JAPAN INTERNATIONAL COOPERATION AGENCY
DEPARTMENT OF LANDS AND SURVEYS (DL&S)

# THE STUDY

# FOR

# ESTABLISHMENT OF GEOGRAPHIC DATABASE

# IN

# THE REPUBLIC OF THE GAMBIA

## FINAL REPORT

## (MAIN)

JANUARY 2003

KOKUSAI KOGYO CO., LTD.

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# Preface

In response to a request from the Government of the Republic of Gambia, the Government of Japan decided to conduct the Study for Establishment of Geographic Database in the Republic of Gambia and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Akira Nishimura of Kokusai Kogyo Co., Ltd to Gambia, four times between March 2001 and January 2003.

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

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

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Gambia for their close cooperation extended to the team.

January 2003

Takao Kawakami
President
Japan International Cooperation Agency

# Letter of Transmittal

Mr. Takao Kawakami
President
Japan International Cooperation Agency

It is a great honor to submit herewith the final report of the Study for Establishment of Geographic Database in the Republic of the Gambia.

The study team, led by myself, implemented the study from March 2001 to January 2003 in accordance with the contract established with the Japan International Cooperation Agency (JICA).

The study team held discussions with the concerned officials of the Government of the Republic of the Gambia, and carried out field work, e.g. aerial photography, field identification, ground control point survey, technology transfer, etc., at the site. In Japan, aerial triangulation, digital plotting and digital compilation were carried out to produce topographic map data and 1/50,000-scale printed topographic maps. This report compiles the details of the study and its results, and offers suggestions to solve future issues.

On behalf of the study team, I wish to express my heartfelt appreciation to the concerned officials of the Government of the Republic of the Gambia and the concerned agencies for the warm friendship and cooperation they have extended to us during our stay in the Gambia.

I also wish to express my sincere gratitude to JICA, the Ministry of Foreign Affairs, the Ministry of National Land and Transportation, and the Embassies of Japan in Senegal, as well as the government authorities concerned for the valuable advice and cooperation they have provided us during the implementation of this study and the preparation of the reports.

January 2003

Akira Nishimura
Study Team Leader
Study for the Establishment of Geographic Database in the Republic of the Gambia

# The Study for Establishment of Geographic Database in the Republic of the Gambia Location Map

# Photography

**Banjul City**

**Banjul City**

**Main Street in Banjul**

**Main Street in Banjul**

**Rice field of the Suburbs of Janjangbure**

**River Gambia near by Temdaba**

# Photography

The Entrance of DL&S

The Entrance of DL&S

**National Control Point**

**National Control Point and Photo Signal**

**GPS Survey for National Control Point**

**GPS Survey for Photo Control Point**

# Photography

**Field Identification**

**Supplementary Field Identification**

**The Lecture of Technology Transfer**

Technology Transfer of GPS Survey

**The Technology Transfer of Field Identification**

**The Technology Transfer of Photo Interpretatior**

# Photography

The Presentation of Inception Report

The M/M Meeting of Inception Report

The Presentation of Progress Report

The M/M Meeting of Progress Report

The Presentation of Draft Final Report

The M/M Meeting of Draft Final Report

# Photography

**Technology Transfer of GPS Software**

**Technology Transfer of GPS Software**

**Technology Transfer of Map Revision**

**Technology Transfer of Map Revision**

**Technology Transfer**

**Technology Transfer**

# Photography

**Technology Transfer**

**Technology Transfer**

**Technology Transfer**

**Technology Transfer**

**Technology Transfer**

**Technology Transfer**

# Abbreviations

| | |
|---|---|
| C/P: | Counter Part |
| B/W: | Black And White Film |
| DF/R: | Draft Final Report |
| DL&S: | Department of Lands & Surveys |
| DTM: | Digital Terrain Model |
| F/R: | Final Report |
| GAMTEL: | Gambia Telecommunications Co., Ltd. |
| GIS: | Geographic Information System |
| GPS: | Global Positioning System |
| GPTC: | Gambia Public Transport Corporation |
| GUI: | Graphical User Interface |
| IC/R: | Inception Report |
| IGS: | International GPS Service |
| IEC: | Independent Election Committee |
| ITRE2000: | International Terrestrial Reference Frame 2000 |
| JICA: | Japan International Cooperation Agency |
| M/M: | Minutes Of Meeting |
| NAWEC: | National Water and Electricity Company Ltd. |
| NEA: | National Environment Agency |
| OJT: | On the Job Training |
| PM: | Permanent Munumentation |
| RINEX: | Receiver Independent Exchange Format |
| PR/R: | Progress Report |
| S/W: | Scope of Work |
| TIFF: | Tag Image File Format |
| USAID: | United States Agency International Development |
| WGS-84: | World Geodetic System 1984 |

Preface

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# 1． Summary of the Study

## 1.1 Background and Objective of the Study

### 1.1.1 Background of the Study

In 1999, the Republic of the Gambia (hereinafter referred to as “the Gambia”) formulated “VISION 2020”, which laid down the long-term economic goals for the nation. The vision included such things as the provision of information on social foundations, the promotion of industry and an increase in agricultural productivity. However, the current map data from which such development programs are planned and implemented, were analog maps produced in the 1970’s and due to significant topographic changes, represented only limited data on roads, rivers, etc. There was thus an urgent need to create digital topographic maps at a scale of 1:50,000 and a topographic map database operable on a geographic information system (hereinafter referred to as “GIS”) for the various development projects.

Meanwhile, an Environmental Information System data center was established in the Gambia consisting of five government agencies, including the Department of Lands and Surveys (hereinafter referred to as DL&S), which is responsible for the creation of geographic information. The center focused its efforts on formulating development programs and environmental measures using GIS, giving priority to digitizing and creating databases for various kinds of information.

However, DL&S lacked the skills for geodetic surveying, photogrammetric mapping and GIS operation necessary to generate and maintain geographic information as well as the concerned equipment. Training staff in such skills as well as the formulation of short-term and long-term plans for DL&S were important issues.

Based on the above-mentioned background, the Government of the Gambia made a request to the Government of Japan in July 1999 for the creation of national base maps covering the entire nation as well as the transfer of the technology to be used in doing so. In response to this request, the Japanese government dispatched a preliminary Study Team and the S/W was signed and exchanged on December 18, 2000.

## 1.2 Objectives of the Study

Considering the lack of up-to-date basic topographic maps used in the formulation of development plans, the urgent need to construct a GIS topographic map database, as well as the maintaining and developing of DL&S's technical level after completion of the Study Works, the objectives of the Study were as follows:

- ♦ To produce digital topographic maps (national base maps) at a scale of 1:50,000 and prepare basic data for GIS
- ♦ To transfer technology relevant to the study to DL&S

### (1) Production of 1:50,000-scale Digital Topographic Maps and the Preparation of Basic GIS Data

The first objective of the Study was to produce printed topographic maps covering the entire country of the Gambia at a scale of 1:50,000, and to develop 1:50,000-scale digital topographic map data and a topographic map database for GIS use at the Environmental Information System data center, etc.

The Study further aimed for these data and databases to be used in the conservation and improvement of the environment as well as in the formulation and administration of various development programs.

### (2) Transfer of Technology to DL&S

The second objective of the Study was to transfer the various technologies applied at each stage of implementation to DL&S staff through joint works undertaken with the Study Team, OJT (on-the-job training), and technical transfer seminars to ensure that they could independently create and maintain geographic information.

## 1.3 Study Area

The study area covered the entire country of the Gambia, approximately 11,295km$^2$. (Refer to the study area map)


Study Area Map

## 1.4 Contents of the Study

### 1.4.1 Outline of Work Contents and Volume

The contents and volume of work implemented under the Study is summarized in Table 1.1.

Table 1.1 Outline of Work Contents and Volume

| Year | Phase | Contents | Description | Volume |
|---|---|---|---|---|
| First Year | Preparations in Japan | a-1: Collection/arrangement of relevant documents/information | Existing documents and other relevant data was collected, partly from the Internet, and then arranged. | |
| | | a-2: Examination of specifications for digital map symbols and GIS data | The specifications for digital map symbols of the 1/50,000-scale topographic maps and GIS data were examined. | |
| | | a-3: Examination of equipment for technology transfer | The equipment to be used in technology transfer was examined. | |
| | | a-4: Planning of the national control point network and ground control point survey | The national control point and ground point surveys were planned. | |
| | | a-5: Formulation of the Inception Report | The Inception Report, which included the entire contents of the Study, was prepared. | 20 copies in English |
| Second Year | Phase 1 in Gambia | b-1: Explanation/discussion of the Inception Report | Meetings were held in Gambia to explain and discuss the entire contents of the Study, and an agreement was reached. | |
| | | b-2: Assessment of the current situation relevant to the preparation of geographic information | DL&S' current operation and management of geographic information was assessed. | |
| | | b-3: Discussions on technical specifications | Discussions were held with DL&S on technical specifications for control points, etc. | |
| | | b-4: Selection/monumentation of national control points and selection of ground control points | National control points were selected and monumented and ground control points were selected. | 17 national control points, 11 ground control points |
| | | b-5: Discussions on the equipment used in the transfer of map revision techniques | Discussions were held with DL&S on the equipment to be used in the transfer of map revision techniques. | 15 GPS benchmarks |
| | Phase 2 in Gambia | c-1: Observations and computations of national control points | GPS observations were performed on national control points (with the cooperation of DL&S) . | 17 national control points |
| | | c-2: Ground control survey | GPS observations, and simple leveling when necessary, was carried out on the ground control points (with the cooperation of DL&S) . | 11 ground control points, 15 GPS benchmarks |
| | | c-3: Aerial Photography | B/W aerial photos at a scale of 1/50,000 were taken (local subcontractor) 。 | Approx. 11,295km$^2$ |
| | | c-4: Discussions on specifications for map symbols and GIS data | The specifications for map symbols and GIS data were discussed with DL&S. | |
| | | c-5: Photo interpretation and field identification | Photos were interpreted and field identification was conducted. | Approx. 11,295km$^2$ |
| | Phase 1 in Japan | d-1: Formulation of manuals for technical transfer | A manual for the transfer of map revision techniques was prepared. | |
| | | d-2: Aerial triangulation | The coordinates of pass points and tie points required for digital plotting were computed. | 456 models |
| | | d-3: Formulation of Progress Report | The Progress Report including the results of the study work in the first and second years was formulated. | 20 copies in English |

| Year | Phase | Contents | Description | Volume |
|---|---|---|---|---|
| Third Year | Phase 2 in Japan | e-1: Digital Plotting | Topographic and planimetric features were digitally plotted. | Approx. 11,295km$^2$ |
| | | e-2: Digital compilation (Encoding) | The data obtained from digital plotting was compiled in accordance with the map symbols | Approx. 11,295km$^2$ |
| | | e-3: Proposal of geographic information applications system | A proposal was formulated after examining the results of (b-2) . | |
| | Phase 3 in Gambia | f-1: Explanation/discussion of Progress Report | Meetings were held with DL&S to explain and discuss the Progress Report and an agreement was reached | |
| | | f-2: Discussions on contents of technical transfer seminars | The contents of the technical transfer seminars were examined and discussed with DL&S and then decided on. | |
| | | f-3: Field completion | Items that were obscure in the digital plotting/compilation work were investigated in the field, and the administrative boundaries and names were finalized. | Approx. 11,295km$^2$ |
| | Phase 3 in Japan | g-1: Supplementary digital compilation | The results of the field completion were digitally compiled. | Approx. 11,295km$^2$ |
| | | g-2: Preparation of GIS data | Several GIS databases were prepared | Approx. 11,295km$^2$ |
| | | g-3: Creation of data for printed maps | Data for printed maps were created in sheet units | Approx. 11,295km$^2$ |
| | | g-4: Production of printed maps | Plate films were created and 1/50,000-scale topographic maps were printed. | 27 sheets at a scale of 1/50,000 |
| | | g-5: Formulation of the Draft Final Report | The Draft Final Report including the results of all the study work and proposals for DL&S was formulated. | 20 copies in English |
| | Phase 4 in Gambia | h-1: Transfer of Technology | Mainly map revision techniques were transferred. | |
| | | h-2: Technical transfer seminar | The seminar presented the contents of the Study and the technologies that were transferred, as well as the possibilities of GIS. | |
| | | h-3: Explanation/discussions on Draft Final Report | The Draft Final Report was explained to and discussed with the DL&S, and an agreement was reached. | |
| | Phase 4 in Japan | i-1: Formulation of Final Report | The Final Report was formulated taking into consideration the opinions of the DL&S. | 20 copies in English |

## 1.4.2 Schedule of Study Work Implemented

The flowchart of all of the works implemented under the Study is shown in Figure 1.1. In addition, the flowchart of the implemented technology transfer is shown in Figure 1.2.

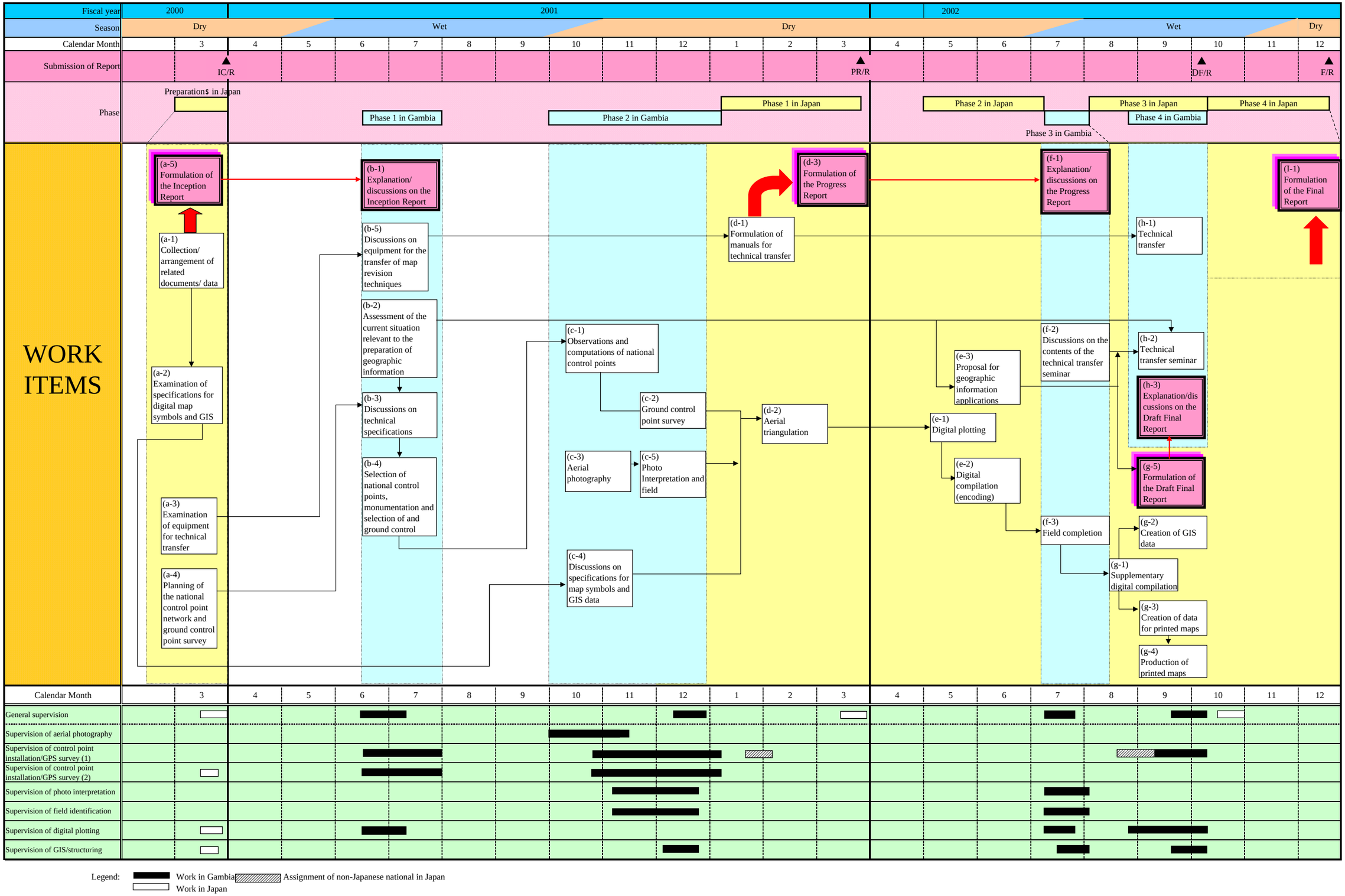



**Figure 1.1 Flowchart All Works**

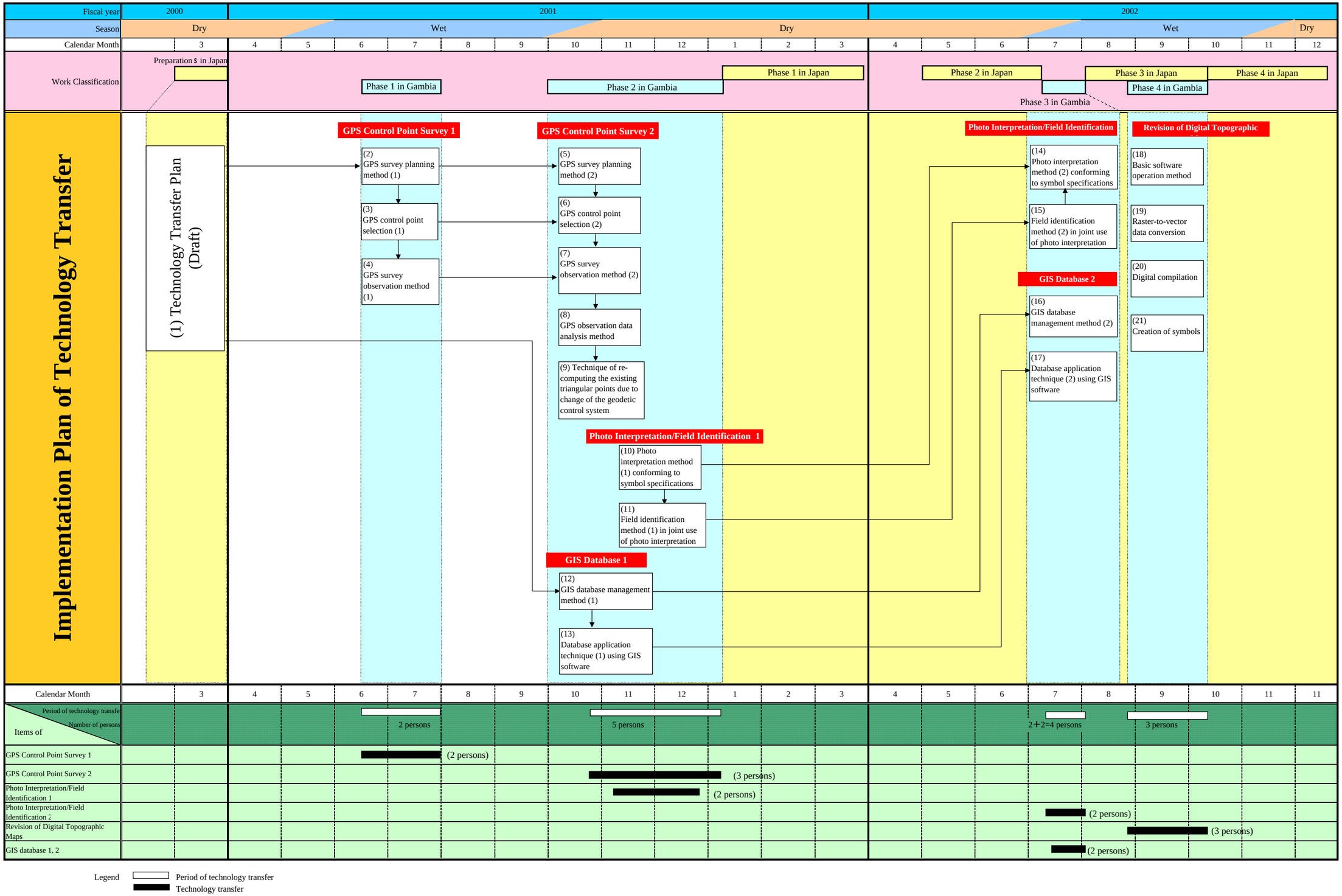



**Figure 1.2 Flowchart of Technical Transfer**

## 1.5 Outline of the Study Output

### 1.5.1 Main Products of the Study

The main products of the Study are as follows:

#### (1) Study Reports

①Inception Report

②Progress Report

③Draft Final Report

④Final Report

#### (2) Products

①Aerial Photographs (negative films、contact prints)

②Results of control point survey

③Results of aerial triangulation

④Printed topographic maps (scaled at 1:50,000)

⑤Topographical map data (scaled at 1:50,000)

⑥GIS databases

### 1.5.2 Outline and Significance of the Study Results

#### (1) Results and significance of the Study Work

Through implementation of the Study Works, the following significant results were obtained.

| Results | Specification of result | Features and significance of results |
|---|---|---|
| 1. Preparation of basic geographic data | | |
| * Digital topographic maps (including topographic map database) | Scale: 1:50,000, 27 sheets (Printed maps and digital data) | Topographic maps expressing the latest geographic information were obtained in the existing printed map form as well as in digital form to replace the existing topographic maps.<br>As the topographic maps were produced in digital form, the updating of geographic information corresponding to developments and changes in land use is much simpler, and DL&S is more likely to update topographic maps independently. Also, the services that use geographic information based on GIS spatial data shall be greatly broadened. |
| * Establishment of national control point network | First order national control points: 17 points | A new national control point network, tied to the World Geodetic System with WGS84 as the reference ellipsoid, was established by GPS surveying to replace the |

| Results | Specification of result | Features and significance of results |
|---|---|---|
| | | existing control point network.<br>By doing so, all geographic information in the Gambia can be tied to the World Geodetic System and 2 (of the 17) control points, which are of particularly high accuracy, can be used as reference control points for the World Geodetic System in West Africa. |
| * Preparation of various databases | Road network, DTM, and national control point databases | The road network and DTM databases were constructed using the topographic map database. These are basic databases that are expected to be used for road administration and disaster simulation.<br>With the national control point database, the national control points, which were managed by an analogue base in the past, can now be managed in digital format. In future, by successively inputting control points determined by the new geodetic system it is possible to consolidate management of geographic information. |
| 2. Technology transfer<br>GPS survey techniques | | GPS survey techniques, from observation planning to analysis, were transferred mainly through OJT; DL&S is now able to carry out such works on their own. In future, based on this outcome, the densification of control points based on the new geodetic system can be expected. |
| Revision techniques for digital topographic maps | | Technology transfer was conducted focusing on digital compilation, and digital data on topographic and planimetric features can now be handled at DL&S.<br>In future, DL&S will be able to carry out the digitization of topographic maps and revision of digital topographic maps independently based on these techniques. |
| Techniques for the operation and maintenance of GIS | | Basic techniques for the operation and maintenance of the GIS using the various databases constructed were transferred to DL&S.<br>This was the first step in the practical operation and maintenance of GIS, and the use at DL&S is likely to broaden. |
| 3. Preparation of work specifications | Map symbols regulation for 1:50.000-scale digital topographic maps, work regulations for national control point survey | Two work specifications (drafts) were prepared based on the digital topographic maps (1:50,000) and GPS control point survey carried out in the Study.<br>In future, DL&S shall carry out works based on these drafts, and the details and results shall be examined to create official regulations. |

### (2) Equipment Supply

DL&S will be provided with the following equipment upon completion of the Study. DL&S personnel are expected to be able to operate it independently.

