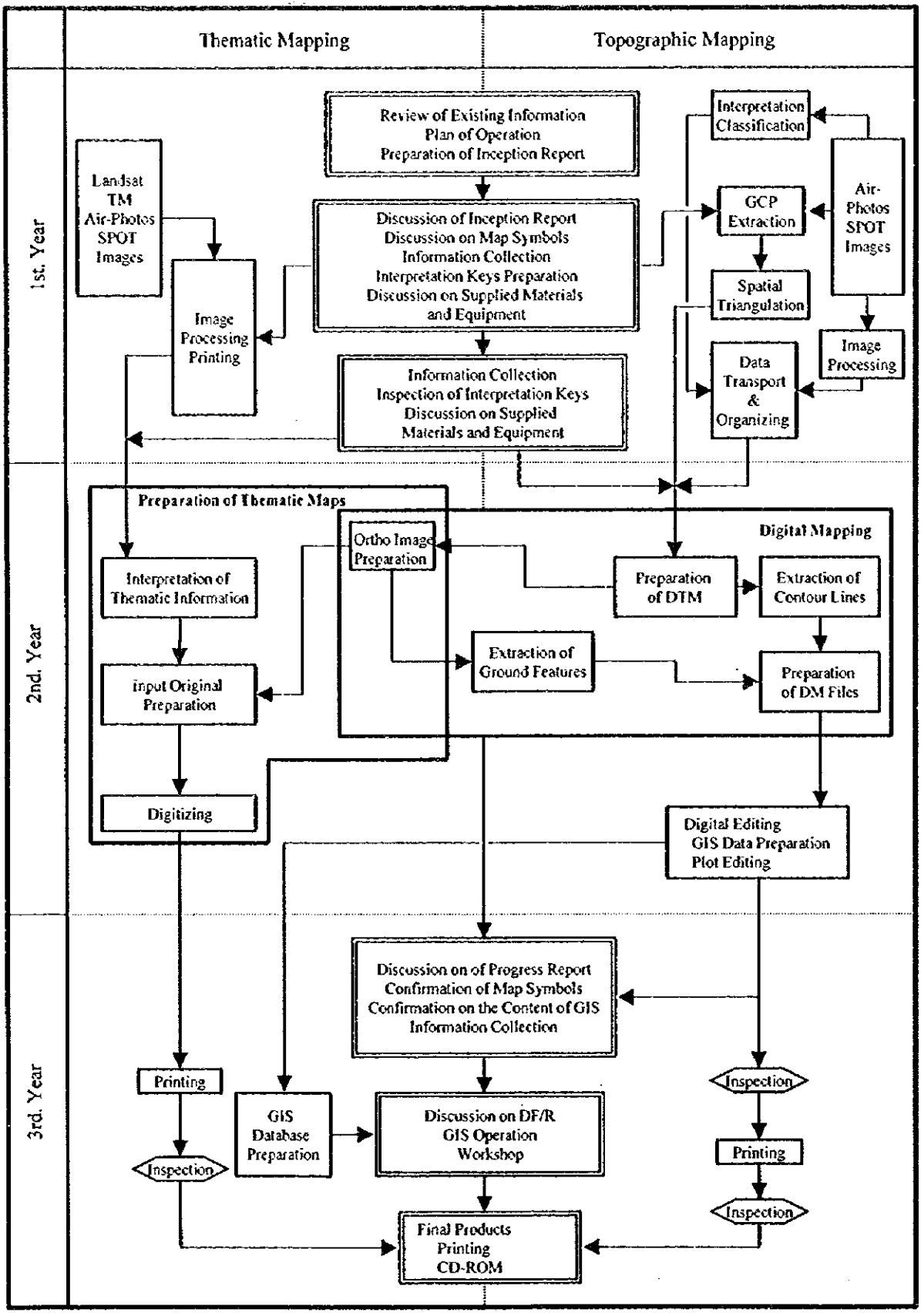
2.2.2 Thematic Mapping

As in the topographic mapping, land use maps (1/100,000) and geology/geomorphology maps(1/500,000) needed to be produced in a large area within a limited period, satellite remote sensing technology was used. Ortho-images produced from SPOT imagery were used as the base maps. Prints of TM Landsat imagery were interpreted to identify vegetation and other land use. To enhance accuracy of the interpretation, existing aerial photographs were also interpreted.

