Islamic Republic of Mauritania
Ministry of Habitat, Urbanism and Land Development
Direction of Cartography and Geographic Information

THE STUDY ON FORMULATION OF GEOGRAPHIC DATABASE OF NOUAKCHOTT IN THE ISLAMIC REPUBLIC OF MAURITANIA

FINAL REPORT

June 2010

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

PASCO CORPORATION
ASIA AIR SURVEY CO., LTD.

EID
J R
10-089

THE STUDY ON FORMULATION OF GEOGRAPHIC

DATABASE OF NOUAKCHOTT

IN THE ISLAMIC REPUBLIC OF MAURITANIA

FINAL REPORT

June 2010

PASCO CORPORATION
ASIA AIR SURVEY CO., LTD.

Currency Equivalents

Currency Unit : Mauritania Ouguiya (MRO)

1 EUR = 336.046 MRO (Interbank Rate May 13, 2010)

1 EUR = 117.65 YEN (Interbank Rate May 13, 2010)

PREFACE

In response to the request from the Government of the Islamic Republic of Mauritania, the Government of Japan decided to conduct "the Study on Formulation of Geographic Database of Nouakchott" and entrusted the study to the Japan International Cooperation Agency (JICA).

The JICA organized the study team headed by Mr. Eisaku Tsurumi of Pasco Corporation in association with Asia Air Survey Co., Ltd. and dispatched it to Mauritania eight times from April 2007 to April 2010.

Having discussions with the Ministry of Habitat, Urbanism and Territorial Development, Ministry of Environment, Nouakchott City and other organs, the study team formulated the digital geographic database of Nouakchott and conducted technology transfer to the technical staff of Mauritania.

More than 30 stakeholder meetings were held to collect information from various organs concerned during the period; and a seminar in the final stage of the study was held to diffuse the database utilization. After then, the team finalized this report in Japan.

I hope that the database would contribute to rehabilitation and development of Nouakchott and the transferred technologies would be fully utilized for maintaining the database and distributing the data to the public. I also hope that this report would contribute to promote future project and to enhance friendly relationship between the two countries.

Finally, I wish to express my deep appreciation to the officials concerned of the Government of Mauritania for their cooperation extended to this study team.

June 2010

Kiyofumi KONISHI
Director of Economic Infrastructure Department
Japan International Cooperation Agency

Mr. Kiyofumi KONISHI
Director of Economic Infrastructure Department
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Mr. Kiyofumi KONISHI,

It is my great honor to submit you the Final Report on “The Study on Formulation of Geographic Database of Nouakchott in the Islamic Republic of Mauritania” that was implemented based on the contract with your agency.

The study was carried out by the joint venture of PASCO CORPORATION and ASIA AIR SURVEY CO., LTD. from April 2007 to May 2010. The results are 1/20,000 aerial photographs, 1/10,000 topographic maps and their digital data with the GIS database and GIS model systems, and we transferred mapping technologies to technical staffs of the Mauritanian Government.

This report summarizes all the works processed through three phases from fiscal year 2007 and suggests some schemes for diffusing the data to various fields of use. I am convinced that the report will contribute as the base to support the rehabilitation of Nouakchott and its future development.

Finally, on behalf of the Team, I wish to convey my sincere appreciation to the officials in the Direction of Cartography and Geographic Information, and other organs concerned for providing us with facilities and cooperation. I wish also to express my thanks to the officials of your agency and the organs of Japanese Government concerned for providing us with suggestive advices and directions during the implementation of the study.

June 2010

Eisaku TSURUMI
Leader of the Study Team

Direction of Cartography and Geographic Information

Presentation of results of the Study

Discussion between DCIG and the Team

Discussion with technical staffs

Seminar on April 4, 2010

Contents

List of Figures

List of Tables

List of Appendices

List of Abbreviations

ADU	Urban Development Agency
AFD	French Development Agency
CAD	Computer-Aided Design
CC-PDU	Unit of Coordination of Urban Development Program
CUN	City of Nouakchott
DATAR	Direction of Land Development and Regional Action
DCE	Direction of Environmental Control
DCIG	Direction of Cartography and Geographic Information
DEM	Digital Elevation Model
DFE	Direction of Finance and Evaluation
DFIS	Direction of Finance and Infrastructures of School
DGPC	Direction General of Civil Protection
DHU	Direction of Habitat and Urbanism
DIT	Direction of Infrastructures of Transport
DP	Direction of Purification
DPCIE	Direction of Environmental Planning, Coordination and Information
DPRL	Direction of Regional and Littoral Protection
DS	Direction of Healthcare
DTC	Direction of Topography and Cartography
DTP	Direction of Public Works
DU	Direction of Urbanism
EU	European Union
FAO	Food and Agriculture Organization
GCP	Ground Control Point
GIS	Geographic Information System
GPS	Global Positioning System
JICA	Japan International Cooperation Agency
LPS	Leica Photogrammetric Suite
MS	Ministry of Health
OJT	On-the-Job Training
OMRG	Mauritanian Office for Geological Surveys
ONS	National Office of Statistics
RTO	Round Trip Observation

SNDE	National Society of Water
SOMELEC	Mauritanian Society of Electricity
TIFF	Tagged Image File Format
TIN	Triangulated Irregular Network
UNDP	United Nations Development Programme
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations International Children’s Emergency Fund
UTM	Universal Transverse Mercator
WFP	World Food Programme
WHO	World Health Organization
WGS84	World Geodetic System 1984

CHAPTER 1. INTRODUCTION

In response to the request of the Government of the Islamic Republic of Mauritania, the Government of Japan decided to conduct "the Study on Formulation of Geographic Data Base of Nouakchott in the Islamic Republic of Mauritania" (hereinafter referred to as "the Study"). The Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan, sent the Preparatory Mission to Mauritania and made an agreement with the Mauritanian Government on the Scope of Works for the Study (S/W) on December 15, 2006.

JICA organized the Study Team for implementing the project, (hereinafter referred to as "the Team"). The counterpart agency of Mauritanian side is the Direction of Cartography and Geographic Information, Ministry of Habitat, Urbanism and Land Development (hereinafter referred to as "DCIG").

The project started in April 2007 with the aim of providing technical assistance to the Islamic Republic of Mauritania in preparing new maps indispensable for development of the Capital, Nouakchott. The period was divided into three phases. The project finished in May 2010 with achievement of all objectives of the Study.

In the course of the Study, Inception Report, Interim Report, and Progress Report were presented. This Final Report presents all the processes and the final results of the project. It also presents recommendations or suggestions to the Mauritanian Government on geographic data usage, data updating, and data maintenance and distribution.

1.1. Objectives of the Study

The objectives of the Study are:

(1) To take color aerial photographs of Nouakchott and its vicinities at the scale of 1:20,000 and to make digital topographic map at the scale of 1: 10,000.

(2) To create GIS model systems for city planning and management based on the digital topographic map.

(3) To transfer the necessary technology for digital mapping, data updating, and data usage to technical staffs of DCIG and other relevant agencies.

1.2. Study area

The Study area is shown in Figure 1.1 on the next page. The size of the Study area is 2,000 km^2, 69 km at the longest distance in north-south and 32 km in east-west. Color aerial photographs were taken at a scale of 1:20,000 for the whole study area as shown with red lines. Ground control point survey and Aerial triangulation were conducted for the whole photographed area. Based on the aerial photographs and the results of ground control point survey and aerial triangulation, the area of 1,200 km^2 shown with blue lines was mapped at a scale of 1:10,000. The mapped area is divided into 47 map sheets as shown with thin black lines.

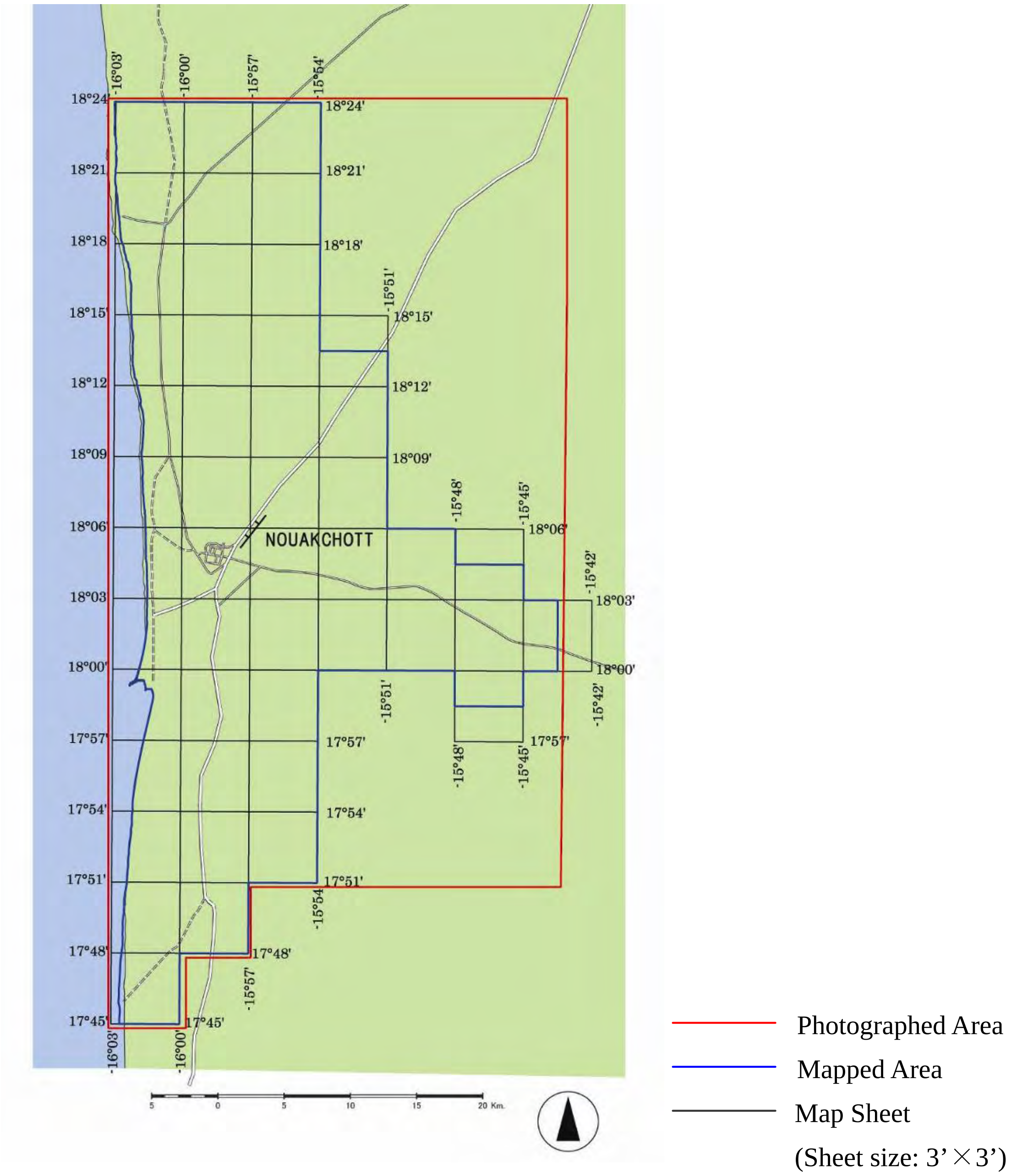


Figure 1.1 Study area

1.3. Context of the Study

(1) Growth of population in Nouakchott

The population of Nouakchott, the capital of Mauritania, has rapidly grown with increasing speed for these decades due to mass migration from rural regions for better employment opportunities and living conditions. Most of the migrants have formed informal settlements in and out of the town. These settlements are poorly equipped with basic public facilities and services such as water supply, sewage disposal and garbage disposal.

The above conditions have caused serious problems in sanitation, protection against disasters and so on. Moreover, the rapid population growth has caused a variety of urban problems. The national government and the government of Nouakchott (CUN) are required to take urgent measures against these problems.

(2) Urban development planning

On the other hand, there are new urban development plans for future and some ongoing projects at present in Nouakchott. They are, for instance, constructions of main road networks, new international airport, and resort development. These plans are expected to make big effects encouraging economic activities of the city. The recent project of offshore oil production may have a big impact upon the activities as well.

(3) Necessity for new geographic data

Any planning of new project of urban development requires updated geographic data. Geographic data is also required for executing and managing ongoing projects of urban development. For the Nouakchott area, however, geographic data which satisfy these requirements had been unavailable for many years.

The existing maps covering the areas where the above-mentioned problems take place are outdated and they are not in digital form. The absence of useful data had made it difficult for decision makers and urban planners to perform their tasks. Therefore, they had been anxious to use some well-updated and detailed geographic data in digital form for their analyses and designing. In order to catch up with their requirements, this mapping project was started and achieved.

This mapping project aims to supply the data indispensible for taking measures against the problems from various viewpoints such as protection from disasters, environmental conservation, urban rehabilitation and new urban development, and economic development and stabilization.

1.4. View of the Study area

As mentioned in Section 1.3, the population of Nouakchott has grown rapidly due to mass migration. According to the Census 2000, the population of Nouakchott Capital District (Wilaya de Nouakchott) was 558,195. It was about 22% of the national population. There is an estimated population of 800,000 for 2008. Some source says that the ratio to the national population is one-third at present.

It is reported that the recent serious droughts caused the migration from rural regions, where most people are nomadic. According to the Bureau of Statistics, nomadic people were 12% of the total population in 1988, while it is 5.1% in 2000. The present percentage is presumably much less.

Most of the migrants settled down in several places in the town and its surroundings without being controlled. They built small houses to live disorderly with materials available at hand. Especially in communes of El Mina, Arafat and Toujounine, large-sized precarious settlements are developed. These small houses are precisely plotted on the map produced under this project. These settlements have raised difficult problems for the urban planning of the capital.

As a whole, the population growth has raised not only the above-mentioned problems but also various problems such as people's safety, sanitation and health, employment and children's education. Public facilities such as water stations and schools are thoroughly shown on the map.

On the other hand, the recent economic activities in some sectors of business raise construction of new buildings and related objects, which make an impact on the conditions of the central part of Nouakchott and brings about a rapid change of land use and environment.

It should be a great concern that the Nouakchott is absolutely limited in capacity for holding such a large population that has grown without care and control. First, it is essential to review and examine the physical geography of this area in order to find the capacity of this area. After then, solutions should be pursued from various points of view.

Mauritania is bordered on the west thoroughly by the coastline of the Atlantic Ocean, which is over 600km in length. Sand beaches are predominant throughout the coast. For the southern-half portion of the coast, from Râs Timirit to the mouth of Senegal River, an arc-shaped sand beach extends for 400km without a break.

Along the coast, there is a long and flat lowland (coastal plain) extending from the north of

Nouakchott to the Senegal River mouth. This is called “Aftout essaheli”

The lowland is bordered on the west by a beach ridge (cordon littoral) which extends parallel with the sand beach. Top of the ridge overlain by coastal sand dunes is less than 10 meters above the sea level and the lowland is -2 to 4 meters.

The lowland is bordered on the east by the sand dune area of the Sahara Desert. Nouakchott is developed over the lowland and sand dune area.

It is inferred from geomorphologic aspect and deposit of a large quantity of shells in the soil that the lowland used to be a lagoon when the beach ridge had not been fully developed or it was broken as the result of some natural event in the recent geologic history. The lowland is characterized by hard and impermeable layers of gypsum on the surface. The Study area is included in arid zone. The average annual precipitation at Nouakchott is less than 130mm. There is no perennial stream in the Study area. However, in case of an intensive rainfall, the lowlands are liable to be flooded. The inundation stays long where the ground is under sea level and/or the surface materials are impermeable. The most recent inundation occurred in September 2009.