- ♦ GPS receivers (3 units)

  Software for GPS survey 1set (including one personal computer)

- ♦ Digital map compilation system 1set (including all hardware and software)

# 2． Basic Policies and Implementation of Study Work

## 2.1 Basic Policies and Approaches of Study Work

The objectives of the Study were to produce topographic maps scaled at 1:50,000 and to transfer the technologies necessary to produce topographic maps. The establishment of national control points based on the World Geodetic System and the creation of topographic map data for the construction of a GIS database were also important tasks.

Based on the above-mentioned background, the Study was implemented in accordance with the following basic technical and operational policies and approaches.

### 2.1.1 Basic Technical Policies and Approaches

#### (1) Basic Policies

The basic policies from a technical aspect included the following five items:

- ♦ Preparation of basic geographic data for general use
- ♦ Preparation of technical specifications and work regulations
- ♦ Thorough quality and accuracy control
- ♦ Implementation of hands-on technology transfer
- ♦ Proposals on the operation/maintenance, applications and long-term plans of geographic information

#### (2) Approaches

In order to achieve the objectives based on the basic policies mentioned above, the Study was approached as follows:

①Preparation of basic geographic data for general use

a. Preparation of digital geographic maps scaled at 1:50,000

Digital maps covering all of the Gambia shall be prepared based on standardized specifications. In addition, topographic map data for general purposes shall be prepared by attaching a systematic code to each topographic and planimetric feature.

b. Installation of national control points

National control points for general use shall be installed in conformance with and tied to the World Geodetic System.

②Preparation of technical specifications and work regulations

Technical specifications and work regulations for control point surveys, digital topographic maps scaled at 1:50,000 and the topographic map database shall be prepared to keep consistency in the quality of the products and to ensure that the work conducted after completion of the Study is based on the same standard.

③Thorough quality and accuracy control

The quality and accuracy in regards to control point surveys, the production of digital topographic maps, the construction of the topographic map database and local subcontracts shall be thoroughly checked to ensure conformance to technical standards.

④Implementation of hands-on technology transfer

Technologies regarding GPS surveying, photo interpretation and field identification, map revision and GIS databases shall be transferred to DL&S in the form of lectures, seminars and OJT. The aim of the technical training shall be for DL&S to reach a level where they can apply these various technologies independently.

⑤Proposals on the operation and maintenance, application and long-term plans of geographic information

Proposals shall be made on the operation and maintenance, applications and long-term plans of geographic information based on the results of a survey on the current situation regarding such information in the Gambia and past experiences.

### 2.1.2 Basic Operational Policies and Approaches

#### (1) Basic Policies

The basic policies from an operational aspect included the following five items:

- ♦ Close interaction with all concerned agencies
- ♦ Flexible schedule to cope with unexpected situations
- ♦ Detailed preparations
- ♦ Active promotion of the products of the study
- ♦ Exhaustive safety measures

#### (2) Approaches

In order to achieve the objectives based on the basic policies mentioned above, the Study was approached as follows:

①Close interaction with concerned agencies

There shall be close interaction with DL&S and other concerned agencies regarding technology transfer, local subcontracting, safety control, schedule changes, quality and accuracy control, workshops, etc. to ensure smooth implementation of the works conducted in the Study.

②Flexible schedule to cope with unexpected situations

The schedule shall be revised in the event of a delay in any individual work so as to minimize the effect on the entire work schedule.

③Detailed preparations

Detailed preparations for all works shall be made in advance in an effort to move up the work schedule.

④Active promotion of the products of the Study

The products of the Study (1:50,000-scale printed maps、topographic map data、topographic map database) shall be actively promoted to other agencies as well as DL&S through technology transfer seminars.

⑤Exhaustive safety measures

In addition to obtaining information on safety and security from DL&S, work in neighboring countries shall be minimized and a guide familiar with local conditions shall accompany the Study Team during all field work. A means of communication shall also be secured for emergency situations.

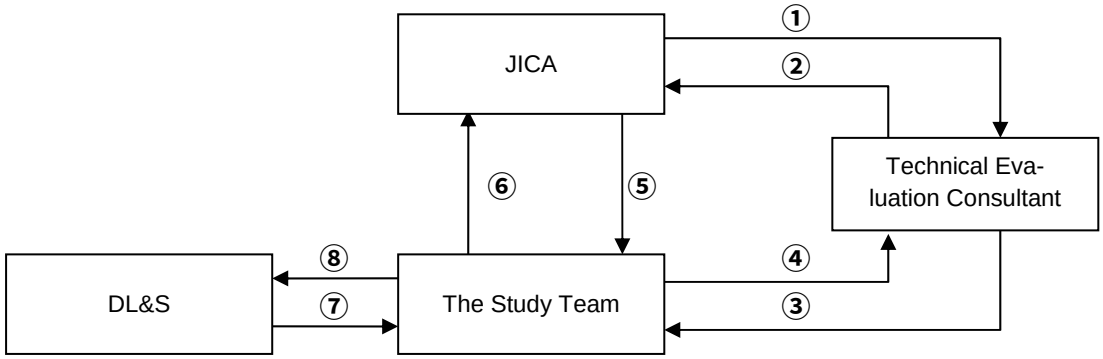
## 2.2 System and Period of Study Work Implementation

### 2.2.1 System of Study Work Implementation

#### (1) Relationship between the Study, Study Team and Concerned Agencies

DL&S acted as the C/P (counterpart) agency in the Study. JICA also appointed technical evaluation consultants to provide the necessary technical advice.

The organization of the Study was as follows:




①: Inquire on technical matters.

②: Make technical evaluations, give technical advice. Report the technical evaluations of the Study work.

③: Assess the contents of the Study work from a technical aspect.

④: Report on the Study work from a technical aspect.

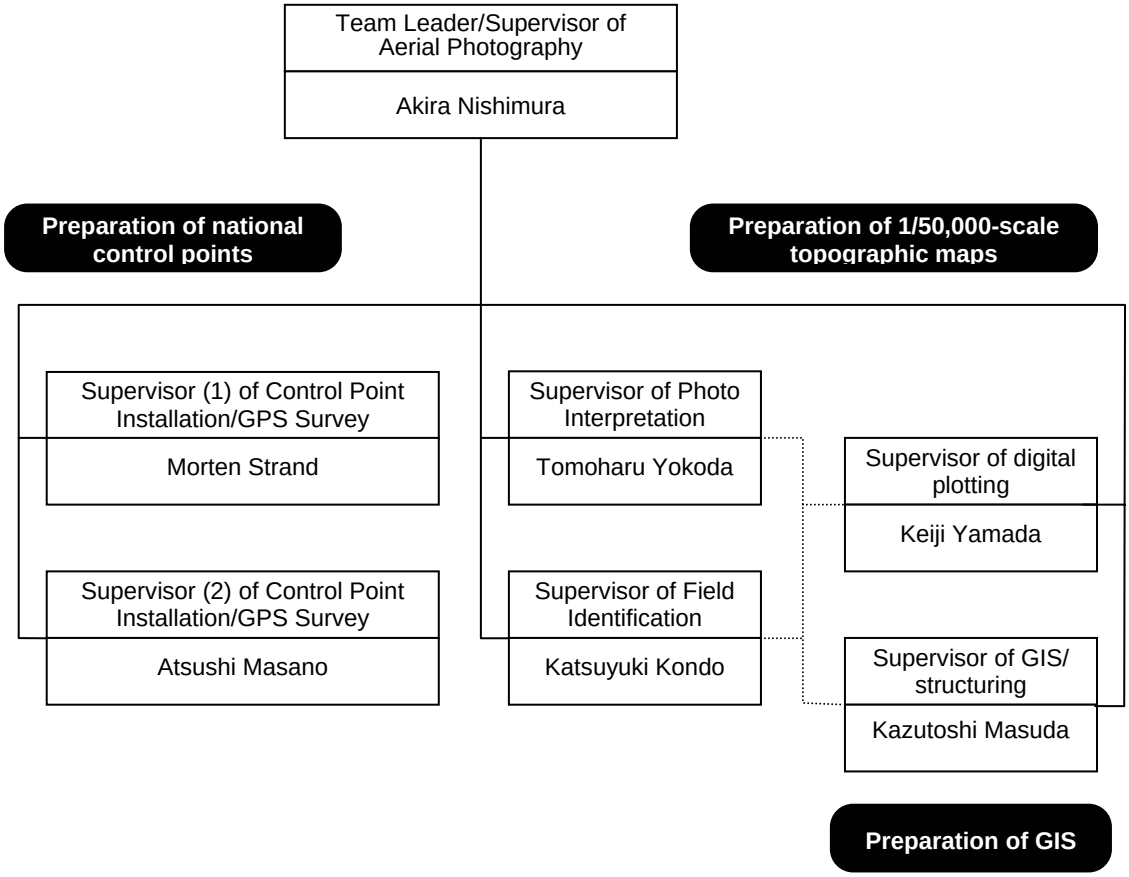
⑤: Instruct on matters concerning the Study work.

⑥: Report on the progress of the Study work.

⑦: Implement the Study work together with the Study Team. Make requests concerning the Study work.

⑧: Discuss and decide on technical matters of the Study work/Request cooperation in Study work implementation.

### (2) System of Study Implementation




The Study Team

## 2.2.2 Organization and Work Allocation of the Study Team

### (1) Member Organization

The members of the Study Team and their duties are as follows

| Title | Name |
|---|---|
| Team Leader/Supervisor of Aerial Photography | Mr. Akira Nishimura |
| Supervisor (1) of Control Point Installation/GPS Survey | Mr. Morten Strand |
| Supervisor (2) of Control Point Installation/GPS Survey | Mr. Atsushi Masano |
| Supervisor of Photo Interpretation | Mr. Tomoharu Yokoda |
| Supervisor of Field Identification | Mr. Katsuyuki Kondo |
| Supervisor of Digital Plotting | Mr. Keiji Yamada |
| Supervisor of GIS /Structuring | Mr. Kazutoshi Masuda |
| Coordinator (1) | Mr. Masahiko Takahashi |
| Coordinator (2)/Database | Ms. Chiyo Kigasawa |

## (2) Allocation of Work

①Contents of Work

The contents of the work allocated to each member of the Study Team were as follows.

Work Content of The Study Team

| Name | Responsibilities | Content of Work |
|---|---|---|
| Akira Nishimura | Team Leader/ Supervisor of Aerial Photography | **First year** |
| | | **Preparations in Japan** |
| | | (a-1) Collection/arrangement of related documents/data |
| | | (a-2) Examination of specifications for digital map symbols and GIS data |
| | | (a-3) Examination of equipment for technical transfer |
| | | (a-4) Planning of national control point network and ground point survey |
| | | (a-5) Formulation of the Inception Report |
| | | **Second year** |
| | | **Phase 1 in Gambia** |
| | | (b-1) Explanation/discussions on the Inception Report |
| | | (b-2) Assessment of the current situation concerning the preparation of geographic information |
| | | (b-5) Discussions on the equipment for the transfer of map revision techniques |
| | | **Phase 2 in Gambia** |
| | | (c-3) Aerial photography |
| | | (c-4) Discussions on specifications for map symbols and GIS data |
| | | **Phase 1 in Japan** |
| | | (d-3) Formulation of Progress Report |
| | | **Third year** |
| | | **Phase 2 in Japan** |
| | | (e-3) Proposal on applications system of geographic information |
| | | **Phase 3 in Gambia** |
| | | (f-1) Explanation/discussions on Progress Report |
| | | (f-2) Discussions on contents of technical transfer seminars |
| | | **Phase 3 in Japan** |
| | | (g-5) Formulation of Draft Final Report |
| | | **Phase 4 in Gambia** |
| | | (h-2) Technical transfer seminar |
| | | (h-3) Explanation/discussions on Draft Final Report |
| | | **Phase 4 in Japan** |
| | | (i-1) Formulation of the Final Report |

| Name | Responsibilities | Content of Work |
|---|---|---|
| Morten Strand | Supervisor(1) of Control Point Installation/GPS Survey | **First year** |
| | | **Preparations in Japan** |
| | | (a-4) Planning of national control point network and ground control point survey |
| | | **Second year** |
| | | **Phase 1 in Gambia** |
| | | (b-1) Explanation/discussions on Inception Report |
| | | (b-3) Discussions on technical specifications |
| | | (b-4) Selection/Monumentation of national control points and selection of ground control points |
| | | **Phase 2 in Gambia** |
| | | (c-1) Observations/Computations of national control points |
| | | (c-2) Ground control point survey |
| | | **Third year** |
| | | **Phase 4 in Gambia** |
| | | (h-2) Technical transfer seminar |
| | | (h-3) Explanation/discussions on Draft Final Report |
| Atsushi Masano | Supervisor (2) of Control Point Installation/GPS Survey | **First Year** |
| | | **Preparations in Japan** |
| | | (a-1) Collection/arrangement of related documents/data |
| | | (a-4) Planning of national control point network and ground control point survey |
| | | **Second year** |
| | | **Phase 1 in Gambia** |
| | | (b-1) Explanation/discussions on Inception Report |
| | | (b-3) Discussions on technical specifications |
| | | (b-4) Selection/monumentation of national control points and selection of ground control points |
| | | **Phase 2 in Gambia** |
| | | (c-1) Observations/computations of national control points |
| | | (c-2) Ground control point survey |
| Tomoharu Yokoda | Supervisor of Photo Interpretation | **First Year** |
| | | **Preparations in Japan** |
| | | (a-1) Collection/arrangement of related documents/data |
| | | (a-2) Examination of specifications on digital map symbols and GIS data |
| | | **Second Year** |
| | | **Phase 2 in Gambia** |
| | | (c-4) Discussions on specifications on digital map symbols and GIS data |
| | | (c-5) Photo interpretation and field identification |
| | | **Third Year** |
| | | **Phase 3 in Gambia** |
| | | (f-1) Explanation/discussions on Progress Report |

| Name | Responsibilities | Content of Work |
|---|---|---|
| | | (f-3) Field completion |
| | | **Phase 3 in Japan** |
| | | (g-4) Production of printed maps |
| **Katsuyuki Kondo** | **Supervisor of Field Identification** | **First Year** |
| | | **Preparations in Japan** |
| | | (a-1) Collection/arrangement of related documents/data<br>(a-2) Examination of specifications on digital map symbols and GIS data |
| | | **Second Year** |
| | | **Phase 2 in Gambia** |
| | | (c-4) Discussions of specifications on digital map symbols and GIS data<br>(c-5)Photo interpretation and field identification |
| | | **Third Year** |
| | | **Phase 3 in Gambia** |
| | | (f-1) Explanation/discussions on Progress Report<br>(f-3) Field completion |
| **Keiji Yamada** | **Supervisor of Digital Plotting** | **First Year** |
| | | **Preparations in Japan** |
| | | (a-1) Collection/arrangement of related documents/data<br>(a-2) Examination of specifications for digital map symbols and GIS data<br>(a-3) Examination of equipment for technical transfer |
| | | **Second Year** |
| | | **Phase 1 in Gambia** |
| | | (b-2) Assessment of the current situation concerning the preparation of geographic information<br>(b-5) Discussions on the equipment for the transfer of map revision techniques |
| | | **Phase 1 in Japan** |
| | | (d-1) Formulation of manuals for technical transfer<br>(d-2) Aerial triangulation |
| | | **Third Year** |
| | | **Phase 2 in Japan** |
| | | (e-1) Digital plotting<br>(e-2) Digital compilation (encoding) |
| | | **Phase 3 in Gambia** |
| | | (f-1) Explanation/discussions on Progress Report<br>(f-2) Discussions on contents of technical transfer seminars |
| | | **Phase 3 in Japan** |
| | | (g-1) Supplementary digital compilation<br>(g-2) Creation of GIS data<br>(g-3) Creation of Data for printed maps |

| Name | Responsibilities | Content of Work |
|---|---|---|
| | | **Phase 4 in Gambia** |
| | | (h-1) Technical transfer<br>(h-2) Technical transfer seminar<br>(h-3) Explanation/discussions on Draft Final Report |
| Kazutoshi Masuda | Supervisor of GIS/Structuring | **First Year** |
| | | **Preparations in Japan** |
| | | (a-1) Collection/Arrangement of related documents/data<br>(a-2) Examination of specifications for digital map symbols and GIS data |
| | | **Second Year** |
| | | **Phase 2 in Gambia** |
| | | (c-4) Discussions on specifications for digital map symbols and GIS data |
| | | **Third Year** |
| | | **Phase 3 in Gambia** |
| | | (f-1) Explanation/discussions on Progress Report<br>(f-2) Discussions on the contents of the technical transfer seminar |
| | | **Phase 3 in Japan** |
| | | (g-2)Creation of GIS data |
| | | **Phase 4 in Gambia** |
| | | (h-2) Technical transfer seminar<br>(h-3) Explanation/discussions on the Draft Final Report |

②Relationship between Study Team Members and Study Work

| Responsibility / Work Items / Name | Team Leader/Aerial Photography Supervisor | Control Point Installaiton/ GPS Survey Supervisor (1) | Control Point Installation/ GPSSurvey Supervisor (2) | Photo Interpretation Supervisor | Field Identifcation Supervisor | Digital Plotting Supervisor | GIS Specialist |
|---|---|---|---|---|---|---|---|
| | Akira Nishimura | Morton Strand | Atsushi Masano | Tomoharu Yokodo | Katsuyuki Kondo | Keiji Yamada | Kazutoshi Masuda |
| **First Year** | | | | | | | |
| **Preparation work in Japan** | | | | | | | |
| (a-1)Collection/arrangement of related documents/data | ◎ | | ○ | ○ | ○ | ○ | ○ |
| (a-2)Examination of specifications for digital map symbols and GIS data | ○ | | | ○ | ○ | ◎ | ○ |
| (a-3)Examination of equipment for technology transfer | ○ | | | | | ◎ | |
| (a-4)Planning of national control network and ground control point survey | ◎ | ○ | ○ | | | | |
| (a-5)Formulation of Inception Report | ◎ | | | | | | |
| **Second Year** | | | | | | | |
| **Phase 1 in Gambia** | | | | | | | |
| (b-1)Explanation/discussions on Inception Report | ◎ | ○ | ○ | | | | |
| (b-2)Assessment of the current situation related to the generation of geographic information | ◎ | | | | | ○ | |
| (b-3)Discussions on technical specifications | | ◎ | ○ | | | | |
| (b-4)Selection/monumentation of national control points and selection of ground control points | | ◎ | ○ | | | | |
| (b-5)Discussions on equipment for the transfer of map revision techniques | ○ | | | | | ◎ | |
| **Phase 2 in Gambia** | | | | | | | |
| (c-1)Observations and computations of national control points | | ◎ | ○ | | | | |
| (c-2)Ground control point survey | | ◎ | ○ | | | | |
| (c-3)Aerial photography | ◎ | | | | | | |
| (c-4)Discussions on specifications for map symbols and GIS data | ○ | | | ◎ | ○ | | ◎ |
| (c-5)Photo interpretation and field identification | | | | ◎ | ◎ | | |
| **Phase 1 in Japan** | | | | | | | |
| (d-1)Formulation of manuals for technology transfer | | | | | | ◎ | |
| (d-2)Aerial triangulation | | | | | | ◎ | |
| (d-3)Formulation of the Progress Report | ◎ | | | | | | |
| **Third Year** | | | | | | | |
| **Phase 2 in Japan** | | | | | | | |
| (e-1)Digital plotting | | | | | | ◎ | |
| (e-2)Digital compilation (encoding) | | | | | | ◎ | |
| (e-3) Proposal on geographic information application system | ◎ | | | | | | |
| **Phase 3 in Gambia** | | | | | | | |
| (f-1)Explanation/discussions on the Progress Report | ◎ | | | ○ | ○ | ○ | ○ |
| (f-2)Discussions on the contents of the technology transfer | ◎ | | | | | ○ | ○ |
| (f-3)Field completion | | | | ○ | ◎ | | |
| **Phase 3 in Japan** | | | | | | | |
| (g-1)Supplementary digital compilation | | | | | | ◎ | |
| (g-2)Creation of GIS data | | | | | | ○ | ◎ |
| (g-3)Creation of data for printed maps | | | | | | ◎ | |
| (g-4)Production of printed maps | | | | ◎ | | | |
| (g-5)Formulation of the Draft Final Report | ◎ | | | | | | |
| **Phase 4 in Gambia** | | | | | | | |
| (h-1) Technology transfer | | | | | | ◎ | |
| (h-2) Technology transfer seminar | ◎ | ○ | | | | ○ | ○ |
| (h-3)Explanation/discussions on the Draft Final Report | ◎ | ○ | | | | ○ | ○ |
| **Phase 4 in Japan** | | | | | | | |
| (i-1)Formulation of the Final Report | ◎ | | | | | | |

### 2.2.3 Schedule of Implemented Study Work

The schedule of the study work implemented over a period of three years is summarized in Table 2.1.