2.2.3 Database for Geographic Information System (GIS)

The data obtained under the study were systematically organized into database to manage the data comprehensively. Therefore, all the topographic and thematic data were stored in Arc/Info compatible format and structure.

Figure 1 Study Flow Chart



2.3 Study Team

Only limited field verification was conducted under the Study, because of the limited time of the Study and security consideration. Therefore, satellite imagery and existing information including aerial photographs were used as much as possible to complement the limited fieldwork. Qualified engineers with expertise in the respective fields of sophisticated technologies were involved. For those parts implemented in Japan, consideration was given that engineers who are familiar with the status of the Study in Cambodia should be assigned. The members of the Study Team are shown as follows:

Team Leader:	Dr. Yoshitake EGAWA
Deputy Team Leader:	Mr. Takeshi HIRAI
	Mr. Yoshiaki OTOKU
Mapping Planner:	Mr. Tetsuro IMAKIIRE
	Mr. Hiroyuki MATSUDA
Topo-Mapping, Chief Engineer:	Mr. Fujio ITO
Land Use Mapping:	Mr. Awadh Kishor SAH
Geology/Geomorphology	Mr. Eichi HAYAKAWA
	Mr. Hideaki UMEDA
GIS Planner:	Mr. Reese W. PLEWS
	Mr. Myo THANT
Database Engineer:	Mr. Kazushi ENDO

2.4 Concerned Agencies

2.4.1 Counterpart Agency

Despite the fact that detailed and precise information was necessary, the field verification could not be conducted. Although major sources of information were satellite images and aerial photographs, intensive search of existing information was necessary more than the cases in the ordinary topographic mapping projects. For this reason, good relationship with the counterpart agency, which coordinated search of information store in other agencies, and negotiated uses of information, was important. It was meaningful that the Study Team maintained good relationship with the counterpart agency not only on search of existing information but also other tasks involved in conducting the Study during the whole study period.

2.4.2 Other Agencies

Cooperative relationships established with other agencies were meaningful. The National Geography Department cooperated in the demarcation of boundaries, location of settlements, toponomy and other information. The Ministry of Agriculture provided staff for interpretation of land use. The Geology Department assigned geologist to conduct the interpretation of geology/geomorphology. Other agencies concerned with irrigation, flooding, river control, and forest management/conservation have been contacted for information.

2.5 Technology Transfer

2.5.1 Training in Japan

Personnel of the counterpart agency have attended training courses in Japan as part of the technology transfer under the Study. They learned the skills involved in each process of from creating and managing geographic data.

The following engineers participated in the training:

Mr. Nuon Kunthea	
Technical background :	GIS
Duration:	17 Mar ～ 15 May '97
Training content:	Digital Mapping and GIS
Mr. Khum Ponnaban	
Technical background:	Geodesy and Photogrammetry
Duration:	14 Oct ～ 9 Dec '97
Training content:	Digital Mapping, compilation and GIS
Dr. Khun Sokha	
Technical background:	Project coordinator, Hydrology
Duration:	18 Jan ～ 17 Feb '98
Training content:	Digital Mapping, compilation and GIS

2.5.2 Training in Cambodia

Throughout the Study period, the Study Team conducted on the job training (OJT) in the following areas:

Aerial photo and satellite image interpretation;
GIS data structuring;
Map annotations and toponomy;
Map editing and formatting;
Map Digitizing

The participants of the OJT were as follows:

Name	Field of Study
KHUN Sokha	ANPC
TENG Peng Seang	GIS Application
MAO Phannarith	Mapping
SAN Sophat	Mapping
MENG Sakheara	Geology
BIN Yoy	Geology
SOUS Samouth	Geology
NUON Chamnes	Geology
MAK Sophearktra	Geology
Oey David T.	Assistant of Dr Heng Thung
PHOK Monica	Archiology

2.5.3 Organizing Workshop

As part of the technology transfer, a workshop was held when the draft final report was presented to the counterpart agency. Contents of the workshop

were carefully planned and organized so that engineers of the counterpart agency and other agencies who are not directly involved in the Study could benefit from the seminar. The total number of participants including GIS users in other agencies reached seventy.