Historic record says that Nouakchott suffered inundations which originated from Senegal River in 1890, 1932, 1950 and 1987. Flood water came to Nouakchott traveling through Aftout essaheli for a distance of 180km. It is reported that the risk of Senegal-origin floods have been minimized since the construction of dams in 1986 and 1987.

Inundations are also caused by outbreak of the beach ridge when a storm surge attacks the coast. A gap (brèche) on the ridge is liable to be broken. It is reported that some gaps were formed by production of sand and shells for materials of concrete, and some are by driving vehicles on the beach. It is reported, however, that such mining and driving are restricted today. Several gaps have been filled up and conserved by planting.

Gaps in high risk of outbreak are found on the south of the Port de l’Amitié. They were formed by beach erosion caused by strong shore current. The coastline of Nouakchott had ever been very simple in arc-shape. Shore current along the Mauritanian coast flows from north to south at a constant speed, but after construction of the jetty of the port, the current was forced to change its behavior subject to hydromechanics. As a result, the coastline became exceptional in shape only around the port, that is, on the north of the jetty sand sedimentation occurred to form a large sand beach, and on the south of the jetty the beach was eroded and retreated to form gaps.

In addition to the above-mentioned, Nouakchott has another risk, that is, sand dune encroaching on the fringes of the town. Attempts to apply vegetation belts have been made on the surrounding areas. On the map produced under this project, details of sand dunes are shown with precise contour lines of 2 meter interval and green belts are plotted.

Above-viewed aspects of the Study area are summarized in the diagram below.

Relation between physical condition and social problems in Nouakchott

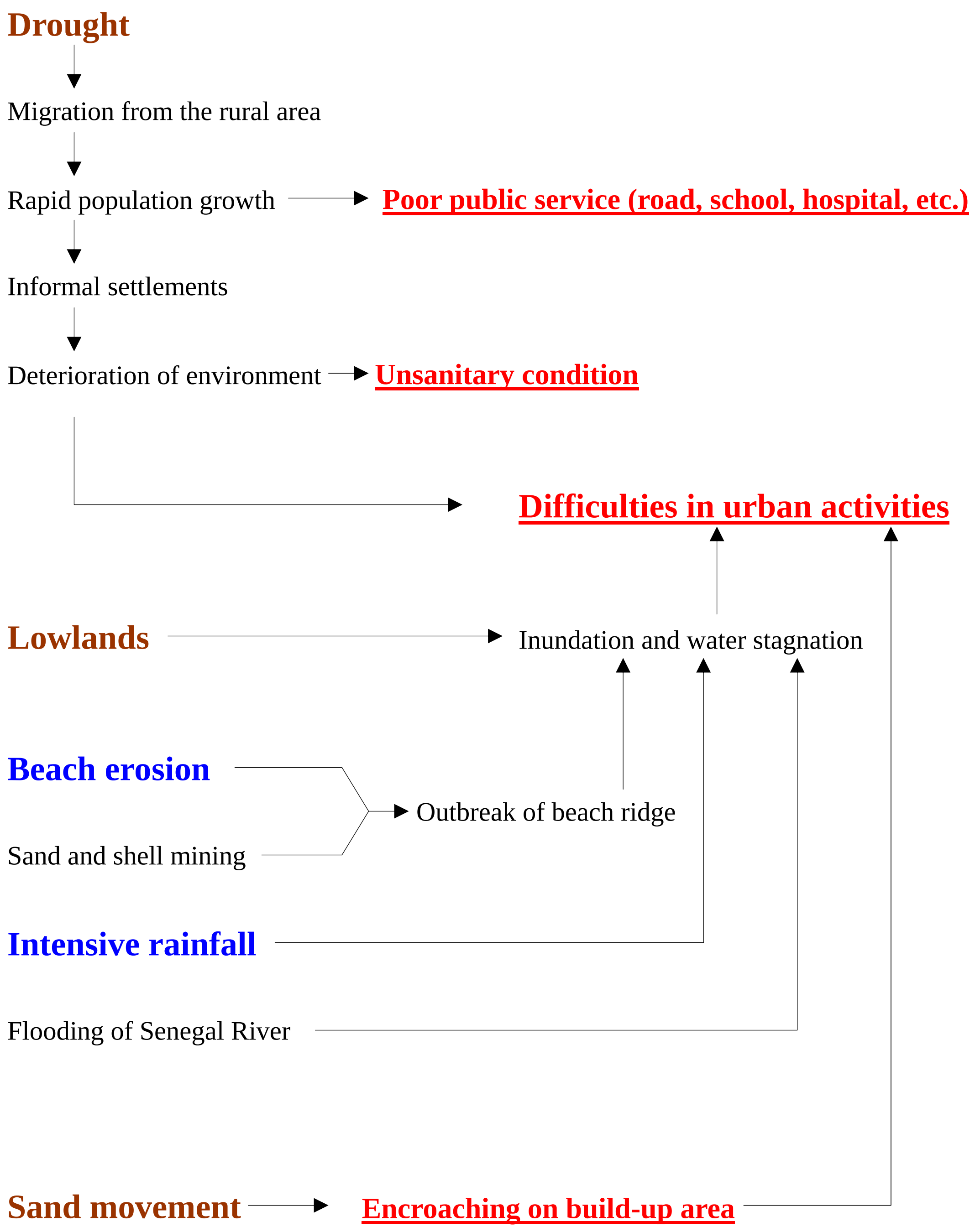


Figure 1.2　Residential area of Nouakchott

Figure 1.3　Precarious settlement

Figure 1.4　Main water pipe

Figure 1.5　Water station and donkey

Figure 1.6　Water station and water truck

Westward

2007 2010

Southward

2007 2010

Northward

2007 2010

Figure 1.7 View from Hotel Al Khaima - Land use change in the central part of the city

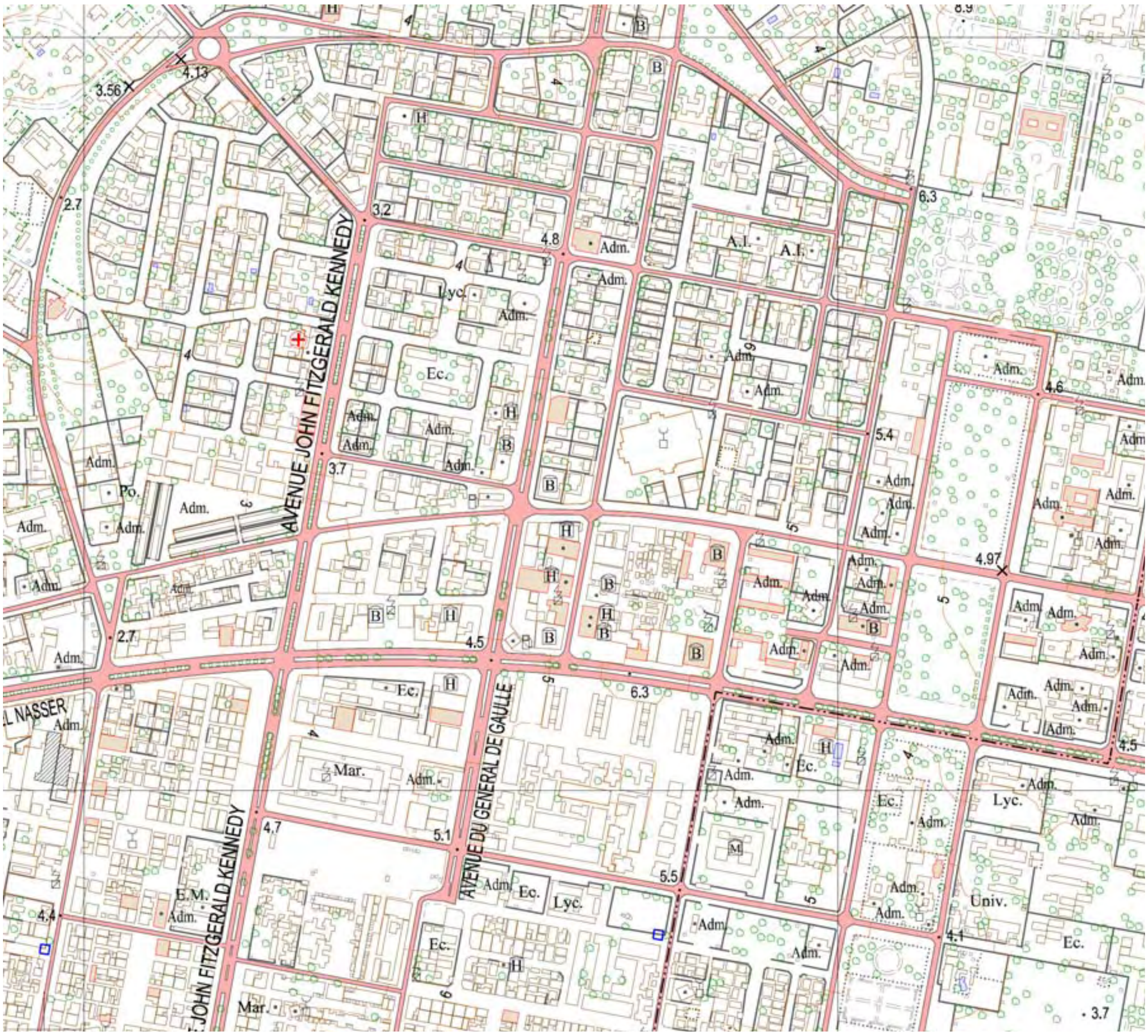


Figure 1.8 Topographic map of the central part of the city

Figure 1.9 Residential district under construction

Figure 1.10 Central part of the city

Figure 1.11 Shells on the surface of the lowland

Figure 1.12 Gypsum layer

Figure 1.13 Port of Friendship

Figure 1.14 Beach ridge with planted vegetations

Reference materials

Ministére de la Culture, de la Jeunesse et des Sports : Nouakchott, Capitale de la Mauritanie, 50 ans de défi. Editions SEPIA (2006)

Office National de la Statistique: Population des Communes, R.G.P.H 2000

Office National de la Statistique: Recensement général de la population et l'habitat 2000 (2003)

Office National de la Statistique: Projections démographiques 2001 – 2015 (2004)

Ministére de l'Equipement et des Transports : Schema Directeur d'Aménagement Urbain de Nouakchott, Horizons 2010 - 2020. Agence de Développement Urbain (Mai 2003)

Ministère de la Santé et des Affaires Sociales: Annuaire des Statistiques Sanitaires Année 2004 (2005)

Cellule de Coordination Programme de Développement Urbain: Etude de l'environnement aux abords de Nouakchott 1. Etude de l'environnement littoral, 2. Recherche de zones d'extraction de matériaux de construction. (Mai 2004)

Plan d'action national de gestion des risques de catastrophes (PANGRC) (Octobre 2007)

Plan d'action national pour la prévention et la gestion des risques de catastrophes en Mauritanie, Résumé executive

DCIG: Plan d'action annuel 2008

DCIG: Plan d'action annuel 2009

DCIG: Plan d'action annuel 2010

BSA ingénierie: Plan général de la ville de Nouakchott (1:30,000 et 1:14,000) (2004)

1.5. Sequence of the project

In the first phase (from April 2007 through March 2008), Aerial photography, Ground control point survey, Field identification, Aerial triangulation and Digital plotting were carried out as planned. They were completed with satisfactory results. The Ground control point survey and Field identification were done as an OJT. In addition, formulation of the concept of GIS data and model system was investigated with collected documents and on-site surveys. The Interim Report concerning these works was presented to DCIG in July 2008.

In the second phase (from May 2008 through March 2009), Digital compilation, Field completion, Supplementary map compilation, Map symbolization, Data structurization, and Creation of GIS model systems were carried out. The above Field completion was done as an OJT. In addition, technology transfer of Aerial triangulation and Data structurization were conducted to technical staff members. The Progress Report reporting the processes and results of these mapping works and the technology transfer was presented to DCIG in February 2009.

In the third phase (from May 2009 through May 2010), topographic mapping at a scale of 1:10,000 and formulating its geographic database were carried out to complete the final products, and technical training on the remaining subjects were conducted. In the last stage of the phase, a seminar was held on April 4, 2010 in Nouakchott to diffuse the usage of the results of the Study to potential users who were interested in the products. Program of the seminar is attached as APPENDIX 9.

Whole process of the project is shown in Figure 1.15. Because of a suspension of works due to political movement in Mauritania, the original plan of works for the second and third phases was partially changed.

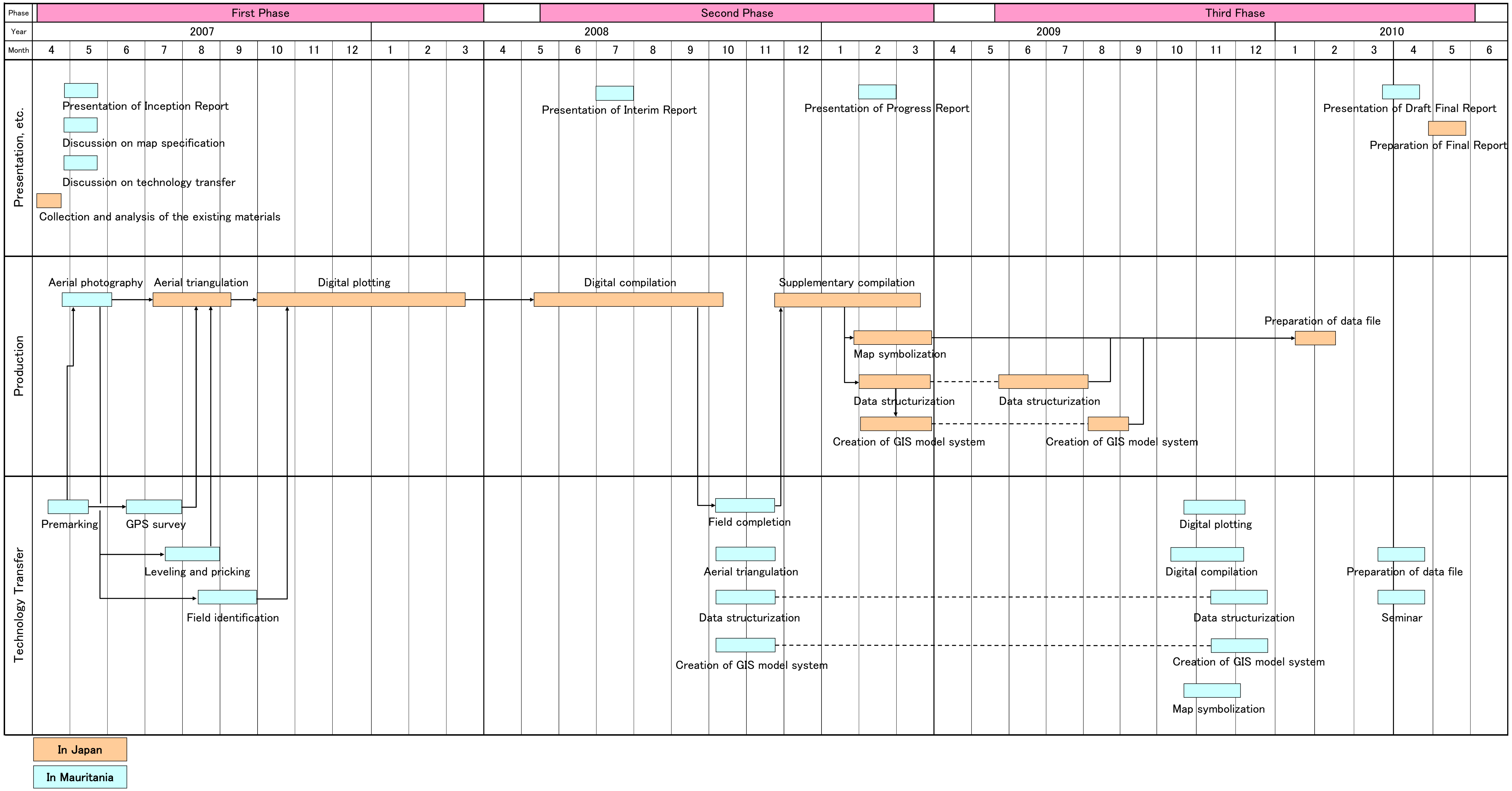


Figure 1.15 Chronogram of the works of the project

1.6. Counterpart agency

The Direction of Topography and Cartography in the Ministry of Equipment and Transport (hereinafter referred to as “DTC”) was the counterpart agency to the Team in the beginning of the first phase of the Study. Soon after then, with reorganization of the Government, DTC moved to the Ministry of Equipment, Urbanism and Habitat. Soon after then again, DTC was reorganized as the Direction of Cartography and Geographic Information (hereinafter referred to as “DCIG”) belonging to the Ministry of Decentralization and Land Development. With this reorganization, the counterpart agency to the Team has been changed to DCIG, which succeeded the discussions and agreements already made between DTC and the Team. After the political change of August 2008, DCIG moved to the Ministry of Habitat, Urbanism and Development of Territory.