The study work schedule is broken down as follows:

| | | |
|---|---|---|
| First Year | 「Preparations in Japan」 | March 8 - March 22, 2001 |
| Second Year | 「Phase 1 in Gambia」 | June 13 - July 30, 2001 |
| | 「Phase 2 in Gambia」 | October 2, 2001 - January 10, 2002 |
| | 「Phase 1 in Japan」 | January 11 - March 29, 2002 |
| Third Year | 「Phase 2 in Japan」 | July 1 - July 12, 2002 |
| | 「Phase 3 in Gambia」 | July 13 - August 14, 2002 |
| | 「Phase 3 in Japan」 | August 15 - August 22, 2002 |
| | 「Phase 4 in Gambia」 | August 23 - October 13, 2002 |
| | 「Phase 4 in Japan」 | October 14, 2002 - January 8, 2003 |

# Table 2.1 Work Schedule

| | Work Items (Fiscal year / Month) | 2000 | 2001 | | | | | | | | | | | | 2002 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| Year | Work Classification (in Gambia ■ in Japan □) | | | | ■ | ■ | | | ■ | ■ | ■ | ■ | | □ | □ | □ | | ■ | □ | ■ | □ | | | |
| | Submission of Reports | ▲ IC/R | | | | | | | | | | | | ▲ PR/R | | | | | | | ▲ DF/R | | | ▲ F/R |
| First Year | Preparations in Japan | □ | | | | | | | | | | | | | | | | | | | | | | |
| | (a-1) Collection/arrangement of related documents/data | □ | | | | | | | | | | | | | | | | | | | | | | |
| | (a-2) Examination of specifications for digital map symbols and GIS data | □ | | | | | | | | | | | | | | | | | | | | | | |
| | (a-3) Examination of equipment for technical transfer | □ | | | | | | | | | | | | | | | | | | | | | | |
| | (a-4) Planning of the national control point network and ground control point survey | □ | | | | | | | | | | | | | | | | | | | | | | |
| | (a-5) Formulation of the Inception Report | □ | | | | | | | | | | | | | | | | | | | | | | |
| Second Year | Phase 1 in Gambia | | | | ■ | ■ | | | | | | | | | | | | | | | | | | |
| | (b-1) Explanation/discussions on the Inception Report | | | | ■ | | | | | | | | | | | | | | | | | | | |
| | (b-2) Assessment of the current situation relevant to geographic information use | | | | ■ | ■ | | | | | | | | | | | | | | | | | | |
| | (b-3) Discussions on technical specifications | | | | ■ | | | | | | | | | | | | | | | | | | | |
| | (b-4) Selection of national control points, monumentation and selection of ground control points | | | | ■ | ■ | | | | | | | | | | | | | | | | | | |
| | (b-5) Discussions on equipment for the transfer of map revision techniques | | | | ■ | | | | | | | | | | | | | | | | | | | |
| | Phase 2 in Gambia | | | | | | | | ■ | ■ | ■ | ■ | | | | | | | | | | | | |
| | (c-1) Observations and computations of national control points | | | | | | | | ■ | ■ | | | | | | | | | | | | | | |
| | (c-2) Ground control point survey | | | | | | | | | ■ | ■ | ■ | | | | | | | | | | | | |
| | (c-3) Aerial photography | | | | | | | | ■ | ■ | ■ | | | | | | | | | | | | | |
| | (c-4) Discussions on specifications for map symbols and GIS data | | | | | | | | | | ■ | ■ | | | | | | | | | | | | |
| | (c-5) Photo interpretation and field identification | | | | | | | | | ■ | ■ | ■ | | | | | | | | | | | | |
| | Phase 1 in Japan | | | | | | | | | | | □ | □ | □ | | | | | | | | | | |
| | (d-1) Formulation of manuals for technical transfer | | | | | | | | | | | □ | □ | | | | | | | | | | | |
| | (d-2) Aerial triangulation | | | | | | | | | | | □ | □ | | | | | | | | | | | |
| | (d-3) Formulation of the Progress Report | | | | | | | | | | | | | □ | | | | | | | | | | |
| Third Year | Phase 2 in Japan | | | | | | | | | | | | | | □ | □ | □ | | | | | | | |
| | (e-1) Digital plotting | | | | | | | | | | | | | | □ | □ | | | | | | | | |
| | (e-2) Digital compilation (encoding) | | | | | | | | | | | | | | | □ | □ | | | | | | | |
| | (e-3) Proposal for geographic information applications | | | | | | | | | | | | | | □ | □ | | | | | | | | |
| | Phase 3 in Gambia | | | | | | | | | | | | | | | | | ■ | ■ | | | | | |
| | (f-1) Explanation/discussions on the Progress Report | | | | | | | | | | | | | | | | | ■ | | | | | | |
| | (f-2) Discussions on the contents of the technical transfer seminar | | | | | | | | | | | | | | | | | ■ | ■ | | | | | |
| | (f-3) Field completion | | | | | | | | | | | | | | | | | ■ | ■ | | | | | |
| | Phase 3 in Japan | | | | | | | | | | | | | | | | | | □ | □ | □ | | | |
| | (g-1) Supplementary digital compilation | | | | | | | | | | | | | | | | | | □ | □ | | | | |
| | (g-2) Creation of GIS data | | | | | | | | | | | | | | | | | | | □ | □ | | | |
| | (g-3) Creation of data for printed maps | | | | | | | | | | | | | | | | | | | □ | □ | | | |
| | (g-4) Production of printed maps | | | | | | | | | | | | | | | | | | | | □ | □ | | |
| | (g-5) Formulation of the Draft Final Report | | | | | | | | | | | | | | | | | | | | □ | | | |
| | Phase 4 in Gambia | | | | | | | | | | | | | | | | | | | | ■ | ■ | | |
| | (h-1) Technical transfer | | | | | | | | | | | | | | | | | | | | ■ | ■ | | |
| | (h-2) Technical transfer seminar | | | | | | | | | | | | | | | | | | | | | ■ | | |
| | (h-3) Explanation/discussions on the Draft Final Report | | | | | | | | | | | | | | | | | | | | | ■ | | |
| | Phase 4 in Japan | | | | | | | | | | | | | | | | | | | | | □ | □ | □ |
| | (i-1) Formulation of the Final Report | | | | | | | | | | | | | | | | | | | | | □ | □ | □ |
| The Results of Team Plan | General supervision | □ | | | ■ | | | | | | ■ | | | □ | | | | ■ | | | | ■ | □ | |
| | Supervision of aerial photography | | | | | | | | ■ | ■ | | | | | | | | | | | | | | |
| | Supervision of control point installation/GPS survey (1) | | | | ■ | ■ | | | | ■ | ■ | ■ | ▨ | | | | | | | | ▨ | ■ | ■ | | |
| | Supervision of control point installation/GPS survey (2) | □ | | | ■ | ■ | | | | ■ | ■ | ■ | | | | | | | | | | | | |
| | Supervision of photo interpretation | | | | | | | | | ■ | ■ | | | | | | | ■ | ■ | | | | | |
| | Supervision of field identification | | | | | | | | | ■ | ■ | | | | | | | ■ | ■ | | | | | |
| | Supervision of digital plotting | □ | | | ■ | | | | | | | | | | | | | ■ | | | | ■ | ■ | |
| | Supervision of GIS/structuring | □ | | | | | | | | | ■ | | | | | | | ■ | ■ | | | | ■ | |

Legend: ■ Work in Gambia ▨ Assignment of non-Japanese national in Japan
□ Work in Japan

# 3． Results of Study Work

## 3.1 Details and Results of Study Work

### 3.1.1 Preparatory Work

Detailed preparations were carried out based on the basic operational policies and approaches of the Study.

#### (1) Preparations for the Creation of 1:50,000-scaleTopographic Maps

The preparatory study team and the study team of the Study works (hereinafter referred to as "the Study Team") collected topographic maps of various scales (1:250,000, 1:50,000, 1:25,000, etc.). Using these maps, the following preparations were made for the creation of the 1:50,000-scale topographical maps.

①Formulation of digital map symbols draft

After examining the symbols of the collected maps, a digital map symbols draft was formulated.

a. Method of map symbol representation

After examining the shapes and color tones of the symbols on existing 1:50,000-scale topographical maps, the digital map symbols were digitized without making any significant changes to the current map symbols.

b. Required additions and revisions of map symbols

In consideration of the items represented on current maps and the geographic features of the Gambia, new symbols for vegetative boundaries and additional contour lines were added. Some of the symbols of existing maps also had to be simplified for digitization.

c. Determination of coding system and data type for map symbols

A systematic code number and a data type (point, line, polygon) was assigned to each map symbol for future construction of the GIS topographic map database.

The 1:50,000-scale digital map symbols draft was formulated in accordance with the above policies.

②Sheet division and marginal information

a. Sheet division

There were many inconveniences from an administrative point of view, as the existing map sheets were not of uniform sizes. Therefore, two sheet division drafts with standardized sheet sizes and an existing sheet division draft were formulated and presented during discussions held with DL&S.

b. Marginal information

The digital marginal information draft was to be formulated based on the marginal information of the existing maps. The digital map symbol draft was adopted for the map symbol legend.

### (2) Preparations for GPS Surveying

The preliminary study team and the Study Team collected the national control point distribution maps, which were prepared from 1:50,000-scale topographic maps. Preparations for GPS surveys were made using these point distribution maps and topographic maps scaled at 1:250,000.

①National control point survey

Based on the basic technical policies and approaches, a survey plan for establishing a national control point network in conformance with and tied to the World Geodetic System was formulated.

a. Point distribution plan

A plan was formulated to uniformly distribute the national control points throughout the entire country at an interval of 40～50km. Two (2) points, one in the east of the Gambia and the other in the west, were to be established as zero order control points to serve as tie points to the World Geodetic System. Another fifteen (15) points were to be established as first order control points. The planned positions of these seventeen (17) national control points (2 zero order and 15 first order) were indicated on the 1:250,000-scale topographic maps.

b. Observation Plan

The planned observation time of the zero order control points was 48 hours or more. The observation data of given points were to be acquired from IGS points in the vicinity of the zero order control points.

The planned observation time of the first order control points was six hours or more per session.

②Ground Control Point Survey

The ground control point survey was planned so that the subsequent aerial triangulation could be carried out with the prescribed accuracy.

a. Aerial photography plan

The aerial photographs were to be taken with B/W film at a scale of 1:50,000. An aerial camera equipped with a GPS to determine the taking position and a super wide angle lens with a focal length of 15cm was to be used.

Based on the above, a plan to cover all of the Gambia with 19 flight strips (including four cross strips) was formulated and indicated on a 1:250,000-scale topographic map.

b. Point distribution plan

Considering the aerial photography plan and scope of mapping (all of the Gambia), the number and position of ground control points required for subsequent aerial triangulation were determined and a point distribution plan was formulated. Every effort was made to substitute required ground control points with zero order and first order control points if they were nearby.

The resulting number of newly planned ground control points was twenty-six (26).

c. Observation plan

The planned observation time for ground control points was two hours or more per session with zero order and first order control points as given points.

### (3) Preparations for GIS database

In consideration of the GIS to be introduced and applied in the Gambia in the near future, GIS databases that could be effectively used were determined and specifications for them were to be examined.

①Determination of GIS databases

GIS databases that would make effective use of the digital topographic map data produced under the Study were to be constructed. It was decided that the following GIS databases be created.

- ♦ Topographic map database
- ♦ Road network database

- ♦ Digital Terrain Model (DTM) database

②Examination of specifications for GIS databases

Many parts of the specifications for the topographic map database were to be based on those of the topographic map data. Therefore, the coding system and data types of the map symbols decided on in the digital map symbol draft were to be included in the specifications for the topographic map database.

The rest of the topographic map database specifications and those for the road network and digital terrain model databases were to be determined after examining the equipment used in technology transfer and that possessed by DL&S.

### (4) Preparations for technology transfer

Preparations for the transfer of technology were made in accordance with the second objective of the Study.

①Determination of technology to be transferred

Various technologies were to be applied during the Study. Of those, the following were selected for technical transfer.

a. Aerial signalization techniques
b. GPS surveying techniques (point distribution plan, observation, analysis)
c. Photo interpretation/field identification techniques
d. Map revision techniques (digitization of existing maps, revision of digital topographic maps)

②Examination of equipment for technology transfer

Equipment was needed in the transfer of some of the above techniques. The equipment required for the transfer of techniques in “b” and “d” in particular was large-scale and therefore examined.

a. Equipment for GPS surveying

The equipment used in GPS surveying generally consisted of GPS receivers and analytical software for observation data. Specifications for the equipment were prepared in consideration of their use during the Study as well as by DL&S after completion of the Study.

b. Equipment for map revision

The techniques to be transferred in the map revision work were initially determined

and an equipment configuration plan was formulated in consideration of the following points:

- Software that is easy to operate using a GUI
- Hardware and software maintenance and the support system
- Software that does not require special hardware
- Easy operability for updating topographic map data, GIS databases and printed map data

The resulting configuration plan was a diagram that showed the connection between a computer and peripheral equipment. The software was to have desktop mapping functions and be capable of producing simple output maps with an ink-jet plotter.

### (5) Preparations for assessing the current situation of geographic information and proposals

Based on the information collected by the preliminary study team and the Study Team on national control points, the situation of topographic map production and the present situation of DL&S (organization, work content, possessed equipment, technical level, etc.), the items to be studied to assess the current situation and formulate proposals were examined

As a result, preparations were made for the following items:

- DL&S organizations and their services:
  - Organizational system of DL&S (personnel, structure, budget)
  - Work content of each organization
  - Mutual relationship between the organizations
  - Possessed equipment
- Geographic information:
  - Information on existing control points
  - Information on existing topographic maps and aerial photos
  - Map symbols specifications
  - Information on secular changes
- Situation of GIS use:
  - Applications and needs for geographic information
  - Applications and needs for GIS
- Other:
  - Information on long-term plans of DL&S

## 3.1.2 Establishment of National Control Point Network

### (1) Determination of specifications for national control points

① Distribution of national control points and ground control points

The positions and network of national control points and the positions of ground control points planned in the preparatory stage of the Study were explained and discussed using the 1:250,000-scale topographic map.

Discussions on technical specifications

The planned positions on the 1:250,000-scale topographic map were approved and it was agreed that the final position of the points would be determined in the field.

②Method for tying national control network

It was agreed that two zero order control points near Banjul and Fatoto, would be used as tie points to link with IGS points. Furthermore, the observation data used in analytical computations would be acquired from IGS points in the vicinity of the two points.

③Observation time and computation method

It was agreed that the observation time at the points tied to IGS point (zero order control points), national control points (first order control points), and ground control points would be about 48 hours, 6 hours and 2 hours, respectively, and that the baseline analysis and net adjustment would be carried out using BERNESE, Trimble and software provided by JICA.

④Surveying standard

In order to tie up with the World Geodetic System, the reference ellipsoid was changed from Clarke 1880 to WGS-84.

⑤Monumentation standard

An original standard (draft) for monumentation of zero and first order control points was proposed and approved.

### (2) Point Selection and Monumentation

The points indicated on the planning map were selected based on the following policies:

- ♦ Use already established control points whenever possible
- ♦ Select points that are suitable for GPS surveying
- ♦ Select points that are suitable for aerial signalization and pricking

The aim of the first item was to reduce the amount of monumentation work as well as to clarify the correlation between the old and new reference ellipsoids (determining the parameters for coordinate transformation).

①Selection and monumentation of zero/first order control points

a. Point selection

After making preparations based on the policies above and the planning map, a reconnaissance was conducted and points were selected.

Existing control points could be used as they were for 10 (N4, N5, N7, N11, N12, N13, N14, N15, N16, N17) of the 17 planned zero order and first order control points. The existing control points of 4 points (N1,N3,N8,N10) were damaged and had to be reinforced, and the existing control points of the remaining 3 (N2,N6,N9) had to be newly installed. Also, N2 (Banjul) and N17 (Fatoto) were used as the tie points to connect to the World Geodetic System.

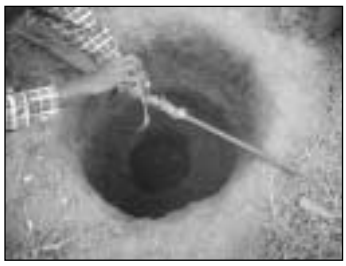
Existing control point
(Distant view of PM point)

Existing control point
(Close-range view of PM point)

b. Monumentation

The existing control points of 4 points (N1, N3, N8, N10) were reinforced and three points (N2, N6, N9) were newly installed in accordance with the monumentation standard decided on during the discussions on specifications.

Present state of monument



Excavation work

Setting of stone pillar

Inscribing of monument

Completed monument

②Selection of ground control points

As with the zero and first order control points, a reconnaissance was conducted and ground control points were selected after making preparations based on the stated policies and planning map.

Natural target (block wall)

Existing control points were used for 11 of the 26 ground control points. As for the remaining 15 points, natural targets suitable for aerial signalization and pricking, such as wells, cultivated land boundaries, fences, etc, were selected.

### (3) GPS Survey

①Zero order control point survey

As for the zero point control survey, observations were performed at two points within Gambia and analytic computations were carried out after deciding the observation network using the observation data of nearby IGS points available on the Internet.

a. Observations

GPS observations were performed at the two zero order control points, N2 (Banjul) and N17 (Fatoto), in accordance with the following specifications.

Equipment used: Trimble 4000 SSI, 2 units

| | |
|---|---|
| Observation time: | 48 hours or more |
| Elevation angle mask: | 10 degrees or more |
| Data Acquisition interval: | 15 seconds |
| Positioning system: | Static positioning |
| Survey method: | Junction traverse method |

The observation network shown in Figure 3.1 is based on the observation data of IGS points later obtained from the Internet. Analytic computations were carried out using the four IGS points as known points.

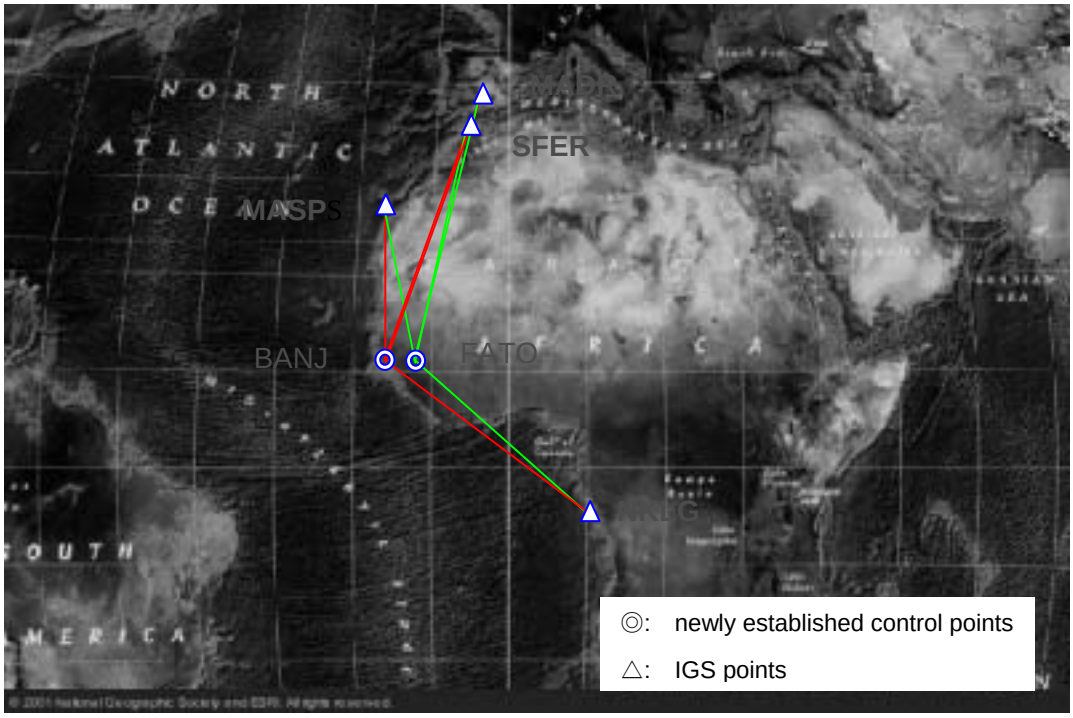



Figure 3.1 Observation map for zero order control point survey

b. Analytic computations

Prior to analytic computations, nearby IGS points where observation data could be normally obtained at the same observation period as the zero order control points were identified through the Internet. It was found that the data acquired at the points MADR, SFER, MASP and NKLG shown in Figure 3.1 was normal observation data that could be used in the analytic computations.

As the distance between the zero order control points and the four IGS points reached as much as 2000 - 3000km, BERNESE processing software developed at Bern University in Switzerland and suitable for long baselines was used for the baseline analysis.

c. Determining the coordinates of zero order control points

The coordinates of the zero order control points serving as tie points to the World Geodetic System were based on the ITRF2000-EPOCH1997 coordinates available to the public. The following procedures were adopted to determine the coordinates.

- ♦ The coordinate values of the IGS points at the time ITRF2000-EPOCH2001, 192nd day (the final observation day at the zero order control points) were estimated from their established ITRF2000-EPOCH1997 coordinate values, taking plate motion into consideration.
- ♦ Based on the estimated coordinate values of the IGS points, baseline analyses between the IGS points and zero order control points were carried out, and the results of the check computations (i.e. Divergence, etc.) were evaluated.
- ♦ Adjustment computations were carried out using the results of each baseline analysis to establish the coordinate values of the zero order control points at the time of ITRF2000-EPOCH2001, 192nd day. Furthermore, the mean square error of the coordinate values after the adjustment computations was evaluated.
- ♦ The secular change of the zero order control points were determined by interpolation from the secular change of the IGS points due to plate motion.
- ♦ The coordinate values of the zero order control points at the time of ITRF2000-EPOCH2001, 192nd day were established by converting them into their ITRF2000-EPOCH1997 coordinates by interpolation, taking secular change into consideration.

The final coordinate values of the zero order control points were determined by the procedures above. The divergence in the baseline analyses and final zero order coordinate values are shown in Table 3.1 and Table 3.2.

Table 3.1 Divergence

| Site | X(ECEF) | Y(ECEF) | Z(ECEF) |
|---|---|---|---|
| N2 (BANJ) | 10.7mm | 6.2mm | 3.1mm |
| N17 (FATO) | 5.3 mm | 8.2mm | 2.3mm |

Table 3.2 Final values

| Site | Latitude (N) | Longitude (W) | Ell.Hgt. |
|---|---|---|---|
| N2 (BANJ) | 13° 27′ 08.56154 | 16° 35′ 22.27207 | 37.863 |
| N17 (FATO) | 13° 24′ 22.30210 | 13° 53′ 29.64585 | 67.147 |

②First order control point survey

The first order control point survey was conducted with the zero order control points (N2,N17) as known points.

a. Observations

Observations were performed according to the following specifications over a total of 13 sessions. The observation network map is as shown in Figure 3.2.

| | |
|---|---|
| Equipment used: | ASHTECH's Z-Xtreme, 3 units |
| Observation time: | 6 hours or more |
| Elevation angle mask: | 10 degrees |
| Data acquisition interval: | 15 seconds |
| Positioning method: | Static positioning |
| Survey method: | Junction traverse method |

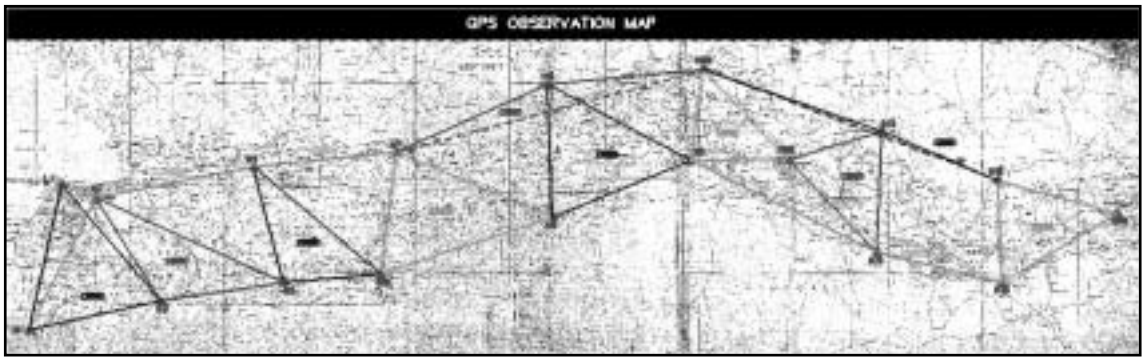



Figure 3.2 Observation map for first order control point survey

b. Analytic computations

The baseline analysis was performed with the BERNESE baseline analysis software used in the zero order control point survey. Leica's SKI GPS processing software version 1.1 was used in the three dimensional net adjustment computations that determined the final coordinate values of the first order control points

As for the results of the three dimensional net adjustment computations, the mean square error was less than a few cm at all the control points as shown in Table 3.3.

