Democratic Socialist Republic of Sri Lanka
Survey Department of Sri Lanka (SDSL)

THE DIGITAL TOPOGRAPHIC MAPPING PROJECT
FOR
RECONSTRUCTION OF NORTHERN REGION

FINAL REPORT
(Summary)

January 2012

JAPAN INTERNATIONAL COOPERATION AGENCY
KOKUSAI KOGYO CO.,LTD
AERO ASAHI CORPORATION

1 USD = 77.95 Yen 1 LKD = 0.685 Yen

PREFACE

In response to a request from the Government of Sri Lanka, the Government of Japan decided to conduct "The Digital Topographic Mapping Project for Reconstruction of Northern Region in the Democratic Socialist Republic of Sri Lanka" 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., and consisting of KOKUSAI KOGYO CO., LTD. and AERO ASAHI CORPORATION, between February 2010 and November 2011.

The team held discussions with the officials concerned of the Government of Sri Lanka and conducted field surveys in 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 digital topographic mapping in Sri Lanka and to the enhancement of friendly relations between our two countries.

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

January 2011

Kiyofumi KONISHI
Director General
Economic Infrastructure Department
Japan International Cooperation Agency

Letter of Transmittal

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

It is a great honor to submit herewith the final report of Digital Topographic Mapping Project for Reconstruction of Northern Region in the Democratic Socialist Republic of Sri Lanka. This report incorporates the suggestions received from the Japan International Cooperation Agency (JICA) and concerned authorities, as well as the agencies concerned of the Government of Sri Lanka including the Survey Department of Sri Lanka (SDSL).

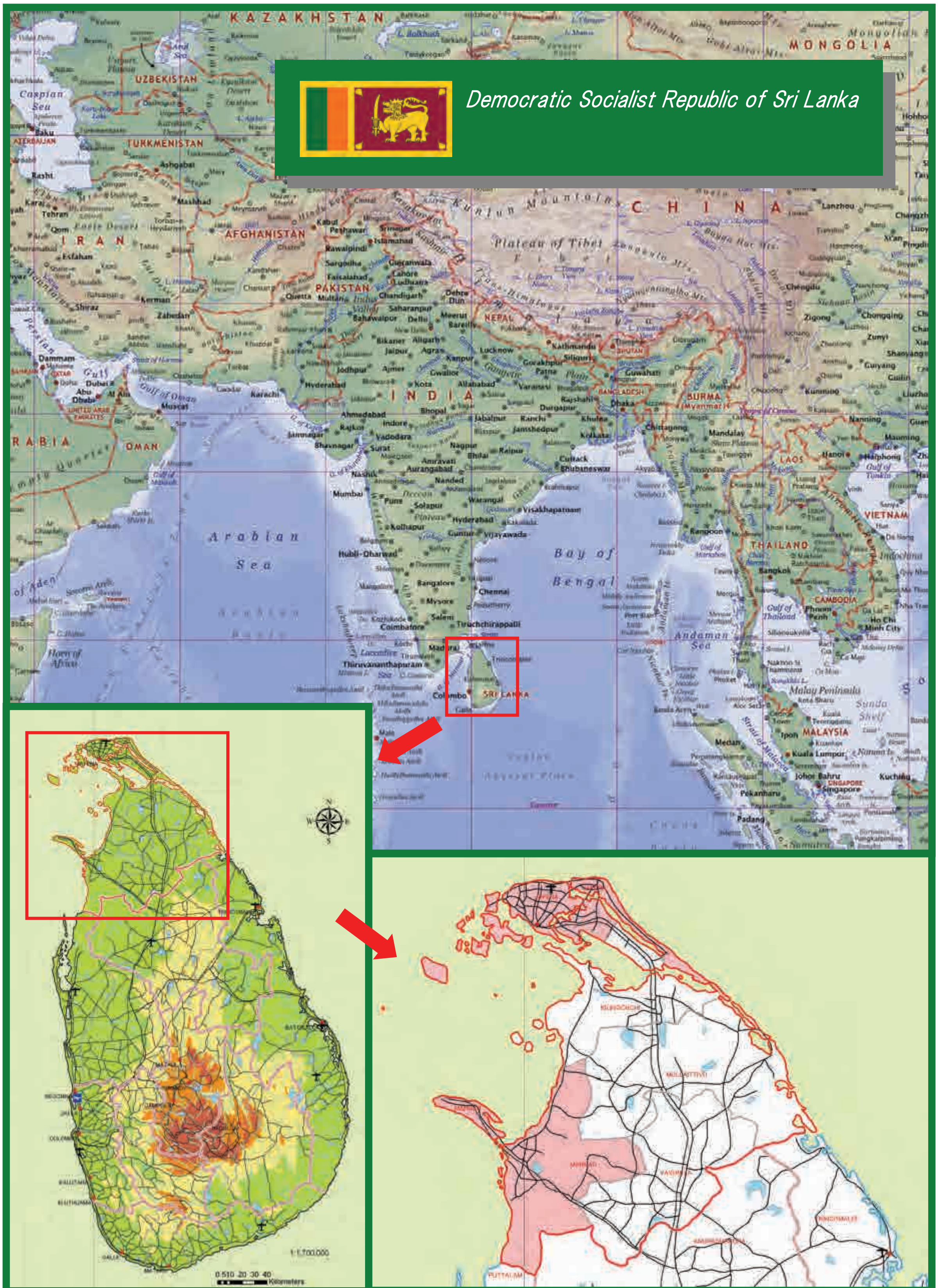
During the Study, a digital topographic map at the scale level of 1:10,000 for part of the Northern Region was developed, and the techniques (GPS survey, leveling, digital aerial triangulation, digital plotting/editing, GIS structualization and map symbolization) concerned with this work were transferred to the SDSL. Furthermore, activities (seminar/workshop) concerning the dissemination of geographic information were implemented.

In the final part of this report, specific issues and recommendations are made based on the results of the study, and the work manual (Guideline), which covers developing, maintaining and managing the geospatial data and GIS database, is attached in the report. From the viewpoint of maintaining and developing the results of the study, I hope that these issues, recommendations and the work manual (Guideline) are promptly accepted for implementation and the manual used by the agencies concerned of the Government of Sri Lanka.

On behalf of the study team, I would like to express my sincere gratitude to JICA, the Ministry of Foreign Affairs, the Ministry of Land, Infrastructure, Transport and Tourism, and the agencies concerned for the valuable advice and cooperation they provided us during the implementation of this study. I would also like to extend my deep appreciation to the agencies concerned of the Government of Sri Lanka, including SDSL, for their generous assistance and cooperation during our stay in Sri Lanka.

January 2011

Akira NISHIMURA
Team Leader
Digital Topographic Mapping Project for
Reconstruction of Northern Region in the
Democratic Socialist Republic of Sri Lanka



Location map of Digital Topographic Mapping Project for Reconstruction of Northern Region in Sri Lanka

Photo Album

Office of SDSL

Entrance of SDSL

Triangulation point

Bench mark

Aerial Photography

Aerial Photography

Photo Album

Photo Signalization

Photo Signalization

Photo Control Point Survey（GPS Survey）

Photo Control Point Survey (GPS Survey）

Photo Control Point Survey(Leveling）

Photo Control Point Survey(Leveling）

Photo Album

Field identification

Field identification

Supplementary Field Identification

Supplementary Field Identification

Technology Transfer（Field Identification）

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Photo Album

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Technology Transfer（Digital Plotting）

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Photo Album

Technology Transfer（GIS）

Technology Transfer（GIS）

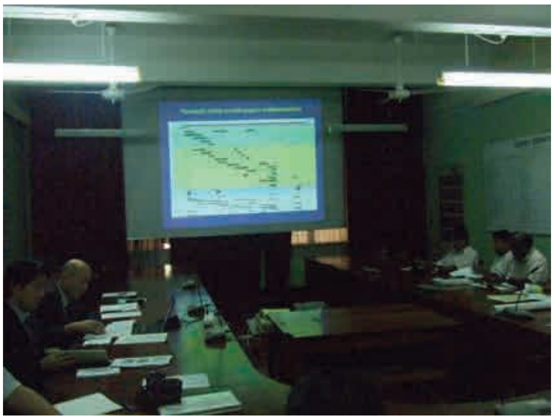
Technology Transfer（Map symbolization）

Technology Transfer（Map symbolization）

Technology Transfer（Sup Field Identification）

Technology Transfer（Sup Field Identification）

Photo Album



Inception Report (Explanation and Discussion)

Inception Report (Explanation and Discussion)

Interim Report (Explanation and Discussion)

Interim Report (Explanation and Discussion)

DF Report (Explanation and Discussion)

DF Report (Explanation and Discussion)

Photo Album

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Photo Album

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Executive Summary

1. Outline of the Study

1.1 Objective of the Study

Nearly 30 years of armed conflict in Sri Lanka came to an end in May 2009. This long armed conflict inflicted severe damage on people's lives and on the social infrastructure required for their livelihoods, especially in the Northern Region.

The reconstruction of the region and the livelihoods of its people has always been an important issue since the end of the armed conflict. The formulation of reconstruction plans and their implementation requires the latest geographic information.