In this report, the counterpart agency of Mauritania is to be called “DCIG” instead of “DTC”.

1.7. Constitution of the project

Works in Mauritania were carried out in collaboration between the Team and Mauritanian side.

Field works, that is, Control point survey, Field identification and Field completion were performed by technical staff members of DCIG and other organizations under the control of the Team members as the on-the-job-training (OJT) scheduled in the program of technology transfer. Results of these works were fully employed in map making in Japan.

All members of the Team sent to Mauritania are listed in APPENDIX 1. The technical staff members of Mauritania are listed in APPENDIX 2.

1.8. Coordinating Committee

During the first phase, the Team recommended to Mauritanian side to organize the Coordinating Committee for coordinating user’s needs and promoting usage of geographic database. On May 24, 2007, DTC invited the Standing Commission of the National Committee of Remote Sensing (CNT) to a meeting on organizing the Coordinating Committee. Then, the Mauritanian side started the preparation to organize it, and completed the draft of the ordinance for organizing the National Commission of Geographic Information (CNIG). The draft depends on approval of the government now.

The product of this study will be subjected to this committee, after it is established.

The Team had recommended to set up the committee soon, where the Team would present usefulness of the geographic database produced under this project.

In addition, since the beginning of the project, the Team had visited governmental and non-governmental organs and collected a lot of information relating to the needs of these organs,

in order to develop reliable databases and GIS models.
The organs are as follows,

National Office of Statistics (ONS)
Direction of Habitat and Urbanism (DHU)
City of Nouakchott (CUN)
Urban Development Agency (ADU)
Unit of Coordination of Urban Development Program (CC-PDU)
Direction of Areal Protection and Littoral (DPRL)
Direction General of Civil Protection (DGPC)
Direction of Public Works (DTP)
Direction of Infrastructure and Transport (DIT)
Direction of Environmental Control (DCE)
Direction of Environmental Planning, Coordination and Information (DPCIE)
Ministry of Health (MS)
Direction of Purification (DP)
National Society of Water (SNDE)
Direction of Finance and Infrastructures of School (DFIS)
Mauritanian Society of Electricity (SOMELEC)
Mauritanian Society of Telecommunications (MAURITEL)
Mauritanian Office of Geological Survey (OMRG)
World Bank

In addition, the Team visited several organs to present GIS models for the purpose of diffusion of GIS usage, which is presented in CHAPTER 4.
The themes selected for GIS model systems are given in CHAPTER 4.

1.9. Technology transfer

Technology transfer to DCIG technical staffs and other organization's staffs was made. All the trainees are listed APPENDIX 2. The subjects are Premarking (Setting of Aerial Signal), GPS Survey, Leveling and pricking, Field Identification, Field Completion, Aerial Triangulation, Digital Plotting, Digital Compilation, Digital Map Symbolization, and Data Structurization. They are summarized in Table 1.1.

Table 1.1 Technology transfer sessions

Subject	Period	Number of trainees
Premarking (Setting of Aerial signal)	May 2007	4
GPS Survey	June - July 2007	4
Leveling and Pricking	July - August 2007	4
Field Identification	August - September 2007	4
Filed Completion	October - November 2008	11
Aerial Triangulation	October - November 2008	2
Digital Plotting	November - December 2009	1
Digital Compilation	November - December 2009	2
Data Structurization	October - November 2008	2
	November - December 2009	5
Symbolization	November - December 2009	2

1.10. Final products of the Study

The final products of the Study delivered to the Government of Mauritania are listed in Table 1.2 below.

Table 1.2 Final products

	Items		Quantity	Remarks
(1)	Study Report			
	1) Inception Report	English	10 copies	
		French	10 copies	
	2) Interim Report	English	10 copies	
		French	10 copies	
	3) Progress Report	English	10 copies	
		French	10 copies	
	4) Draft Final Report			
	Main Report	English	10 copies	
		French	10 copies	
	Summary	English	10 copies	
		French	10 copies	
	5) Final Report			
	Main Report	English	10 copies	
		French	10 copies	
	Summary	English	10 copies	
		French	10 copies	
	CD-ROM		1 set	
(2)	Study Results			
	1) Aerial Photograph (1:20,000 Color)			2,000km^2
	Original negative film		1 set	2 rolls
	Digital data		1 set	478 frames
	Contact prints		1 set	487 frames
	Flight index		1 set	
	2) Results of Control Point Survey		1 set	2,000km^2
	3) Results of Aerial Triangulation		1 set	2,000km^2 463 models
	4) Digital Data File		2 sets	1,200km^2 DXF, KML, PDF
	5) GIS Models, etc		2 sets	

CHAPTER 2. PROCESS AND RESULT OF THE STUDY

The Team started the first phase of the project in April 2007. At the beginning of the project, in May 2007, the Team presented the Inception Report to DTC. Both sides had discussion on this report and agreed on basic policies for the Study, surveying standards, methods, schedule, etc. Then, both sides had a series of meetings to discuss specifications for acquisition of topographic data, map symbols and marginal information, and program of technology transfer and they reached agreements on these matters.

Processes of the mapping works and the results are presented in this CHAPTER. The volumes of the works are shown in Table 2.1, Table 2.2 and Table 2.3 below.

Figure 2.1 Presentation of the Inception Report

Table 2.1 Mapping works and their volumes in the first phase

Item	Area	Description and volume	Remarks
Aerial photography	2,000 km^2	Scale: 1:20,000 Color photography 14 runs 478 frames	Airborne GPS method
Ground control point survey	2,000 km^2	Premarking of GPS points (22 points) GPS observation (23 points, 11 sessions and one base line) Leveling (6 routes, 200km) Pricking (135 leveled points)	OJT in Mauritania

Photo scanning	2,000 km^2	Acquisition of digital data of photo image by film scanner 478 frames	In Japan
Orthophoto printing	1,200 km^2	Scale: 1:10,000 47 sheets	In Japan
Field identification	1,200 km^2	Preliminary photo-interpretation On-site verification and checking	OJT in Mauritania
Aerial triangulation	2,000 km^2	463 models	In Japan
Digital plotting	1,200 km^2	Scale: 1:10,000 47 sheets	In Japan

Table 2.2 Mapping works and their volumes in the second phase

Item	Area	Description and volume	Remarks
Digital compilation	1,200 km^2	Scale: 1:10,000 47 sheets	In Japan
Provisional map symbolization	1,200 km^2	Scale: 1:10,000 47 sheets	In Japan
Field completion	1,200 km^2	On-site verification and checking	OJT in Mauritania
Supplementary map compilation	1,200 km^2	Scale: 1:10,000 47 sheets	In Japan
Map symbolization	1,200 km^2	Scale: 1:10,000 47 sheets	In Japan
Data Structurization	900 km^2	Structurization from the compiled plotting data	In Japan
Creation of GIS model system	900 km^2	GIS Model System for Address Search / Display GIS Model for Potential Flood Risk Management GIS Model for Water Supply Facility Management GIS Model System for Facility Management	In Japan

Table 2.3 Mapping works and their volumes in the third phase

Item	Area	Description and volume	Remarks
Data Structurization	300 km^2	Structurization from the compiled plotting data	In Japan
Creation of GIS model system	300 km^2	GIS Model System for Address Search / Display GIS Model for Potential Flood Risk Management GIS Model for Water Supply Facility Management GIS Model System for Facility Management	In Japan

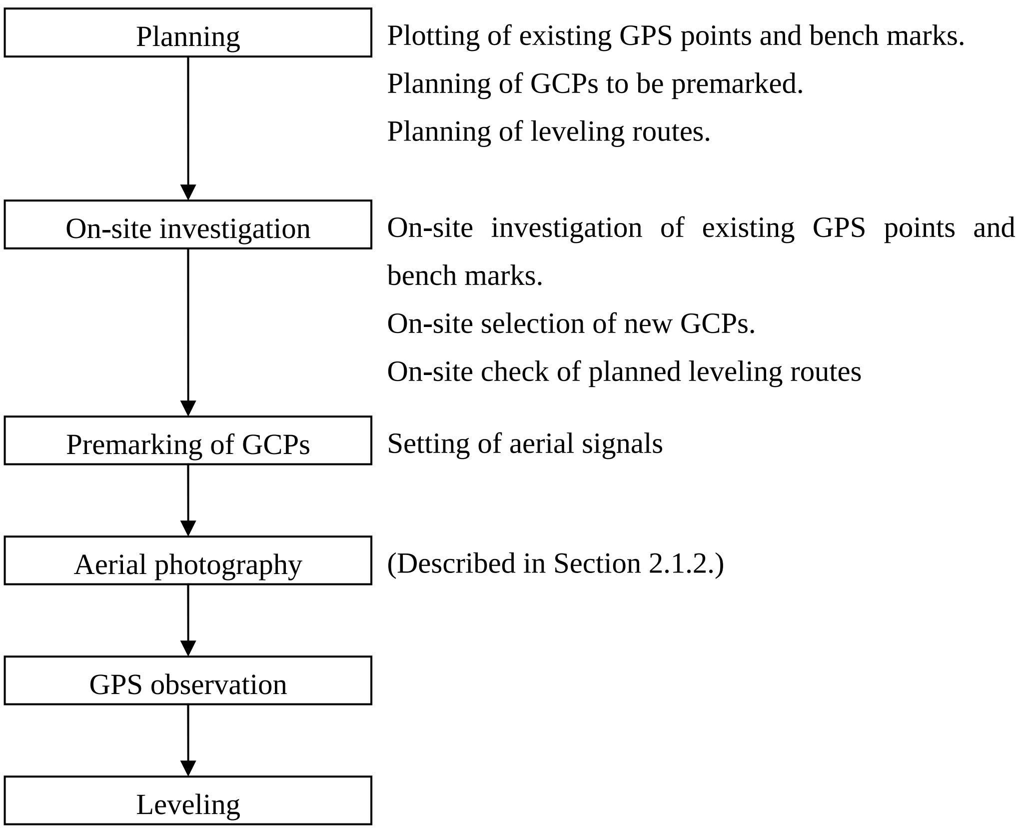
In addition to these mapping works, technology transfer was made. The result is presented in CHAPTER 3.

2.1. Works for the first phase

After the above-mentioned agreement with DTC on implementing the project, Aerial photography, Ground control point survey, Field identification, Aerial triangulation and Digital plotting were carried out as planned. The first phase finished in March 2008.

2.1.1. Ground control point survey (in Mauritania)

Ground control point (GCP) survey was conducted from April through August 2007 in the following work flow.



Ground control points are required to be definitely identified on the photographs for making an effective aerial triangulation. Since it was foreseen that pricking of GCPs would be very difficult for the greater part of the Study area because the area was too monotonous in topography and lacks peculiar objects, the Team adopted Premarking of GCPs with aerial signals before aerial photography.

Figure 2.2　　Technical staffs of Mauritania　　Figure 2.3　　Existing GPS point (AZ 001)

First of all, GCPs to be premarked were planned in the office. Leveling routes were also planned.

The points to be premarked were planned considering the following points.

- Adoption of the existing control points and bench marks.
- On the corners of the mapping area.
- Easy accessibility.
- Easy recognition on the aerial photograph.

Next, these planned GCPs were investigated on-site and exactly determined for setting up.

On-site investigation and verification of all the planned points and leveling routes were done keeping the following points in mind.

- Accessibility to each point.
- Suitability of grounds.
- Open space where there was no obstacle to aerial photograph shooting.

As the result of the on-site investigation, 23 points were set up. Among them 22 points were those to be premarked. The southernmost existing GPS point (AZ 003) is not included because it is out of the photographing area.

According to the above points, leveling routes were also decided with on-site investigation. Five existing bench marks were found available for reference. Among the GCPs, 13 points were planned to be leveled. They are also shown in Figure 2.4.

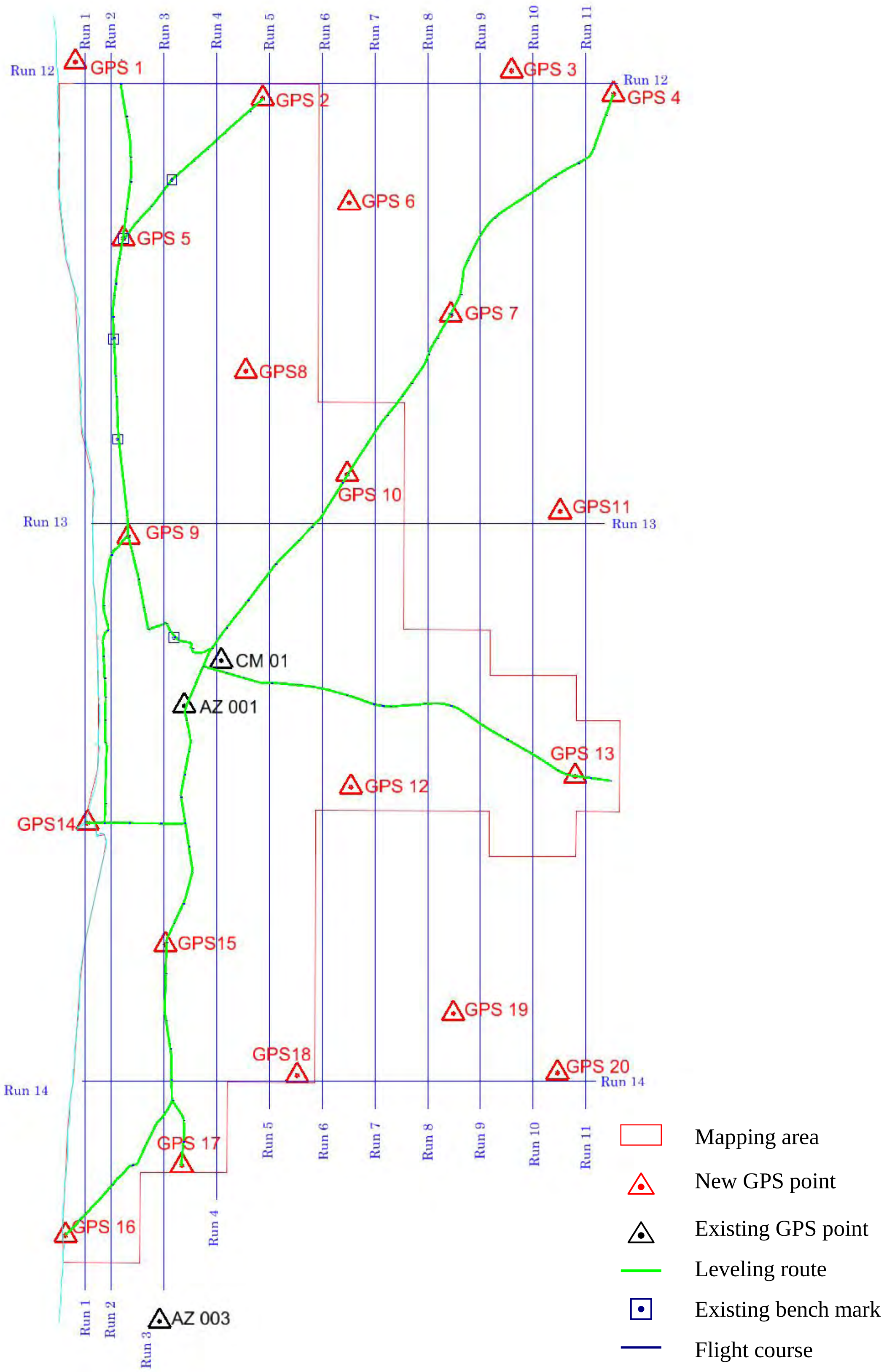


Figure 2.4 GPS points and leveling routes

a) Premarking of ground control points

Aerial signals were set up at the 22 GCPs before the aerial photography in April 2007. A signal is made of following materials,

- It is composed by a block and three blades.
- A blade is formed by 5 black-painted sand bags.
- The size of a blade is 3m x 0.7m.
- The block is made of concrete and a nail is driven on the center of the top.