3. Detail of the Study

3.1 First Year

3.1.1 Preliminary Study

(1) Preliminary Work

The detailed work plan was prepared after studying and evaluating work methods. The plan included:

- Basic policy for the Study,
- Study methodology,
- Work processes,
- Undertakings by the counterpart government, and
- Map symbol designing.

(2) Preparation of the Inception Report

The Inception Report, which explains the work plan and organization of the Study, was prepared. The report was reviewed by MPWT and modified based on its comments.

3.1.2 Acquisition of SPOT Data

SPOT 3 data was acquired based on red programming as required for this project. However, the SPOT 3 broke down in November 1996. Therefore SPOT 1 and SPOT 2 images were used to recover missing frames. 48 stereo pairs were acquired with the following specifications:

- Red programming
- Three attempts
- Less than 10% cloud cover in each scene
- Overlap (between scenes): 10%
- B/H ratio: 0.7

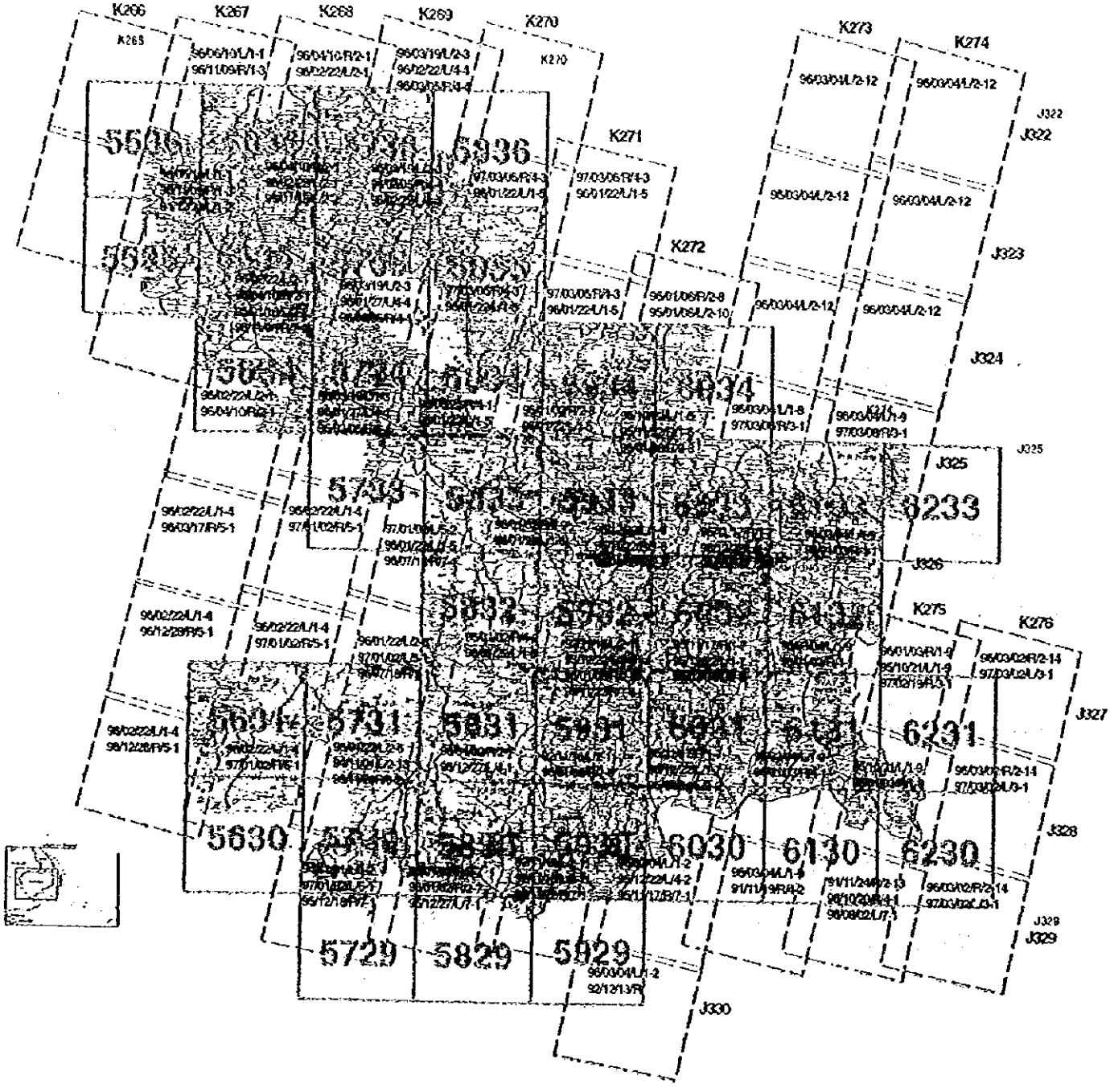
3.1.3 Acquisition Aerial Photography

Existing 1:25,000 aerial photographs were obtained through the assistance coordination of MPWT for the photo-interpretation.

3.1.4 Preparation of SPOT Images

The aerial photographs were interpreted to extract ground features to produce topographic maps. In order to transfer and organize the results, SPOT images were printed directly on high quality paper at a scale of about 1:75,000.

Figure 2 SPOT Imagery Index Map



3.1.5 Production of Landsat Imagery

The Landsat TM data were rectified by means of a digital image processing, and false color composite images were produced. A total of 7 full scenes and 4 sub-scenes imagery data needed to be supplied to cover the whole study area. Those data were acquired and controlled by the receiving station in Bangkok, Thailand.

The combination of red, green and blue bands of the Landsat TM sensor (Bands 4, 3, and 1 or 5, 4 and 1) was considered the most appropriate for interpreting the vegetation coverage in the humid tropical lands in the Study area. Therefore, the spectral bands were used for land use and geology/geomorphology interpretation. The color composite negatives were produced at a scale of 1:100,000.

3.1.6 Interpretation for Topographic Map