Table 3.3 First Order Control Point Survey Adjustment Results

| Point Id | Class | Latitude | Longitude | Ellip Hgt | Sd. X | Sd. Y | Sd. Z |
|---|---|---|---|---|---|---|---|
| N2 | Control | 13° 27' 08.56154" N | 16° 35' 22.27207" W | 37.8630 | 0.000 | 0.000 | 0.000 |
| N17 | Control | 13° 24' 22.30210" N | 13° 53' 29.64585" W | 67.1468 | 0.000 | 0.000 | 0.000 |
| L1 | Adjusted | 13° 28' 52.33167" N | 16° 40' 50.54748" W | 44.2311 | 0.018 | 0.006 | 0.005 |
| N1 | Adjusted | 13° 05' 55.57910" N | 16° 45' 49.03416" W | 35.7217 | 0.016 | 0.005 | 0.005 |
| N10 | Adjusted | 13° 46' 59.13647" N | 14° 59' 33.45374" W | 45.1392 | 0.023 | 0.007 | 0.007 |
| N11 | Adjusted | 13° 32' 50.63285" N | 15° 01' 14.98621" W | 58.5378 | 0.022 | 0.007 | 0.006 |
| N12 | Adjusted | 13° 33' 11.36680" N | 14° 44' 54.04608" W | 50.9523 | 0.023 | 0.007 | 0.007 |
| N13 | Adjusted | 13° 37' 30.89831" N | 14° 30' 57.18141" W | 75.9958 | 0.021 | 0.006 | 0.006 |
| N14 | Adjusted | 13° 18' 58.72146" N | 14° 31' 42.63683" W | 58.6953 | 0.022 | 0.006 | 0.006 |
| N15 | Adjusted | 13° 30' 07.56842" N | 14° 12' 22.68712" W | 76.8046 | 0.018 | 0.005 | 0.005 |
| N16 | Adjusted | 13° 13' 09.81567" N | 14° 11' 15.11171" W | 89.7529 | 0.020 | 0.006 | 0.006 |
| N3 | Adjusted | 13° 10' 04.52137" N | 16° 24' 59.74873" W | 56.0345 | 0.016 | 0.005 | 0.005 |
| N4 | Adjusted | 13° 31' 43.12949" N | 16° 10' 36.05240" W | 62.6834 | 0.017 | 0.005 | 0.005 |
| N5 | Adjusted | 13° 13' 42.41408" N | 16° 05' 48.31298" W | 44.5012 | 0.018 | 0.006 | 0.005 |
| N6 | Adjusted | 13° 14' 50.70676" N | 15° 50' 06.57357" W | 41.1258 | 0.021 | 0.007 | 0.006 |
| N7 | Adjusted | 13° 34' 15.15276" N | 15° 48' 41.35211" W | 59.3074 | 0.023 | 0.007 | 0.007 |
| N8 | Adjusted | 13° 44' 18.16614" N | 15° 23' 46.85361" W | 55.4986 | 0.023 | 0.007 | 0.007 |
| N9 | Adjusted | 13° 23' 51.97874" N | 15° 23' 28.20885" W | 42.6921 | 0.023 | 0.007 | 0.007 |

③Ground control point survey

The ground control point survey was conducted using the zero and first order control points as known points.

a. Observations

Observations were performed according to the following specifications over a total of 24 sessions. The observation network map is shown in Figure 3.3.

| | |
|---|---|
| Equipment used: | ASHTECH's Z-Xtreme , 3 units |
| Observation time: | more than 2 hours |
| Elevation angle mask: | 10 degrees |
| Data acquisition interval: | 15 seconds |
| Positioning method: | Static positioning |
| Survey method: | Junction traverse method |

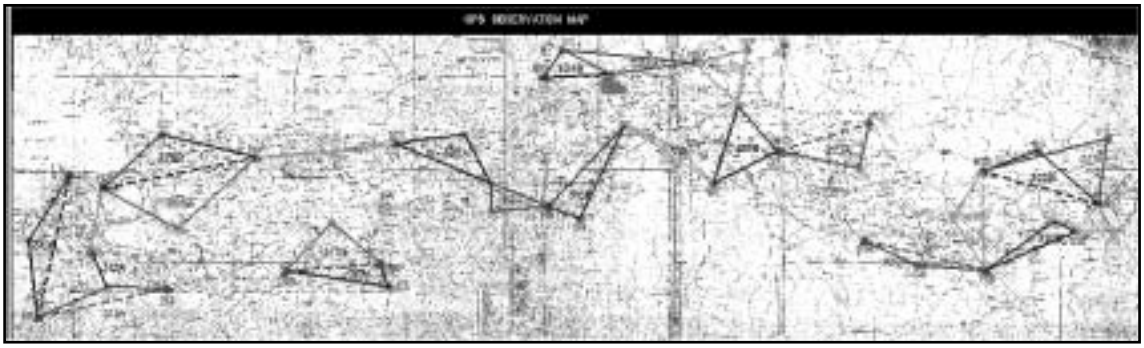


Figure 3.3 Observation map for ground control point survey

b. Analytic computations

Trimble's "Gpsurvey Ver2.35" was used for the baseline analysis and Trimble's "TRIM NET Ver2.35" was used for the three dimensional net adjustment computations that determined the final coordinate values of the ground control points.

The results of the three dimensional net adjustment computations were favorable at all the points as shown in Table 3.4. The standard is as shown in the table below.

| | Horizontal position | Height |
|---|---|---|
| Standard deviation | 0.1 m | 0.3 m |

Table 3.4 Coordinates and standard deviation of ground control points

| Point Id | Latitude | Longitude | Ellip Hgt | φ(m) | λ(m) | ELL HT(m) |
|---|---|---|---|---|---|---|
| G1 | 13° 18' 34.34069" N | 16° 47' 09.28606" W | 39.169 | 0.013 | 0.013 | 0.037 |
| G2 | 13° 35' 23.69764" N | 16° 25' 20.69608" W | 67.857 | 0.014 | 0.018 | 0.136 |
| G3 | 13° 10' 43.94695" N | 15° 48' 32.13743" W | 43.476 | 0.029 | 0.033 | 0.157 |
| G4 | 13° 21' 34.69058" N | 15° 17' 50.97591" W | 75.788 | 0.011 | 0.013 | 0.124 |
| G5 | 13° 44' 52.52519" N | 15° 16' 42.06503" W | 73.488 | 0.010 | 0.011 | 0.065 |
| G6 | 13° 27' 48.10335" N | 14° 56' 24.51859" W | 65.087 | 0.012 | 0.014 | 0.094 |
| G7 | 13° 45' 37.70286" N | 14° 51' 56.25512" W | 78.051 | 0.087 | 0.299 | 0.427 |
| G8 | 13° 14' 21.06039" N | 14° 23' 14.18069" W | 63.248 | 0.027 | 0.037 | 0.252 |
| G9 | 13° 32' 52.75088" N | 14° 03' 18.56270" W | 79.198 | 0.018 | 0.021 | 0.216 |
| G10 | 13° 20' 06.85477" N | 13° 56' 34.87234" W | 45.654 | 0.014 | 0.015 | 0.131 |
| G11 | 13° 32' 58.68276" N | 13° 53' 25.40467" W | 47.534 | 0.034 | 0.051 | 0.207 |
| L2 | 13° 17' 10.05005" N | 16° 37' 05.55770" W | 44.735 | 0.027 | 0.072 | 0.155 |
| L3 | 13° 10' 48.20742" N | 16° 34' 31.91352" W | 46.080 | 0.009 | 0.012 | 0.077 |
| L4 | 13° 19' 59.77416" N | 16° 23' 04.23327" W | 32.574 | 0.028 | 0.035 | 0.267 |
| L5 | 13° 21' 07.03308" N | 15° 58' 02.08557" W | 58.238 | 0.038 | 0.033 | 0.227 |
| L6 | 13° 33' 27.73807" N | 15° 54' 53.16970" W | 56.373 | 0.023 | 0.023 | 0.158 |
| L7 | 13° 23' 02.64002" N | 15° 31' 47.65292" W | 62.730 | 0.021 | 0.028 | 0.202 |
| L8 | 13° 27' 31.78708" N | 15° 32' 09.18157" W | 61.390 | 0.019 | 0.025 | 0.18 |
| L9 | 13° 34' 33.95901" N | 15° 36' 16.27877" W | 54.103 | 0.027 | 0.035 | 0.253 |
| L10 | 13° 36' 52.20314" N | 15° 10' 14.97213" W | 41.517 | 0.021 | 0.029 | 0.144 |
| L11 | 13° 40' 39.38941" N | 14° 52' 27.40182" W | 46.606 | 0.022 | 0.024 | 0.165 |
| L12 | 13° 30' 10.50734" N | 14° 29' 58.47598" W | 54.375 | 0.035 | 0.057 | 0.168 |
| L13 | 13° 22' 12.35086" N | 14° 17' 03.92469" W | 53.717 | 0.030 | 0.047 | 0.191 |
| L14 | 13° 21' 32.59331" N | 14° 00' 18.47807" W | 77.030 | 0.021 | 0.022 | 0.188 |
| L15 | 13° 19' 35.36952" N | 13° 50' 57.55162" W | 86.247 | 0.015 | 0.016 | 0.152 |

### (4) Determination of Elevation

The elevations obtained after the GPS survey analysis and adjustment computations represent the vertical height (distance) from the reference ellipsoid, that is to say the “ellipsoid height”. However, the elevations (conventional height) based on the Gambia’s surveying standards are defined as the vertical height (distance) from the geoid, not from the ellipsoid. Therefore, it was necessary to determine the elevations of zero/first order control points and ground control points obtained by GPS surveys based on this definition.

①Determining the elevations of zero/first order control points and ground control points of which existing control points were used

Of the zero /first order control points and ground control points of which existing control points were used, if the existing control points had elevation data, those values were used as the elevations in the results of this GPS survey.

②Determining elevations by direct leveling

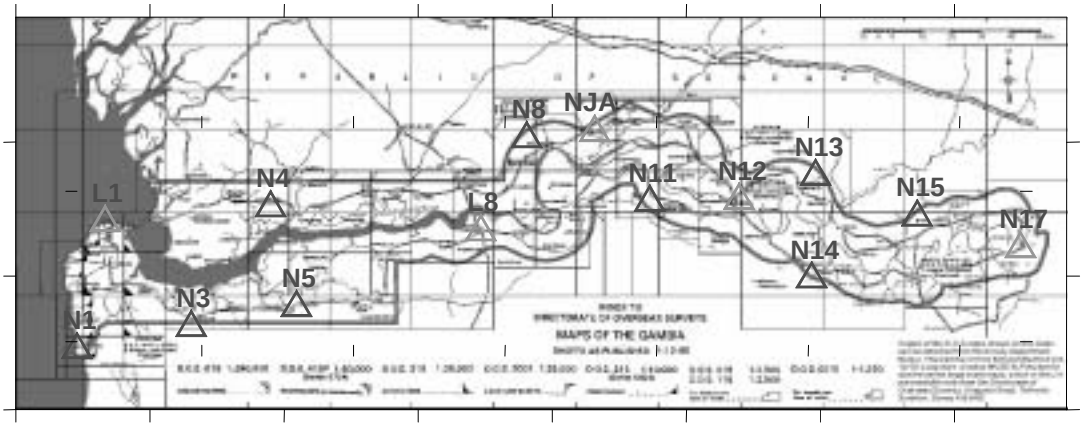
If there were bench marks in the vicinity, the heights of zero/first order control points and ground control points were determined by direct leveling.

③Determining the elevations of newly installed and reinforced zero/first order control points and ground control points

The elevations of zero/first order control points and ground control points that were newly installed, reinforced or did not have elevation data as an existing control point were determined by the following procedures:

Procedures

1. For the points that had ellipsoid height and conventional height data, the geoid height was estimated from the difference of both values. (Refer to Figure 3.4)
2. Using the points with the estimated geoid height, a geoid map covering all of Gambia was prepared by interpolation. (Refer to Figure 3.5)
3. Using the geoid map, the geoid heights of the zero/first order control points and ground control points that were newly installed or reinforced were estimated by interpolation
4. The elevations of the newly installed and reinforced zero/first order control points and ground control points were calculated from the ellipsoid height based on the estimated geoid height.




△(green): points with elevation data △(red): points with elevations determined by direct leveling

Figure 3.4 Control point distribution map for production of geoid map

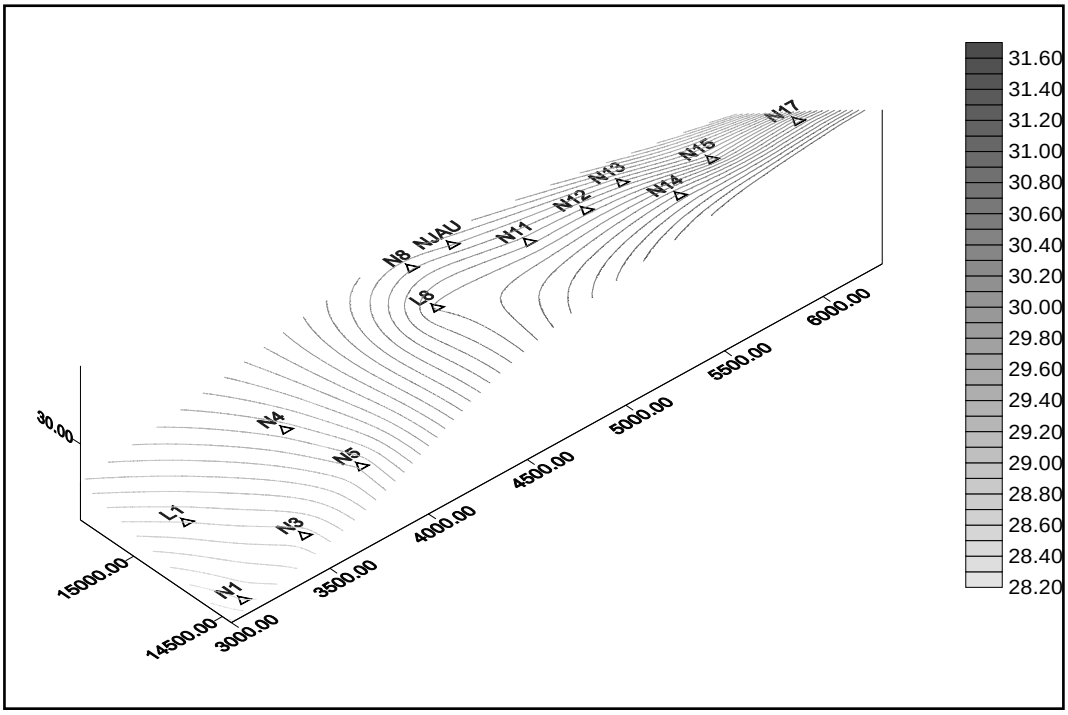



Figure 3.5 Geoid map of Gambia

The horizontal coordinates, ellipsoid heights, geoid heights and standard heights that were obtained for each point based on the above procedures are summarized in Figure 3.5.

Table 3.5 List of Horizontal Coordinates and Ellipsoid, Geoid and Standard Heights

| Pt Name | Easting | Northing | Ellip Hgt | Geoid Hgt | Std Hgt |
|---|---|---|---|---|---|
| N1 | 308799.219 | 1448725.639 | 35.722 | 28.407 | 7.315 |
| N2 | 327928.009 | 1487718.776 | 37.863 | 28.879 | 8.984 |
| N3 | 346472.130 | 1456138.196 | 56.035 | 28.756 | 27.279 |
| N4 | 372666.538 | 1495903.916 | 62.683 | 29.460 | 33.223 |
| N5 | 381169.728 | 1462659.470 | 44.501 | 29.322 | 15.179 |
| N6 | 409521.854 | 1464648.187 | 41.126 | 30.055 | 11.071 |
| N7 | 412204.125 | 1500414.022 | 59.307 | 30.177 | 29.130 |
| N8 | 457149.764 | 1518827.885 | 55.499 | 30.475 | 25.024 |
| N9 | 457649.364 | 1481157.992 | 42.692 | 30.858 | 11.834 |
| N10 | 500797.061 | 1523737.746 | 45.139 | 30.282 | 14.857 |
| N11 | 497746.273 | 1497671.793 | 58.538 | 30.650 | 27.888 |
| N12 | 527228.063 | 1498322.651 | 50.952 | 30.624 | 20.328 |
| N13 | 552364.257 | 1506333.514 | 75.996 | 30.398 | 45.598 |
| N14 | 551063.985 | 1472164.243 | 58.695 | 31.112 | 27.583 |
| N15 | 585895.847 | 1492801.327 | 76.805 | 30.475 | 46.330 |
| N16 | 588029.867 | 1461540.536 | 89.753 | 31.344 | 58.409 |

| Pt Name | Easting | Northing | Ellip Hgt | Geoid Hgt | Std Hgt |
|---|---|---|---|---|---|
| N17 | 620008.084 | 1482325.174 | 67.147 | 30.810 | 36.337 |
| NJAU | 479607.344 | 1520876.709 | 62.568 | 30.383 | 32.185 |
| G1 | 306547.815 | 1472061.137 | 39.169 | 28.519 | 10.650 |
| G2 | 346109.606 | 1502822.728 | 67.857 | 29.213 | 38.644 |
| G3 | 412339.469 | 1457057.969 | 43.476 | 30.106 | 13.370 |
| G4 | 467786.374 | 1476926.421 | 75.788 | 30.901 | 44.888 |
| G5 | 469908.035 | 1519865.574 | 73.488 | 30.435 | 43.053 |
| G6 | 506478.609 | 1488378.896 | 65.087 | 30.793 | 34.294 |
| G7 | 514526.023 | 1521240.123 | 78.051 | 30.271 | 47.780 |
| G8 | 566381.948 | 1463667.654 | 63.248 | 31.280 | 31.968 |
| G9 | 602234.832 | 1497934.247 | 79.198 | 30.356 | 48.842 |
| G10 | 614470.385 | 1474452.402 | 45.654 | 31.027 | 14.627 |
| G11 | 620064.028 | 1498191.396 | 47.534 | 30.322 | 17.212 |
| L1 | 318075.898 | 1490973.347 | 44.231 | 28.806 | 15.425 |
| L2 | 324701.271 | 1469346.574 | 44.735 | 28.691 | 16.044 |
| L3 | 329251.811 | 1457583.142 | 46.080 | 28.643 | 17.437 |
| L4 | 350051.664 | 1474409.202 | 32.574 | 28.978 | 3.596 |
| L5 | 395255.825 | 1476261.667 | 58.238 | 29.754 | 28.484 |
| L6 | 401023.572 | 1498996.793 | 56.373 | 29.970 | 26.403 |
| L7 | 442625.444 | 1479670.258 | 62.730 | 30.780 | 31.950 |
| L8 | 441995.882 | 1487940.015 | 61.390 | 30.813 | 30.577 |
| L9 | 434598.239 | 1500926.843 | 54.103 | 30.554 | 23.549 |
| L10 | 481522.051 | 1505099.172 | 41.517 | 30.596 | 10.921 |
| L11 | 513595.509 | 1512075.367 | 46.606 | 30.420 | 16.186 |
| L12 | 554155.858 | 1492807.918 | 54.375 | 30.663 | 23.712 |
| L13 | 577483.305 | 1478175.884 | 53.717 | 30.910 | 22.807 |
| L14 | 607732.424 | 1477058.794 | 77.030 | 30.946 | 46.084 |
| L15 | 624623.727 | 1473530.128 | 86.247 | 31.051 | 55.196 |

### 3.1.3 Production of 1:50,000-scale Topographic Maps

#### (1) Determination of specifications for 1:50,000-scale topographic maps

In the production of 1:50,000-scale topographic maps, specifications for ①the production of topographic maps, ②digital map symbols and ③digital marginal information were determined presuming they were to be prepared in digital format.

①Standards for the production of topographic maps

Based on a series of discussions with DL&S, the standards for producing topographic maps were determined to be as follows.

| | |
|---|---|
| Reference ellipsoid: | WGS-84 (Transformed from the existing Clarke1880) |
| Method of projection: | Universal Transverse Mercator projection (UTM projection) |
| UTM zone: | 28 |
| Origin of coordinates: | 15°west longitude, 0°north latitude |
| Values of origin coordinates: | E=500,000.0m N=0.0m |
| Scale factor on central meridian: | 0.9996 |

②Digital map symbols

Digital map symbols were also decided on following discussions with DL&S. The selected digital map symbols were based on the 1:50,000-scale analog map symbols and included those necessary to conform to secular change as well as those necessary to represent the geographical features particular to the Gambia. The symbols were also simplified as required for digitization.

The digital map symbols are defined in the "National Base Map Symbols Regulations (Draft)".

③Marginal information

A consensus was reached with DL&S that as a rule, the marginal information should be prepared in the same form as on the analog maps. However, the map symbol legend was changed to digital map format and the map name and magnetic declination of each map sheet were presented by DL&S

There was also mutual agreement with DL&S that the following English text would be indicated on all printed maps as part of the marginal information.

"This map was prepared jointly by the Japan International Cooperation Agency (JICA) under the Japanese Government Technical Cooperation Program and the Government of the Republic of the Gambia"

④Sheet division

The existing map set consists of twenty (20) sheets that are not uniform in size. Discussions were held with DL&S and a system of map sheet division covering the entire country of Gambia with 27 sheets of a standardized size (15minutes×15minutes) was adopted.

### (2) Aerial Photography

Prior to taking aerial photos, a subcontractor to carry out the work was selected and aerial photo signals were installed.

①Selection of subcontractor

Based on the specifications for aerial photos of which permission was obtained, various subcontractors were selected from Europe and South Africa. After examining information collected on the personnel, equipment possessed and work experience of each of the companies, the following South African company was selected as the subcontractor.

Digital Topographic Mapping Services (D.T.M )

②Aerial photo signalization

Prior to taking photos, four types of signals were installed at a total of 28 points (i.e. 15 of the 17 established control points and 13 of the 26 established ground control points after point selection and monumentation) based on site conditions. For the remaining 2 control points and 13 ground control points, natural markers that could be pricked (e.g. wells, etc) were used in place of conventional signals.

The specifications for aerial photo signals and signal types are as shown in Table 3.6 and Table 3.7, respectively.

Table 3.6 Specifications for aerial photo signals

| SHAPE | Y SHAPE (3-WING) | ＋ SHAPE (4-WING) | T SHAPE (3-WING) | □ SHAPE (SQUARE) |
|---|---|---|---|---|
| Color | White | White | White | White |
| Size | 1m×3m (1wing) | 1m×3m (1wing) | 1m×3m (1wing) | 3m×3m |

Table 3.7 Signal Types

| Survey Point Name | Signal | Type | Survey Point Name | Signal | Type | Survey Point Name | Signal | Type |
|---|---|---|---|---|---|---|---|---|
| N1 (Reinforced) | Aerial photo signal | Ｙtype | G1 | Bridge | Prick | L1 | Aerial photo signal | Ｙtype |
| N2 (New) | Pump station house | Prick | G2 | Vegetative boundary | Prick | L2 | Well | Prick |
| N3 (Re-monumented) | Aerial photo signal | Ｙtype | G3 | Aerial photo signal | □type | L3 | Well | Prick |
| N4 | Aerial photo signal | Ｙtype | G4 | Aerial photo signal | □type | L4 | Concrete floor | Prick |
| N5 | Aerial photo signal | □type | G5 | Intersection | Prick | L5 | Aerial photo signal | □type |
| N6 (New) | Structure within GS | Prick | G6 | Aerial photo signal | Ｙtype | L6 | Block wall | Prick |
| N7 | Aerial photo signal | Ｙtype | G7 | Well | Prick | L7 | Aerial photo signal | Ｙtype |
| N8 (Reinstalled) | Aerial photo signal | Ｙtype | G8 | Wooden fence | Prick | L8 | Aerial photo signal | □type |
| N9 (New) | Aerial photo signal | Ｙtype | G9 | Well | Prick | L9 | Aerial photo signal | Ｙtype |
| N10 (Re-monumented) | Aerial photo signal | ＋type | G10 | Well | Prick | L10 | Aerial photo signal | Ｙtype |
| N11 | Aerial photo signal | Ｙtype | G11 | Well | Prick | L11 | Aerial photo signal | ＋type |
| N12 | Aerial photo signal | ＋type | | | | L12 | Well | Prick |
| N13 | Aerial photo signal | Ｙtype | | | | L13 | Aerial photo signal | Ｙtype |
| N14 | Aerial photo signal | Ｙtype | | | | L14 | Aerial photo signal | Ｙtype |
| N15 | Aerial photo signal | Ｙtype | | | | K15 | Aerial photo signal | Ｔtype |
| N16 | Aerial photo signal | Ｔtype | | | | | | |
| N17 | Aerial photo signal | Ｙtype | | | | | | |

Aerial photo signal（Y type)

Pricking of natural marker (well)

③Permit for photography

Requests for a landing and airport use permit and photography permit were made with the

concerned agencies in both Gambia and Senegal mentioned below.

a. In the Gambia

Department of Aviation: Permit for landing and airport use (Issued on October 12, 2000)

Ministry of Defense:Permit for photography (Issued October 29, 2002)

b. In Senegal

Government of Senegal:Permit for photography (November, 2002)

④Aerial photography

a. Aerial photography

After obtaining permits from the concerned agencies, photography work began on November 7, 2002 and photographs were actually taken on the $12^{th}$, $13^{th}$ and $14^{th}$ of November.

b. Inspection of photographs

After taking the photos, the film was developed and printed and the prints were inspected. As there were no problems found with any of the photos, it was decided to employ all of them thereby completing the photography work.