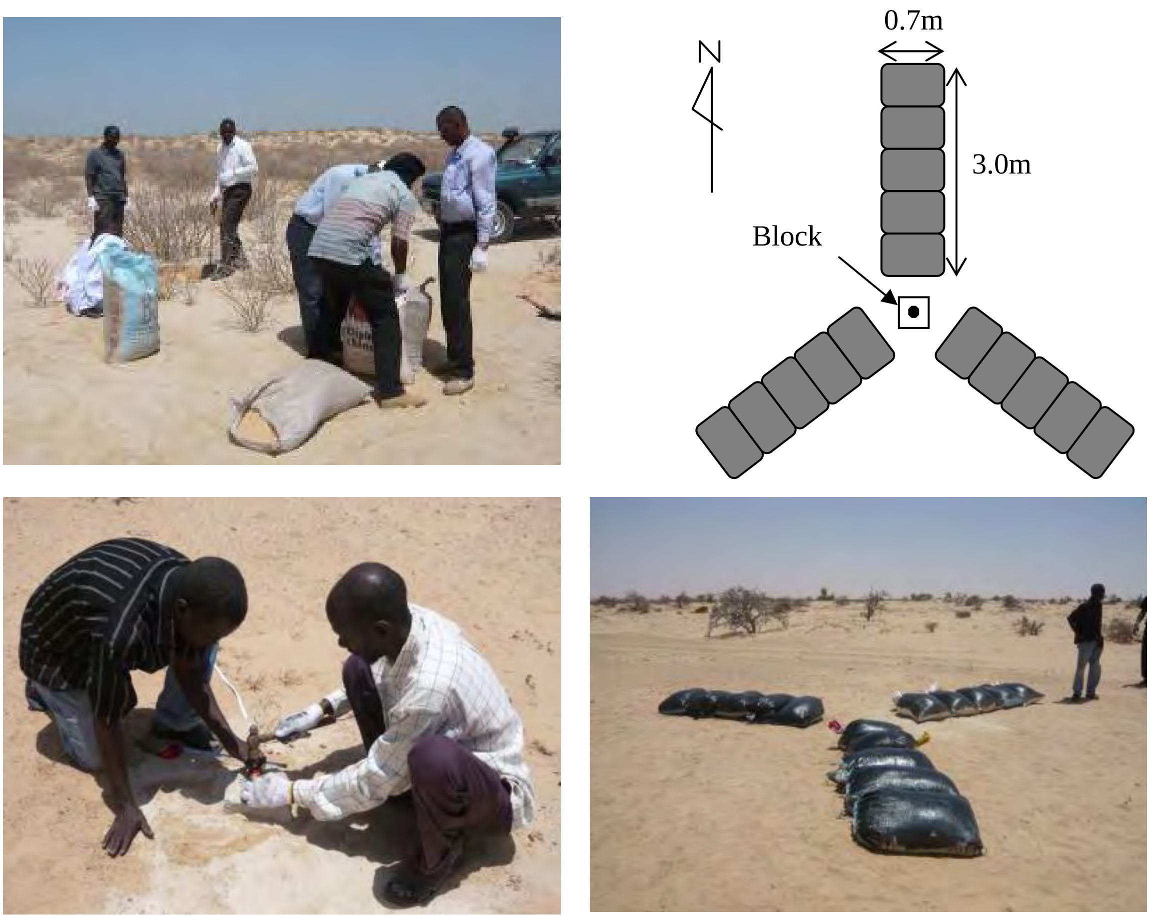


Figure 2.5 Aerial signal setting

b) GPS observation

GPS observation was performed in July 2007 for a total of 11 sessions and one base line organized with the 20 new GCPs and 3 existing GPS points. The sessions are shown in Figure 2.6.

The loop closing error was designed as not to exceed plus or minus 10mm + 2ppm x D (distance of baseline) in any closed polygonal route on the network after the baseline processing.
A total of 13 points were directly leveled and the elevations of the remaining 10 points were determined based on a geoid obtained by the GPS leveling.
The following observation method was applied to the geodetic network.

- Method: Simultaneous data receiving with more than three observation points.
- Type of GPS receiver: Dual frequency.
- Observation time: 2 hours as a rule
- Number of satellites received at one time: More than 5
- Number of existing control points to be connected: 3

As a result of pre-network adjustment, inconsistency between the 3 existing GPS points (CM01, AZ001, AZ003) was found to occur. DCIG specified CM01 to take part of the reference point in the network adjustment, because this point had been used as reference point for other surveys and would be well-protected in the future due to its location in an international airport.
3D Network adjustment was automatically made by Leica Geo Office with the result of Leveling. The result of 3D network adjustment was projected to UTM Zone 28.

The GPS coordinates obtained by the computation are listed in APPENDIX 3.
The result of loop and misclosure is shown in APPENDIX 4.

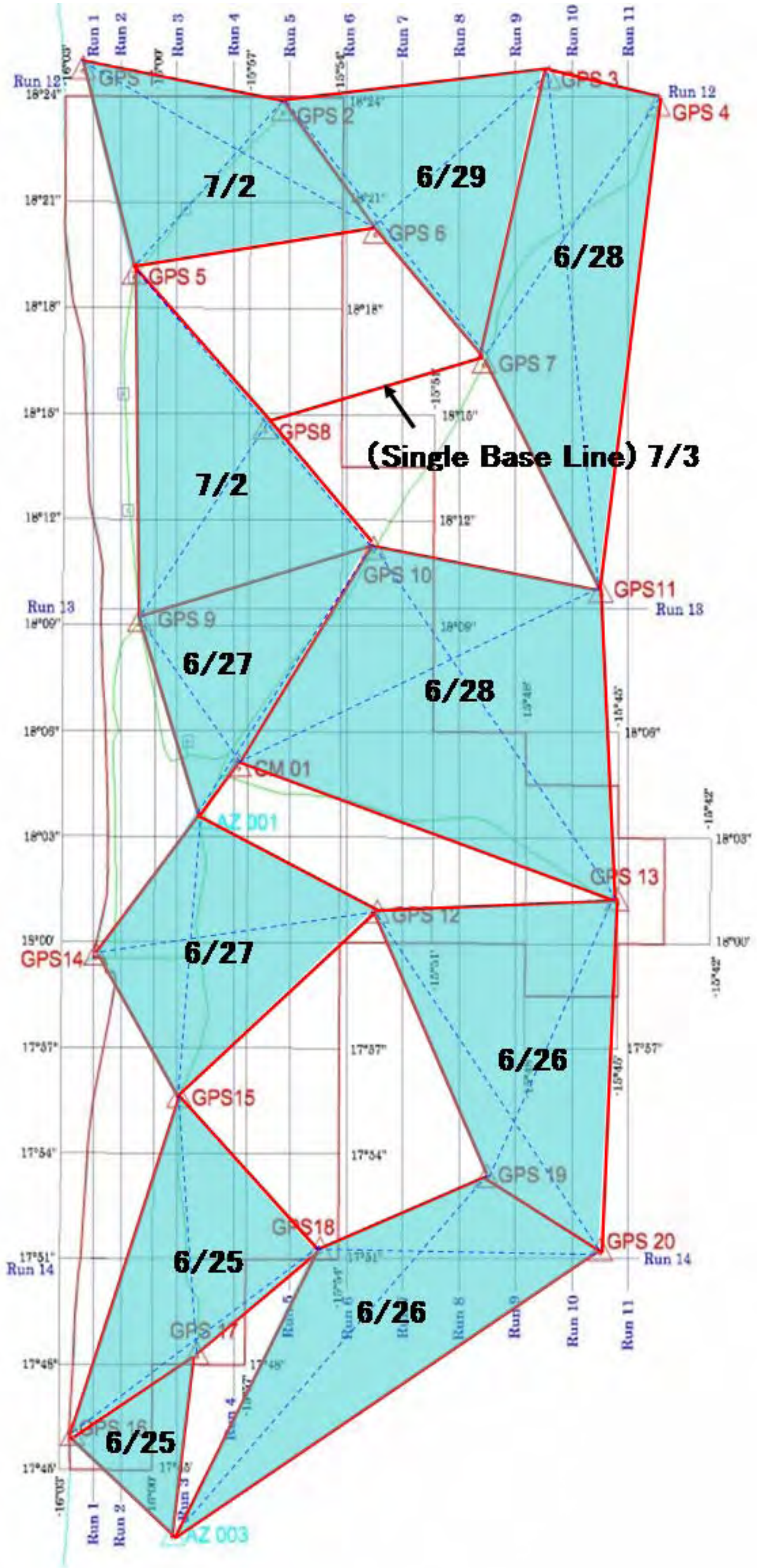
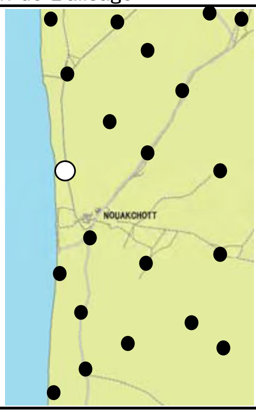


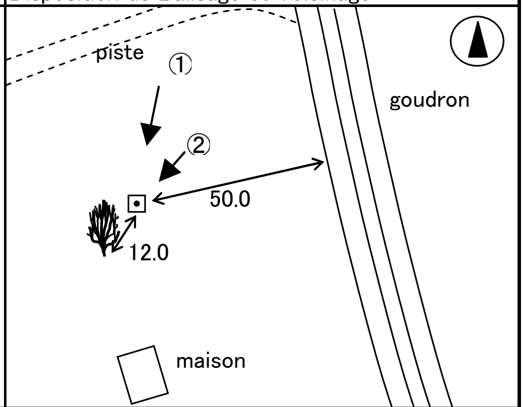
Figure 2.6 GPS observation network

c) <u>Preparation of point description</u>

Descriptions of GPS point were prepared after completion of the observation. The description of GPS point No 09 is shown in Figure 2.7 as an example.

Description de point de balisage(GPS)				
Numéro de Station	U.T.M (WGS84 Ellipsoid)	Préparé par	Date	
GPS 09	Zone28	JICA	Mai 2007/Jul 2007	
Point	Nord (x)	Est (y)	H	GH
Point Principal	2007024.199	393248.407	1.287	5cm
Point Excentrique				
Disposition de Balisage		Disposition de Balisage et Voisinage		





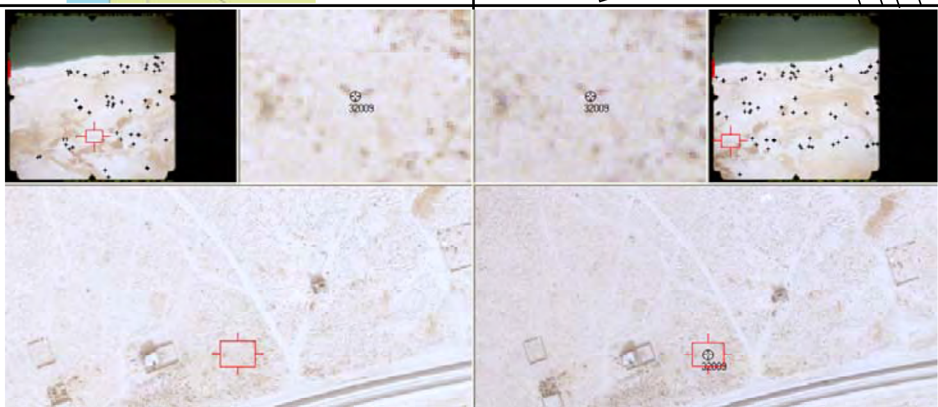


Figure 2.7 Point description of GPS point

Figure 2.8 GPS observation at a point (GPS20)

d) Leveling

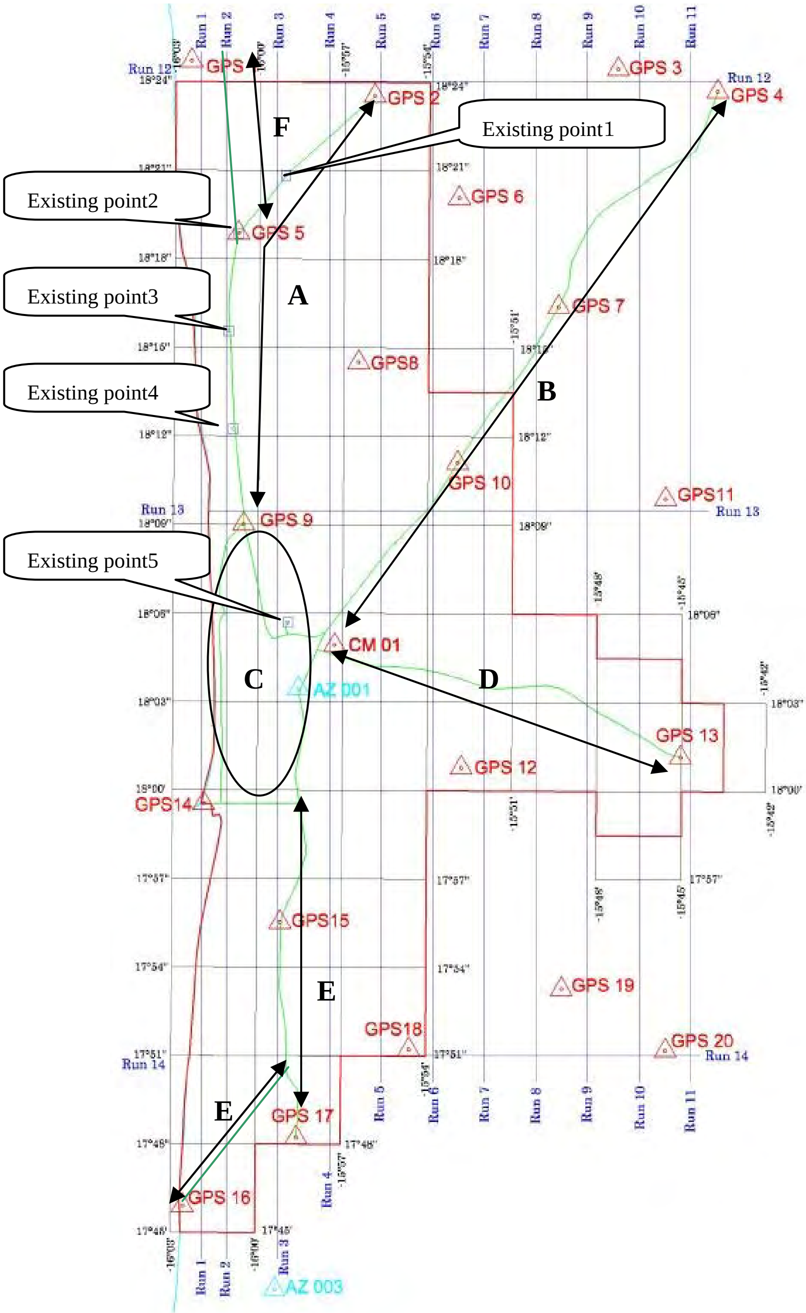
As a result of on-site investigation, 5 existing bench marks were found to be available for reference. A total of six leveling sections were set up along major roads including three national roads. The existing bench marks and 13 of the observed GPS points are included. Observation was performed in August 2007 for a total length of 200 km.