Against this background, this Study was implemented for the following objectives:

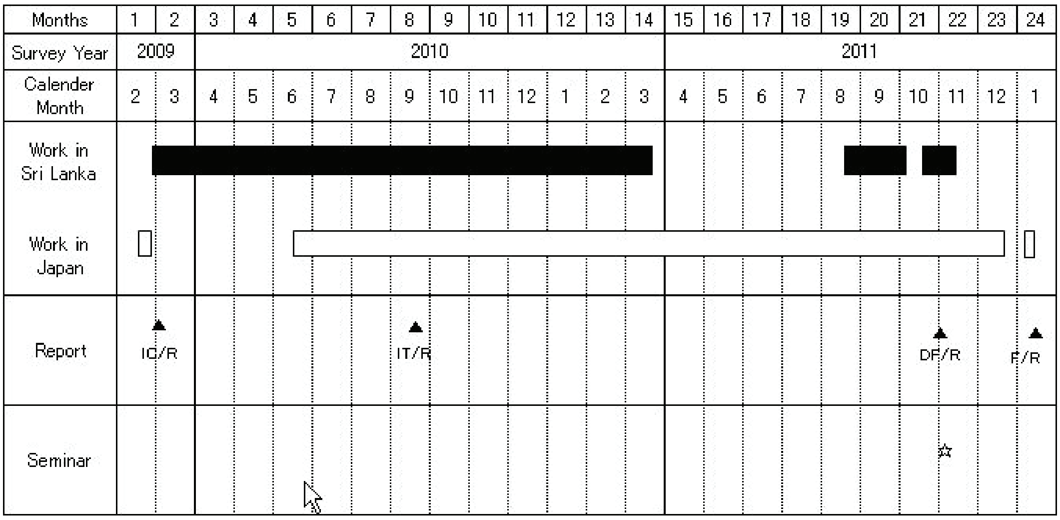
a. Aerial photographs of the entire Northern Province of Sri Lanka

b. Production of 1/10,000-scale digital topographic maps of Mannar and Jaffna Districts in Sri Lanka

c. Technology transfer for the production of digital topographic maps through implementation of a and b.

1.2 Study Implementation Schedule

The chart below gives an outline of the schedule for implementation of the Study.



The Study commenced in February 2011 and was completed in January 2011. It consisted of "Work in Japan" and "Work in Sri Lanka."

(1) Work in Japan

The work in Japan consisted of such tasks as aerial triangulation and digital plotting/compilation. It was implemented in six phases. (Phase 1 began on 10th February 2010 and Phase 6 was completed on 15th January 2012).

(2) Work in Sri Lanka

The work in Sri Lanka consisted of such tasks as control point survey and the transfer of various technologies. It was implemented in six phases. (Phase 1 began on 28th February 2010 and Phase 6 was completed on 9th November 2011).

1.3 Implementation of the Survey

1.3.1 Implementation of the Digital Topographic Mapping

Digital photogrammetry was used to carry out the following work in order to achieve objectives 'a' and 'b' of the Study.

(1)Discussion of Specifications

Discussions were held between the Survey Department of Sri Lanka (SDSL) and the Study Team on the geodetic reference system (ellipsoid of reference and coordinate system) and the digital map specifications required for the production of digital topographic maps. Discussions were also held on the areas to be mapped in Mannar and Jaffna Districts.

(2) Aerial Photography

The aerial photography was subcontracted to a local company, Finnmap FM International, which was awarded the contract in a competitive tender.

The subcontractor took aerial photographs of the entire Northern Region over two periods, the first in June 2010 and the second in March 2011, after permits had been obtained from the various relevant authorities, including the Ministry of Defence and the Civil Aviation Authority. The main specifications for the aerial photography were as follows:

* Scale of photography:	1/20,000
* Type of photography:	Colour photography
* Method of photography:	GPS/IMU method
* Percentage of duplicate coverage:	Overlap: 60 % (standard)
	Sidelap 30 % (standard)

(3) Photo Control Point Survey

Photo control point survey (GPS survey and levelling) to establish photo control points required for the subsequent aerial triangulation was implemented with technical assistance from SDSL. Before the implementation of the photo control point survey, air photo signals had been placed at all photo control points (horizontal control points).

1) GPS Survey

The GPS receivers of SDSL were used for 8-hour continuous observation of the existed control points and 1-hour simultaneous observation of newly-established photo control points.

After the analysis of the observed data, the coordinates of each photo control point were calculated in the geodetic reference system stipulated in the specifications. The elevation of each of the photo control points was measured, wherever possible, in the levelling work described below.

2) Levelling

Levelling was carried out on the routes deduced from the data on aerial photographs and satellite imagery, with technical assistance from SDSL and its equipment.

Sketches of the vertical control points established in the levelling work were made and used as reference materials for pricking on aerial photographs.

As mentioned above, the elevations of the horizontal control points surveyed in the GPS surveying were measured, wherever possible, in the levelling.

(4) Field Identification

Field identification was implemented in Jaffna District and elsewhere using the aerial photographs, with technical assistance from SDSL.

1) Photo Interpretation for Field Identification

Before the field surveys, aerial photographs were interpreted in the office.

In the photo interpretation, interpretable features were identified on aerial photographs in accordance with the established map symbol specifications.

2) Field Identification

Field surveys were carried out with the aerial photographs used in the photo interpretation. Feature data which could not be obtained from photo interpretation (such as data on features which could not be identified in the photographs, names of roads and structures, etc.) were collected in the surveys.

(5)Aerial Triangulation

Aerial triangulation was implemented separately for the area for which digital topographic maps were to be produced and for the entire Northern Region including the area for which digital topographic maps were to be produced, because of the delay in carrying out the aerial photography.

1) Aerial Triangulation for Digital Topographic Mapping

Aerial triangulation for digital topographic mapping was implemented in four blocks, namely, the southern part of Jaffna District, the islands, the northern part of Jaffna District and Mannar District, over two periods.

Before the implementation of the aerial triangulation, the number and locations of photo control points in each block were evaluated for the purpose of accuracy control. It was concluded from this evaluation that aerial triangulation with the established photo control points would satisfy the degree of accuracy required for the 1/10,000-scale digital topographic maps if it was used together with the results of the GPS/IMU analysis.

After the evaluation, aerial triangulation using the bundle method was implemented for the image data obtained from the aerial photography and the results of the photo control point survey.

2) Aerial Triangulation of the entire Northern Province

Digital and analog aerial triangulation of the entire Northern Region was carried out. Part of the island area was excluded from the calculation of the aerial triangulation of the entire region. Instead, the orientation elements required for plotting were calculated separately.

a. Digital aerial triangulation of the entire Northern Region

Digital aerial triangulation of the entire Northern Region was carried out using the same method as the aerial triangulation of the area for digital topographic mapping.

b. Analog aerial triangulation of the entire Northern Region

Analog aerial triangulation of the entire Northern Region was carried out by means of the following procedures:

Selection of points: Tie points were established in overlapped aerial photograph.

Pricking: Tie points selected as described above and other points was pricked on diapositive film.

Observation: Machine coordinates of the pricked tie points and photo control points were observed.

Inner orientation: The machine coordinates of the tie points and photo control points were transformed into photographic coordinates in the inner orientation.

Relative orientation: The photographic coordinates of the tie points and photo control points were transformed into model coordinates in the relative orientation.

Adjustment calculation by the bundle method:

Adjustment calculation by the bundle method was carried out using the photographic coordinates of the tie points and photo control points and the results of the photo control point survey.

(6)Digital Plotting/Compilation

Digital plotting and compilation was carried out using the results of the aerial triangulation and the field identification in accordance with the map symbol specifications.

1) Digital Plotting

Digital data of topographic features were obtained in accordance with the map symbol specifications, using various types of digital plotters. The digital data of topographic features that were obtained are either point, line or polygon in form, in accordance with the map symbol specifications.

2) Digital Compilation

Digital compilation was carried out using the digitally-plotted data and CAD software for data compilation, MicroStationV8.

In practice, in the digital compilation each symbol was moved to the appropriate location, annotations and administrative boundaries were added and consistency between topographic features data was established. In the final stage, items for supplementary field verification were identified.

7) Supplementary Field Verification

Uncertainties identified in the digital plotting/compilation were eliminated and administrative boundaries and names were confirmed definitively in the supplementary field verification. The supplementary field verification was implemented with technical assistance from SDSL.

1) Implementation Period and Organizations Involved

The supplementary field verification was implemented over two periods, with technical assistance from SDSL. Eleven teams of SDSL staff members carried out the supplementary field verification in the period of October 2010 and 12 teams in the period of September 2009.

2) Details of the Work

Data on administrative boundaries and names, road classifications and the results of the control point were obtained in the indoor work. Meanwhile, uncertainties identified in the digital plotting/compilation were eliminated and data on additional features to be represented on the maps were obtained in the field work. Data on road kilometer posts, high-voltage transmission lines and a disused railroad, the names of major road intersections and major facilities and annotations were also obtained.

(8) Supplementary Digital Compilation

The results of the supplementary field verification (the results of the elimination of uncertainties, acquisition of data on road kilometer posts, high-voltage transmission lines, etc.) were added to the topographic map data in such a way as to maintain data consistency with nearby features.

(9)Digital Data Structuralization

The data processed in the digital compilation after field completion were structuralized.

1) Structuralizing Compilation

The data processed in the supplementary digital completion were inspected and corrected for logical errors and were structuralized topologically.

2) Data Format Conversion

The data processed in the structuralizing compilation were converted into data in DXF and SHPE formats per each map sheet.

(10) Map Symbolization

AI data for printing 1/10,000-scale maps were produced from the structuralized digital topographic map data.

1) Map Symbolization of Topographic Map Data

Map symbols were created in accordance with the map symbol specifications and correspondence was established between the symbols created and each topographic feature data. The order of feature layers was rearranged for better representation on the output topographic maps. Where two or more feature symbols overlap, the location of symbols on the map was transferred so as to make all the symbols distinguishable.

2) Map Symbolization of Marginal Information

Topographic features in legends included in marginal information were symbolized in accordance with the map symbol specifications. The other marginal information was also symbolized.

3) Integration of Symbolized Topographic Map Data and Symbolized Marginal Information Data

AI data for output maps were produced by integrating symbolized topographic map data and marginal information data and adding data such as the map sheet number and title to each sheet.

(11)Production of Digital Data File

Vector data in DXF and SHPE formats produced in the digital data structuralization and symbolized AI data converted into raster format (PDF format) were stored on DVDs and other recording media.

1.3.2Implementation of Technology Transfer

Technologies in the technical fields relevant to digital photogrammetry were transferred to the counterparts in order to achieve objective ‘c’ of this Study.

(1) Photo Control Point Survey

Since SDSL already had sufficient experience in photo control point survey (GPS survey and levelling), the focus of the technology transfer in photo control point survey was on the technologies required for the implementation of aerial triangulation.