The specifications of aerial photography and the quantity of photos were as follows:

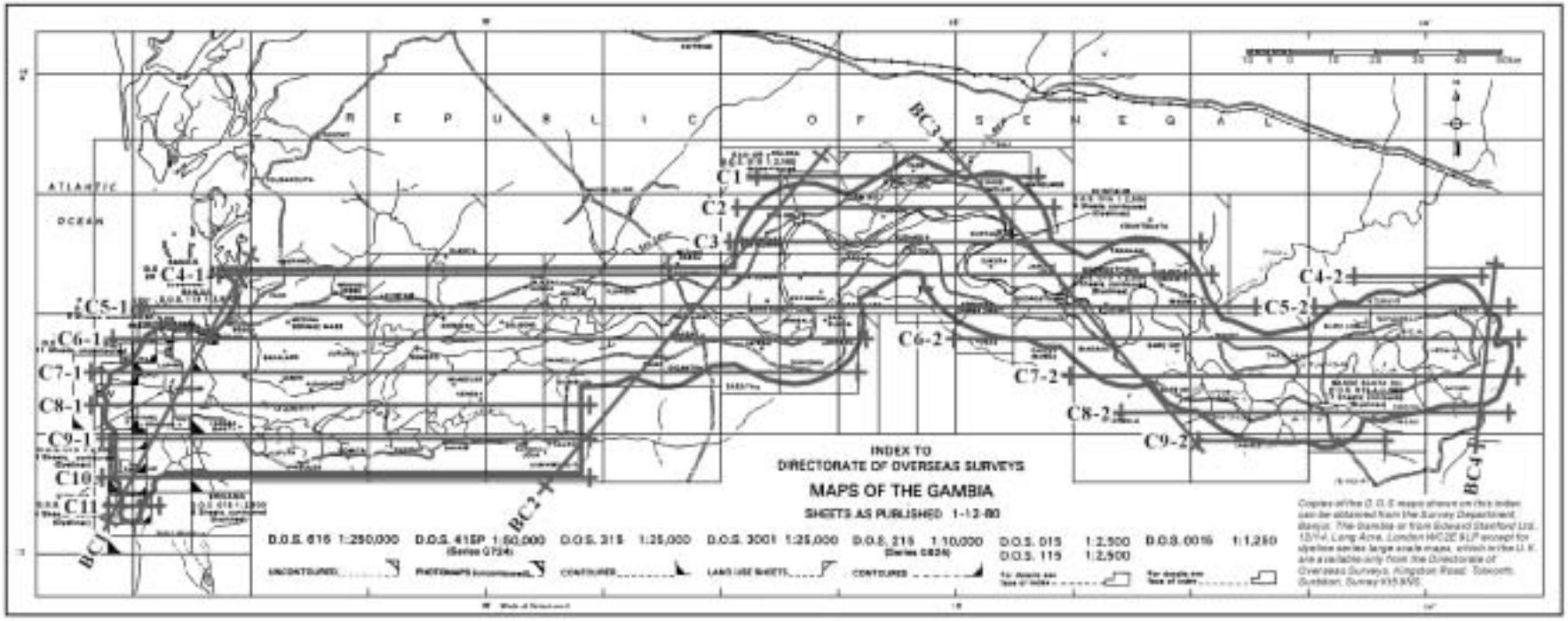
| | |
|---|---|
| Camera: | LEICA RC-30 15/4 (Lens: UAG-S13352) |
| Focal length: | 153.69mm |
| Photo scale: | 1:50,000 |
| Photographic film: | Black/white film |
| Photo size: | 23cm×23cm |
| Photographed area: | approx.11,298K ㎡ |
| No. of flight strips: | 15 strips (east-west direction) , 4 strips (Cross strip) |
| No. of photos: | 513 |
| Overlap: | 60% (overlap) and 30% (side lap) as standard |
| Photographic center: | Acquired by GPS |

The index map is shown in Figure 3.10.

c. Permit to take out photographic film

As the film was to be used in successive works, a permit to take photographic film out of the Gambia was obtained from DL&S and the film was taken to Japan.

THE STUDY
FOR
ESTABLISHMENT OF GEOGRAPHIC DATABASE
IN
THE REPUBLIC OF THE GAMBIA




| | | |
|---|---|---|
| Study area | | 11,295km² |
| Aerial photography | | 1/50,000 (W/B) |
| | | 21 strips |
| | | 497 photographs |

### (3) Photo Interpretation/Field Identification

①Field identification

Due to a slight delay in the aerial photography schedule, the field identification was conducted using existing maps (existing 1:50,000-scale topographic maps: map sheets indicating only roads and administrative names) . The field identification consisted of the following:

- ♦ Verification of geographic names, administrative names and annotations
- ♦ Verification of markers such as schools, churches and mosques
- ♦ Collection of information necessary for preparing the "Photo Interpretation Handbook"

The criteria for classifying roads were obtained from the administrator of roads and the data on administrative boundaries and names from DL&S.

The results of the field identification were indicated on the existing maps used. Furthermore, after obtaining the aerial photos, the results were indicated on the contact print overlays.

②Aerial photo interpretation

Based on the information collected in the field identification, an "Aerial Photo Interpretation Handbook" was prepared including the following information on each item defined in the map symbol specifications.

- ♦ Name of feature item
- ♦ Feature code
- ♦ Topographic map (1/250,000)
- ♦ Photo of site
- ♦ Characteristics
- ♦ Precaution
- ♦ Aerial photo

Sample of Photo Interpretation Handbook

Aerial photos were interpreted based on the Aerial Photo Interpretation Handbook and the results were indicated on the contact print overlays.

## (4) Aerial Triangulation

①Aerial triangulation

Aerial triangulation was implemented based on the WGS-84 coordinate system.

a. Implemented area of aerial triangulation

Aerial triangulation covered all of the Gambia, in consideration of the plotted area. As a result, there were 456 models for carrying out aerial triangulation.

Tie point selection

b. Control points used for adjustment computations (horizontal position/height)

All the control points planned to be used in adjustment computations were employed.

Forty (40) control points were used for horizontal positions, and forty-three (43) for heights.

In order to maintain height accuracy in the periphery of the implemented area, the spot heights indicated on the existing 1:50,000-scale topographic maps were used as control points for heights in the adjustment computation.

c. Method of adjustment

The required number of control points for adjustment in normal aerial triangulation could be obtained by examining the volume of the national control points and ground control points and the aerial photo signals and pricking points. Based on the number of control points, adjustment computations were carried out by the bundle method treating the entire area as one block.

Pricking in aerial triangulation

d. Results of adjustment computations

The residuals of control points after the adjustment were within the given limited values (max: 3.0m, standard deviation: 1.5m), thus ensuring the required accuracy. The residuals of the control points were as follows.

| | | | |
|---|---|---|---|
| Horizontal position: | 2.094m max. | Standard deviation: | 0.874m |
| Height: | 2.469m max. | Standard deviation: | 0.700m |

②Raster conversion of aerial photos

The aerial photos were converted to raster format by scanning the negatives in accordance with the specifications below. The data specifications, etc. were determined in consideration of the fact that the images would be reproduced from the raster data.

♦ Specifications

Resolution: 20μm/pixel (equivalent to 1m on the ground)
Data format: TIFF (non-compressed line)
Data storage: Hard disk (external)
Scanner used: VEXCEL Ultra Scan 5000

Film scanner

The extent of raster conversion of the aerial photos was equivalent to that of aerial triangulation.

### (5) Digital Plotting/Compilation

①Digital plotting

Using the results of the field identification and aerial triangulation, the topographic and planimetric features were digitally plotted while referring to the Photo Interpretation Handbook.

In digital plotting, representation was adopted in consideration of the characteristics of the geographic features in the Gambia (particularly, the lack of change in elevation). Furthermore, the digital national boundary data provided by DL&S was used to specify the extent of digital plotting after being transformed to data based on the new reference ellipsoid.

After digital plotting was complete, the data was divided into sheets so that it could be effectively used in the subsequent digital compilation work.

The implemented work volume and equipment used are as follows:

Plotted area: 11,375.6km$^2$
Equipment used: Analytical plotter, Planicomp P2, P3

②Digital compilation (encoding)

Using the results of the digital plotting work and field identification, the topographic and planimetric features as specified in the digital map symbols regulations were digitally compiled (encoded) while referring to the Photo Interpretation Handbook.

In digital compilation, the features were sorted according to their characters and compiled taking into account the GIS databases. In the final stage of digital compilation, the sheets were digitally tied.

The implemented work volume and software used were as follows:

Compiled area: 11,375.6km$^2$

Software used: Micro Station 95

TNT mips

### (6) Field Completion Survey

The field completion survey consisted of confirmation in the field, confirmation indoors using the collected information and data, and the arranging of the results.

①Confirmation in the field

Any uncertainties that arose during digital plotting/compilation concerning the positions and representation of building symbols, power lines/radio towers, etc were confirmed in the field. Any changes in road form or vegetation on cultivated land were also verified. Furthermore, the names of places (e.g. village names) indicated in materials were also surveyed in the field, and any changes were investigated and confirmed.

Confirmation in the field

Confirmation in the field

②Confirmation indoors

The symbols and annotations were checked based on the information collected in the field to make sure they were represented in conformance with the map symbols regulations. The revised data and data on secular change was also examined to determine whether or not they could be represented by a method conforming to the map symbols regulations.

Confirmation indoors

Confirmation indoors

③Arrangement of the results

The additional data regarding uncertainties during digital plotting/compilation and secular change confirmed in the field and indoors as well as other information were compiled on two output map sheets in consideration of subsequent compilation work. One sheet indicated the annotations of place names and the other indicated all other revised information based on the field completion survey.

④Supplementary digital compilation work

Using the two output map sheets indicating the results of the field completion survey obtained in "③", the compiled data was recompiled accordingly. The sheets were rechecked in the final stage of the supplementary digital compilation to ensure they were properly tied.

### (7) Production of Printed Maps

①Sheet division

The plan to cover the entire country of the Gambia with 27 map sheets, each 15' x 15' in size decided on in "(1) Determination of Specifications for 1:50,000-scale topographic maps, ④ Sheet division" was formulated.

②Marginal information

As with the sheet division, the digital marginal information draft based on printed analog maps was formulated in accordance to decisions made during discussions. Sample printed maps having slightly different tones of color were produced and the positioning of the marginal information and coloring of the topographic map symbols were discussed and decided on.

③Collection of data on marginal information

Data regarding marginal information included the map sheet name, magnetic declination and the direction of true north. Sheet names had to be altered due to the change in sheet division and were discussed and determined by DL&S. The magnetic declination was also recalculated by DL&S.

The direction of true north was recalculated based on the change in reference ellipsoid and sheet division.

④Production of printed map data

Printed map data in sheet units including both marginal information and topographic map were generated by combining the marginal information data in sheet units produced from the results of "②Sheet division" and "③Collection of data on marginal information" and the map data produced in sheet units in the supplementary digital compilation.

⑤Production of films for printing

From the printed map data (topographic map data and marginal data) in sheet units generated in "④Production of printed map data", reproduction films for each color were produced. Five reproduction films were produced for each sheet.

⑥Printing

Aluminum plates were produced using the reproduction film to carry out printing. For each sheet, 1003 copies were made.

### 3.1.4 Construction of GIS Databases

Discussions were held with DL&S on the three GIS databases specified during preparations for the Study, and it was agreed that the three databases would be constructed. A proposal for the creation of a management system for the newly established national control points was also made, resulting in the decision to construct a national control point database.

#### (1) Examination/Discussions/Determination of Databases to be Constructed

①Examination of databases to be constructed

GIS databases expected to be effectively used were identified in consideration of a GIS that should be introduced and applied in the Gambia based on the collected material, particularly the topographic maps. They are as follows:

- ♦ Topographic map database

- ♦ Road network database
- ♦ Digital Terrain Model (DTM) database
- ♦ National control point database

②Examination of specifications for GIS databases (draft)

The GIS databases are to be constructed based on the topographic map data created under this Study. Therefore, the specifications for GIS data shall conform to the topographic map specifications as much as possible, and were examined giving particular consideration to the items below.

- ♦ Categories
- ♦ Feature class
- ♦ Feature item
- ♦ File name
- ♦ Data format
- ♦ Attribute code

### (2) Discussions/ Determination of Specifications for GIS database

Discussions were held with DL&S regarding data specifications for the "topographic map database", "road network database", "DTM database" and "national control point database" stated in (1) and the results were as follows.

①Specifications for topographic map database

In order to operate the topographic map data on the GIS, it was necessary for the topographic and planimetric feature data to be structured (topology). Moreover, a systematic code had to be attached to each map feature in order to identify it.

a. Structuring of data (topology)

The topographic and planimetric feature data shall be structured by classifying it as "polygon data", "line data" or "point data".

b. Systematic code for map features

Based on the attributes of the topographic and planimetric features, a systematic 4-digit code, consisting of a 2-digit class code and a 2-digit item code, shall be developed and attached to each map feature.

②Specifications for road network database

The road network database was to be created by extracting the necessary data from the

topographic map database and processing it.

a. Data extraction and network formation

The centerline of the road data shall be extracted from the topographic map database in the form of sheet units. The extracted data shall then be adjoined in order to form the road network data covering the entire country.

b. Data specifications

The data extracted and adjoined shall be classified as line data and a 4-digit code number consisting of a 2-digit class code and a 2-digit item code shall be attached to it.

③Specifications for DTM database

The DTM database was to be created from the contour line data and spot height data of the topographic map database to be constructed.

a. Data specifications

The data shall be mesh and in raster format with the elevation data attached to each mesh. The mesh shall be at 50m intervals.

④Specifications for national control point database

In the Study, seventeen (17) national control points tied to and in conformance with the World Geodetic System were established. Managing these national control points and those to be established in future is important for operating and maintaining the Gambia's geographic information.

a. Database

The positions of the national control points on the map shall be produced as point data and the values (X.Y.H) and point description of the national control points shall be produced as attribute data. Furthermore, these two types of data shall be linked.

### (3) Creation of GIS Database

Based on the results of the discussions on GIS database specifications in 3.1.4, (2), the "topographic map database", "road network database", "DTM database" and "national control point database " were constructed.

①Topographic map database

The constructed topographic map database has topology and is composed of the following

eight main layers, of which a systematic code for the topographic and planimetric features has been attached. An output map of the constructed topographic map database is shown in Figure 3.6.

- ♦ Administrative boundary
- ♦ Transportation
- ♦ Buildings
- ♦ Small object
- ♦ Water
- ♦ Specific area
- ♦ Vegetation
- ♦ Topographic features

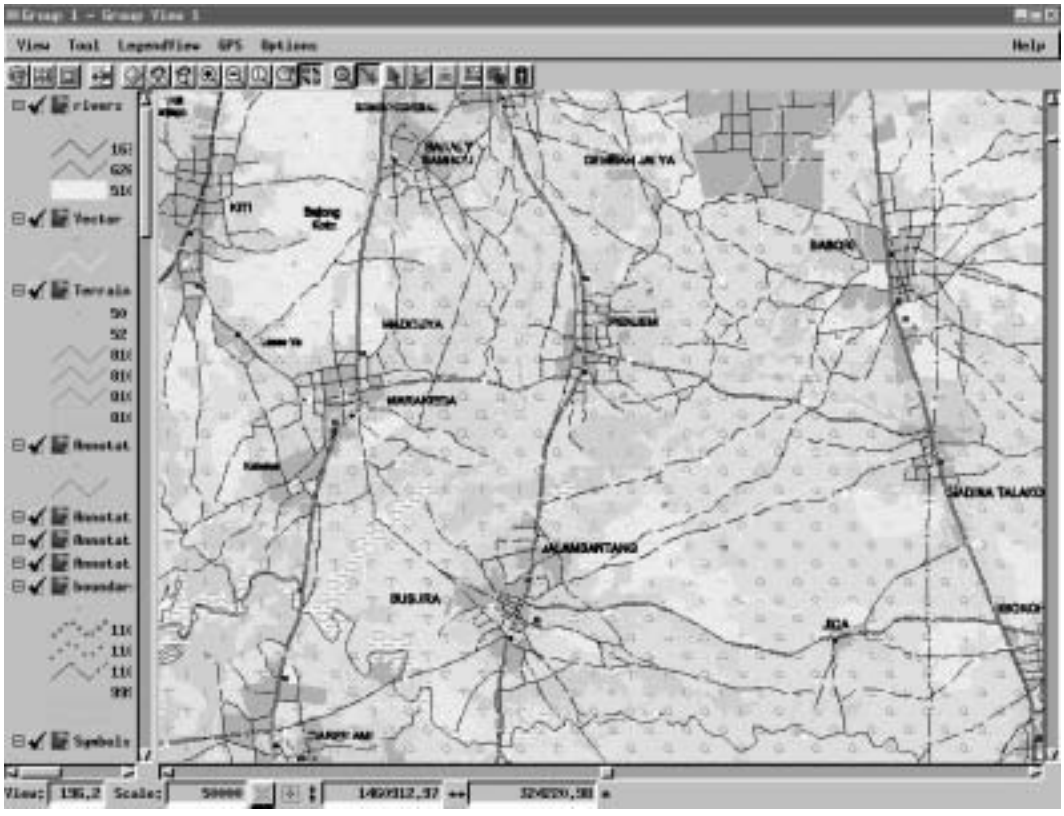



Figure 3.6 Topographic map database

②Road network database

One of the main layers of the constructed topographic map database is transportation. This layer contains road data and road-related facility data.

Meanwhile, the constructed topographic map data has been developed in topographic

map sheet units, not as a single data covering the entire country of Gambia.

Therefore, in the Study a road network database covering the entire country was constructed by extracting the road data from the transportation layer and tying the road data prepared in sheet units with it. An output map of the constructed road network database is shown in Figure 3.7.

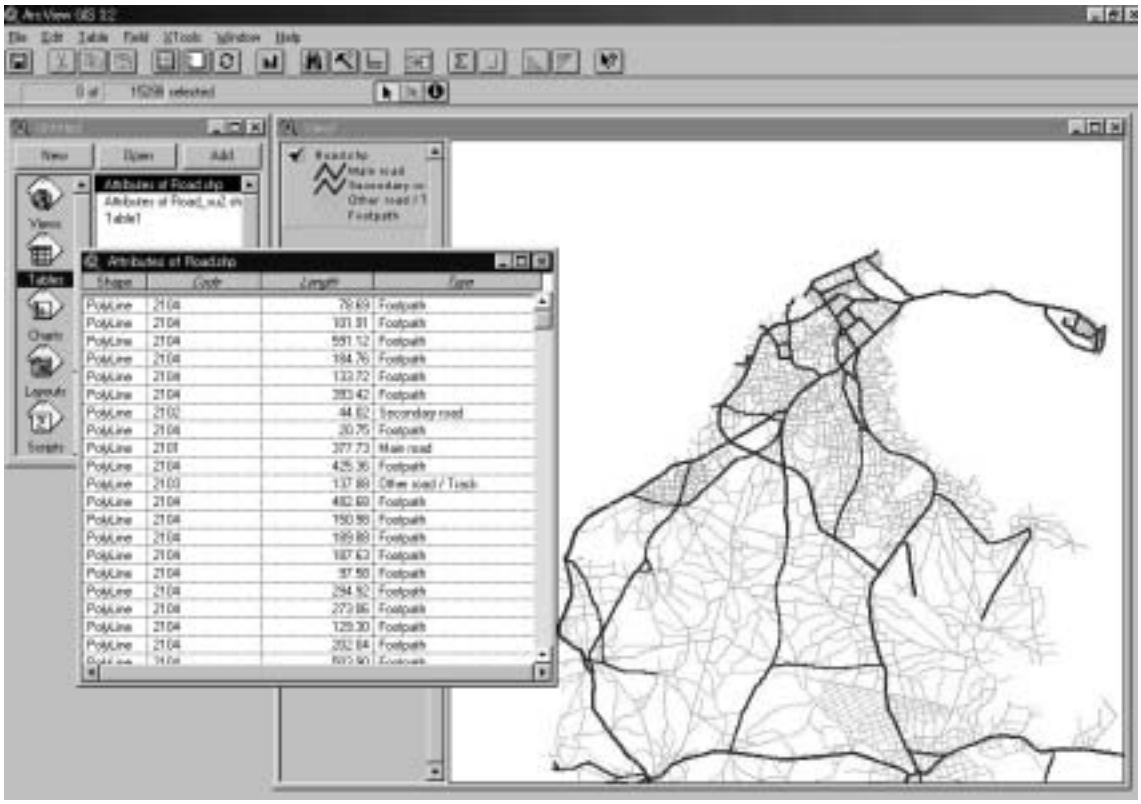


Figure 3.7 Road network database

③DTM database

In the Study, a digital terrain model database (DTM) was constructed. This database was constructed as 50m-interval mesh data using the contour line data and spot elevation data from the constructed topographic map database. Elevation values have also been put on each mesh.

The DTM database can be effectively used to grasp the undulations of the terrain in Gambia. By using the DTM database with GIS, it is also possible to calculate slope gradients and azimuths, which can be in turn be used to analyze and select suitable lands in the fields of terrain analysis, agriculture/forestry, etc. An output map of the constructed DTM database is shown in Figure 3.8.