In the leveling work, the round trip observation (RTO) is performed in general. In this project, however, the Team adopted simultaneous one-way observations by 2 parties, because it was found that the skill and experience of the trainees were not enough for RTO and the Team considered that the method of one-way observation is the best way for effective instruction to the trainees under the condition of limited number of Team members and period.

The following observation method was applied to the leveling.

- Type of leveling equipment: Auto-Level (Leica SPRINTER100)
- Number of leveling equipment: 2 Auto-Levels, 2 staffs
- Staffs: Aluminum, Sectional, 3m
- Observation method: Simultaneous observation by 2 groups
- Pricking: At the pitch of 1km

The results were checked and found to be satisfactory in accuracy.



Leveling Section	Definition
LS_A	LS-C -GPS2
LS_B	LS-C -GPS4
LS_C	The circle based on French embassy
LS_D	LS-C -GPS13
LS_E	LS-C -GPS17
	GPS17-GPS16
LS_F	GPS5-near GPS1

Figure 2.9 Leveling sections

Figure 2.10 Leveling

e) <u>Pricking</u>

Those selected from the leveled points at the pitch of approximately 1 km were pricked on the photographs in order to acquire the vertical control points for aerial triangulation. A total of 135 points were pricked. The pricked points are shown in Figure 2.11. The coordinates of pricked points are shown in APPENDIX 5.

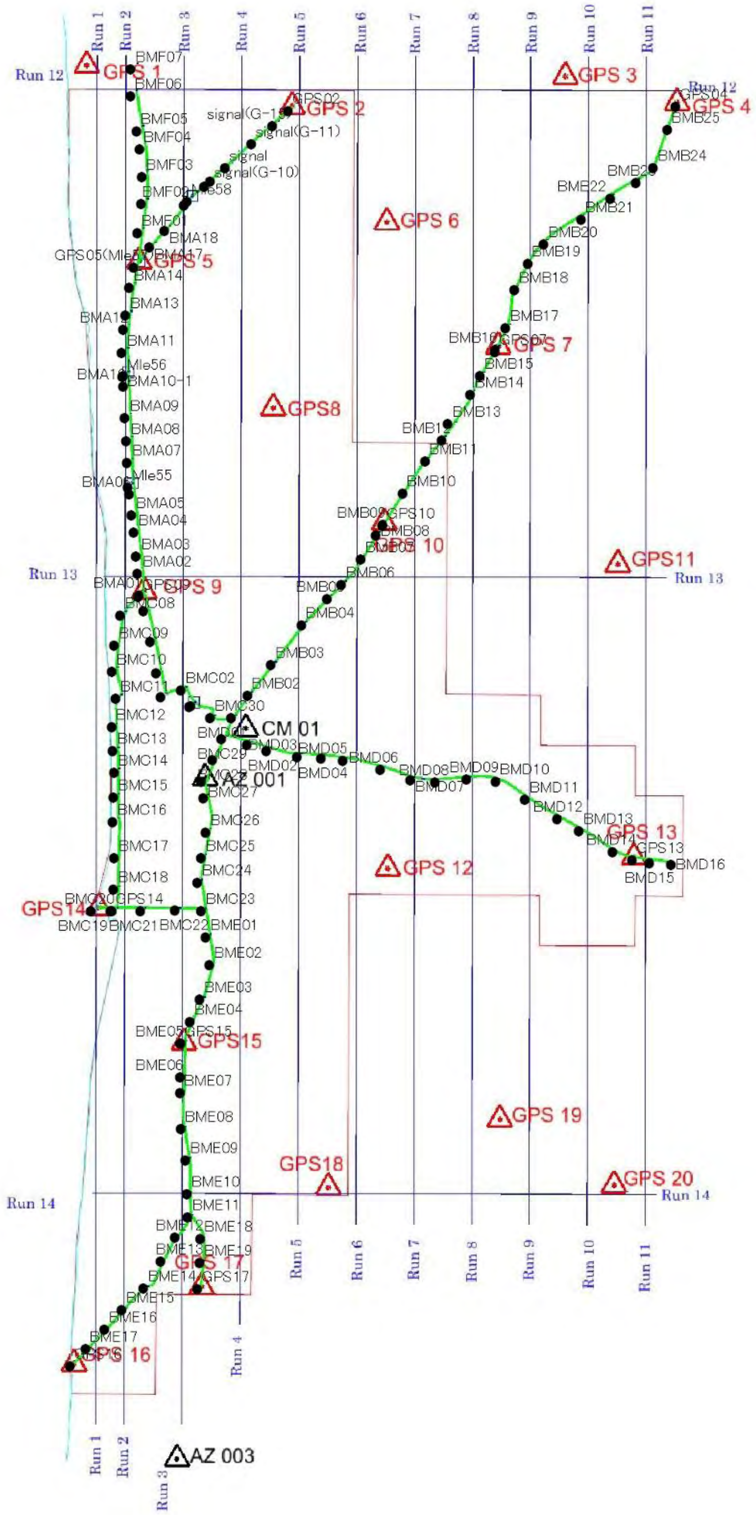


Figure 2.11 Pricked points

2.1.2. Aerial Photography (in Mauritania and Japan)

Aerial photography took place from April through June 2007 by a subcontractor under the control of the Team. The Study area (2,000 km^2) was completely photographed with a scale of 1:20,000 in color. A total of 478 frames were obtained.

Figure 2.12 Aircraft used for the aerial photography

The aerial photography was made by the airborne GPS method, with which the number of ground control points to be observed were much reduced.

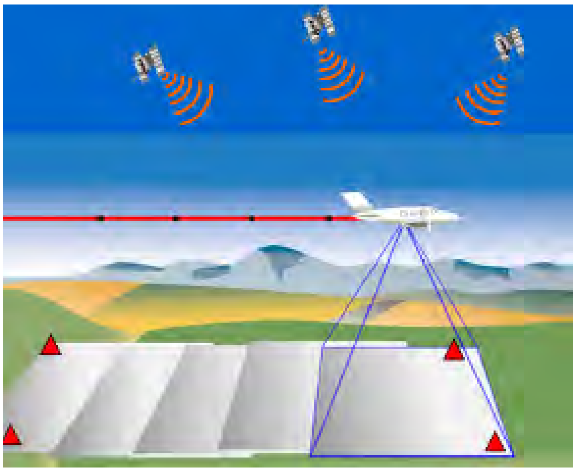


Figure 2.13 Diagram of aerial photography by airborne GPS Method

After shooting, the Team inspected all the photographs using the rush prints. These photographs were found satisfying the specifications.

a) Permit

DTC sent letters to Ministry of Interior and Ministry of Defense on 18 April 2007 asking for necessary permits to conduct the aerial photography. A permit document was received on 16 May 2007.

b) Planning and implementation

- **Preparation:** The tentative flight plan that had been made in advance was finally checked and necessary adjustment was made prior to the installation of data in the navigation system.
- **Flight Plan** : All the flight lines were decided using the Tracker flight planning software.
- **Shooting** : All the aerial shootings took off from Nouakchott International Airport. The first flight was carried out on May 29, 2007 and photography of the entire study area was completed on May 30, 2007.
- **Condition of photography** : The aerial photography was performed only when the angle of the sun above the horizon was 30 degrees or more.

c) Specifications

The shooting was made on the following specifications.

- **Used specification for aerial photography**

Scale of Photography	1:20,000
Camera specifications:	LeicaRC-30 or equivalent (f= 152 mm, 23 cm ×23 cm)
Flight altitude to planned elevation:	within 3,000m ± 5% from the ground
Overlap	Forward overlap 60 ± 5%
	Sidelap 30 ± 10%
Tolerable cloud cover:	Within 3% of successive 5 frames of photographs (excluding parts necessary for plotting orientation)
Condition	The coordinates of the principal points are measured using airborne GPS
Film	Color

- **Used equipment, materials and navigation system :**

Aircraft	Camera type	Calibration Date	Navigation system
Rockwell Turbo Commander 690B	LEICA RC30	19.09.2005	CCNS4r

- **Film type used**: KODAK LX 2405 color film was used for the entire project.
- **Airborne GPS**: Airborne GPS observation was conducted under the following conditions.

Station	Model	Memory	Recording interval	Cut off angle
Base station	Leica	10 mb	1 second	Less than 10 degrees
Aircraft N700RG	Ashtech Z-Surveyor	16 mb	1 second	0 degrees

The base station was located on the rooftop of Hôtel Al Khaima in the center of the city. All the data were downloaded daily after the aerial photography flights. Leica SKI-Pro V3.0 software was used for photo center coordinate computations using the backward and forward processing method. The processed data and final coordinates of each photo center, were saved on CD-ROM.

Figure 2.14 The base station

d) Inspection of photographs

After shooting, the Team carried out a quality control of the photographs using the rush prints. All the photographs were inspected to judge if they satisfy the specification or not. As the results of inspection, all the photographs were found satisfying the above-mentioned specifications. A flight index map was prepared in the AutoCAD format and saved on CD-ROM for a total number of 14 strips with 487 frames.

Flight index map is shown in Figure 2.15.

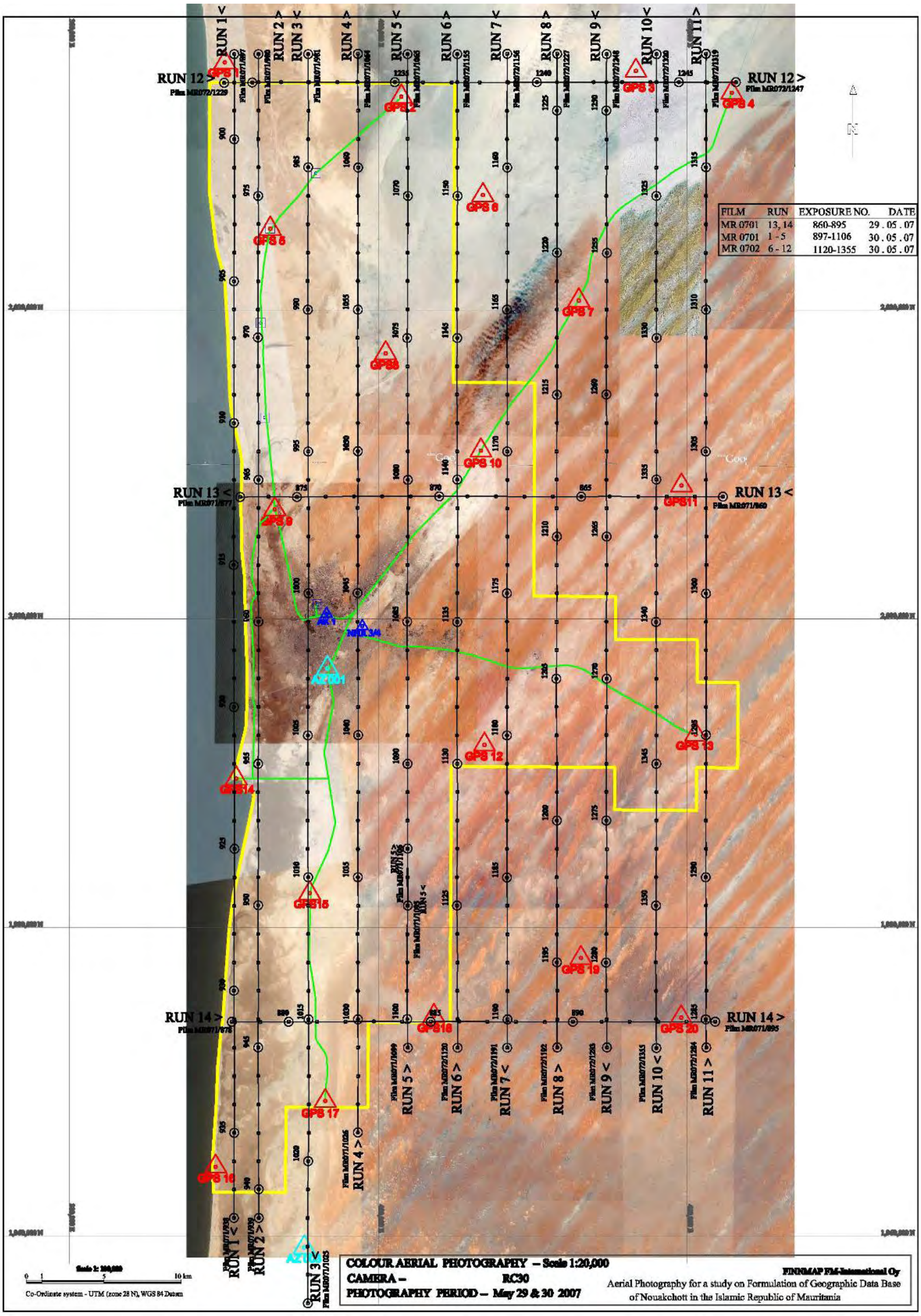


Figure 2.15 Flight index map

e) Photo scanning

In order to obtain digital data of the photographs, all the frames of film were scanned in Japan in June 2007 by the scanner shown Figure 2.17. It was done under the following conditions.

Mode:	Color
Resolution:	12.5 micrometer
File format:	Tiff (un-tiled, uncompressed)

Scanning direction was designed in such a way that the film rotation with respect to the ground would be reversed in alternate strips because the airplane was flying in the opposite direction in alternate strips.

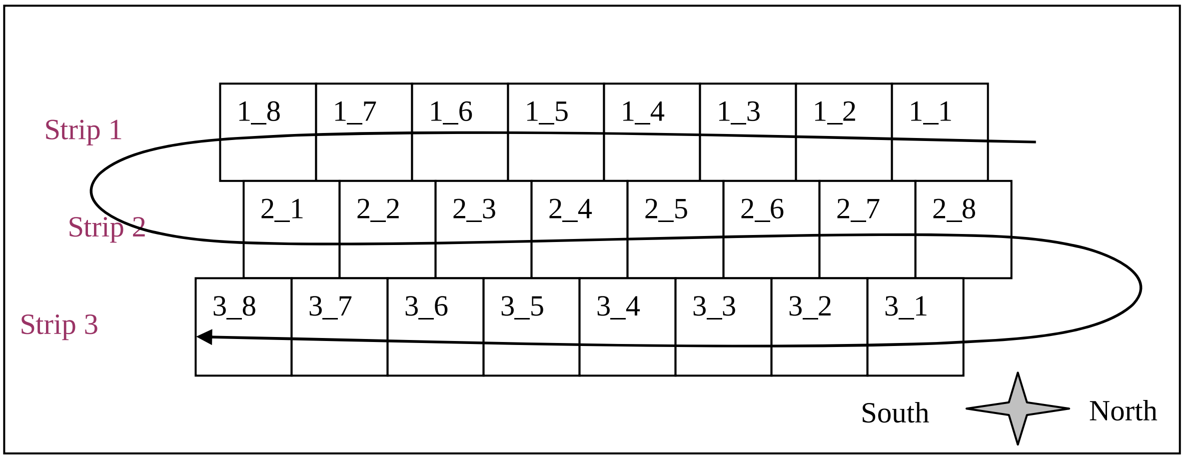


Figure 2.16 Rotation needed for reversed flight direction

Each frame of the scanned aerial photograph was checked for brightness and contrast using graphic editing software. The result was satisfactory. The image is exemplified in Figure 2.18.