1) GSP Survey

Methods of calculating the number of photo control points and distributing photo control points required for the implementation of aerial triangulation were transferred to the counterparts.

2) Levelling

Methods of calculating the number of vertical control points and distributing vertical control points required for implementing aerial triangulation and for determining levelling routes were transferred to the counterparts.

3) Installation of Air Photo Signal and Pricking

Since the focus of the technology transfer was on the implementation of aerial triangulation, technologies for installing air photo signals and pricking, including the preparation of detailed drawing of air photo signals and pricking points, were also transferred to the counterparts.

(2) Field Identification

Since SDSL had no experience of field identification using aerial photographs, technologies required for this, including indoor photo interpretation and practical work in field identification, were transferred to the counterparts.

(3) Aerial Triangulation

SDSL had abundant experience in analog aerial triangulation and knew the general technologies for aerial triangulation. Therefore, technology transfer in aerial triangulation was implemented with the focus on how to use the software for digital aerial triangulation introduced in this project.

(4) Digital Plotting/Compilation

SDSL had abundant experience in digital plotting/compilation. SDSL owns digital plotters, though none of them are of the same model as the plotter used in this Study, and is routinely implementing digital plotting work. Similarly, SDSL is implementing digital compilation using an older version of the digital compilation software which was introduced in the project.

Under these circumstances, the technology transfer in digital plotting/compilation was implemented with the focus on how to use the digital plotting system to be introduced in the project, and how to use the latest digital compilation software.

(5) Supplementary Field Verification

SDSL had abundant experience in supplementary field verification using output maps of digitally edited data. Based on this, technology transfer in supplementary field verification included the following:

a. How to eliminate uncertainties identified in the digital plotting/compilation;
b. How to make a final confirmation on certain features
c. How to create and use annotation data files
d. Schedule management and accuracy control technologies

(6) Digital Data Structuralization

SDSL had experience in various kinds of works in which Arc GIS software was used. Therefore, the focus of the technology transfer in digital data structuralization was on the development and use of technologies to facilitate and automate data processing (including structuralization), in which the staff of SDSL were involved routinely in their work, instead of the basic operation of the latest ArcGIS software introduced in the project.

(7)Map Symbolization

Technologies for the use of the software introduced in the project (Adobe Illustrator) for transforming the data processed in the supplementary digital completion into AI data for maps to be printed out were transferred to the counterparts in the technology transfer in map symbolization. The actual technologies transferred are listed below.

a. Establishment of printing environments
b. Basic operation of Adobe Illustrator CS5
c. Production of topographic map symbols in accordance with the map symbol specifications
d. Special map symbolization technologies (change of scale, rearrangement of the layer order, trimming, etc.);
e. Production of data files for printout topographic maps

1.3.3 Other Work

(1)Holding of Seminar/Workshop

A seminar/workshop was held on 4th November 2011 with the participation of the Secretary of the Ministry of Land and Land Development, the ministry in charge of SDSL.

At the seminar/workshop, the process by which the project was implemented and the results of its implementation were presented, and the results of the technology transfer (including demonstrations) was revealed to a wide public audience. Samples of the digital topographic maps that had been produced were also shown at the seminar/workshop. SDSL announced its plan to produce digital topographic maps of the unmapped areas of the Northern Region. In addition, the guidelines for the future production of geospatial data by SDSL were presented.

(2)Reports

1) Preparation of the Reports

The following reports were prepared in the project:

a. Inception Report: Describing the outline of the project and methods of implementation.
b. Interim Report: Describing the achievements of project implementation by the end of September 2010 and the work scheduled for implementation thereafter.
c. Draft Final Report: Describing the progress and results of the implementation of the project in its entirety.
d. Final Report: Describing the progress and results of the implementation of the project in its entirety, tasks remaining and recommendations for future activities.

2) Explanation and Discussion of the Reports

After the completion of the Inception Report, Interim Report and Draft Final Report respectively, an explanation of the report was given to SDSL and discussions were held with them on the report.

At each explanation/discussion meeting, the SDSL side approved the report after raising some technical questions and making a few requests.

1.4 Results of the Implementation of the Survey

1.4.1 Results of the Production of Digital Topographic Mapping

(1) Discussion of the Specifications

In discussions between the SDSL and the Study Team, it was decided to use the following geodetic reference system in the project:

Reference ellipsoid:	Everest 1830
Coordinate system:	Sri Lanka Datum 1999 (SLD-99-2)
Projection method:	Transverse Mercator projection

The map symbol specifications for 1/10,000-scale digital topographic maps were established. The areas in Mannar and Jaffna Districts for topographic mapping (100 map sheets covering an area of 2,008.2 km^2) were also determined.

(2) Aerial Photography

Aerial photography of the entire target area of approximately 9,000 km^2 (2,494 photographs from 61 flight courses) was eventually completed after many difficulties.

(3) Photo Control Point Survey

One hundred and five control points were established in GPS survey, and levelling was carried out over a length of approximately 550 km over several phases.

(4) Field Identification

Field identification was carried out in a 36 km^2 area in Jaffna District.

(5)Aerial Triangulation

While aerial triangulation was implemented initially for the area for topographic mapping, in the end digital aerial triangulation (2,127 photographs from 61 flight courses) and analog aerial triangulation (2,031 photographs from 61 flight courses) of the entire region were carried out.

(6) Digital Plotting/Compilation

Data for the area of 2,008.2 km^2 on the 100 map sheets were digitally plotted and compiled.

(7)Supplementary field verification

Supplementary field verification of the area of 2,008.2 km^2 on the 100 map sheets was implemented over two phases.

(8) Supplementary Digital Compilation, Digital Data Structuralization and Map Symbolization

Supplementary digital compilation, digital data structuralization and map symbolization of topographic map data on the area of 2,008.2 km^2 on the 100 map sheets were implemented.

(9)Production of Digital Data File

Files in the various formats of topographic map data corresponding to the area of 2,008.2 km^2 on the 100 map sheets were produced.

1.4.2 Results of the Implementation of Technology Transfer

(1)Photo Control Point Survey

1) GPS Survey

The counterparts have fully mastered how to calculate the number of photo control points for GPS survey. At the same time, they are not considered to have sufficiently mastered the method of distributing photo control points, because of a lack of practice.

2) Levelling

The counterparts have completely mastered how to select levelling routes and how to make reasonable observations.

(2)Field Identification

Because only a limited amount of field identification has been carried out, it is not considered that the counterparts have sufficiently mastered the technologies for field identification. They will need more experience to gain complete mastery of the technologies.

(3)Aerial Triangulation

The counterparts have become able to make full use of the software for digital aerial triangulation that was introduced. This proves that they have completely mastered the technologies used in the aerial triangulation.

(4) Digital Plotting/Compilation

The counterparts have completely mastered the use of the latest digital plotting/compilation system introduced in the project, partly due to their prior practical experience in digital plotting/compilation.

(5) Supplementary Field Verification

The counterparts have completely mastered the technology in supplementary field verification partly due to their prior practical experience in supplementary field verification. However, they have yet to master the technology for the preparation of a supplementary field verification manual.

(6) Digital Data Structuralization

The transferred technologies were at higher levels than originally planned and the counterparts have fully mastered the technologies that enable them to use the software to facilitate and automate data structuralization.

(7) Map Symbolization

Although the counterparts had not had experience in map symbolization using the map symbolization software that was introduced, they have completely mastered the basics of it and have become able to carry out map symbolization.

1.5 Production of Project

The implementation of the Study has produced the following outputs:

(1) Study Reports

a. Inception Report		in English, 25 copies
b. Interim Report		in English, 25 copies
c. Draft Final Report		
	Main	in English, 25 copies
	Summary	in English, 25 copies
d. Final Report		
	Main	in English, 25 copies
	Summary	in English, 25 copies

(2) Products

a. Aerial photographs		
	Exposed films	1 set
	Digital data files	1 set
	Contact prints	2 sets
	Aerial photography index maps	1 set
b. Field survey results		1 set
c. Aerial triangulation results		1 set

d. Digital data files (scale 1/10,000 topographic maps) 1 set

2. Efforts toward the Development of Digital Topographic Maps

2.1 Effective Use of the Project Outputs

2.1.1 Effective Use of the Digital Topographic Maps

Digital topographic maps covering approximately a quarter of the entire Northern Region were produced in this project in accordance with the specifications.

The following are required for the use of the digital topographic maps that were produced:

*Publication and dissemination of the specifications for the digital topographic maps

*Public availability of the digital topographic maps and the implementation of publicity activities to promote their use

*Establishment of a mechanism for the supply of digital topographic maps (including a pricing policy and supply method)

2.1.2 Effective Use of the Results of the Technology Transfer

The Study Team has evaluated the results of the technology transfer carried out during the implementation period of this project. Apart from the evaluation by the study Team, SDSL should implement an independent evaluation of the results of the technology transfer using the reports of the recipients of the technology transfer. This evaluation will mark the first step for SDSL toward the effective use of the results of the technology transfer.

2.2 Tasks based on the Results of the Technology Transfer

Since the technology transfer was carried out over a number of different technical fields, some difference has been noted in the level of the results of the technology transfer depending on the technical field.

The level of mastery is high in the fields where SDSL had prior experience in the use of similar technologies (observation and analytical calculation in the photo control point survey, digital plotting/compilation, supplementary field verification and digital data structuralization). The level of mastery of the transferred technologies is also high in those fields where the transferred technologies have been used repeatedly (installation of air photo signals and production of sketches of pricked points).

At the same time, the level of mastery of the transferred technologies is low in technical fields in which the counterparts had little prior experience or where the transferred technologies have not been used repeatedly (distribution of photo control points and map symbolization).

These findings reveal the need for improvement in the level of mastery of the transferred technologies in those technical fields where the level of mastery is low, by means of repeated practice, dissemination of the mastered technologies and improvement in productivity of the mastered technologies.

2.3 Production of Digital Topographic Maps for the Remaining Unmapped Areas in the Northern Region

At the end of the completion of the Project there have been high expectations for the production of digital topographic maps of the unmapped area of the Northern Region.