Interpretation and classification was performed in as much as possible on the satellite imagery. The high resolution aerial photographs of 1:25,000 scale, existing topographic maps and other materials were used to verify the satellite interpretation in order to minimize the field verification. Some field works were conducted only to gather reference keys for interpretation. Roads, missing parts of waterways, villages, and small features (schools, temples, etc.) were identified and classified on the aerial photographs by referring to the keys and using reflective mirror stereoscopes and outlined on the photos with a drawing pen. The items interpreted and classified above were used to correct the data on the enlarged photos of SPOT images (scale: 1:75,000). They were represented in accordance with the rules of map symbol application.

The main items interpreted were:

- Public facilities (government buildings, schools, temples, public organizations)
- Roads
- Vegetation
- Water bodies and streams

3.1.7 Collection and Updating of Existing Information

The existing data for topographic map were provided by the following government agencies concerned.

Village data:	Land Use Mapping Office in Ministry of Agriculture
Drainage and irrigation data:	Land Use Mapping Office in Ministry of Agriculture
Road network and other infrastructure data:	MPWT
Geographical names:	National Geographic Department
Administrative boundaries:	National Geographic Department
Existing geodetic control points:	National Geographic Department

Those original data were updated using aerial photos and satellite imagery, and some were further checked in the field.

3.2 Second Year

3.2.1 Production of Topographic Maps

(1) Major instrument used

Hardware:	Lica-Helva DPW
Software:	Socet Set Ver. 3.2.0
	V3D/Arc Info

(2) Space block triangulation

About 170 ground control points (GCPs) were selected from existing topographic maps (1/50,000). The tie-points were automatically selected using the SOCET SET software. The space block triangulation was conducted using the data. The optimum values of the parameters relating to each image, segment, data strip, etc. are computed by Gauss-Newton type algorithm. The accuracy of the space block triangulation was set in accordance with the three classes reported by European Organization for Experimental Photogrammetric Research (OEEPE) after thorough discussion with the MPWT.