Figure 2.17 Scanning of a roll film by “Vexcel Ultrascan 5000”

Figure 2.18 Scanned image

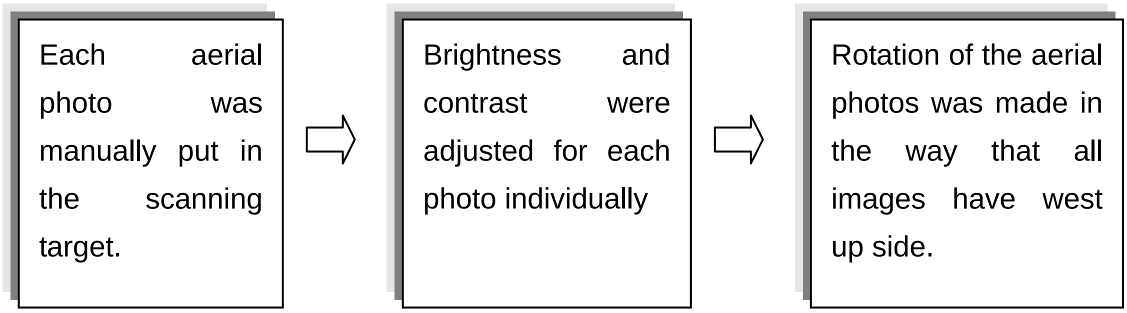


Figure 2.19 Scanning process of aerial photographs

2.1.3. Field identification (in Mauritania)

The purpose of the field identification for the first phase was to obtain information for digital plotting described later according to the specifications of topographic data acquisition agreed upon between DTC and the Team. This work includes preliminary photo-interpretation, on-site check of geographical features and annotations on the maps using photo images.

In addition, for the purpose of constructing basic GIS data, on-site survey of water supply facilities was conducted.

a) <u>The constitution of survey parties</u>

The following survey parties were organized.

- For the survey of topographic features and annotations, 4 parties were organized.
- For the survey of facility of water supply, 2 parties were organized.
- Each party consisted of 2 counterparts.

b) <u>Preliminary photo-interpretation</u>

For the sake of efficient field identification, items appearing on existing topographic maps were organized in comparison with other existing data and marked on the photos to be used in the indoor work in advance, in accordance with the list of the symbols for field remarks.

The preliminary photo-interpretation was carried out with an emphasis on the followings.

- Added or demolished buildings
- Newly-constructed or demolished roads
- Supply systems including water, public wells, power and so forth

- Public facilities such as mosques and schools

As a preliminary photo-interpretation, the following works were done.
The stereoscopic view training was done initially because the counterparts had no experience of photogrammetry. The preliminary photo-interpretation was performed depending on the local knowledge of counterparts, existing tourism map and other material. The result of survey was marked on twice enlarged photos. The main subjects of preliminary photo-interpretation were buildings such as school, mosque, hospital, police office, public office, market and others and their lots.

c) <u>Field identification</u>

With twice enlarged photo and handy GPS, items to be put on the topographic maps were surveyed and confirmed on-site. The confirmed information was organized and updated on the photos for field identification in accordance with the field identification symbols so as to serve as the base data for digital plotting. And also CAD data was created with the information.
On the other hand, the parties for GIS conducted hearing survey for the facilities of water supply and their location with the photos and handy GPS. All the data collected were organized and arranged to CAD and spread sheet data.

Figure 2.20 Data input for creating CAD and spreadsheet data

Figure 2.21 Field identification for water supply facility

Figure 2.22 Result of field identification

2.1.4. Aerial Triangulation (in Japan)

Aerial triangulation was carried out for the Study area of 2,000 km^2 in September 2007 in Japan. The Specification of the Aerial Triangulation is shown in the table.

Geodetic Datum	WGS84
Map Projection	UTM, Zone 28
Number of Models	463
Software	Match AT

The Aerial triangulation followed the work flow below.

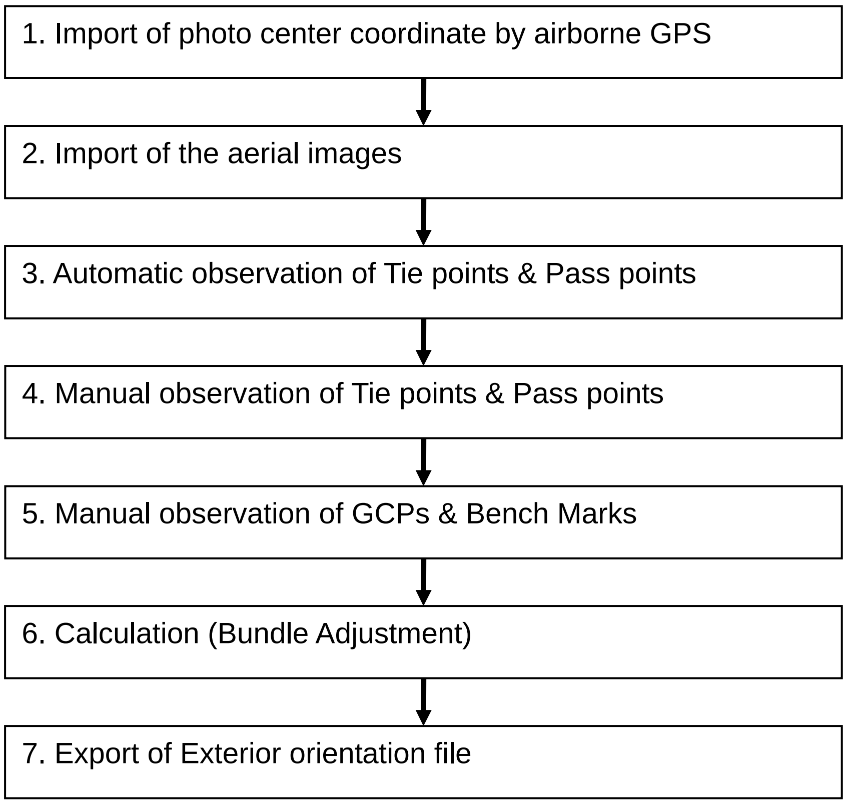
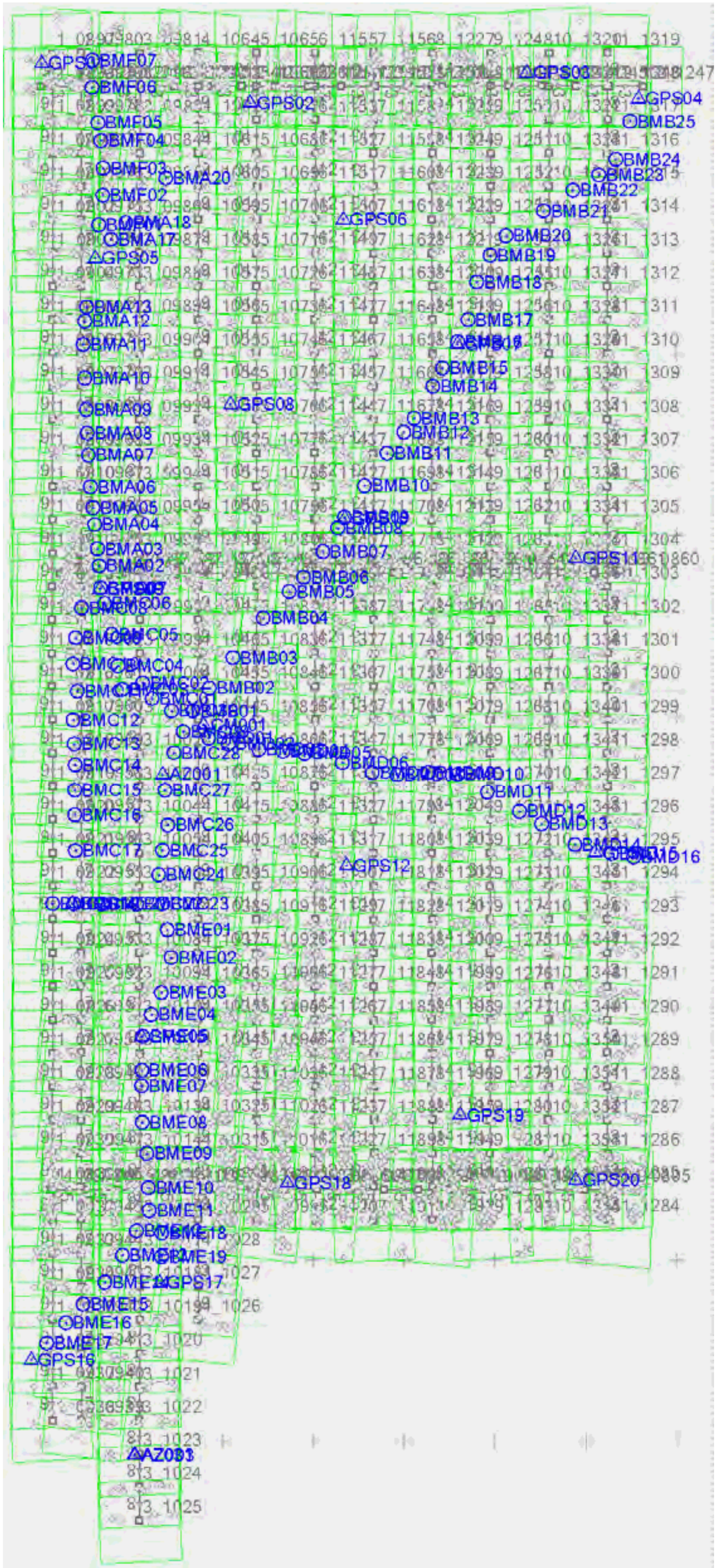


Figure 2.23 Work flow of aerial triangulation



Aerial Photos

Tie Points & Pass Points

Pricked points

GCP

Figure 2.24 The allocation of each point in Aerial Triangulation

The standard deviation and maximum of residual of control points used, in the horizontal and vertical directions, are shown in Table 2.4.

Table 2.4 The results of adjustment computation of residual

Standard Deviation	X Y	0.374 (m)
	Z	0.265 (m)
Maximum	X Y	0.826 (m)
	Z	0.691 (m)

The standard deviation and maximum of residual of control points in aerial triangulation based on the bundle method satisfied the limitation values of 0.02% (0.6m) of flight height for the aerial photography as shown in Table 2.5 in the Manual of Overseas Basic Map Production stipulated by the JICA.

Table 2.5 Accuracy standards of residual errors

Standard Deviation	XY:	less than 0.6 m (“altitude above ground level” x 0.02 %)
	Z:	less than 0.6 m (“altitude above ground level” x 0.02 %)
Maximum	XY:	less than 1.2 m (“altitude above ground level” x 0.04 %)
	Z:	less than 1.2 m (“altitude above ground level” x 0.04 %)

2.1.5. Digital plotting (in Japan)

The digital plotting work was completed for the mapping area of approximately 1,200 km^2 in the first phase. This area is divided into 47 map sheets.

According to the specifications of topographic data acquisition agreed upon between DTC (DCIG) and the Team, planimetric features such as road, building, vegetation and other ground objects were plotted digitally referring to the results of Field identification with the 3 dimensional models of aerial photograph.

a) Process of digital plotting

The work flow of digital plotting is shown in Figure 2.25. Data required for plotting were imported into a digital photogrammetric system, “SUMMIT EVOLUTION” and “CAD software“.

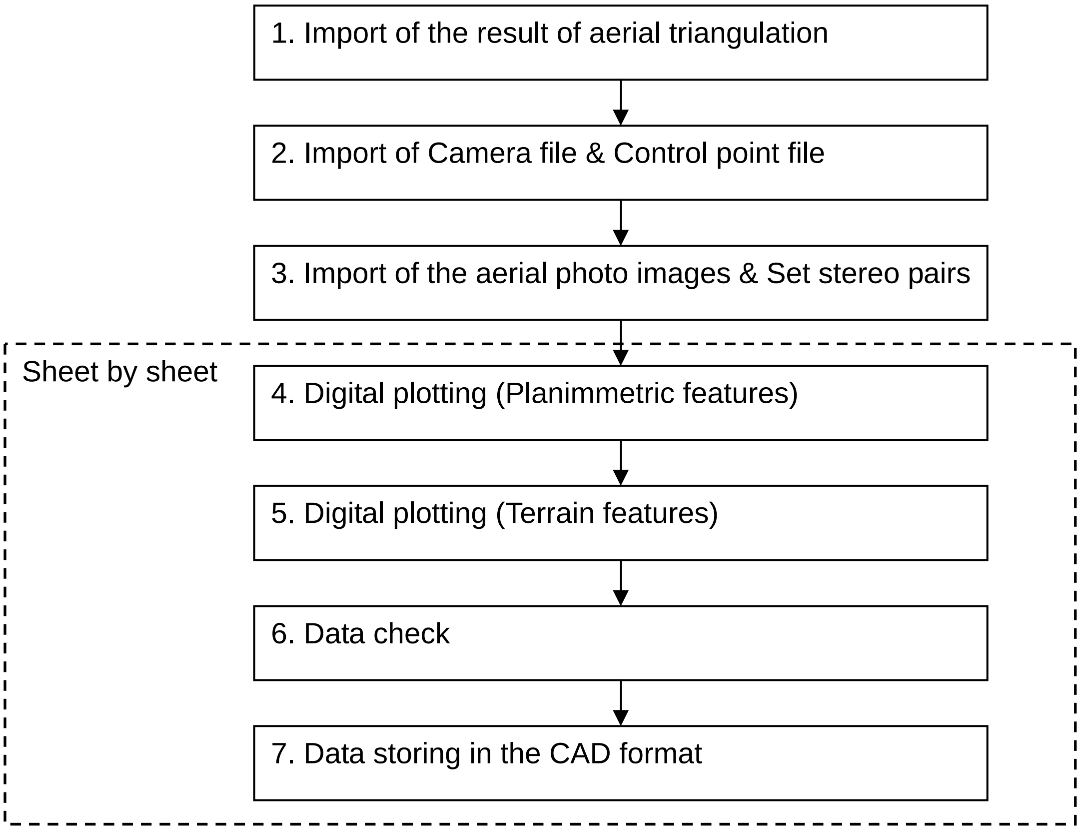


Figure 2.25 Work flow of aerial triangulation

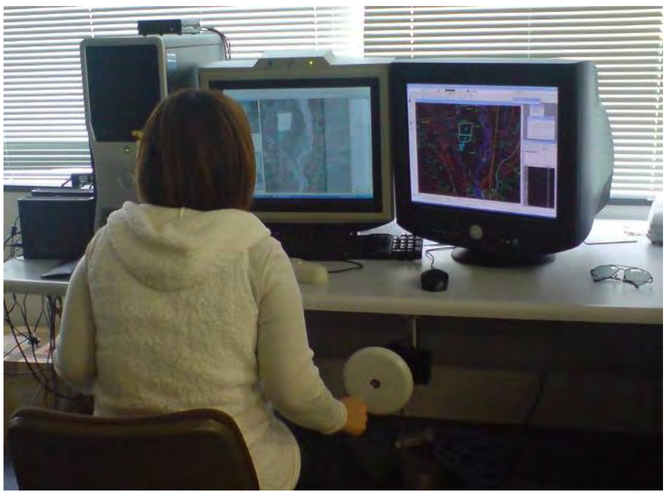


Figure 2.26 Data setting by using “SUMMIT EVOLUTION”

b) <u>Import of the result of aerial triangulation</u>

Import the exterior orientation file.