2.3.1 The Map Production Project for the Unmapped Areas in the Northern Region by SDSL

SDSL announced its plan for the production of digital topographic maps of the unmapped areas based on the relevant government office. The announced plan assumes completion of digital plotting/compilation of the entire area, which is to be carried out according to the order of priority of each map sheet by June 2014. In an alternative plan, which assumes doubling of the work force, the date for the completion is set in March 2013.

2.3.2 Issues Requiring Attention in the Production of Digital Topographic Maps of the Unmapped Areas of the Northern Region

There are several issues requiring attention (in the processes following digital plotting, in particular) before SDSL's plan for the production of the digital topographic maps can be implemented.

(1) Improvement of the Technical Capacity to Produce Digital Topographic Maps

The results of the Project include the results of the digital and analog aerial triangulation. While it is expected that these outputs will be used in the production of digital topographic maps, the following issues require attention:

*Effective use of the results of the digital and analog aerial triangulation

*Dissemination of technical capacity and improvement of productivity in digital plotting/compilation

*Establishment of an implementation mechanism and improvement of productivity in supplementary field verification

*Improvement of productivity in map symbolization.

(2) Production Plan of Digital Topographic Maps of the Unmapped Areas of the Northern Region

SDSL has already formulated a plan for the production of digital topographic maps of the remaining areas. However, the following issues require attention while details of the plan are being finalized.

*Human and material resources available to SDSL as inputs to the map production plan

*Production per unit time in each technical process following digital plotting (digital compilation, supplementary field verification and map symbolization).

(3)Production of Digital Topographic Maps of the Unmapped Areas of the Northern Region

After the production of digital topographic maps commences, measures must be taken to ensure the quality of the maps, *i.e.* accuracy control in each process and evaluation of the quality of final products.

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Chapter 1 Outline and Purposes of the Project

1.1 Backgrounds of the Project

In the Socialist Republic of Sri Lanka (hereinafter Sri Lanka) the civil war that lasted nearly 30 years ended in May 2009 when government forces and took control of the whole country. However, the Northern Province is faced with urgent issues such as mine clearance, rebuilding infrastructure, and repatriating the internally displaced persons (IDP).

The Government of Japan has made '*assistance for consolidation of peace and reconstruction*' a main pillar of its country specific assistance plan for Sri Lanka; based on this JICA has made '*improving resident's livelihoods and social environment in war affected areas*' one of its development issues.

On the other hand, JICA undertook a series of information gathering and confirmation surveys in Northern Province from September 2009. These surveys confirmed the needs and high expectations of assistance in fields closely related to the livelihoods and waste management in communities and local governments in Jaffna and Mannar districts.

This project is to undertake aerial photography to grasp the situation in the Northern Province to contribute to its recovery, and to make 1:10,000 scale topographic maps needed to establish a recovery plan for an area covering approx. 2,000 km^2 of Mannar and Jaffna districts.

Moreover, in the process, the project's purpose is to transfer digital topographic mapping techniques.

Further, the counterpart (hereinafter C/P) organisation is the Survey Department of Sri Lanka (hereinafter SDSL).

1.2 Objectives of the Project

The objectives of this Project were as follows:

(1) Aerial photography of the entire Northern Region of Sri Lanka.

(2) Production of 1:10,000-scale topographic maps of Mannar and Jaffna Districts of Sri Lanka.

(3) Technology transfers for production of digital topographic maps through implementation of (1) and (2) mentioned above.

1.3 Outline and Schedule of the Project

1.3.1 Outline of the Project

（１） Digital topographic map production

The target areas by project objective were as follows:

(1) Aerial photography: Approximately 9,000 km^2 area of Northern Region

(2) Area for production of 1:10,000-scale digital topographic maps: Approximately 2,000 km^2 area of Mannar and Jaffna Districts

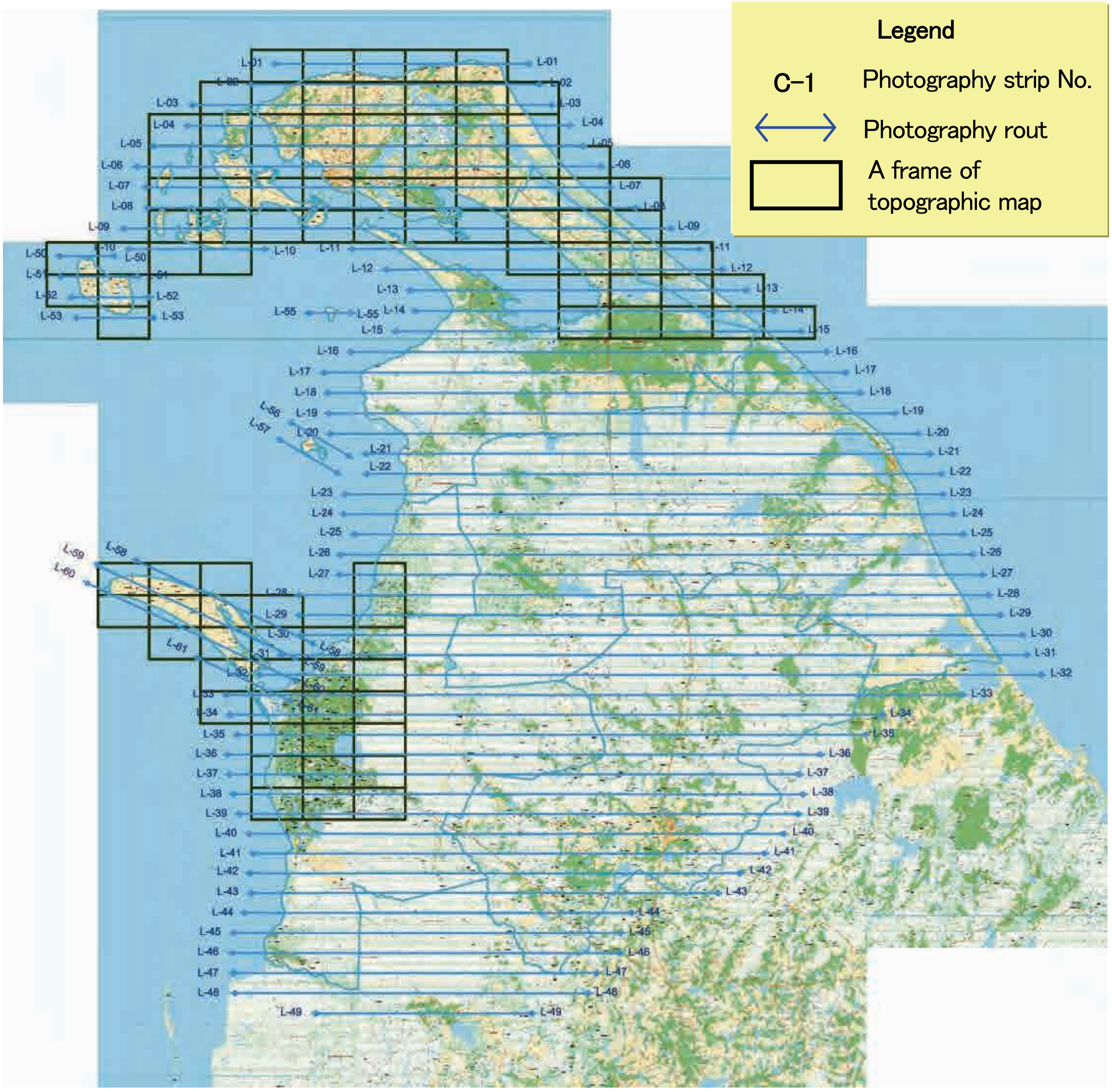


Fig 1-1 Implemented Aerial photography and Plotting targeted areas

（2） Technology transfer

Technology transfer of the following techniques was implemented for the employees of SDSL, the counterpart agency:

GPS Photo control point survey, Levelling, Field identification, Supplementary field verification

Digital photogrammetry (Digital aerial triangulation, Digital plotting/compilation)

GIS Structualization

Map symbolization

（3） Other works

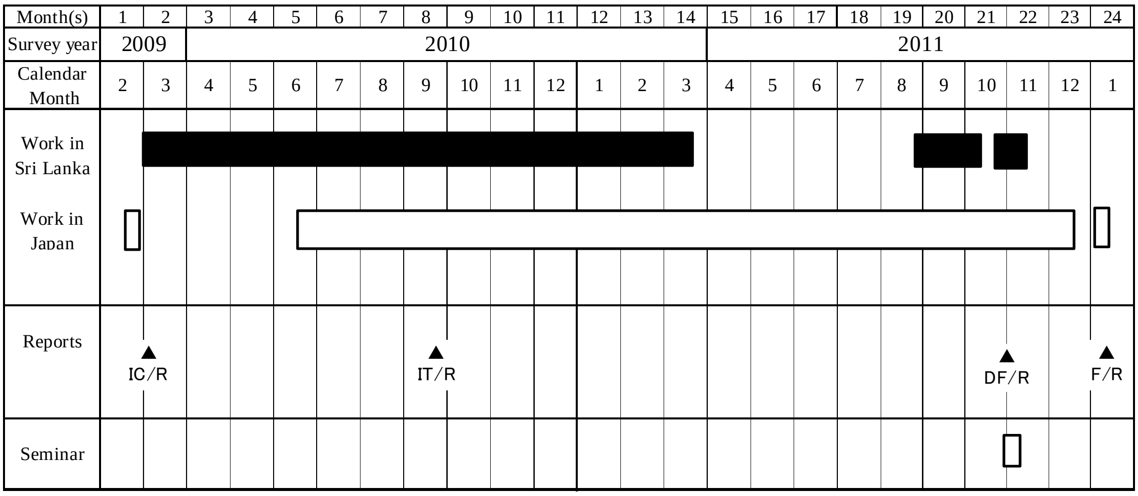
The following works were implemented as other works

Holding of seminar/workshop

Explanation of and discussion on various reports

1.3.2 Work Schedule of the Project

The outline of work schedule for the project was as follows.