The following table shows the residual error on the control point survey.

Root Mean Squires on Selected GCPs

	RMS (m)
X	21.22
Y	20.11
Z	4.94

Number of control points :170

The above result lied within the required tolerance, and the control points were good enough to be applied for this study.

(3) Generation of Digital Terrain Models

In order to capture terrain data, automatic measurement of elevations was conducted using stereo matching technology applying the theory of image relativity based on both right and left images. The results of the previous space triangulation were applied to all stereo-pairs. All images covering the whole study area were rectified by pair-wise, and DTM was generated from each stereo-pair of SPOT scenes in 20 m grid resolution. Those DTMs serve as basic models for automatic delineation of contour lines. As the quality of ortho images depend on the quality of DTMs, the work was carried out carefully.

(4) Generation of SPOT ortho-images

Based the DTMs, the SPOT ortho-images were produced to serve as basic images for thematic mapping. The ground sample distance of the ortho images was 10 meters.

(5) Preparation of Map Symbols and Application Rules

The map symbols and the application rules were determined and prepared jointly with MPWT as agreed in February 1997.

(6) Extraction of contour lines and spot heights

Using DTMs as basic data, contour lines were generated automatically based on TIN (Triangle Irregular Network) models, superimposed on three dimensional images and edited using an interactive computer through visually confirming terrain features. As the Study area includes flat land area, 20m contour lines were drafted. At the same time, 10m-contour lines for the flat area were also added referring to existing 1:50,000 topographic maps.

The elevation data were prepared using the DTM images at locations of road intersections, depression/mound, and other locations that represented the areas' elevations.

(7) Extraction of linear and ground features

Linear features were extracted from the ortho-images for the respective layers in accordance with the map symbol application rules using software for vector-extraction from raster images. Layers were prepared for point, line and polygon data in accordance with geographic features. By interpreting geographic features on screen, the interpreter extracted geographic features by tracing them on-screen. The aerial photographs and results of interpretation were also reviewed in this process.

The vector data were then converted to the ARC/INFO format, since ARC/INFO was to be used to create geographic information under the subsequent work.

(8) Vegetation Information

Vegetation boundaries were re-classed based on the land use classification of the topographic maps. Boundaries were modified to adjust differences in satellite data.

(9) Data Conversion

The GIS is used to store and manage the topographic map data. The various data layers were selected from the database and each specific feature type was then exported to a common file format which can be read by Desk Top Publishing (DTP) software. These features were selected using the attribute codes which have been associated to each group of features in the GIS. A series of commands to control the selection procedure, drawing and

saving of the data was programmed for the GIS. Approximately 100 individual files were created for each map sheet.

(10) Map Editing Preparation

The layers created under the data conversion process were transferred to Macintosh and PC environments in which the DTP software operates. The individual layers, output from the GIS, have been merged into one single drawing to facilitate editing within the DTP software.

(11) Symbols and Coloring

The data layers converted from the GIS are displayed in the DTP software simply as raw lines, points or text strings. The layers were then edited to add colors and line symbols to match the feature types.

(12) Text Annotation

The GIS also stores annotation data for many features such as lakes, rivers, mountains and village names. The amount of data became quite large, since the data was based on the information from 1/50,000 topographic maps. The annotation strings were stored in the form of individual points. The annotation strings in Khmer were provided by the counterpart agency in the compatible format. By installing Khmer fonts to the DTP system, the annotation texts in Khmer were produced.

(13) Graticules

Graticule and grid information for each map sheet was created using specific map projection and graticule commands within the GIS. Both a UTM grid and latitude/longitude references were used.

3.2.2 Production of Thematic Maps

(1) Major Instrument Used

Hardware:	Sun SS Workstation
Software:	Erdas Imaging Version 8.3
	Arc/Info Version 7.1

(2) Land Use

As shown in Table 2, land use types were categorized into 40 classes.