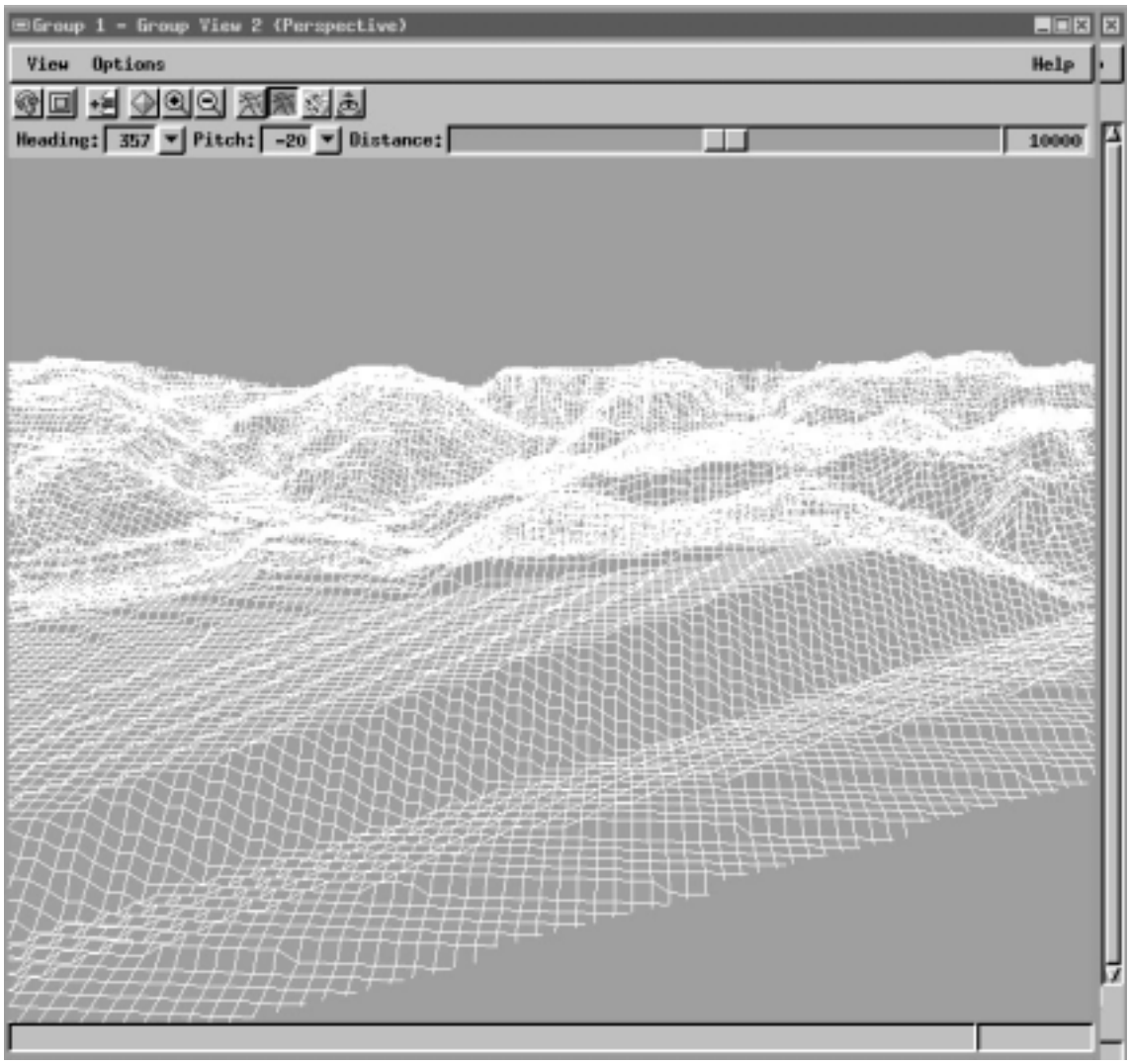



Figure 3.8 DTM database

④National control point database

Until now, the results of field observations in control point surveys were recorded in field books and managed as “point descriptions” and “result tables”. In the Study, a system to manage national control points by handling “point descriptions” and “result tables” using GIS and database software (MS Access) was constructed.

Each control point was stored in the GIS as point data, and the information in the “point descriptions” and “result tables” was added to the point data as attribute tables. In addition, the control point point data was linked to a database containing images of site conditions taken with a digital camera.

Therefore, by clicking on the location of a control point on the GIS, it is now possible to view the image of that spot as well as the database of the “point descriptions” and “result tables”. An example of the constructed control point database management system is

shown in Figure 3.9.

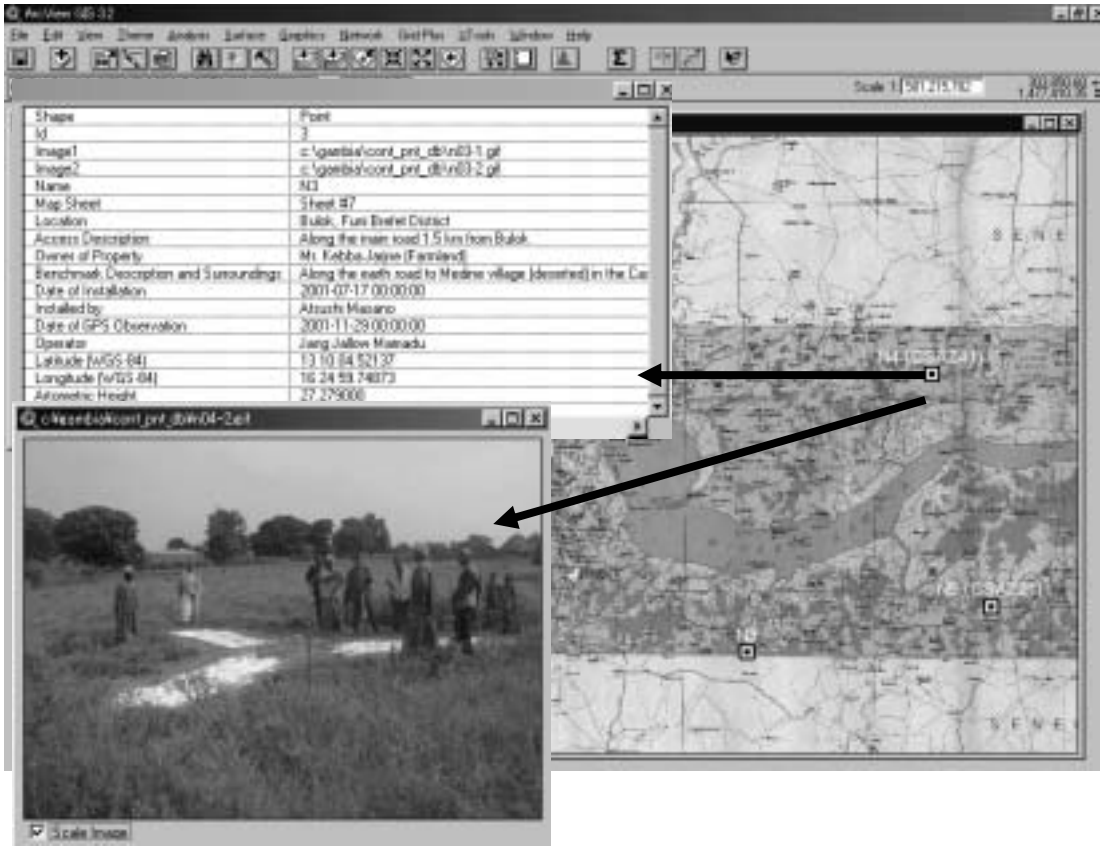



Figure 3.9 Management system for national control point database

### 3.1.5 Technology Transfer

#### (1) Method and Objective of Technology Transfer

Technology transfer was implemented through practical training in accordance with the basic policies and approach

①Method

Technology transfer was implemented by the following methods:

a. Lectures

The counterparts were instructed in the general ideas, theories and processes of the technologies to be transferred through lectures.

b. OJT (On-the-job training)

The counterparts were instructed in the technologies to be transferred during actual

implementation of the study work. With regards to the technology that the counterparts mastered, they were made to undertake a part of the respective study work aiming at achieving a deeper understanding of the technology.

c. Technology transfer seminars

In the seminars, the transfer of technology implemented through lectures and OJT was reviewed, and the development of technical transfer was discussed.

②Objective

The objective of technology transfer was to thoroughly train the counterparts in the required technologies so that that they could apply and manage them independently after completion of the Study. It also aimed to have the counterparts understand the technologies in the fields related to the works targeted for technical transfer.

### (2) Targets of Technology Transfer and Equipment Used

①Targets of technology transfer

The technology transfer targeted the following items:

- ♦ GPS surveying
- ♦ Field identification/photo interpretation
- ♦ Map revision

②Equipment

The equipment that was mainly used in the transfer of technology was as follows.

| | | |
|---|---|---|
| GPS survey: GPS receiver | Trimble 4000 SSI | |
| | Ashtech Z-Xtreme | |
| Analytical software | Bernese | Baseline analysis software (University of Bern, Switzerland) |
| | Gpsurvey | Baseline analysis software (Trimble) |
| | SKI GPS processing software | 3-dimensional net adjustment (Leica) |
| | TRIM NET | 3-dimensional net adjustment (Trimble) |

Field Identification/photo interpretation: None in particular

Map revision:

Digital compilation system

| | |
|---|---|
| Personal computer | 1 unit |
| PC server | 1 unit |
| Ink-jet plotter | 1 unit |
| Image scanner | 1 unit |
| Software (TNTMips, etc.) | 1 unit |

### (3) Technology Transfer for GPS Surveying

The transfer of GPS surveying technology was implemented in the form of lectures and OJT.

①Theory and planning of GPS survey

Three (3) technical experts from DL&S received instruction in the general theory and planning of GPS surveys in the form of lectures.

Technology Transfer Lecture

As understanding the theory requires a grounding in high-level mathematics and a great deal of time, the transfer focused on basic concepts, which the counterparts were able to adequately grasp.

As for the transfer of GPS planning techniques, the GPS survey planning maps prepared by the Study Team were used as teaching material and, as a result, the counterparts were able to master the techniques. In the future it is important that the counterparts actually plan and implement GPS surveys based on this experience in the densification of control points.

②Point selection and monumentation

Three (3) technical experts from DL&S were trained in point selection techniques in the form of OJT, while implementing point selection for national control points (zero/first order) and ground control points based on the planning map.

During monumentation, they received further training in how to carry out monumentation in accordance with the standards agreed on and monument control methods using photos.

As a result of the technical transfer, DL&S was able to acquire the skills for point selection and the monumentation of common control points in GPS surveys to the extent that they could carry out such works independently.

③Aerial photo signalization

Under the study, twenty-eight (28) aerial photo signals were installed. The transfer of signal installation techniques was carried out in the form of OJT during actual implementation of such work. Lectures were also held giving instruction on the relationship between the size of aerial photo signals and photo scale as well as the shapes of signals, as previously arranged.

As a result, DL&S obtained the ability to install aerial photo signals according to the site conditions on their own.

④Observations

In Phase 1 and Phase 2 in Gambia, the transfer of technologies for performing observations with GPS receivers was conducted in the form of OJT. In Phase 1 in Gambia, two technical experts from DL&S received training using Trimble GPS receivers. In Phase 2 in Gambia, three experts from DS&S, including the previous two, received training using Ashtec GPS receivers. The training included the steps from installing the receivers to beginning observations as well as techniques until withdrawal from the site after completion of observation work.

Upon completion of Phase 1 in Gambia, one of the experts was able to master the observation techniques and, in Phase 2 in Gambia, was able to perform observations independently without the support of the Study Team. Furthermore, by the end of Phase 2 in Gambia, the remaining experts could thoroughly master the observation techniques thereby ensuring that DL&S was prepared to carry out observations independently.

⑤Analytic computation

During the analysis of observation data, three technical experts from DL&S received training in the form of OJT and lectures.

The training included, the downloading of observation data from GPS receivers, conversion to standard RINEX format, baseline analysis, 3-dimensional net adjustment computations and the evaluation of analysis results. First, the complete analytical process and the individual computations were generally explained through lectures. On-the-job training was then conducted for the individual analytic computations using actual observation data. Calculations in technology transfer were performed using BERNESE and Gpsurvey (baseline analysis software) and SKI GPS and TRIM NET (3-dimentional net adjustment computation software).

Furthermore, after completion of the Study work, Ashtech's analytic software "AOSS: Ashtech Office Suite for Survey" was introduced so that DL&S would be able to carry out

analytic computations independently. The techniques for carrying out baseline analysis and 3-dimensional net adjustment using this software as well as evaluating the analysis results were transferred to DL&S.

### (4) Technology Transfer for Field Identification/Aerial Photo Interpretation

①Field identification

The transfer of field identification techniques was conducted for two technical experts from DL&S in the form of lectures and OJT.

Before beginning the field identification, the concepts and items of digital symbols for 1:50,000-scale maps were explained through lectures. During the actual survey, counterparts received on-the-job training in methods for determining one's present position on the map from surrounding topographic and planimetric features, finding and selecting the topographic and planimetric features to be indicated on the 1:50,000-scale maps and wrapping up the field identification results.

As for the outcome, the counterparts were able to adequately understand the concepts and items of map symbols. The counterparts also acquired the techniques for finding the topographic and planimetric features based on the map symbol specifications and for selecting the features to be indicated on 1:50,000-scale maps to the extent that they could generally carry out such work on their own. Regarding wrapping up the field identification results (including the completion survey), the counterparts obtained additional experience during the completion survey and were able to reach a level where they could implement such works without difficulty.

②Aerial photo interpretation

The technology transfer for aerial photo interpretation techniques was to be implemented while collecting the necessary information in the field for the preparation of the "Aerial Photo Interpretation Handbook". However, as the counterpart's experience with aerial photos was less than expected, training at that time would not have produced satisfactory results. The technology transfer was therefore implemented during the field completion survey using the "Aerial Photo Interpretation Handbook" prepared. The counterparts were trained by comparing the stereoscopic images of the aerial photos in the Handbook with those of the aerial photos being interpreted.

Because experience is essential in mastering aerial photo interpretation techniques, it is expected that the counterparts shall continue to build on this experience using the "Aerial Photo Interpretation Handbook" based on the technology transfer and their technique will improve.

### (5) Transfer of Map Revision Techniques

Prior to training, the map revision techniques to be transferred were determined and the concerned manuals were prepared. Training was then implemented in accordance with these manuals.

①Determination of technologies to be transferred

The following three techniques were transferred: a. techniques for digitizing existing maps, b. techniques for revising digitized topographic maps and c. basic digital techniques.

a. Techniques for digitizing existing maps

The techniques for scanning analog topographic maps and for converting the scanned raster data into vector data were to be transferred. The aim was for the counterparts to learn how to input and indicate the secular change information (in analogue format) concerned with map revision on the digital topographic map.

b. Technique for revising digitized topographic maps

Digital compilation techniques for revising the topographic maps were to be transferred using the information on secular change to be indicated on the digital topographic maps. At the same time, the techniques of creating digital map symbols and digital reduction compilation were also targeted in consideration of development in future,

c. Basic digital techniques

The aim was to transfer basic techniques for handling digital data (data input/output, printout, data storage, data exchange, etc.) and the equipment used.

②Preparation of manuals

Before preparing the manuals, the procedures for map revision and the configuration of the equipment to be used in the technical transfer were analyzed.

Based on the analysis, three types of manuals were prepared: a. work specifications manuals, b. work method manuals and c. manuals for the use of the equipment in technical transfer. In preparing the manuals, a great deal of flow charts, photos and illustrations were included in an effort to enhance efficiency of use and motivation.

a. Work specifications manuals

The “Specifications for the Digitization of Existing Maps (Draft)” and the “Specifications for the Revision of Digitized Topographic Maps (Draft)” were prepared as the work regulations manuals. The outline of each work, the progress of

work, the specifications for the equipment used, and the quality of the results were clearly stated in these manuals.

b. Work method manuals

The "Manual for the Digitization of Existing Maps" and the "Manual for the Revision of Digitized Topographic Maps" were prepared as the work method manuals. The general concrete work procedures and content, the method of quality control, etc. in accordance with the regulations (draft), were clearly stated in these manuals.

c. Manuals for the use of the equipment in the technology transfer

The following manuals were prepared for the variety of hardware and software used in the transfer of map revision techniques:

- Manual for the creation of 1:50,000 maps using TNTmips
- Manual for the revision of 1:50,000 maps using TNTmips
- Manual for the conversion of coordinates
- Manual for map scanner
- Manual for maintenance of equipment
- Manual for building network
- Manual for basis of TNTmips
- Manual for basis of Photoshop
- Manual for basis of Illustrator

The manuals contained material that would be effective in the actual execution of works such as descriptions of application methods directly related to map revision not mentioned in the application manuals accompanying the various equipment.

③Technology transfer for map revision

Technology transfer for map revision was conducted in the form of lectures and on-the-job training. From the equipment to be used, the period and the objective, it was assumed that 2-3 people would be targeted for the technology transfer. However, due to circumstances on the DL&S side, 6 people were trained. The implementation period of the technology transfer was one month, from the beginning of September 2002.

a. Items of technology transfer

In the technology transfer for map revision, a great deal of hardware and software was used. Therefore, the following specific items were set for the technology transfer.

- Training in the set-up of hardware/software used in the technology transfer
- Training in the basic operation of hardware/software used in the technology

transfer

- Training in the basic techniques for revising 1:50,000-scale topographic maps
- Training in advanced/application techniques for map revision software

b. Set-up of hardware /software

The technology transfer for setting up the hardware and software introduced was implemented while the hardware and software was set-up. The techniques transferred included checking the working voltage of the hardware, physically connecting the hardware, constructing a network as well as installing, uninstalling and reinstalling the software.

Furthermore, as part of network construction, network management techniques were transferred to the server controller.

c. Training for basic operation of hardware/software

Regarding operation of the hardware (i.e. server, computer, printer, plotter, scanner, external devices, etc.), basic techniques such as the starting up and shutting down of the equipment was transferred. The techniques for the basic operation of the following software were also transferred:

- TNTmips
- Photoshop
- Illustrator

In the transfer of these techniques, the manuals attached to the software and the equipment manuals specially prepared for the transfer of map revision techniques were used.

d. Training in the basic techniques for revising 1:50,000-scale maps

The aim was to transfer the basic techniques for revising marginal information on topographic maps as well as the topographic maps themselves using the TNTmips manual specially prepared for map revision.

- Revision of marginal information on topographic maps

  The kind of marginal information included on topographic maps (i.e. margins, sheet name, sheet number, edition number, index to boundaries, legend, magnetic declination, etc.) was explained and the techniques for collecting information necessary for map revision and for handling marginal data on TNTmips (i.e. downloading data, revising marginal information, adjusting graphic/annotation data, etc) were transferred.

- Revision of topographic maps

  The method of collecting material on secular change necessary for topographic

map revision as well as of formulating a work plan for topographic map revision were explained.

After describing how to scan the collected material on secular change and download that data to TNTmips, the techniques for orienting the data on the TNTmips and for inputting each layer separately were transferred.

As the importance of frequent quality control in map revision work has been pointed out, the method of implementing quality control was also explained in this technology transfer.

e. Training in advanced/application techniques for map revision software

TNTmips used in map revision has various functions. Of them, the following techniques, of which it is thought can be effectively used in map revision and with GIS, were transferred.

- ♦ Planning and creating of digital symbols of various scales
- ♦ Data input/output for GIS databases
- ♦ Basic analysis of GIS databases
- ♦ Handling of aerial photo data
- ♦ Handling of 3-dimensional data
- ♦ Production of a bird's eye view

### (6) Technology transfer concerning GIS

In the Study, technology transfer regarding GIS knowledge and operation was carried out for three staff members from DL&S, the C/P. The contents of the implemented technology transfer are as follows:

①Brief overview of GIS

When implementing the technology transfer concerning GIS, the C/P were given a brief overview of GIS (e.g. what GIS is, what you can do with GIS, etc.).

②Explanation of basic functions of ArcView GIS

DL&S is using ArcView GIS provided by another donor. Therefore, the Study Team reviewed the basic functions of ArcView GIS with the C/P.

③Creating new GIS data (polygon, line, point)

The techniques for creating new polygon, line and point data were transferred by actually using ArcView GIS.

④Establishing map projection and transformation

In handling GIS data, knowledge concerning map projection is extremely important. Therefore, techniques for establishing map projection and for transforming the existing data based on the geographic coordinate system to the UTM coordinate system were transferred.

⑤Creation of attribute tables and revision

It is possible to manipulate GIS data by linking the graphic data and attribute data. Techniques for creating, revising and deleting attribute data associated with the graphic data using ArcView GIS attribute tables were transferred.

⑥Calculating polygon area and line length

In GIS, there is a function for calculating the areas of polygons and the lengths of roads, rivers, etc. Technology transfer concerning the above-mentioned function was carried out for the C/P so that all types of area calculations would be possible.

⑦Linking graphic data and existing database

In GIS, there is a function for downloading external databases (i.e. existing and new databases) and linking them to the graphic data in GIS. Technology transfer concerning this function was implemented.

⑧Linking graphic data and image data

In GIS, there is a function for linking and managing point data and photographs taken at these points. Using this function, techniques for linking images taken with a digital camera and point data were transferred.

⑨Data input/output

At present, as various GIS are used at each agency in each country, there exist various GIS data formats. In order to be able to cope with these various formats, technology transfer concerning the method of data input/output using ArcView GIS was carried out.

⑩Input of image data and geometric correction

When creating new GIS data, image data is frequently downloaded into the GIS and digitized on the computer screen as background data. The images downloaded into the GIS must possess information on geographical position. Therefore, techniques for downloading images into GIS and for geometric correction were transferred.

## 3.1.6 Current Situation of Geographic Information

In order to assess the current situation concerning geographic information, a survey was conducted on the organization and services of DL&S, geographic information and the situation of geographic information use.

### (1) DL&S Organizations and their Services

DL&S is under the "Department of State for Local Government & Lands" as shown in Figure 3.10.

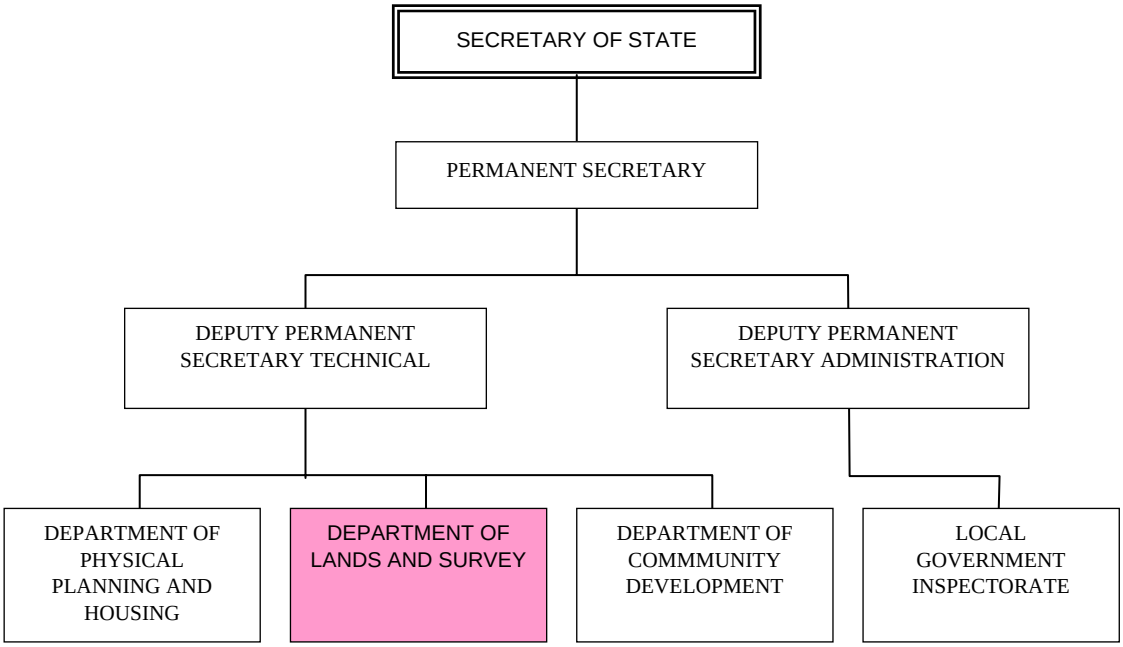



Figure 3.10 Organization of Department of State for Local Government & Lands

①DL&S Organizations

a. Structure of DL&S

DL&S's head office is located in the present capital of Banjul and there are plans to establish branch offices in major cities throughout the country.