1.4 Products of the product

（1） Project reports

The following reports were made and submitted:

a. Inception report English 25sets

b. Interim report English 25sets

c. Draft final report

Main report English 25sets

Summary English 25sets

d. Final report

Main report English 25sets

Summary English 25sets

（2） Products

The following products were made and submitted during this project

a. Aerial photography（scale 1/20,000：color）

Exposed film 1 set

Digital data file 1 set

Contact prints 2 sets

Aerial photograph index map 1 set

b. Field survey result	1 set
c. Aerial triangulation result	1 set
d. Digital data file (scale 1/10,000topographic map)	1 set

Chapter 2 Project Implementation

2.1 Basic policies of the project

On the basis of the objectives of the Project, the following basic implementation policies had been established:

（1） Basic Polices

Basic Policy 1: Aerial photography will be carried out at appropriate times and the results of the photography will be promptly used in the subsequent works.

Basic Policy 2: Topographic maps will be produced in accordance with specifications to be determined in a discussion based on the conventional specifications of SDSL and JICA's specifications for their use in drafting a future reconstruction plan

Basic Policy 3: Technology transfer to SDSL will be implemented in such a way that SDSL will be able to produce digital topographic maps of the remaining area independently after the completion of the Project

2.2 Contents of the project work implemented

（1） Contents of project

To achieve the objectives, the project work was divided into four parts and was implemented.

Part 1：Production of digital topographic maps

Part 2：Technology transfer

Part 3：Seminar/Workshop

Part 4：Production of, Explanation of and Discussion on various reports

（2） Flow chart

The following is a flowchart of project works.

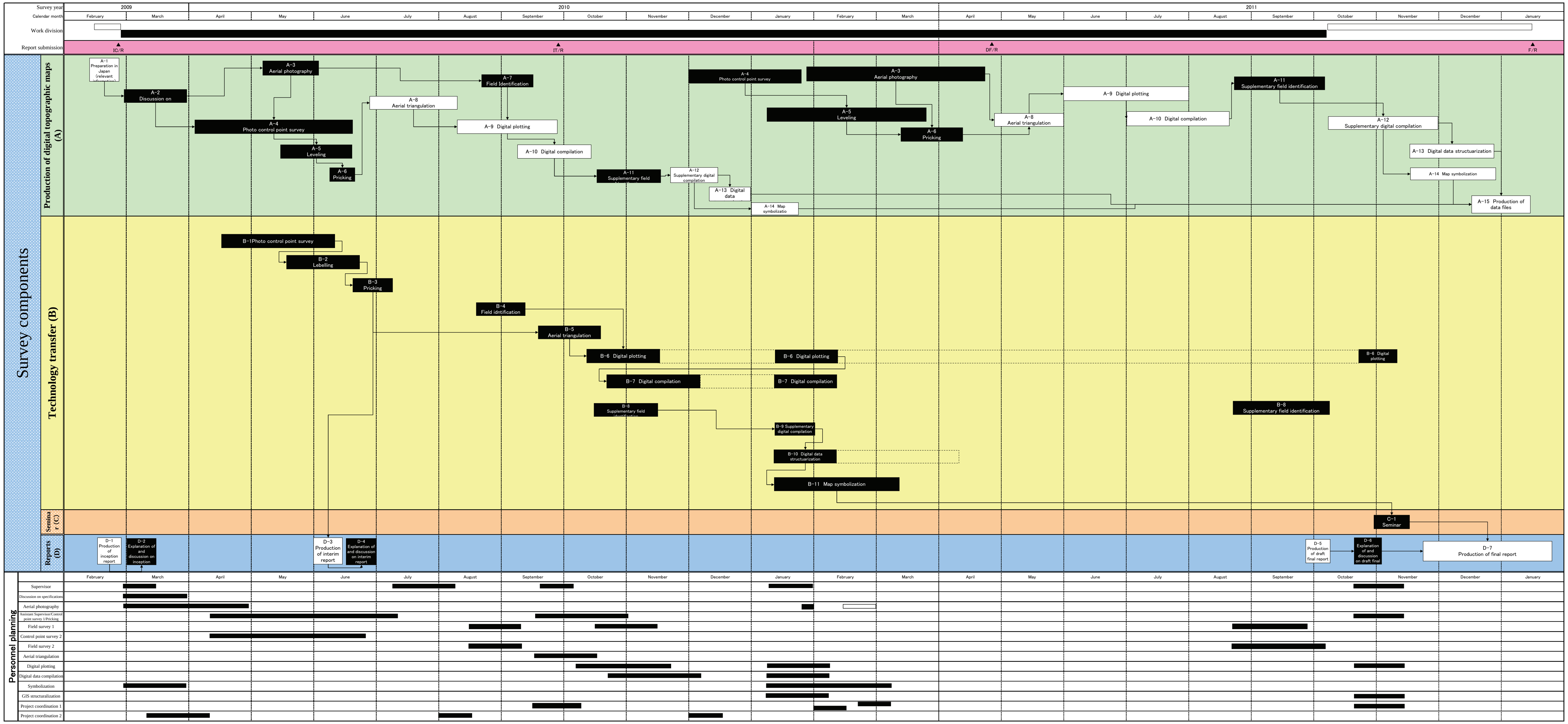


Fig 2-1 Flowchart

2.3 Composition of the study team

The Study Team that was made up as follows implemented the project.

Study Work in charge	Name of Member	Main Work Items
Team leader	Nishimura Akira	• General operation and management of all the study works
Map specification	Chiba Zenichi	• Discussion of the specifications for digital topographic mapping
Aerial photography	Usuda Kentarou	• Selection of local subcontractor for aerial photography • Drawing up of the specifications for aerial photography • Supervision of aerial photography
Sub-leader/Photo control point survey/ 1/Pricking	Harada Takashi	• Support of operations in all the works covered by the Study • Operation and supervision of photo control point survey for digital topographic mapping as well as technology transfer of the same • Operation and supervision of pricking for digital topographic mapping as well as technology transfer of the same
Photo control point survey 2	Ishizuka Kazuhiro	• Operation and supervision of photo control point survey for digital topographic mapping as well as technology transfer of the same
Field identification1	Nishio Satoru Ishizuka Kazuhiro	• Operation and supervision of field survey (incl. supplementary field verification) for digital topographic mapping as well as technology transfer of the same
Field identification2	Usuda Kentarou	• Operation and supervision of field survey (supplementary field verification) for digital topographic mapping as well as technology transfer of the same
Aerial triangulation	Nakamura Mitsutomo	• Technology transfer of digital aerial triangulation
Digital plotting	Ikeda Yoshiaki	• Technology transfer of digital plotting
Digital compilation	Hoshino Jyun	• Technology transfer of digital compilation
GIS structualization	CHE Wentao	• Technology transfer of conversion (structualization) of topographic mapping data into GIS database
Map symbolization	Fukumoto Yoshimitsu	• Technology transfer of map symbolization of topographic mapping data
Coordinator 1	Katou Takayuki Usuda Kentarou	• Assistance in technology transfer of aerial triangulation

Study Work in charge	Name of Member	Main Work Items
	Takahashi Masahiko Ishijima Norio	• Coordination of the supervision assistance work for aerial photography • Coordination of the Study works
Coordinator２	Oouchi Yuuji Hirahara Naomi	• Coordination of the Study works

Chapter 3 Results of the Project Implementation

3.1 Production of digital topographic maps

（１） Specification of digital topographic mapping

１） Discussion and decision on Survey standards

The survey standards to be used in the photo control point survey and digital plotting were discussed and decided upon as follows.

Coordinate System: Sri Lanka Datum 1999 (SLD-99-2)

Reference Ellipsoid: Everest (1830)

a (long radius) = 6377,276.345m

b (short radius) = 6356,075.413m

Projection: Transverse Mercator projection

Origin point of coordinate: Pidurutalagala Easter 80° 46' 18.16710"

Northing 7° 00' 1.69750"

Standards elevation: In accordance with the existing Bench mark

２） Discussion and decision on Map symbol specification

The map symbol specification was discussed based on the map symbol specification in analog format made by SDSL, *Basic Cartographic Principles* edited by SDSL, and *Data Capture Model -10K Geo-database-* specifications made by SDSL and was decided.

Marginal information of output topographic maps that comprises part of the map symbol specification was discussed using the existing 1/10,000 analog topographic maps as basis, re-examined using sample output maps, and determined.