In order to create land use data at a scale of 1:100,000, the manual interpretation of Landsat TM satellite imagery has been conducted. In addition, aerial photographs were interpreted, and some field survey was conducted to prepare interpretation keys.

(3) Interpretation of the Shoreline of the Tonle Sap Lake in the rainy season

The shoreline of the Tonle Sap Lake changes between the dry and the rainy seasons due to the difference in amount of the water inflow from the Tonle Sap River and the Mekong River. Therefore the shoreline of the dry season

was delineated from the land use data of dry season, while the interpretation of JERS-1 SAR imagery was used to delineate the one of the rainy season.

(4) Geology / Geomorphology

Geology / Geomorphology was analyzed through the manual interpretation of Landsat TM imageries. Aerial photos were also used for some parts. This analysis was conducted jointly with Cambodian geologists of the Cambodian Department of Geology. The interpretation results were prepared onto the images at a scale of 1:100,000. The original data of 1:100,000 scale was entered into the GIS database to be further adjusted using other information. The data was then reduced to 1:500,000 and edited to create the Geology/Geomorphology maps.

Table 2 Legend for Land Use Map of Cambodia (Scale 1/100,000)

Previous 43 LU Legend		Modified 40 LU Legend	
S. N.	*Code* *Class Name*	*S. N.*	*Code* *Class Name*
Urban, Built-up Areas:		**Urban, Built-up Areas:**	
1	U Cities, towns	1	U Settlement
2	V Villages	2	I Infrastructure (Airfield, Playground, Cemetery, etc.)
Infrastructures:		**Infrastructures:**	
3	Ip Airfields, harbors		
4	Io Other (Playgrounds, stations, schools, etc.)		
Agricultural lands:		**Agricultural lands:**	
5	Ar Paddy field	3	Ar Paddy field
6	Af Receding and Floating rice fields	4	Af Receding and Floating rice fields
7	Au Field crop	5	Au Field crop
8	As Swidden agriculture (Slash and burn)	6	As Swidden agriculture (Slash and burn)
9	Ao Orchard	7	Ao Orchard
10	Ap Plantation (Rubber plantation)	8	Ap Plantation (Rubber plantation)
11	Av Village garden crops	9	Av Village garden crops
12	Ag Garden crops	10	Ag Garden crops
13	Arv Paddy field with villages	11	Arv Paddy field with villages
Grasslands:		**Grasslands:**	
14	G Grassland (Undifferentiated)	12	G Grassland (Undifferentiated)
15	Ga Abandoned field covered by grass	13	Ga Abandoned field covered by grass
16	Gf Flooded grassland	14	Gf Flooded grassland
17	Gs Grass savannah	15	Gs Grass savannah
18	Gm Grass with termite mounds	16	Gm Grass with termite mounds
19	Ms Marsh and Swamp	17	Ms Marsh and Swamp
Shrublands:		**Shrublands:**	
20	S Shrubland (Undifferentiated)	18	S Shrubland (Undifferentiated)
21	Sa Abandoned field covered by shrub	19	Sa Abandoned field covered by shrub
22	Sf Flooded shrub	20	Sf Flooded shrub
23	St Woodland (C < 10%)	21	St Woodland (C < 10%)
Forest covers:		**Forest covers:**	
24	Fe Evergreen broad leafed forest	22	Fe Evergreen broad leafed forest
25	Fc Coniferous forest	23	Fc Coniferous forest
26	Fd Decidous forest	24	Fd Decidous forest
27	Fdo Dry decidous (Open) forest	25	Fdo Dry decidous (Open) forest
28	Fx Mixed forest	26	Fx Mixed forest
29	Fr Riparian forest	27	Fr Riparian forest
30	Fs Bamboo and Secondary forests	28	Fs Bamboo and Secondary forests
31	Ff Flooded forest	29	Ff Flooded forest
32	Fm Mangrove forest	30	Fm Mangrove forest
33	Fmd Degraded mangrove forest	31	Fmd Degraded mangrove forest
34	Fp Forest plantation	32	Fp Forest plantation
Water features:		**Water features:**	
35	Wl Lake (>8 ha)	33	Wl Lake (>8 ha)
36	Wp Pond (< 8 ha)	34	Wp Pond (< 8 ha)
37	Wr Reservoir	35	Wr Reservoir
38	Ws Shrimp/Fish farm and Salt pan	36	Ws Shrimp/Fish farm and Salt pan
39	Wo Others (Sea, Bay, etc.)	37	Wo Others (Sea, Bay, etc.)
Soils and Rocks:		**Soils and Rocks:**	
40	B Barren land	38	B Barren land
41	Bs Sand bank	39	Bs Sand bank
42	Br Rock outcrop	40	Br Rock outcrop
43	Bo Others (Bare soil, areas after mining, etc.)		