The head office in Banjul comprises an administration section and three (3) technical sections (Refer to Figure 3.11). The three technical sections are as follows:

Survey Section

Map Production Section

Land & Valuation Section

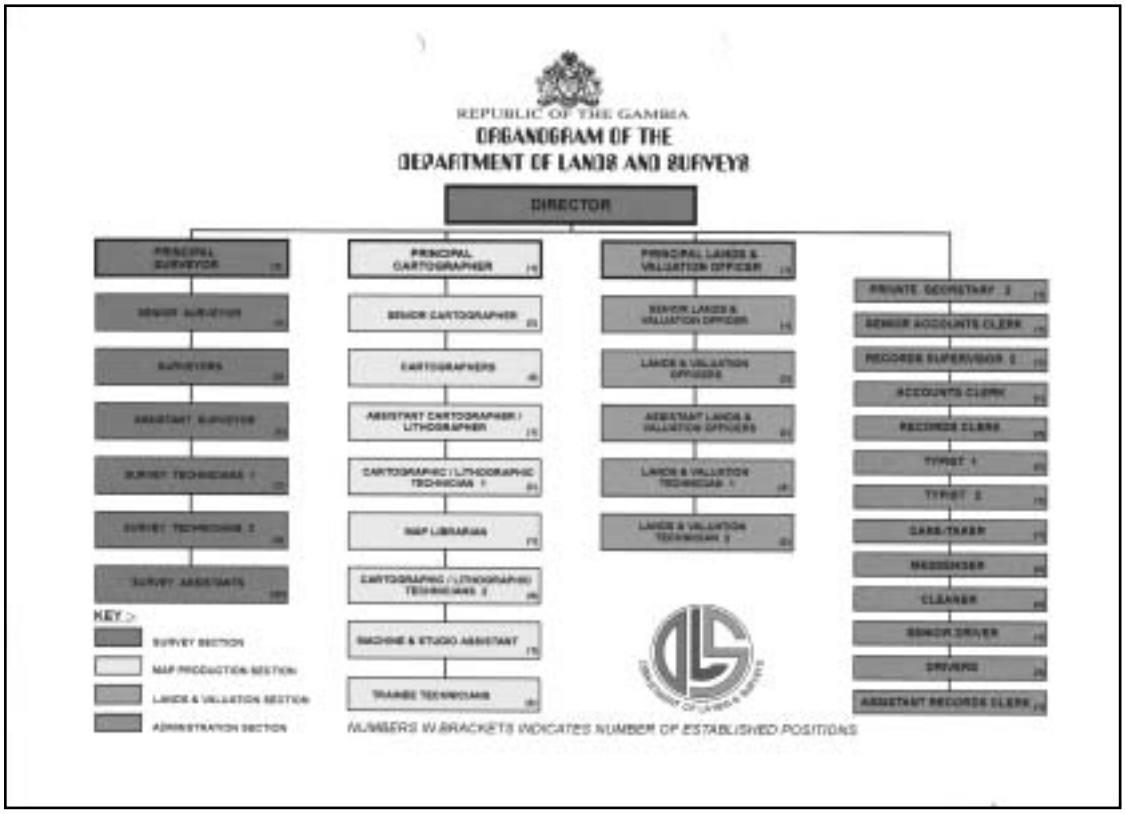



Figure 3.11 Organizations of DL&S

The local branch offices are to be established in the following cities:

Brikama

Basse

Farafenni

Mansakonko

Bansang

b. Function of each section

- Survey Section

  The Survey Section is in charge of the establishment as well as the operation and maintenance of the national control points throughout the entire country of the Gambia. This section is also responsible for surveys to confirm the national boundary. At present, ground surveys being carried out include small-scale traversing and leveling.

  In addition, ground surveying equipment (total station, level, etc.) is being lent out

♦ Map Production Section

The Map Production Section is responsible for the generation of topographic maps of all scales. They are also in charge of managing aerial photography (i.e. contact prints, film), topographic maps (i.e. manuscripts, printed maps) as well as sales of topographic maps and aerial photos.

Due to a lack of equipment, budget and personnel, however, the production and revision of maps is currently not being implemented.

♦ Land and Valuation Section

The Land and Valuation Section is responsible for such duties as the maintaining and updating of information on land registration. It also compulsorily collects the land information necessary for the evaluation of land prices, public objectives and various land development plans. Furthermore, it administers authorizations by the country to use national land.

c. Current situation of personnel organization

At the time the study work began (June 2001), eighty-four (84) workers were employed at DL&S. Since then, there have been a few changes due to retirement, etc.

The staff have been rated from Grade 1 (junior officials) to Grade 11 (senior officials) and the number of employees of each grade is as follows:

| | |
|---|---|
| Grade 1 | 31 employees |
| Grade 2 | 3 employees |
| Grade 3 | 7 employees |
| Grade 4 | 8 employees |
| Grade 5 | 2 employees |
| Grade 6 | 18 employees |
| Grade 7 | 5 employees |
| Grade 8 | 6 employees |
| Grade 9 | 1 employee |
| Grade10 | 2 employees |
| Grade11 | 1 employee |

The personnel organization of each of the sections was as follows: (As of June 2001) .

| | |
|---|---|
| Administration Section: | 13 employees, including the Director |
| Survey Section: | 40 employees, including the Section Chief |
| Map Production Section: | 18 employees, including the Section Chief |
| Lands & Valuation Section: | 13 employees, including the Section Chief |

d. Equipment possessed

DL&S possesses the following equipment:

- ♦ Equipment for ground surveys

  DL&S possess the equipment required for conducting traverse surveys such as transits, levels, distance meters, etc. Furthermore, in June 2001, a total station and automatic level was newly introduced and much of the damaged equipment was discarded.

- ♦ Equipment for photogrammetric surveys

  As for photogrammetric equipment, DL&S only possesses equipment for printing aerial photos to sell and for taking blue proofs of topographic maps.

## (2) Geographic Information

①Control points

a. Control points

The national control points based on the Clarke1880 reference ellipsoid were established by Great Britain in the 1960's, and have hardly been maintained for the approx. forty years since their installment. There have been various construction works and coastal erosion over the years and many of the control points are expected to have been lost. However, as no surveys have been conducted to verify such losses, the current situation of the control points in not known.

b. Documentation on control points

The documentation on control points consists of a "point distribution map (scale: 1:50,000)" indicating the point positions, "control point data lists" and "control point descriptions". As the "control point data lists" are of a prescribed form, there should be no problems in constructing the database.

②Aerial photography

There are 1:50,000-scale and 1:25,000-scale aerial photos that cover the entire country and also large-scale photos (1:22,000, 1:20,000, 1:12,500, 1:10,000, etc.) that cover sections of the country. Recent ones include 1:25,000-scale color photos taken of the entire country in 1993. However, the storage conditions of the film is not very good so care needs to be taken when handling. Furthermore, although the aerial photos are being sold, it is difficult to purchase them as the printing equipment is becoming too old for use, etc.

③Topographic maps

Small-scale (1:250,000, 1:50,000), medium-scale (1:25,000, 1:10,000) and large-scale (1:5,000, 1:2,500, 1:1,250) topographic maps are produced. However, aside from two 1:50,000-scale map sheets, there is no stock of printed maps and they are impossible to obtain.

As for the medium-scale and large-scale topographic maps, they cover only a very small portion of the country.

In addition to topographic maps, photomaps and orthophotos are also generated. However, all the maps, including the topographic maps were produced before the 1980's and map revision of secular change has not been carried out.

④Other

"SURVEY REGULATION 1995" has been published as the regulations for surveying, and states the qualification system for surveyors and the required accuracy.

There are no particular regulations for map symbols. Map legends of various scales are the only regulation for map symbols.

### (3) Actual Conditions of GIS Use

The survey on the actual conditions of GIS use was conducted in the form of interviews. The main interview questions were as follows:

Q1: Which products of the Project do you expect to be useful for your service?
(Aerial photos; results of GPS survey; printed maps of 1/50,000-scale topographic maps; digital map images; GIS data)

Q2: How do you think the newest topographic map information will be used in your field?

Q3: Please give any information on your experience in GIS.

Q4: Please give the information on the ongoing projects and important tasks or problems, if any.

| No. | Organization | Answer to Q1 | Answer to Q2 | Answer to Q3 | Answer to Q4 |
|---|---|---|---|---|---|
| 1 | DLS | Printed maps of 1/50,000-scale topographic maps, digital topographic map images, GIS data | Maintenance, production and updating of cadastral maps | Have used. (PC ArcInfo and ArcView) | · The GIS project has been implemented by USAID but has not been brought into practical use.<br>· The cadastral database is being developed with the assistance of the Netherlands. |
| 2 | NEA | All digital data | No answer | In use. (ArcInfo, ArcView) | · GIS data are being created using aerial photos. Plotting and sales. (Land use and revetment maps, river basin maps, disaster prevention maps, eco-tourism maps) |
| 3 | NEA | Aerial photos, digital map images, GIS data | For reference in plotting work at NEA | In use. (ArcInfo, ArcView) | · As the implementing agency for the GIS project by USAID, NEA continues to make technical transfer and produce maps.<br>· The implementation of technology transfer with the related organizations as well as having common use of the products of the Project is strongly expected |
| 4 | Ministry of Agriculture/ Department of Forestry | Aerial photos, printed maps of 1/50,000-scale topographic maps, GIS data | Production of forest maps, community forest maps for reference for Mangrove conservation project | Knows, but has not used GIS. | · Have participated in USAID GIS project, which seems to have reached a deadlock before mastering sufficient technology.<br>· Mangrove management and conservation<br>· Conservation of species threatened with extinction<br>· Prevention of landslides and soil deterioration<br>· Lake and swamp conservation<br>· Protected district operation and maintenance project |
| 5 | GAMTEL | Digital map images, GIS data | Creation of town maps for use in collecting telephone charges | Knows, but has not used GIS. | · A topographic map covering the whole country is needed because some areas have no map.<br>· It is expected that the data generated in this Project will be used for producing road data to be used in road-related works. |
| 6 | NAWEC | Aerial photos, printed maps of 1/50,000-scale topographic maps, digital map images, GIS data | Digitization of water supply pipe network map, and its integration with GIS database | Knows, but has not used GIS. | · Lack of new information on roads and buildings because of outdated and faulty management of topographic maps<br>· All data is paper-based and difficult to manage.<br>· Difficult to respond to an emergency in case of damage to infrastructure network.<br>· Having common use of the products of this Project and the wide promotion of technical transfer is expected. |

| No. | Organization | Answer to Q1 | Answer to Q2 | Answer to Q3 | Answer to Q4 |
|---|---|---|---|---|---|
| 7 | Ministry of Fisheries | Aerial photos, printed maps of 1/50,000-scale topographic maps, GIS data | Data on coastlines, grasping of topographic changes due to land avalanche | Knows, but has not used GIS. | · Lobster-culture industry has been affected by the decrease of mangrove forests, for which measures are under study.<br>· It is expected that the newest topographic map data will be used for defining fishing sea areas.<br>· It is expected that road data will be developed for the transportation of marine products.<br>· Interested in developing electronic seas charts. |
| 8 | GPTC | All | All bus stops under control of GPTC can be indicated in maps, from which passengers can plan their traveling routes. | Knows and wants to use GIS if it is usable. | · It is expected that the map covering the whole country of Gambia will be used to inform passengers of all bus routes. |
| 9 | Ministry of Health and Social Welfare, Eye Care Prog. | No answer | No answer | Has used GIS before. | · No answer |
| 10 | Ministry of Health and Social Welfare, Directorate of Planning & Information | GPS field survey results, GIS data | · Village distribution map with population<br>· Distribution of medical care centers in villages | Knows, but has not used GIS. | · Distribution maps for main infectious diseases.<br>· Distribution maps of the potential for epidemic-disease by village, area and region |

### 3.1.7 Formulation of Reports and Explanation/Discussions

#### (1) Formulation of Reports

The following four repots were formulated in the Study:

- ♦ Inception Report
- ♦ Progress Report
- ♦ Draft Final Report
- ♦ Final Report

①Inception Report

The Inception Report was formulated upon completion of the study preparations made in Japan.

The report included the following items to give a good understanding of the outline and processes of all the study work.

- Objective of the study work
- Basic policies for implementing the study work
- Method of implementing the study work
- Products
- Schedule of the study work
- Plan for required personnel
- Other

The Inception Report containing the content mentioned above was submitted to DL&S in the Gambia.

②Progress Report

The Progress Report was formulated upon completion of the study work in the second year.

The report included the items below in chronological order until the end of the second year aiming at giving a good understanding of the implementation conditions and results of the study work.

- Outline of study work
- Basic policies for implementing the study work
- Results of the implemented study work
- Future study work

The Progress Report containing the above-mentioned contents was submitted to DL&S in the Gambia.

③Draft Final Report

In formulating the Draft Final Report, both a Main Report and a Summary were prepared.

The Draft Final Report included the implementation conditions and results of all the study works as well as the products. A proposal for DL&S was also mentioned based on the experience and knowledge obtained during the study. The report consisted of the following items:

- Outline of the study work
- Results of the study work
- Proposal for DL&S

The Summary is an abridged edition of the Main Report

The Draft Final Report (i.e. Main Report, Summary) was submitted to DL&S in Gambia.

④Final Report

The Final Report (Main、Summary) was prepared making revisions based on DL&S's comments regarding the Draft Final Report and the results of the transfer for map revision techniques and technical transfer seminars.

### (2) Explanation/Discussions

The Inception Report, Progress Report and Draft Final Report were explained to and discussed with DL&S.

①Explanation/discussions on Inception Report

On June 20, 2001, the Inception Report was explained to and discussed with the DL&S side. There were no particular comments concerning the report but a request was made for training in photogrammetric surveying techniques in Japan. The contents of the explanation and discussions were recorded in the M/M, which was signed on June 22, 2001.

Explanation/discussions on the Inception Report

Signing of the M/M

②Explanation/discussions on Progress Report

On July 17, 2002, a meeting was held at the DL&S office to explain and discuss the Progress Report. Participants included the head of DL&S and technical experts who had taken part in the technology transfer activities the year before. During the meeting, queries were made on the software and hardware to be used in the transfer of map revision techniques, the format of the GIS databases to be constructed and the conversion of national control point coordinates. The study team responded to these questions based on the results of the previous year and future plans. At the end of discussions, DL&S requested the provision of the equipment used in the technology transfer, which the study team agreed to convey to JICA.

The details of the explanation and discussions mentioned above were recorded in the minutes of the meeting, which was signed on July 23, 2002.

Explanation/
discussions on Progress Report

Signing of the M/M

③Explanation/discussions on Draft Final Report

On October 3, 2002, a meeting was held at the DL&S office to explain and discuss the Draft Final Report. These explanation/discussions were held for the section head from DL&S and engineers participating in the technology transfer work. In the explanation/discussions, an overview of the Study works (basic policy, progress and results) up until now was given. Furthermore, the results of the Study work were explained by breaking them down into the following items: “establishment of the national control point network”, “production of 1:50,000-scale topographic maps”, “creation of GIS databases”, “technology transfer” and “current situation of geographic information”.

Moreover, the proposals for DL&S based on the results of these Study works were explained.

Agreement on the Draft Final Report was obtained from the DL&S side. At the end, it was pointed out that the period of the technology transfer for map revision was too short in consideration of the diversity of the contents, and it was request that measures be taken to cope with this issue. The Study Team promised to inform JICA of this request.

The contents of the above explanation/discussions were recorded in the minutes of the meeting, which was signed on October 8, 2002.

Explanation/discussions on Draft Final
Report

Signing of the M/M

## 3.1.8 Technology Transfer Seminar

### (1) Objective

The objective of the technology transfer seminar was to announce the overall progress and results of the Study works as well as to present information (method of obtainment, application methods) that would promote the general and broad use of the Study's products within Gambia.

### (2) Dates and participants

The technology transfer seminar was held over a period of two days, from October 8 to 9, and there were 77 and 66 participants, respectively.

The participants included high-ranking officials from the ministries and governmental agencies in Gambia along with DL&S staff, top officials from Banjul and local governments, as well as public enterprises (i.e. water, electricity, communications, etc.) and private surveying/consulting companies. A small number foreign donors and concerned persons from NGOs also attended.

### (3) Contents

The technology transfer seminar held over two days included a general outline of the progress and results of the Study works, a ceremony for the granting of equipment, the signing of the M/M, a demonstration of the products and an overview of GIS and its applications.

①Technology transfer seminar on October 8 (Tues)

In the technology transfer on the first day, the opening ceremony was held followed by an explanation of the progress and results of the Study works. Then, the ceremony for the granting of the equipment used in the technology transfer was held. After that, the equipment granted was explained and a demonstration of the Study works' products was given. At the end, the signing of the M/M by DL&S and the Study Team was performed.

②Technology transfer seminar on October 9 (Wed)

The technology transfer seminar on the second day placed particular emphasis on technology. In the morning, a seminar on the "establishment of the national control point network" and "aerial photogrammetry" in the Study was held.

In the afternoon, a seminar describing the basic concepts of GIS and giving specific examples of its applications was held.

## 3.2 Results of Study

### 3.2.1 Products of Study

In the Study, the following products were generated:

*Study Reports

- ♦ Inception Report — 30 copies in English (10 copies for JICA)
- ♦ Progress Report — 30 copies in English (10 copies for JICA)
- ♦ Draft Final Report
  - Main Report — 30 copies in English (10 copies for JICA)
  - Summary — 30 copies in English (10 copies for JICA); 10 copies in Japanese
- ♦ Final Report
  - Main Report — 30 copies in English (10 copies for JICA)
  - Summary — 30 copies in English (10 copies for JICA); 10 copies in Japanese

*Final Products

- ♦ Aerial photographs
  - Negative films — 1 set
  - Contact prints — 1 set
- ♦ Results of ground control point survey
  - Results of control point survey — 1 set
  - Description of national control points — 1 set
  - Results of GPS survey — 1 set
  - Adjustment computation sheets — 1 set
- ♦ Results of aerial triangulation — 1 set
- ♦ 1:50,000-scale topographic maps Printed maps — 1003 sets, 27 sheets/set (3 sets for JICA)
  - Films for printing — 1 set
- ♦ 1:50,000-scale topographic map data — 23 sets (3 sets for JICA)
- ♦ 1:50,000-scale topographic map database — 23 sets (3 sets for JICA)
- ♦ Other GIS databases — 1 set
- ♦ Metadata — 1 set

## 3.2.2 Results of Study

### (1) Results accompanying the production of 1:50,000-scale topographic maps

①Production of 1:50,000-scale topographic maps (printed maps)

Printed topographic maps (scale: 1:50,000) covering the entire country have been produced and can be used in land development and conservation programs. The demand for topographic maps for such programs from other government agencies and the private sector can now be met with the production of these printed maps.

②Production of digital topographic map data

Previous to the Study, if the stock of printed maps ran out, the demand could only be met by reprinting. However, by generating this data it is now possible to meet the demands with plotter output maps until new maps are printed.

③Creation of digital topographic map database

The growing use of GIS can be expected, as it is now possible to provide costly topographic map databases for various agencies applying or planning to apply GIS such as the National Environment Agency.

④Construction of various GIS databases

The basic GIS databases were established by constructing a road network database and a DTM database from the topographic data.

⑤Production of aerial photos

The latest aerial photos (scale: 1:50,000) covering all of the Gambia were produced and used for study works in addition to the production of topographic maps.

⑥Establishment of national control points

Seventeen (17) new highly accurate national control points based on and tied to the world geodetic system were established. As a result, it is now possible to carry out the highly accurate densification of national control points.

### (2) Results of Technology Transfer

①Techniques for installing aerial photo signals

These skills are expected to be useful in DL&S's future production of topographic maps through photogrammetric surveying.

②GPS survey techniques

DL&S was able to independently apply the planning, point selection, observation and analytic computation techniques necessary for GPS surveying. Therefore, it is expected that DL&S will be able to carry out the densification of control points and resurveys by GPS surveying on its own. These skills can also be applied to cadastral surveys.

③Field identification/photo interpretation

As with ①, these skills are expected to be useful in DL&S's future production of topographic maps through photogrammetric surveying.

④Map revision techniques

The map revision techniques transferred to DL&S included techniques for digitizing existing maps and for revising digitized topographic maps. DL&S is now able to independently make revisions to digital topographic maps based on secular change. It is also expected that the technique of digital compilation (one of the map revision techniques transferred) can be applied to the digital topographic map data (scale: 1:50,000) generated in the Study to produce 1:250,000-scale digital topographic maps, which are in big demand.

⑤Provided equipment

It is anticipated that with the equipment used in technology transfer (GPS survey and map revision equipment) and the techniques acquired in ② and ④, the various new works expected in the near future shall be realized.

# 4. Proposal for DL&S

## 4.1 Reinforcement of DL&S organization

### 4.1.1 Reinforcement of Organization

At present, DL&S is composed of three (3) technical sections and one (1) administrative section, which are responsible for the operation and maintenance of the Gambia's geographic information.

#### (1) Reinforcement of the administrative section

Judging from its personnel organization, the present administrative section is mainly responsible for managing the business affairs of the director of DL&S. However, rather than limiting the section duties to merely business administration, the section should be a base of activity for the administration of geographic information by functioning as a staff section. Specifically, the following is proposed:

①Securing of adequate human resources

The administrative section's capacity to function as a staff section should be strengthened by gathering technical experts from the various technical sections.

②Formulation of long-term plans for DL&S

These newly assigned staff members should be responsible for the formulation of long-term operational and technical plans of DL&S, including new plans for the densification of control points and the revision of maps based on secular change mentioned later.

③Examination of external policy

The administrative section should act as a liaison with various foreign aid agencies. The section should also formulate and implement policies (public policy, sales strategies and policy, copyright protection) for providing the geographic information DL&S possesses (printed topographic maps, information on national control points, topographic data, etc) to others outside the department.

Furthermore, the reinforced administrative section should also take part in negotiations (i.e. securing budget and personnel) with the State Department for Local Government and Lands of which it is under.

### (2) Reinforcement of the technical sections

At present, the department contains three technical sections: a survey section, a map production section and a land valuation section. It is time to fundamentally examine the organization of these technical sections along with advances in technologies regarding geographic information. The issue in hand is the reshuffling of staff based on the examination of each section's duties.

Furthermore, new management corresponding to technological developments is requested in each section. Specifically, the following is proposed:

a. Coping with new technologies
   In addition to improving existing technologies in the field of geographic information, a team responsible for the new technologies of GPS, digital photogrammetry and GIS should be organized.

### (3) Establishment of a public relations section

The distribution of geographic information in the Gambia is very limited and such information is not being effectively used.

As there is a need to make the new geographic information produced in the Study (digital topographic maps, national control points) widely and generally known, a public relations section shall be established within DL&S.

The section shall make open to the concerned agencies, educational institutions and the general public the conditions of geographic information prepared in DL&S and the method of obtaining such information through such means as the Internet.