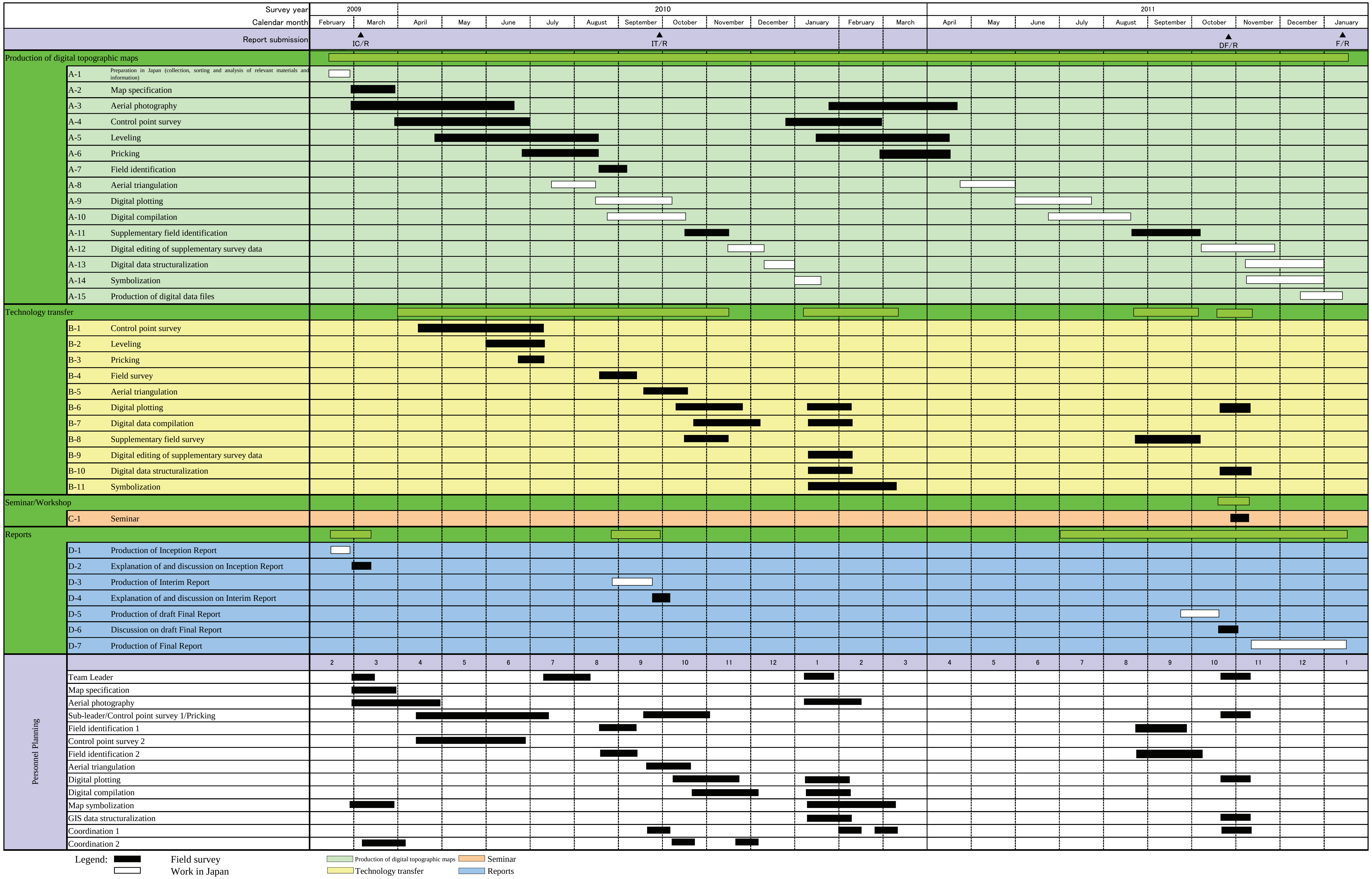
It was agreed that the following annotation would have put into the part of marginal information in a digital topographic map:

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

３） Discussion and decision on plotting area

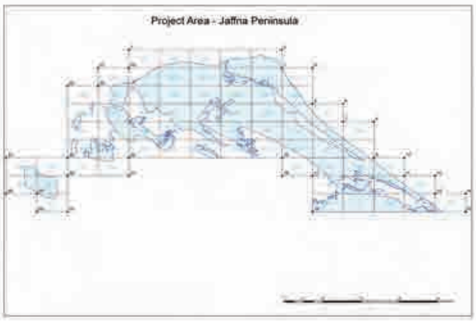
The size of the 1:10,000 topographic map print-outs was discussed. It was decided that the size would be the same as the existing SDSL maps, 5 km high × 8 km wide. Accordingly, the plotting area was decided upon an area of *ca.* 2,008.2 km^2 based on this map size.

Table 3-1 Detailed Schedule



- Jaffna District *ca.* 1,273.6 km^2 (69 sheets)
- Manna District *ca.* 734.6 km^2 (31 sheets)

Further, maps of the plotting area and sheet divisions in each district are as follows.



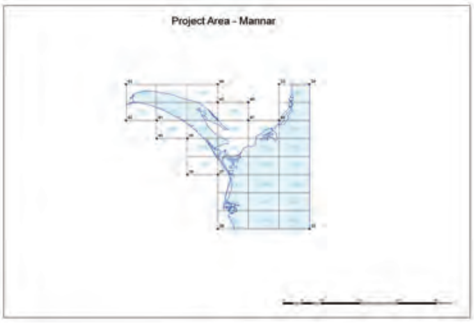


Fig 3-1 plotting area and 1/10,000sheet division

（2） Aerial Photography

１） Selection of aerial photography subcontractor

The local subcontract of the aerial photography was the following company selected by an invited tender.

・Finnmap FM International

Malminkaari 5, F 1-00700 Helsinki, Finland.

２） Consultation prior to aerial photography

The following technical specifications of the aerial photography were confirmed with Finnmap.

Area:	*ca.* 9,000 km^2 of Northern Region
Scale:	1:20,000
Type:	Color photographs
Overlap:	Overlap of 60%±5% and a side lap of 30%±5% side lap, in principle
Method	GPS/IMU method

３） Obtaining permits for aerial photography

Basic permission to photograph the target area (Northern Region) was obtained from the Sri Lankan Ministry of Defense. Therefore, visas for the photography crew to enter Sri Lanka, permits for the entry of the photography aircraft into Sri Lanka, landing, apron space and takeoff, were obtained.

４） Aircraft ferry flight

A Ferry flight of the photography aircraft was implemented according to the abovementioned permits, but this ferry flight was canceled on the way because of engine. As such, Finnmap decided to dispatch a replacement aircraft and various permits were obtained for this ferry flight. Based on these permits, the aircraft(Piper PA-31T Cheyenna Ⅱ) arrived in Katunayaka International Airport in Colombo on 11 May 2010. The aircraft then immediately flew to Ratmalana Airport, an air force base in Southern Colombo, to be fitted with an aerial camera.

Picture 3-1 Aircraft for aerial photo

Picture 3-2 Setting up the aerial camera

5） Implementation of aerial photography (Aerial photography in June 2010 period)

The poor weather continued until 31 May 2010, finally improving the next day, June 1, when 14 strips of approximately 370 photographs were taken in Jaffna District and on the next day, June 2, 3 strips of 15 photographs were taken in isolate island of Manna Districts. However, the remaining aerial photography, unfortunately, could not be completed because of the end of the dry season and unseasonable weathers.

6） Outputs of the aerial photography

The aerial photographs of the completed strips were developed and inspected for adoption or rejection. The inspection found all of the photography met the specifications, and so were adopted. The aerial photos were digitized with a given resolution and the contact prints and the diapositive films were produced with a given numbers.

7） Discussion of implementation plan of remaining aerial photography

Discussions were held with Finnmap to respond to the remaining photography work. The following matters were agreed upon through these discussions:

- The remaining aerial photography will be implemented during the next dry season, in January and February 2011
- The aircraft is to be flown to Sri Lanka by January 2011 to implement this photography

8） Obtaining permission for aerial re-photography

Necessary papers prepared by Finnmap were submitted to the relevant authorities, and necessary permits were obtained by the middle of January 2011.

９） Preparing for photography and aircraft re-entry

After obtaining the various permits, the aircraft arrived in Colombo on January 20, 2011. The photography crew had also assembled in Colombo by that stage.

１０） Implementation of aerial re-photography (Aerial photography in March 2011 period)

On January 26, 2011, the aerial camera and other instruments were equipped with the aircraft and the aircraft went on a test flight and entered a standby state for aerial photography (Ratmalana Airport, SLAF China Bay). In the February 2011 period, however, unfavorable weathers such as downpours were encountered. The weather recovered in March 2011, and the aerial photography in all the areas was completed in the period from March 6 to 11, 2011.

１１） Cancellation of the Cross-line Aerial Photography

The cross-line aerial photography, which the sub-contractor had agreed to implement as an extra-contractual work, could not be implemented because of the poor weather conditions and the priority given to the aerial photography of the entire target area. The Study Team concluded that the accuracy at the stage of the aerial triangulation could be guaranteed with the use of the outputs of GPS/IMU and the number of control points used.

１２） Outputs of aerial re-photography

After the exposed films were developed, the photography outputs were tested in various ways. As a result, all the photos satisfied the specifications and were adopted. Production of outputs (scan data, contact prints, and diapositive films of aerial photographs) followed afterward.

（３） Photo control point survey

The photo control point survey (GPS survey) was to be implemented for the entire photography area. This was implemented with the aerial triangulation of the entire area of aerial photography (*ca.* 9,000km^2) in mind.

１） Establishing the implementation plan of photo control point survey

A distribution plan of photo control points were established based on the form of the survey area and the photography plan. The number of photo control points (horizontal location) was determined in accordance with the Overseas Survey Specification of JICA.

２） Implementation plan of photo control point survey

Discussions were held with SDSL based on the established photo control point implementation plan. The photo control point survey plan was reviewed and renewed by adding the additional information and an agreement on it was reached with SDSL. As a result, the total number of photo control points was 105.

３） Installation of air-photo signals

Initially, the location of all photo control points was to be decided on aerial photographs by pricking. However, as there was a request from SDSL including personnel support, all of the photo control points were installed with air-photo signals basically.

４） Implementation of photo control point survey (GPS survey)

The photo control point survey (GPS survey) was performed with technical cooperation from SDSL using GPS receivers owned by ISM (Institute of Surveying and Mapping).

The GPS survey observation consisted of continuous observation performed for about eight hours using receivers installed at known points and concurrent observation performed for about one hour at new photo control points and known points.

The horizontal analysis calculations performed included baseline analysis, check for closure errors of arbitrary polygons derived from baselines after analysis, three-dimensional net adjustment, and coordinate transformation.

For the closure errors and residuals at the GCP points, the standard deviations were within the limits, causing no problem in the analysis calculation.

In the height analysis calculation, the elevations (orthometric heights) of four known points were used to create a geoid model for this vicinity, and the elevations (orthometric heights) of newly installed photo control points were obtained based on this model.

（４） Levelling

The levelling was implemented for the entire aerial photography area.

１） Establishment of the implementation plan of levelling

Levelling was planned for *ca.* 500 km (ca. 2 km intervals, install height control points by pricking) mostly along main roads according to the aerial photography plan

２） Implementation plan of levelling

Discussions were held with SDSL on the details of the levelling implementation plan. As a result, it was decided to implement the levelling based on the following:

- In principle, fixed points will be installed approx. every 2 km along the levelling route (550km).
- Duplicate observation will be implemented for the entire levelling route (in order to prevent errors such as misreading).