Table 3 Legend for Landform (Geology/Geomorphology) Map of Cambodia
Scale: 1/500,000

Code	Geologic Era	Deposits,Sediments,Rocks
[Unconsolidated material]		
(Remarks : shall be only used existing deposits in study area within following list)		
W	Quaternary	Water
Fp	Quaternary	Floodplain
Af	Quaternary	Alluvial fan
Co	Quaternary	Colluvium(Tallus cones)
Pd	Quaternary	Pediment
Lb	Quaternary	Lake bed deposits
Dd	Quaternary	deltaic deposits
Ft	Quaternary	Tidal flats deposits
Br	Quaternary	Bearch ridge deposits
Sw	Quaternary	Organic deposits
Va	Quaternary	Volcanic deposits
Cp	Quaternary	Costal Plains deposits
Ta	Quaternary	terrace laterite deposits
Pi	Quaternary	Basaltic plateau deposits
[Sedimentary Rocks]		
Mesozoic		
Jurassic-Cretaceous		
Jca	Jurassic-Cretaceous	claystone
JCg	Jurassic-Cretaceous	sandstone
JCg	Jurassic-Cretaceous	conglomerate
J	Jurassic	sandstone
J1-2	Lower-Middle Jurassic	formation
Triassic		
T	Triassic	formation
Tg	Triassic	formation(sandstone and microbreccias)
Tx	Triassic	siltstone,shists and marl
Paleozoic		
Permian-Carboniferous		
C-T	Upper Carboniferous - Lower Triassic	sandstone
CP	Ouralo - Permian	limestone
P	Permian	limestone
Carboniferous - Devonian		
CD	Carboniferous - Devonian	black shists,phtanites,sandstone
Devonian		
DHj	Devonian	phtanites
DHx	Devonian	schists and sandstone faces
DHm	Devonian	marl faces
DHcg	Devonian	conglomerate faces
al/DC	Devonian	DC formation covered by a thin layer of old alluviun

Cambrian - Silurian		
CScg	Silurian	metaconglomerate
CS2q	Cambrian - Upper Silurian	quartzites
CSq	Cambrian - Silurian	quartzites
CSx	Cambrian - Silurian	schists
Archean		
AnteCambrian		
Pt	AnteCambrian	formation
Unknown Geologic Era		
C		Hornfelds,meta-arkose and meta-andesites
Ce/Cm/Cog		Skarn deposit,Marble,Metamorphic conglomerate
[Igneous Rocks]		
Volcanic Rocks		
Basic Rocks		
Bl/B	Quaternary / Pliocene - Quaternary	Basalts
Acidic Rocks		
p2/p2b	Jurassic - Cretaceous	Rhyolites
b	Jurassic - Cretaceous	Dacites
p1	Lower-Middle Triassic	Rhyolites
p	Antepermian	Rhyolites(Old Rhyolites)
Intermediate Rocks		
α l	Jurassic-Cretaceous	Andesites and tuffs
α	Permian	Andesites and their relative rocks
Volcanic sediments		
r2t	Jurassic-Cretaceous	volcanic breccias and acidic tuffs
r1t	Devonian	acidic tuffs
Pultonic Rocks		
Q4	unknown geologic Era	High alumina Granite
g3/g3-4	Post Triassic(Late Jurassic - Cretaceous)	Granites/coarse grained Granites
g3-1	Post Triassic(Late Jurassic - Cretaceous)	aplititic Granites,Aplite
g3-2	Post Triassic(Late Jurassic - Cretaceous)	fine grained Granites
g2	Early - Mid Triassic	Granite
g1	Early - Middle Paleozoic	Granite
g/gb	Late Triassic - Early cretaceous(Post Tria	Granodiorite
	unknown geologic Era	undiscriminated Pultonic rocks
d	Late Cretaceous - Paleogene	Diorite,Gabbro,gabbroic Diorite
[Others]		
	faults	
	proposed faults	