## 4.1.2 Reinforcement of Technical Capacity

DL&S currently possesses a variety of equipment for producing geographic information. This equipment should be utilized in order to strengthen the department's technical capabilities.

### (1) Geodetic survey technology

Through the technical transfer implemented in the Study, three technical experts capable of conducting GPS surveys from the planning stage to analytical computations were cultivated. With these experts as the core, the GPS techniques should be disseminated to increase the potential of GPS survey techniques and strengthen technical capacity regarding the application of such technologies.

### (2) Digital photogrammetry technology

As with GPS surveying, the digital photogrammetry techniques acquired in the Study should be disseminated to the technical experts in concerned sections. The technical experts will learn

how to handle digital topographic map data thereby improving their ability to revise topographic maps with existing information.

Aerial triangulation and digital plotting techniques not targeted in the technology transfer should be acquired when the concerned equipment is introduced, thus covering all fields of digital photogrammetric surveying.

### (3) GIS technology

DL&S currently possesses ArcInfo and ArcView as its GIS software. Meanwhile, three databases were constructed in the Study in a format operable with ArcInfo and ArcView.

Under the above condition, a technical foundation that would enable the daily operation of the database within DL&S should be established by combining the software and databases. The databases should therefore be operated with ArcInfo, and ArcView, mainly by those that received training in map revision techniques. The dissemination of these techniques to experts in the concerned sections should also be planned.

## 4.2 Proposals for Geodetic Surveying

Tasks concerning GPS surveying shall be carried out based on the experience, technology transfer and results of the Study.

### 4.2.1 Establishment of Control Point Survey Work Regulations

The GPS survey in the Study was implemented based on a predetermined observation method, etc. and in conformance to Japanese work specifications. After examining the obtained accuracy, etc., the Study Team prepared "GPS National Control Point Survey Work Specifications (Draft)" (hereinafter referred to as "Work Specifications (Draft)"). The official national control point survey work specifications should be established based on the "Work Specifications (Draft)", taking into consideration the current situation of the Gambia and DL&S.

The official work Specifications should be established as follows:

Step1: Theoretically examine the contents of the "Work Specifications (Draft)", and make the necessary revisions.

Step2: Conduct a control point survey (more than once) in accordance with the revised "Work Specifications (Draft)".

Step3: Analyze the progress and results of the control point survey(s) conducted in Step2.

Step4: After identifying which sections are inadequate based on the results of the analysis in Step3, revise the "Work Specifications (Draft)" once again.

Step5: Establish the revised "National Control Point Survey Work Specifications (Draft)" as the official work specifications.

### 4.2.2 Densification of National Control Points

In the Study, a first order control network with an average side length of approx. 40 km (with points at about 40km intervals) was established. This density, however, is thought to be inadequate for future applications of the control network. Therefore, the national control points should be densified by establishing a second order control network with a side length of 20km (with points spaced at about 20 km) by GPS survey. An effort should also be made to maintain and disseminate GPS survey techniques through such works.

The densification of national control points should be carried out as follows:

Step1: Identify the areas to be densified. Initially, the Greater Banjul area, where the frequent use of control points is presumed, shall be targeted. The second and third targets shall be regional principle cities and their environs.

Step2: Check the identified areas for existing zero and first order control points and

determine which ones shall be used.

Step3: Select second order control points at approx. 20km intervals and monument them.

Step4: Determine the coordinates of the second order control points by performing observations and computations in conformance with the control point survey work specifications.

The densification of national control points should be carried out by repeating the above steps one area at a time.

### 4.2.3 Transformation of Coordinates

In the Study, seventeen (17) national control points and twenty-six (26) ground control points were established by GPS survey based on the new reference ellipsoid (WGS84). Some of these national and ground control points had coordinate values based on the old reference ellipsoid (Clarke1880). Using the points with both coordinate values, two sets of coordinate transformation coefficients (parameters) were determined through the analytical computations in GPS surveying. One set of parameters was to be applied to the Greater Banjul area and the other was to be applied to the region to the east.

In Gambia, there are many control points based on the old reference ellipsoid. In order to make these points consistent with the newly established national control points, they have to be re-surveyed or the coordinates recalculated. At first consideration, transforming the coordinates by a re-survey would be recommended. However, implementing such a survey would be costly and require a considerable amount of time. Coordinates shall therefore be transformed using conversion software, which is neither expensive nor time-consuming.

Transformation of coordinates should be carried out as follows:

Step 1: Digitize the name and coordinates of the old results.

Step 2: Calculate the new results from the old results using conversion software.

Step 3: Save the new results in the results file.

Step 4: Print out the new results from the results file in the prescribed form.

## 4.3 Proposals for Photogrammetry

As with GPS surveying, tasks concerning topographic maps shall be carried out based on the experience obtained in the Study and the skills acquired through technology transfer.

### 4.3.1 Establishment of Topographic Map Symbols Regulations

In producing the 1:50,000-scale topographic maps in the Study, the digital map symbols to be applied were discussed with DL&S and decided on. Rules for the applying the map symbols in field identification and photo interpretation were also prepared to standardize the representation of planimetric and topographic features on 1:50,000-scale topographic maps. The digital map symbols and regulations were then arranged in the National Base Map Symbols Regulations (Draft) and the finalized 1:50,000-scale digital topographic map symbols regulations were established based on the "Regulations (Draft)".

### 4.3.2 Revision and Generation of Topographic Maps

DL&S should actively take part in the revision and generation of topographic maps based on the results of the technology transfer and future plans.

#### (1) Revision of Topographic Maps

a. 1:50,000-scale digital topographic maps

There is still quite some time before the 1:50,000-scale topographic maps produced in the Study will need to be revised due to secular change. However, physical and cultural features continue to change day by day. Information on these changes should therefore be collected in order to prepare for the necessary revisions by a digital method in the near future.

b. Topographic maps of other scales

The revision of analog topographic maps of various scales beginning with 1:25,000 should be carried out simultaneously with their digitization. Information on secular change should be gathered from the aerial photos, etc taken in the Study.

#### (2) Generation of Topographic Maps

a. Generation of 1:250,000-scale topographic maps

In the Gambia, there is currently a demand for topographic maps at a scale of 1:250,000 covering the whole country. However, there are no printed maps in stock. In order to cope with this situation, full use should be made of the skills acquired in the technology transfer (i.e. creation of map symbols and digital compilation) to

generate 1:250,000-scale topographic maps from the 1:50,000 topographic data by scale-reduction techniques.

b. Production of new topographic maps

Positive films and contact prints (covering all of the Gambia) of which aerial triangulation has been completed were produced as intermediate products of the Study. As the photos were taken at a scale of 1:50,000, the products can be used to produce 1:5,000-scale topographic maps.

Plans should therefore be made to produce 1:5,000-scale base maps for principle cities throughout the Gambia, starting with the capital of Banjul. Implementation should be as follows:

Step1: Introduce a plotter (analytic plotter or digital plotter) by some way or another (foreign assistance, national budget, etc.).

Step2: Conduct training in operating the plotter.

Step3: Establish digital map symbols for 1:5,000-scale base maps.

Step4: Produce digital base maps scaled at 1:5,000 by carrying out digital plotting and compilation work using the newly introduced plotter, a compiler and the positive films and contact prints of which aerial triangulation has been completed.

## 4.4 Proposals for GIS

In the Study, a “digital topographic map database (scale: 1:50,000)”, “road network database” and “DTM database” covering the entire country of the Gambia were constructed. The vast amount of geographic information generated can be effectively used in future in the following fields. One example is given for each field.

### 4.4.1 Applications in Socio-economic Fields

The topographic map database constructed in the Study includes administrative boundary data, which can be combined with census data (mainly population data) to grasp the population trends of each administrative district. If information on gender and age is available, it is also possible to have an understanding of the changing conditions of specific population groups. What’s more, with information on the agricultural products and livestock in the various administrative districts, GIS can be applied to identify regional characteristics. An example of how GIS can be used to assess shifts in population is shown in Figure 4.1.

An example of indicating population distribution on a map in bar chart form using statistical data on the populations of cities, towns and villages. (Blue: men, Red: women) The actual figures are stored in table form as attribute data.

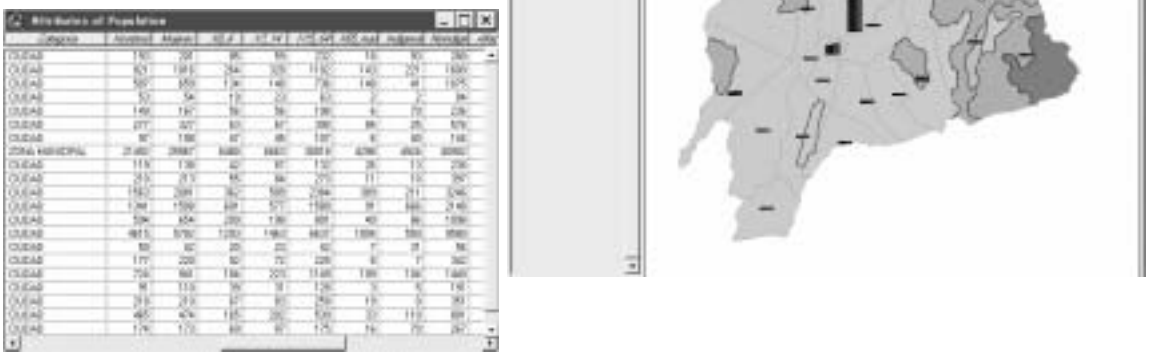


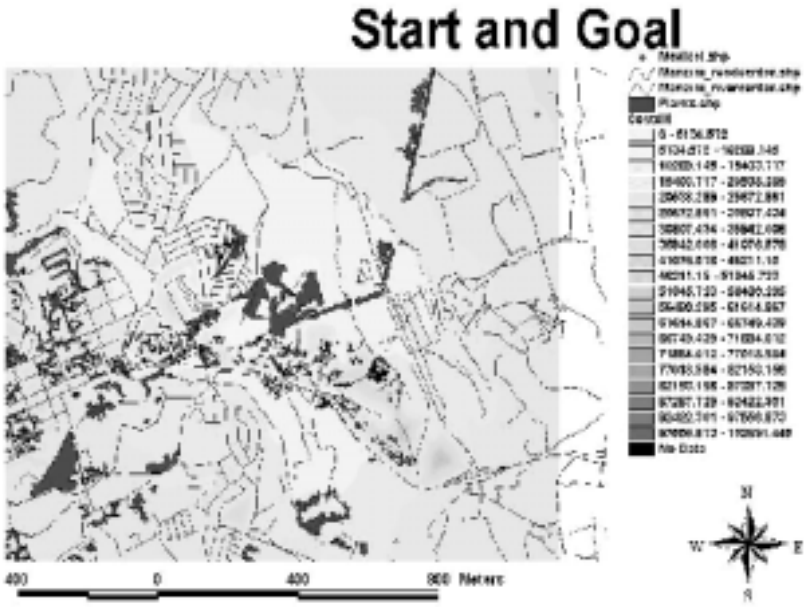
Figure 4.1 Applications in Socio-economic Field

### 4.4.2 Applications in Public Transport

The road network database constructed in the Study can be applied in the following ways.

As there is no railway in the Gambia, the bus network has been developed throughout the country. By constructing a database containing both the network data created and attribute data such as bus timetables, connections, etc, it will be possible to manage an efficient bus route. Moreover, this information can be administered on a travel bureau website to enable users to

have access to bus routes, timetable, connections, etc. over the Internet. An example of use in road planning in the field of public transport is shown in Figure 4.2.




In actualizing the construction of a new road from point A to point B, the cheapest (in terms of land price) and shortest route with a suitable slope for a road is selected using GIS.

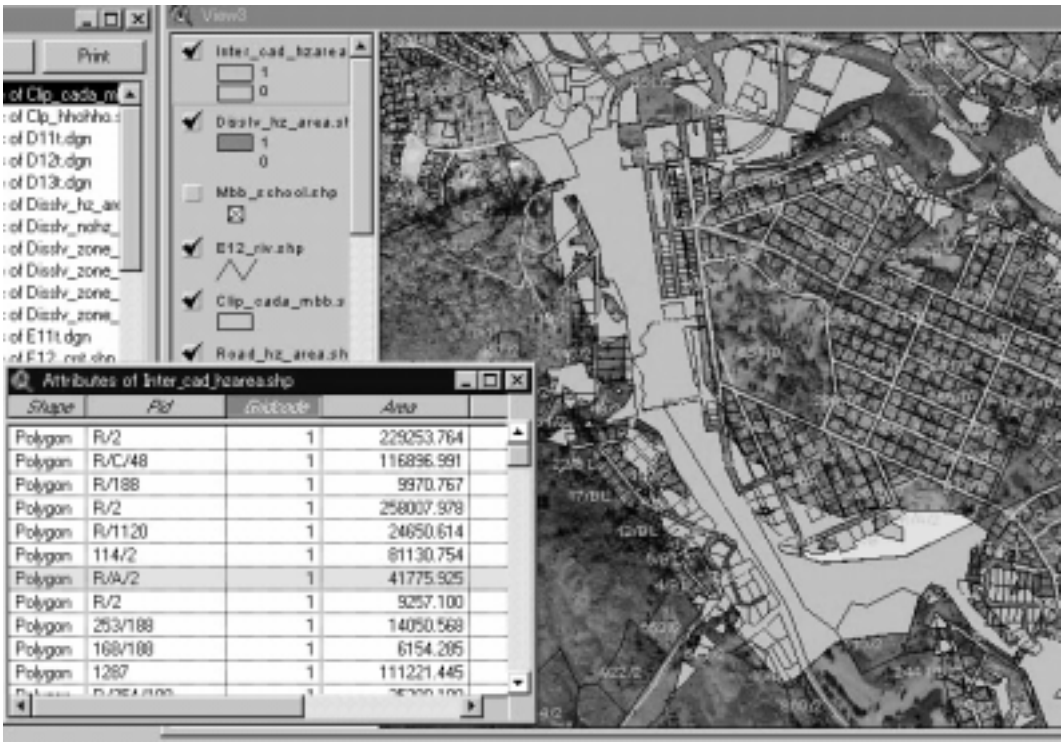
Figure 4.2 Applications in Public Transport

### 4.4.3 Applications in Disaster Management

The Gambia River flows from east to west through the center of the country pouring into the Atlantic Ocean. As the elevation of the Gambia is generally low, flooding of the river can cause considerable damage to the area.

By using the DTM database, road network database and river database (contained in the topographic database) constructed in the Study, it is possible to identify which areas are in danger of inundation as well as places of refuge and evacuation routes.

For example, the DTM database can be used to generate elevation data and slope data to identify areas of low elevation and areas of gentle incline, respectively. Moreover, data indicating distances from the river can be created using the river data. By analyzing these data using the GIS spatial analysis module, areas in danger of flooding and places of refuge can be identified. Figure 4.3 shows an example indicating areas in danger of flooding.




As an example of an application in disaster management, the areas at risk of flood damage in the event of flooding were detected based on slope gradient and soil type, and indicated in red on the map. By layering this with a cadastral GIS database, it is possible to verify which parceled land in which zone is in danger of damage using the attribute database.

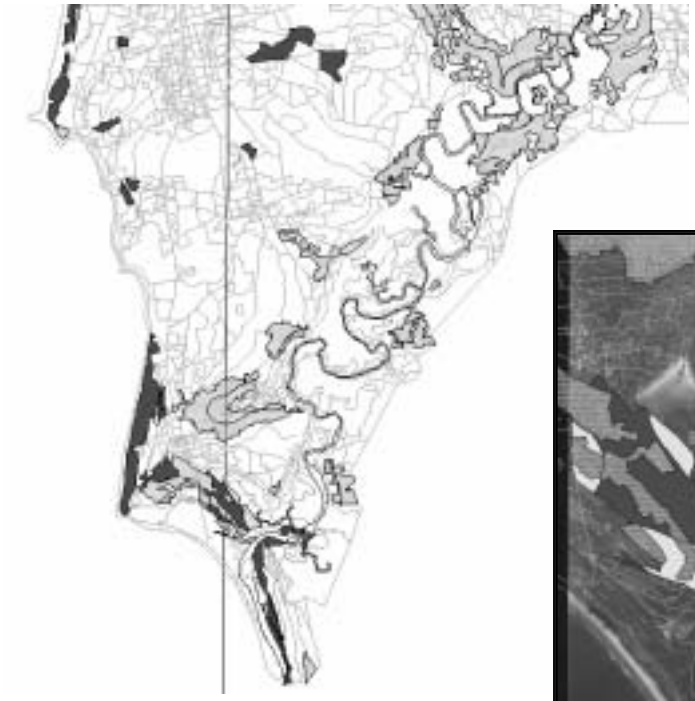
Figure 4.3 Applications in Disaster Management

### 4.4.4 Applications in Agriculture

The Gambia is aiming to increase agricultural productivity as indicated in "VISION 2020". As a GIS is designed for geographic and spatial analysis, the databases constructed in the Study can be used to analyse and select lands suitable for agriculture.

From the DTM database, it is possible to generate elevation, slope and aspect data. Furthermore, considering that water resources are essential to engaging in farming activities, data indicating distances from rivers can be created using the river data. As for the transport of agricultural products, data indicating distances from roads can be generated with the road network database.

By applying the various data mentioned above, it is possible to identify areas suitable for agriculture. And if a wider range of information (i.e. soil data, groundwater data and land used data) is incorporated, identifying areas suitable for agriculture can be done with higher accuracy. An example indicating areas suitable for agriculture is shown in Figure 4.4.



In selecting land suitable for agriculture, the most suitable land (indicated in yellow) is selected by layering the factors for judging the suitability of land such as present land use conditions and distance from rivers, etc.

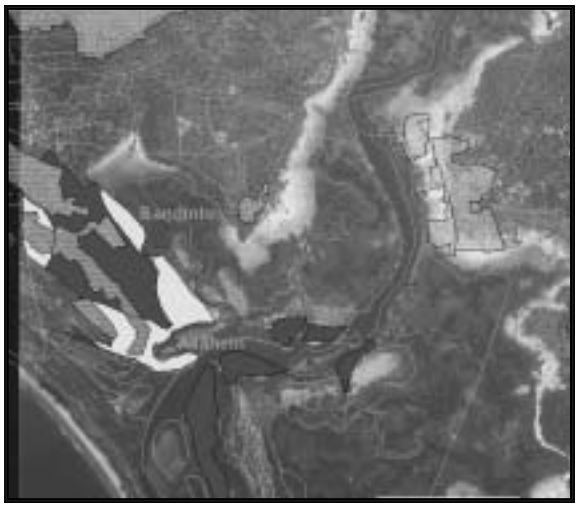
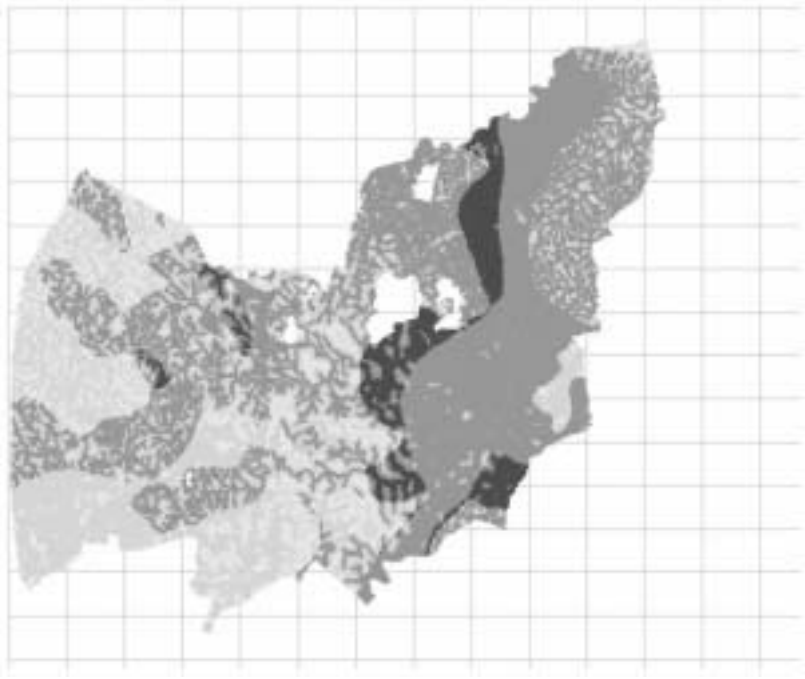


Figure 4.4 Applications in Agriculture

### 4.4.5 Applications in Medicine

Throughout Africa, there are many reported cases of people dying of malaria. One reason is that the environmental conditions in Africa are ideal for the propagation of mosquitoes and the spread of disease. However, another factor is that the systematic implementation of prevention measures against malaria is overdue. In the Gambia as well, measures to cope with malaria is a serious medical issue.

In order to devise countermeasures against malaria, up-to-date topographic data is required to assess conditions regarding the distribution of mosquitoes. Information on medical facilities (i.e. hospitals, health centers, clinics, etc.) is very important. Moreover, data on the habitat of malarial mosquitoes such as water source data (i.e. river, lakes, etc.) and social and statistical data (i.e. meteorological data, etc.) are also necessary.



An example of classifying land in terms of risk level by combining the three factors that influence the incidence of malaria, i.e. precipitation, air temperature and distance from rivers.

Figure 4.5 Applications in Medicine

### 4.4.6 Application of GIS Databases

Various fields of applications regarding the topographic, road network and DTM databases constructed in the Study have been put forward. However, a steering committee needs to be established to administer the actual implementation of such applications. Not only does DL&S need to take part in the steering committee along with the concerned government agencies, it has to play a leading role.

## 4.5 Operation and Maintenance/Application of Study Results

In the Study, 1:50,000-scale topographic maps (printed maps, digital data, etc.), national control point results and equipment were handed over to DL&S as the tangible products.

In order for the development of geographic information in the Gambia, the operation, maintenance and application of these products are important issues.

### 4.5.1 Survey Products

#### (1) Printed topographic maps (scale: 1:50,000)

It is expected that the 1:50,000-scale topographic maps produced in the Study will be widely and generally sold at an appropriate price based on policy for the commercial sale of geographic information. Storage facilities should also be built to adequately manage the stock of printed maps. Through the sales of such products, the organization and expansion of public relations and sales sections as well as the raising of awareness of their profitability is expected.

#### (2) Digital data

It is expected that the topographic data and various GIS databases will be appropriately used at DL&S and related government agencies by devising a means for copyright protection. Further, as with the printed topographic maps, the wide and general sale of the topographic data at an appropriate price is projected.

#### (3) National control point results

The national control results shall be maintained through the effective use of the "National Control Point Management System". This shall also be applied to the densification of national control points.

#### (4) Aerial photos

It is expected that the aerial photos taken in the Study will be used in various photo interpretations. Also, as with the printed maps, they will be widely and generally sold at a suitable price.

### 4.5.2 Equipment Provided

#### (1) Equipment for GPS survey

It is expected that the equipment (i.e. GPS receivers, analytical software, etc.) provided in the Study shall be adequately managed and used in the densification of national control points and

cadastral surveys.

### (2) Equipment for map revision

It is expected that the equipment for map revision, like that for GPS surveys, will be adequately managed and regularly maintained. The equipment shall also be used to produce 1:250,000-scale topographic map data (including output maps) from 1:50,000-scale topographic map data through the process of reduction.