- The closure difference limit value of the duplicate observation will be 50mm√S (km).

3） Implementation of levelling

The levelling was implemented with technical cooperation from SDSL using Kern tilting level owned by ISM.

Furthermore, the closure difference of the duplicate observation ascertained immediately after the observation for all completed routes were within the limit values.

In addition, the calculations of levelling observation values were all processed by single route calculations to decide the elevation.

Picture 3-3 Observation of Levelling

Picture 3-4 Selection of the pricking point

（5） Pricking

1） Pricking of horizontal photo control points

For some of the photo control points whose aerial photo signals were not identified in the aerial photographs that had been taken and the photo control points submerged in the January 2011 downpour, pricking was performed by measuring the positions of these points in the field to obtain approximate coordinates.

2） Pricking of height control points

Since the aerial photography had not been completed, pricking of height control points every 2 km was undertaken by measuring the approximate coordinates with handy GPS of intersections on roads that can be identified on the aerial photos. At the same time, descriptions were made for the detailed blueprint. Their locations were also identified on Google Earth. Then, after the aerial photos were obtained, pricking was implemented based on the position data such as that identified on Google Earth, the approximate coordinate values and the description.

（６） Field identification

１） Procedure of field identification

Field identification was conducted in consideration of the current situation of SDSL and the plotting and compilation operations in Japan using the following techniques:

* A field identification technique using aerial photographs was applied.
* Photo interpretation keys were created only for part of vegetations, land uses, and hydrologies for the sake of plotting and compilation operations.

２） Preparations for field identification

Color mosaic photos and black and white photos of the same scale as the plotting, 1:10,000, were printed in preparation. Also, SDSL was requested to provide geographic information in its possession, and it was provided.

３） Implementation structure of field identification

The implementation structure was made up of two surveyors from the photogrammetry in SDSL headquarters for the preliminary photo interpretation using the aerial photographs (survey by interpreting photographs). On the other hand, for the field identification outdoors, the implementation structure was made up of two groups, each comprised of one SDSL worker and one Study Team member.

４） Timing of field identification

The field identification was implemented over 25 days from 13th August to 8th September 2010.

５） Implementation of field identification

Two surveyors from SDSL undertook the (preliminary) photo interpretation. During the outdoor part of the field identification, emphasis was placed on solving the queries and uncertain points that came up in the (preliminary) photo interpretation, and the features in the field and those on the photographs were visually collated and verified. Also, where necessary, the target feature was surveyed and its location was identified by taking field photographs and using a handy GPS to observe the coordinates.

６） Outputs of field identification

The following outputs were gained through the field identification:

a. Photo interpretation keys (13 topographic features)
b. Mosaic photos with the field identification information written on them
c. Photos of features taken in the field

(7) Aerial triangulation

The aerial triangulation work was implemented in the areas targeted for topographic mapping and over the entire target area, taking into account the progress of aerial photography and the subsequent work processes (such as digital plotting/compilation and supplementary field verification, etc.).

1) Digital aerial triangulation of target area for topographic mapping

The digital aerial triangulation was implemented in 2 periods, dividing the tophographic mapping area into 4 blocks, taking into account the progress of aerial photography and the geographical positions of the areas for topographic mapping.

a. Implementation periods

The implementation periods and the targeted areas were as follows:

July 2010 period: In the south of Jaffna District and islands

May 2011 period: In the north of Jaffna District, and Mannar District

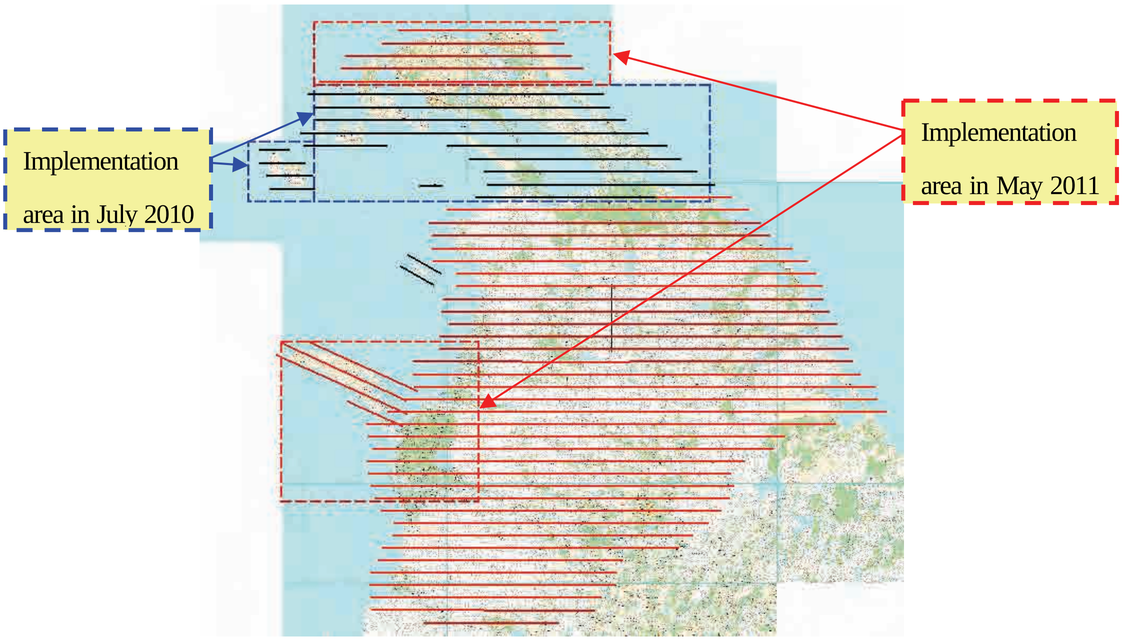


Fig 3-2 Implementation area of aerial triangulation in the target area for topographic mapping

b. Evaluation of number and distribution of photo control points in each block

The photo control point surveys (GPS survey and levelings) were planned (for distribution of photo control points) and implemented on the condition that the aerial triangulation would be implemented over the entire target areas for aerial photography. In implementing the partial aerial triangulation work, therefore, the number and distribution of available photo control points were evaluated.

As a result, the number and distribution of photo control points available in each block was not sufficient to meet the Work Specification, but by also using GPS/IMU results, it was judged that the insufficiency was not at a level at which there was any problem with accuracy in digital plotting of the 1/10,000 topographic maps.

c. Preparatory work

The aerial photos were scanned at the resolution of 1270 dpi (20μm). After that, the results of photo control point surveys and levelings, GPS/IMU results and the camera calibration data necessary were collected.

d. Verification of accuracy of POS data (GPS/IMU data)

The photo control points were observed using the results (exterior orientation elements) from the collected POS data (GPS/IMU data) and the differences from the coordinate values obtained in the field survey were within several meters. As these differences occurred in the same direction, it was estimated that there was an error in the inclination of the POS data. Thus, the weights of ω, φ, κ were set to low weights in the adjustment calculation.

e. Tie-point observations

Tie-points were automatically extracted in the duplicate parts of aerial photos to observe their coordinates using the digital photogrammetry system. For the incomplete models such as islands and coastal areas, tie-points were extracted manually to observe their coordinates.

The model coordinates were calculated using the observed coordinates. If the intersection residuals in the calculated model coordinates between models did not meet the specifications, the observations were repeated.

f. Photo control point observations

The photo control points obtained by photo control point surveys and levelings were identified on aerial photos and their coordinates were observed in the digital photogrammetry system.

The resulting values of these photo control points (XY coordinates and elevation values) were also input into this system.

g. Adjustment calculation by the bundle method and its results

The adjustment calculation in aerial triangulation was made by the bundle method using the results of photo control point surveys, levelings and POS analysis (GPS/IMU analysis).

The control point residuals in each block which were the indexes for evaluation of the results of adjustment calculation were lower than the limit values as shown below. Thus, the results of adjustment calculation were good.

Limit value of standard deviation: 0.61m

Limit value of maximum value: 1.22m

2） Digital aerial triangulation of entire area

Digital aerial triangulation of the entire area was carried out with a method similar to the one used in the digital aerial triangulation of the topographic map production area. The result for the part of the island area was separately prepared.

a. Quantity of work

The quantity of work in the digital aerial triangulation of the entire area was as follows:

Strips: 61 strips

Photo sheets: 2127 sheets

b. Results of adjustment calculation with bundle method

Adjustment calculation with bundle method for the aerial triangulation of the entire area was done with data obtained from the photo control point survey and levelling and results of the POS analysis (GPS/IMU analysis).

As a result of the calculation, the standard deviation and maximum of the photo control point residuals were below the tolerance limits and the results of the digital aerial triangulation of the entire area were accurate.

3） Analog aerial triangulation of entire area

Analogue aerial triangulation of the entire area was implemented in order to enable the counterparts to perform plotting of the entire Northern Region also with an analogue plotter equipped with encoder. The results of independent calculation of orientation elements required for plotting were used for the plotting of the part of the island area.

a. Quantity of Work

The quantity of work implemented in the analogue aerial triangulation was as follows:

Number of flight courses: 61 strips

Number of photographs: 2031 sheets

The difference in the quantities of works between the digital and analogue aerial triangulation derives from the fact that duplicate photographs taken in the same flight course were used in the aerial triangulation.

b. Preparation

Diapositive films etc. of aerial photographs required for analogue aerial triangulation were collected. The collected data were used for creation of aerial triangulation work plan maps, on which the area of the aerial triangulation was established.

In accordance with the work plan maps, photo control points were confirmed and tie points were selected on aerial photographs, and these points were pricked on diapositive films. The locations of the pricked tie points and photo control points were measured and their machine coordinates were obtained.

Relative orientation was performed to create models, after inner orientation, which is a coordinate transformation from machine coordinates to photographic coordinates, had been performed.

c. Adjustment Calculation with Bundle Method and the Results of the Calculation

Adjustment calculation with bundle method was performed using the photographic coordinates of tie points and the results of the photo control point survey.