3.3 Third Year

3.3.1 Printing

Final topographic maps were printed by automatic offset printing. The procedure was as follows:

1) Preparation of film for plate making
4 sheets of positive film for plate making were prepared for each map sheet.

2) Printing Plates
Printing plates for the respective colors were made from the positive film using aluminum PS plates.

3) Proof prints
Proof prints from the printing plates were made by a flatbed offset machine.

4) Proofing
The proof prints were checked for the quality of coloring and matching. Defective sheets in matching were corrected and reprinted. The proof prints were approved by MPWT when the draft final report was discussed.

5) Printing
Printing paper was chosen in terms of representation and endurance. High quality printing ink was used that had good color tones and less change.

6) Inspection
Each printed map sheet was checked for any presence of smears from printing, blurs, missing lines, matching, color tones, etc.

3.3.2 GIS Database

The structure of the GIS database was a prototype design to be flexible to be modified in the future.

Consideration was given on how to structure the data in the best format for the counterpart agency. Although the library is suitable for most applications, it is sometimes useful to have access to each data layer as a single data set (map-joined) covering the whole study area. Thus, the data sets for CD-ROM were prepared in both LIBRARIAN and Map-Joined formats.

The LIBRARIAN is based on the concept of partitioning and distributing the spatial data on the computer or over a network. The data within the Library are divided into spatial area (a tile) and theme (a layer). The tiles of the Library are based on the map-sheet boundaries (30 minutes x 30 minutes) of the 1:100,000 map sheet series.

3.3.3 Interpretation of Old and New Topographic Maps

The new topographic maps were qualitatively compared to the old topographic maps to assess land use changes of the country. The preliminary analysis shows a pattern of land use change due to agricultural development, infrastructure development (road/rail), and conglomeration of population.

3.3.4 Workshop

As stated in the previous section, a workshop was held to during the fourth work in Cambodia.

4. Recommendations

The objective of the Study is to create topographic maps land use maps and surface geology/geomorphology maps along with digital database for establishing a geographic information system to contribute to the nation's reconstruction efforts.

The data prepared under the Study help in regional analyses, preparation and implementation of development plans through the applications of the GIS or through linking the data and information with other agencies concerned. Therefore, the results of the Study shall not end with transferring the data to the counterpart agency, but enhance the uses by all government agencies.

It would be necessary to share data among government agencies, and to establish systems of coordinating production and management of the data. In order to avoid duplicating efforts by different agencies, common data and information need to be shared.

5. Application Examples

Three experimental applications of GIS were developed using the data prepared under the Study. Although these examples are preliminary, they show potential of the GIS application development.

5.1 Agricultural Land Allocation to Former Pol Pot Soldiers

To evaluate agricultural development potential, a "Land Availability Ranking" map, which shows priorities of development, was produced in a selected area having about 4,000km^2. Land use, geology/geomorphology, land mine distribution data were used.

5.2 Road Alignment of Route 5

Route 5 from Kampong Chhnang provincial center to Bat Dambang provincial center become impassable during the rainy season. A model was developed to find an alternative route less affected by rain. The analysis using the data on elevation, slope, geology, and the shoreline data of the Tonle Sap Lake during the rainy season resulted the best route along the existing railway route.

5.3 Changes in Topographic Information

In a sample area of 3600 km^2, an automatic identification of land use changes was conducted using the topographic maps produced in 1960 and the data produced under the Study. Major changes were identified on villages, roads, and canals.