ID	Omega	Phi	Kappa	X	Y	Z
100897	-0.0079073405	-0.0037590382	1.5983386279	390658.2248500000	2036592.0984000000	3061.9792000000
100898	-0.0261816708	-0.0033718612	1.5983975376	390657.0664900000	2034750.2475099999	3044.1417200000
100899	0.0207249934	0.0027126414	1.5973944853	390657.9560900000	2032927.0337600000	3058.6824300000
100900	-0.0260512302	0.0000387525	1.5989143973	390663.1844600000	2031078.9588400000	3066.2082700000
100901	-0.0327946103	0.0023775722	1.5963575706	390665.2375700000	2029230.9090100001	3054.4933100000
100902	0.0051861451	-0.0008248128	1.5943338776	390671.1793500000	2027388.0710100001	3062.7267000000
100903	0.0153287087	-0.0224913912	1.5900741886	390679.9006400000	2025566.0933300001	3073.3189600000
100904	-0.0427995944	0.0119694961	1.5904487996	390658.4581300000	2023720.9622000000	3064.9600600000
100905	0.0494640862	0.0093524167	1.5743291300	390655.8324200000	2021872.6853700001	3037.4235400000
100906	0.0237253322	-0.0018122329	1.5939491805	390654.5689900000	2020049.4569200000	3105.3582800000
100907	-0.0191857789	0.0016053166	1.5922351437	390654.9059200000	2018188.9109100001	3082.0531400000
100908	-0.0016940927	0.0007807865	1.5926299886	390650.2581300000	2016363.8893500001	3088.5751500000
100909	0.0011018208	0.0010472840	1.5932482672	390647.5203200000	2014514.6263900001	3089.5693100000
100910	-0.0165793181	0.0022059896	1.5942438279	390646.6203800000	2012676.9370299999	3080.7552100000
100911	0.0136975059	0.0116877741	1.6016870721	390641.4310600000	2010849.5886200001	3099.0972500000
100912	-0.0309929882	-0.0082140994	1.5833082363	390650.0490800000	2008993.4432000001	3089.8443200000
100913	0.0364820900	0.0078594012	1.5931738747	390637.6653700000	2007147.1342199999	3082.4067600000
100914	-0.0016700504	0.0025719994	1.5951030264	390636.3058300000	2005320.8159800000	3097.0524500000
100915	-0.0011245799	-0.0005785692	1.5953587221	390632.6274000000	2003475.9057000000	3088.4620400000
100916	0.0121177754	0.0192804257	1.6036663426	390628.8386900000	2001654.3180100000	3091.7689700000
100917	-0.0114275095	-0.0036880513	1.5941881490	390646.9925700000	1999804.9440400000	3108.8870400000
100918	0.0055414377	0.0200082436	1.6087005017	390639.4119600000	1997945.6986100001	3087.0634400000
100919	0.0335242822	-0.0052357808	1.6007775703	390657.8785900000	1996124.3332700001	3122.4785500000
100920	-0.0125254109	0.0054615136	1.5953005163	390657.0621600000	1994281.2242099999	3091.9711900000
100921	0.0045342781	0.0047684182	1.5952997575	390657.2124100000	1992430.4251800000	3072.6627400000
100922	0.0495001821	0.0023685134	1.5976183149	390661.7346300000	1990606.5224299999	3110.0968900000
100923	-0.0386742880	-0.0025964560	1.5990355818	390669.1504400000	1988760.9020799999	3090.3483300000
100924	0.0300733203	0.0076339923	1.5943694379	390671.5255800000	1986912.2876500001	3083.2564600000
100925	-0.0276712672	-0.0036336046	1.6007241210	390676.4589300000	1985079.4394000000	3107.3986800000

Figure 2.27 A part of Exterior orientation data (of each aerial image)

c) <u>Import of Camera file & Control point file</u>

The Camera file and Control point file were imported into digital photogrammetric system. Camera file contains information of the camera such as focal length and so on as shown in Figure 2.28 as a sample. Control file contains X, Y, Z coordinate of control point to be used as shown in Figure 2.29 as a sample.

```
OWNER: RC30_13215
TYPE: RC30
SN: 15/4 UAG-S-13215
LENS_SN:
DATE: 9/19/2005
FOCAL_LENGTH: 152.845000
FILM_HEIGHT: 0.000000
FILM_WIDTH: 0.000000
PRINCIPAL_POINT: 0.006000        0.000000
NOTES:
DATA_STRIP_LOCATION: 0
```

Figure 2.28 The contents of Camera file

AZ001	HV	396707.6740000000	1996781.8189999999	1.8860000000
AZ003	HV	395202.6960000000	1959252.8740000001	5.3360000000
AZ031	HV	395148.0570000000	1959258.9439999999	3.7980000000
CM001	HV	398961.7900000000	1999522.6629999999	4.8450000000
GPS01	HV	390043.9200000000	2036030.4380000001	3.7170000000
GPS02	HV	401523.8780000000	2033834.3840000001	-2.5800000000
GPS03	HV	416749.0210000000	2035515.7300000000	-2.1770000000
GPS04	HV	422908.5780000000	2034089.7749999999	-.2100000000
GPS05	HV	392994.2820000000	2025274.7270000000	1.9880000000
GPS06	HV	406657.2030000000	2027410.9509999999	-1.1480000000
GPS07	HV	412938.7510000000	2020523.4680000001	3.0070000000
GPS08	HV	400459.9290000000	2017217.0120000001	.3850000000
GPS09	HV	393248.4070000000	2007024.1990000000	1.2870000000
GPS10	HV	406735.2060000000	2010913.8000000000	2.4470000000
GPS11	HV	419457.7630000000	2008727.4630000000	2.0330000000
GPS12	HV	406828.7900000000	1991742.2860000001	3.4500000000
GPS13	HV	420525.0660000000	1992450.6720000000	.9800000000
GPS14	HV	391733.3950000000	1989641.8759999999	3.1270000000
GPS15	HV	395552.2360000000	1982300.6610000001	.6420000000
GPS16	HV	389468.7890000000	1964485.3110000000	3.3940000000
GPS17	HV	396553.0550000000	1968739.3780000000	1.7850000000
GPS18	HV	403585.5500000000	1974242.4230000000	2.2500000000
GPS19	HV	413086.9930000000	1977991.6650000000	.9770000000
GPS20	HV	419462.1910000000	1974406.5700000001	1.2830000000

Figure 2.29 The Control point file

d) <u>Import of the aerial photo images & Setting stereo pairs</u>

Stereo model is established as shown below after importing above mentioned files.

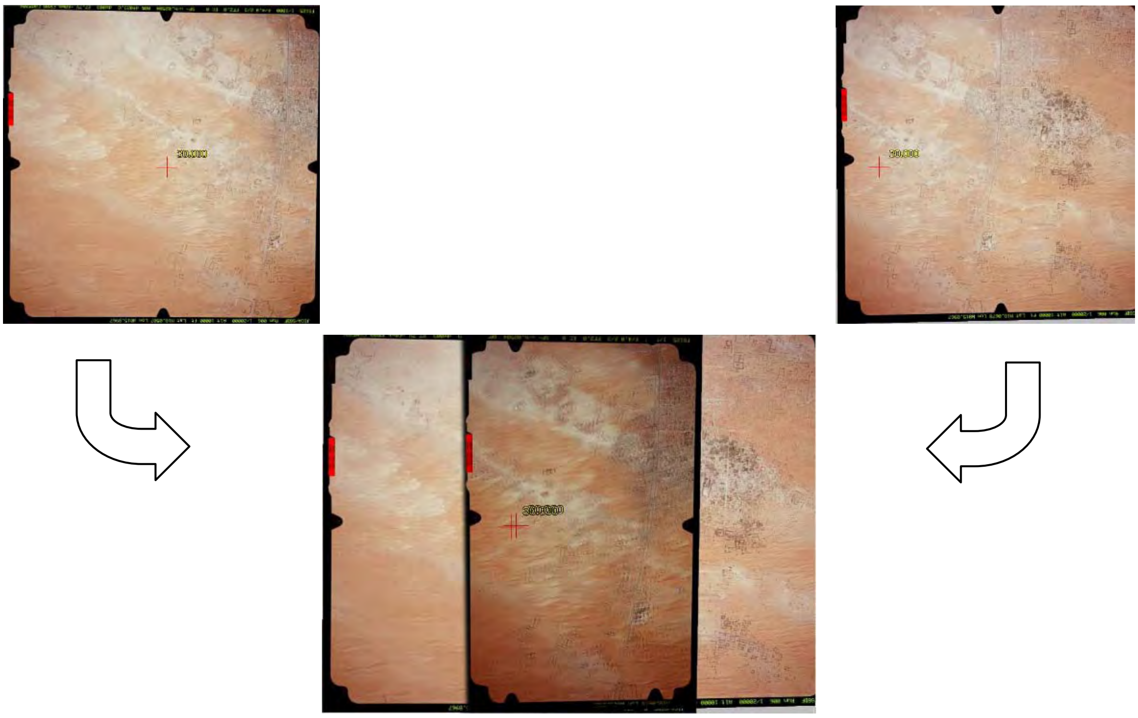


Figure 2.30 Left Image, Right Image, Stereo Image

e) <u>Digital plotting</u>

Data plotted is shown in Figure 2.31 and 2.32 as samples.

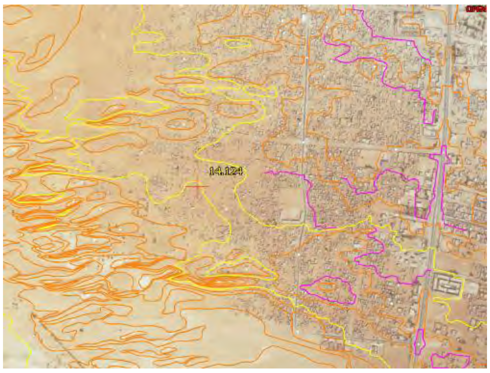
	
Planimetric features plotted	Terrain features plotted

Figure 2.31 Plotted data

f) <u>Data check</u>

Visual checking and logical checking was implemented. The visual checking conducted both on the monitor of PC and on the printed map. The logical checking was conducted by using the tool of CAD software automatically and interactively.

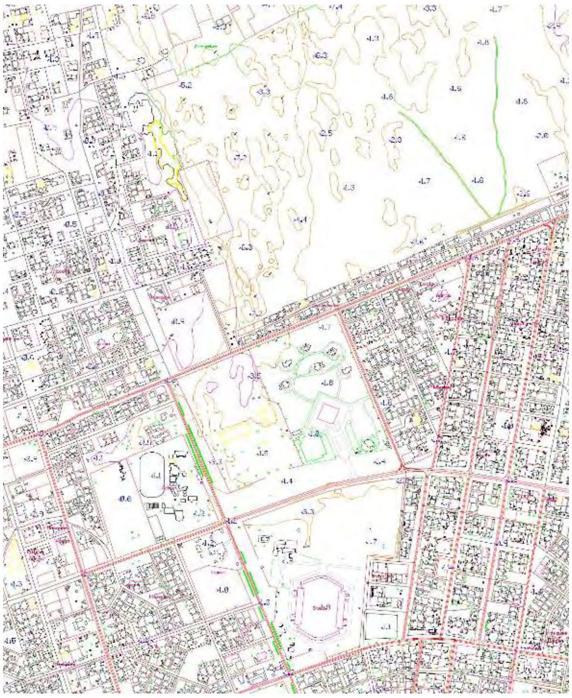


Figure 2.32 Plotted data

2.2. Works for the second phase

The second phase started in May 2008. Digital compilation, Field completion, Supplementary compilation, Map symbolization, Data structurization, and Creation of GIS model systems were carried out until March 2009. Data structurization and Creation of GIS model systems continued in the third phase.

At the end of July 2008, the Team presented the Interim Report to DCIG. Then, both sides had a series of discussions on the Report and made agreements on August 9. After a suspension of the works in Mauritania due to the political change, both sides had discussions on map symbols and other technical matters, and they attained to agreements on October 22.

2.2.1. Digital compilation (in Japan)

This process is separated into 2 main works, one is Data Cleaning and the other is Creating Topology.

Data Cleaning means to omit duplicate data, to erase meaningless lines, gaps and dangles of lines, to correct pseudo nodes, and to check connectivity and consistency of data among adjoining map sheets. Creating Topology means the preparation for creating polygons by associating between symbols and areas which should become polygons.

This work was carried out from May through September 2008 in Japan based on the specifications for topographic data acquisition, by referring to aerial photos and other relevant materials. The data that was cleaned-up, being topological, serves as the basic data for Map symbolization, Data structurization, and GIS data creation.

The flow of this process is shown below.

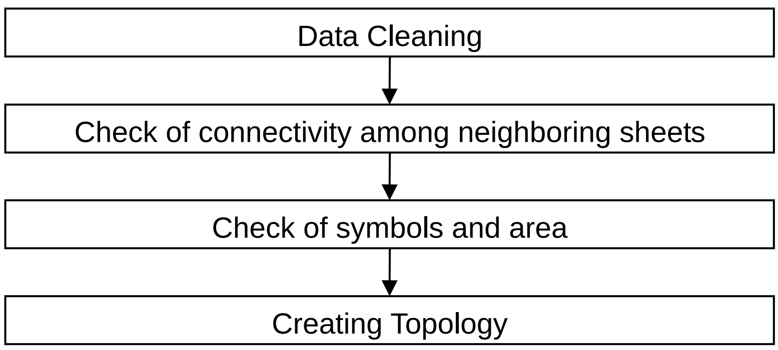


Figure 2.33 Work flow of Digital Compilation

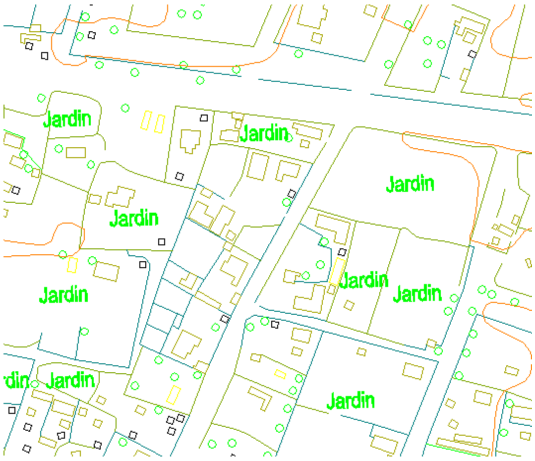
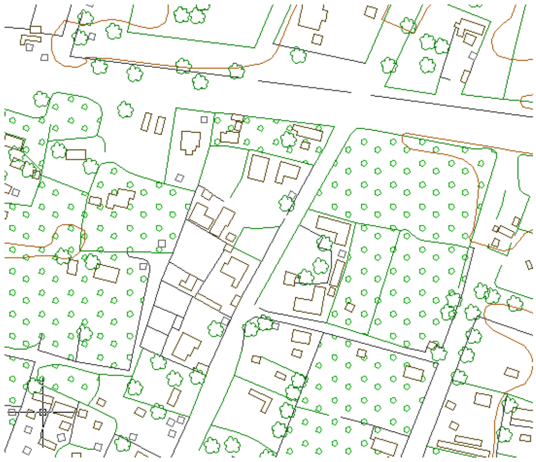
	
Before	After

Figure 2.34 The data before & after Digital Compilation

2.2.2. Provisional map symbolization (in Japan)

This is the process to temporarily symbolize the above digitally compiled map. This symbolized map is to be used as the base map in the succeeding process, Field completion. This work was carried out from May through July 2008 in Japan.

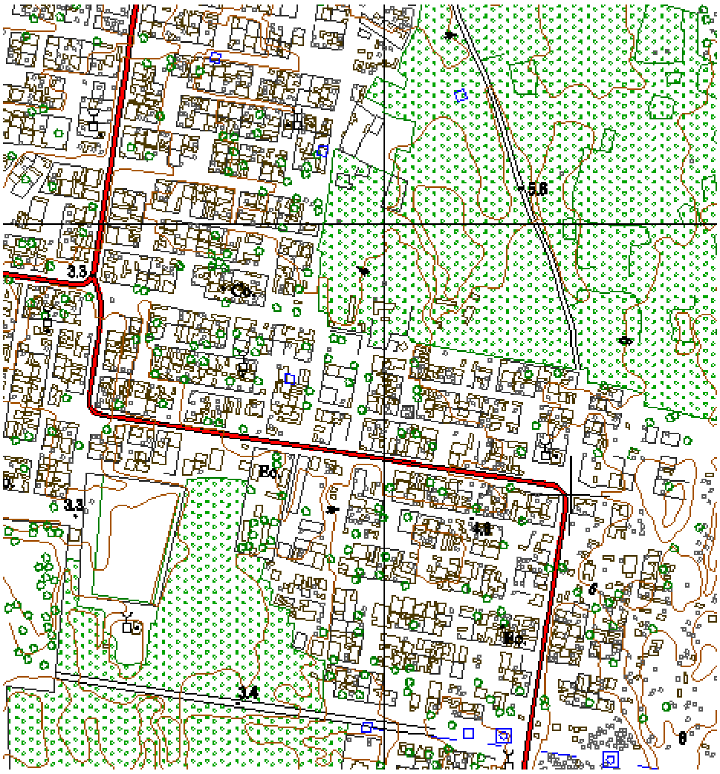


Figure 2.35 The symbolized map for Field completion

2.2.3. Field completion (in Mauritania)

This is the process to complete the contents of map, clarifying on-site all the uncertain features raised during the processes of Digital plotting and Digital compilation, and also clarifying all the objects like geographic names and administrative boundaries, which cannot be acquired from photo-interpretation.

Field work was carried out in October and November 2008 in collaboration with technical staff members of DCIG. It was an on-the-job training for the members under the Technology Transfer Program agreed on between the Team and DTC. For this filed work, 3 parties were organized. Each party consisted of 2 counrterparts.

The result of the work was sent to the next process, Supplementary compilation.

During the field completion, the Team and DCIG had final discussions about map symbols and style, and made an additional agreement on map symbols in November 2008. The agreement is given in APPENDIX 6.

The Team was provided with authorized boundaries of administrative district (moughataa) in digital form by DCIG, and plotted them on the 1:10,000 scale map of this project. It was, however, found that there occurred a small discrepancy between the provided boundaries and the map. In many places, for example, those boundaries authorized on the center lines of roads are slightly out of position on the map. (Figure 2.36)

Figure 2.36 Discrepancy between the provided boundaries and the map

Since the provided boundaries are authorized by the governmental agency concerned, it should be kept without any positional adjustment. But administrative boundary data is essential for usage of the maps and the discrepancy is not so large. Therefore, the Team and DCIG agreed to adopt the data as administrative boundary for the map, noting in the space of marginal information that both sides are not responsible for authorization of the boundary.

2.2.4. Supplementary compilation (in Japan)

This is the process to add the results of the above-mentioned field completion into the primary data and to conclude the contents of map. The items which were cleared from the field completion were modified and the information such as geographic names and administrative boundaries were added.

It was carried out from December 2008 through January 2009 in Japan. It was performed with CAD software. The final results were sent to the processes of Map symbolization and Data structurization.

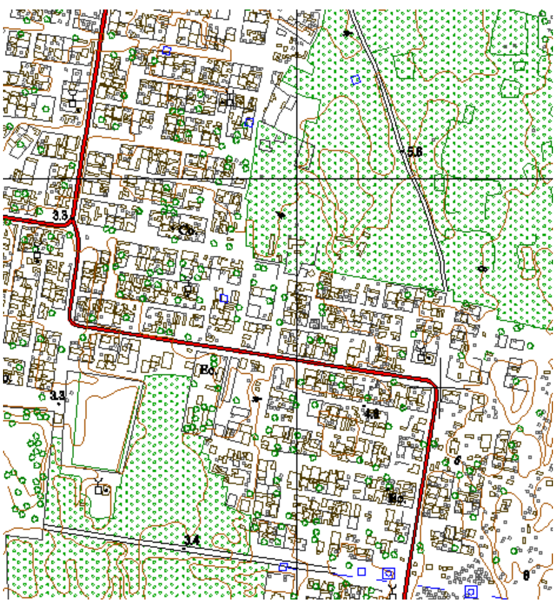
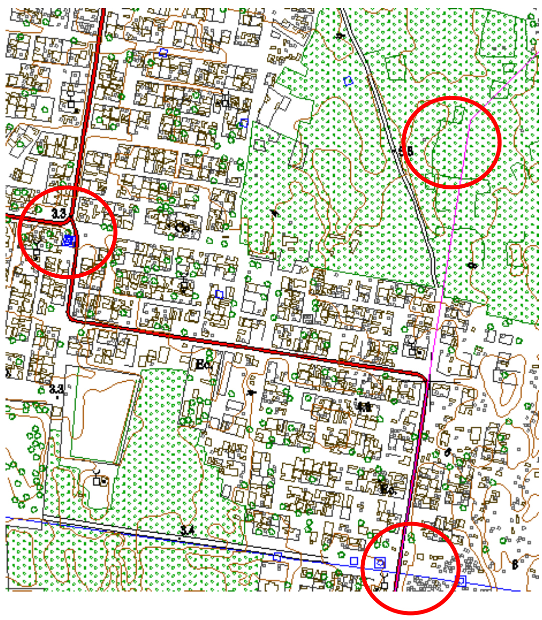
	
Before	After

Figure 2.37 The data before & after the modification from Field completion

2.2.5. Map symbolization (in Japan)

This is the process to give map symbols to the digitally compiled map on screen and complete visual map sheets.

It was carried out from February through March 2009 in Japan. First, according to the specifications of map symbols agreed on between the Team and DCIG, symbols for each layer were designed. Symbols for each layer of point type data and line type data were figured. Colors and patterns for each layer of polygon type data were determined. They were registered for the table of symbols. The map symbols are attached as APPENDIX 6.

Then, these symbols were applied to respective layers on the digitally compiled maps on screen. CAD software was used for this work because it enables efficient performance due to unified application of Digital plotting / Digital compilation.

Marginal information of map sheet was decided after discussion with DCIG. It is shown in Figure 2.38.

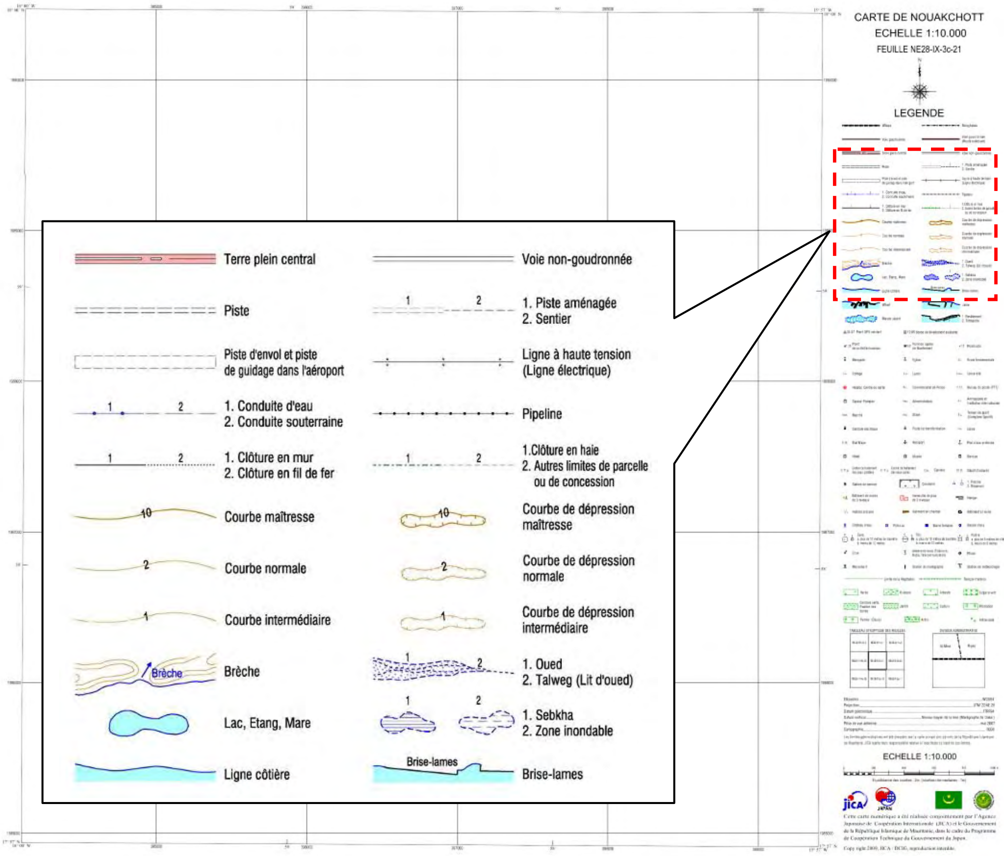


Figure 2.38 Marginal information of map sheet

2.3. Works for the second and third phases

2.3.1. Data structurization (in Japan)

This is the process of converting the digitally compiled map data to GIS data. The converted GIS data mainly included those required for the creating GIS Model Systems. This was carried out by using ArcGIS software and the GIS data files were saved as Shapefile (*.shp*) format, which is supported by wide range of GIS software.

After selecting the desired GIS layers from the list of 120 layers so mentioned in Appendix 6, these were grouped according to data properties. For instance, all the contour line layers (with codes 7102, 7102, 7103, 7104, 7105, and 7106) were included in single file of contour line (*cont_lin.shp*). The schema of useful fields of the converted GIS data is listed in Table 2.6 below.

Table 2.6 General Schema of the Structurized GIS Data

Feature Type	GIS Data Layers (Shape file name)	Useful Fields (Items)	Field Type
Points	Spot Height (*spot_ht.shp*)	layer_code	Integer
		elevation	Float
	Other Point data, such as small building (*bldg_pnt.shp*), water location (*water_pnt.shp*)	layer_code	Integer
Lines	Contour Line (*cont_lin.shp*)	layer_code	Integer
		length	Double
		elevation	Integer
	Other Line data such as road network (*road_network.shp*)	layer_code	Integer
		length	Double
Polygons	Such as large building (*bldg_pol.shp*)	layer_code	Integer
		area	Double
		perimeter	Double

The GIS data was created based on the work flow shown in Figure 2.39 below.

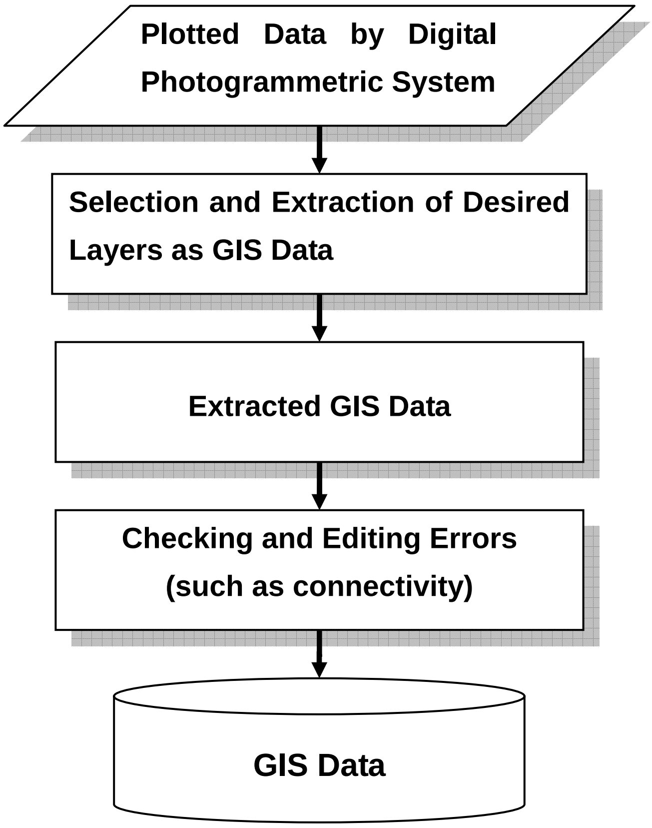
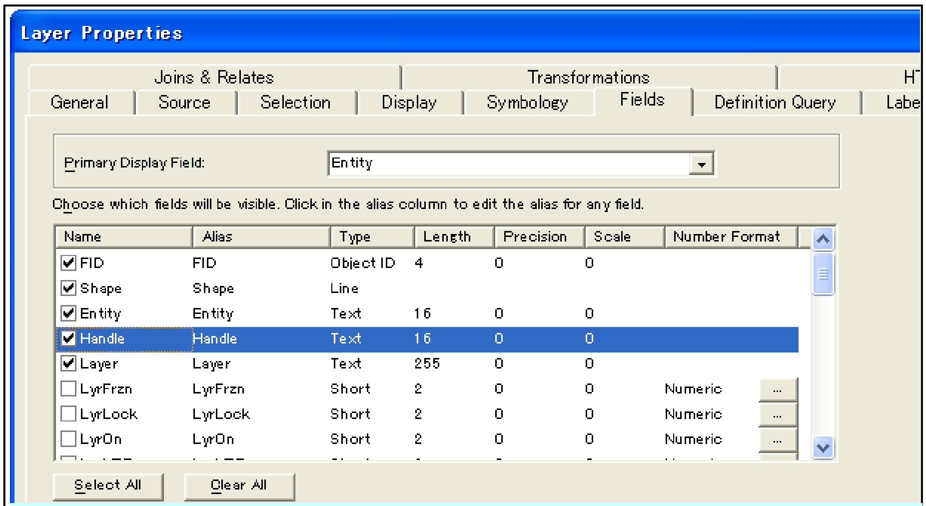


Figure 2.39 Workflow of GIS Data Creation

After displaying the CAD data into ArcGIS software, it was first saved as a temporary (intermediate) Shapefile by discarding the unnecessary fields by checking on only those as presented in Figure 2.40.



Note: for Contour Line or Spot Height data, "elevation" field was also checked on.

Figure 2.40 Fields that need to be checked off before saving as Temporary Shapefile

The converted shape file was defined with map projection UTM with Datum WGS 84, Zone 28N, and Unit meter (as decided for this Project Data). Then the desired fields were added as mentioned in the schema (Table 2.6) and the related data was transferred or calculated in these fields. Then, by selecting the desired groups of layers, it was again saved as new shape file with the name as mentioned in the schema. This extracted GIS data was checked extensively for errors such as connectivity and corrected wherever necessary to achieve the final GIS data.

2.3.2. Creation of GIS model system (in Japan)

Creation of GIS model systems was investigated and designed in the second phase. GIS model systems were created in Japan in the second and third phases. Details of the work are presented in CHAPTER 4.