As a result of the calculation, the standard deviation and maximum of the photo control point residuals were below the tolerance limits and the results of the analouge aerial triangulation of the entire area were accurate.

The results of the adjustment calculation were used for the calculation of orientation elements of each model.

（8） Digital plotting

1） Specifications

Plotting scale	1/10,000
Plotting area	2,008.2 km^2
Plotted map sheets	100 sheets
Contour	Intermediate contour 5m Index contour 25m Auxiliary contour 2.5m

2） Equipment used

Digital stereo plotter	SoftPlotter (BOEING); Summit (DAT/EM); LPS (Leica); ImageStation (INTERGRAPH) etc.

3） Digital plotting implementation

Using stereo models created from the photography image data and the aerial triangulation outputs, the digital plotting work was implemented with reference to the field identification photos. The stereo images that could not be plotted from only the field identification photos were interpreted with reference to the photo interpretation keys to implement the digital plotting.

4） Results of digital plotting

The data for digital plotting was created in Bentley MicroStation V8DGN format

（９） Digital compilation

１） Specifications

Compilation scale	1/10,000
Compilation area	2,008.2k ㎡
Compiled map sheets	100 sheets

２） Equipment used

Compilation CAD	MicroStationV8（Bentley）

３） Digital compilation

Based on the results of the digital plotting, annotations and administrative boundaries were input with reference to the field identification photos, existing maps (1/50,000) and existing data (Shape file) in order to carry out the digital compilation work.

４） Results of digital compilation

The data for digital compilation was created in Bentley MicroStation V8DGN format.

（１０） Supplementary field verification

１） Implementation Periods

The supplementary field verification consisting of data collection in Colombo and field works in Jaffna and Mannar Areas was implemented in two periods.

[First period]

October 15th – November 13th 2010

[Second period]

August 28th – October 11th 2011

２） Inputs

The numbers of people engaged in the supplementary field verification were as follows:

[First period]: 28 people in 11 Teams (the Sri Lankan side) and two people (the Study Team)

[Second period]: 31 people in 12 Teams (the Sri Lankan side) and two people (the Study Team)

３） Description of the Work

The following works were implemented in the supplementary field verification:

a. Data collection in Colombo

   The Study Team collected data on administrative boundaries and names, road classification, control points and magnetic declination from SDSL and other sources.

b. Field works implemented in Jaffna and Mannar Areas

   In the field works, the following activities were carried out: elimination of the uncertainties identified in the digital plotting/compilation; survey of additional topographic features required to be represented on topographic maps; survey of kilometer posts along certain roads, high-voltage power transmission lines, the abandoned railway and the abandoned station; and identification of annotations (names of major road intersections and major facilities).

（１１） Supplementary digital compilation

１） Specifications

Compilation scale	1/10,000
Compilation area	2,008.2k ㎡
Compiled map sheets	100 sheets

２） Equipment used

Compilation CAD	MicroStationV8（Bentley）

３） Supplementary digital compilation

Supplementary digital compilation based on supplementary field verification was carried out.

４） Details

In the supplementary digital compilation, input and compilation of kilometer posts, power transmission lines and other contents concerning the supplementary field verification were carried out.

（１２） Digital data structuarization

Digital data files with data that had been compiled digitally after supplementary completion were structured.

１） Structural compilation

In the structural compilation, data was inspected and corrected for logical errors (edge mismatching, undershoot, overshoot, areal overlap and inconsistency of area classification) and topologically structured (*i.e.* all topographic features were classified into line, polygon or point data) in accordance with the map symbol specifications.　MicroStationV8 was used for the structural compilation.

２） Conversion of data format

Structurally compiled data was converted into DXF format and SHAPE format by sheet.

（１３） Map symbolization

Structured digital topographic map data was used for production of 1:10,000-scale AI data.

１） Details of the symbolization work

The structured digital topographic map data was processed for map symbolization in which line types, colors, symbols, etc. were produced and processed for the data in accordance with the map symbol specifications and the order of the layers were rearranged. In addition, marginal information of topographic map was symbolized.

Printout data for each map sheet was completed by integrating symbolized digital topographic map data and symbolized marginal information data, and entering information such as map sheet number and title.

２） Quantity and outputs of the work

a. Quantity the work

* AI data (topographic map + marginal information): 100 sheets

b. Detalis of the output data

* File format: PostScript file (Adobe Illustrator CS5 format)
* Finished map size (including marginal information):
  657 mm (north-south) x 883 mm (east-west)

（１４） Production of digital data files

１） Production of Vector Data Files

A vector data file in the Shape format and a vector data file in the DXF format were produced for each sheet of maps using the vector data in the respective formats generated by structuralizing digital data. The produced data files were stored on such media as DVDs.

２） Production of Raster Data Files

Marginal information data of a map sheet was integrated with the topographic data processed in the map symbolization of the same sheet. This data was converted into the PDF format and a raster data file was produced for each sheet of the maps using the converted data. The produced raster data files were stored on such media as DVDs.

3.2 Technology Transfer

（１） Photo control point survey

１） SDSL's capacity for implementing photo control point (GPS) surveys

The SDSL already has much experience of GPS survey using GPS receivers and they have sufficient capacity in the various techniques required to establish plans for various types of work such as observation planning, GPS surveying, and analysis of observation data.

２） Implementation of technology transfer on photo control point survey

As mentioned above, because of SDSL's technical capacity in photo control point survey (GPS survey), the technology transfer was implemented focusing on how to calculate the necessary number of photo control points and method of photo control point distribution required for aerial triangulation. Also, techniques were transferred on how to install air-photo signals and on making a description of these.

３） Results of technology transfer of photo control point survey

The following are the results of the transfer of the various techniques that the technology transfer of photo control point survey focused on:

* SDSL sufficiently understood how to calculate the number of photo control points. However, further training and experience on how to distribute the photo control points is necessary.
* For installation of air-photo signals and making a description, they gained a sufficient understanding as a result of repetitious studies.

（２） Levelling

１） SDSL's capacity for implementing levelling

SDSL had a great deal of practical experience implementing, and had sufficient understanding of general theory of levelling, observation, calculation, and output evaluation.

２） Implementation of technology transfer on levelling

From the aforementioned situation on SDSL's capacity for implementing levelling, the technology transfer was implemented with emphasis on planning levelling (a selection of leveling routes and a method of rational observations) for aerial triangulation.

３） Results of technology transfer on levelling

The outputs of technology transfer in this field were as follows:

* Technique for the selection of levelling routes was obtained sufficiently.
* Method of rational observation was also fully understood.

（３） Pricking

１） SDSL's capacity for implementing pricking

SDSL was comparatively inexperienced in this technical field.

２） Implementation of technical transfer on pricking

Techniques were transferred for making descriptions of pricking points (obtaining approximate coordinates of pricking points and sketches of pricking point surrounds) to be ready for when the aerial photographs prepared.

３） **Results of technology transfer on pricking**

Through numbers of practices, techniques of making description gained a footing in SDSL.

（４） **Field identification**

１） **SDSL's capacity for implementation of field identification using aerial photographs**

Employees at SDSL have sufficient technologies for (preliminary) photo interpretation by stereo images. On the other hand, employees at SDSL regional offices had almost no track record in using aerial photographs for field identification.

２） **Implementation of technology transfer for field identification using aerial photographs**

They were taught, based on the map symbol specifications, how to identify the reason for queries and uncertainties that turned up in photo interpretation through characteristics of the photographic images and definitions of topographic features on map symbol specifications. In this way, the transfer of techniques for preliminary photo interpretation of field identification using photo interpretation was implemented.

Picture 3-5　Preparation of field identification

Picture 3-6　Field identification in the field

The technology transfer outdoors using aerial photographs allowed the trainees to acquire the ability to compare the features on the photographs and real objects according to the map symbol specifications and the technology for checking them as well as the technology for solving problems and unknown parts in the field. Furthermore, the technology for recording survey results on photographs was also transferred.

３） **Results of technology transfer for field identification using aerial photos**

As a result of the technology transfer, the trainees:

a. Can undertake (preliminary) photo interpretation of vegetation, land classification, hydrology and so on using a photo interpretation key,

b. Can understand how to compare a feature on aerial photos with a real feature in the field, features in a map symbol specification to pay special attention to, and how difficult each feature in the specifications is to survey.

c. Can succinctly represent the survey results confirmed in the field on aerial photos.

（５） Aerial triangulation

Technology was implemented with an emphasis on the transfer of practical aerial triangulation methods that can obtain usable results with the provided software.

１） Software used for technology transfer

The technology transfer was carried out using digital aerial triangulation modules in the software—LPS and ORIMA—introduced in this Project.

２） Flowchart of technical transfer

The technical transfer was implemented according to the following flowchart:

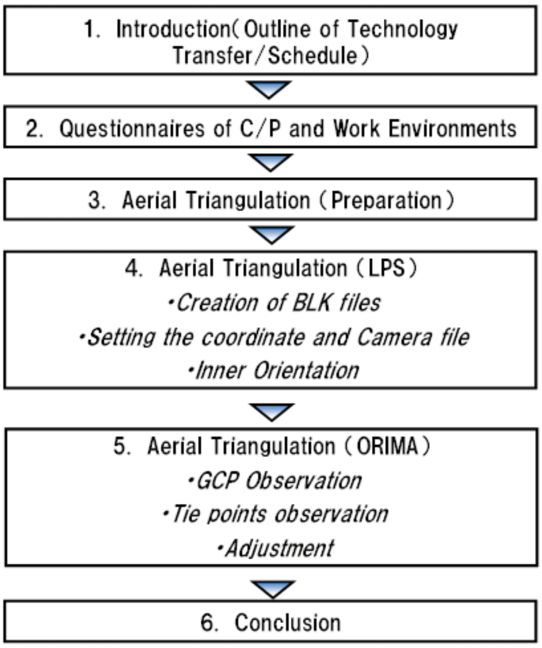


Fig 3-3 Flowchart of the aerial triangulation technology transfer

３） Implementation of technology transfer

The technology transfer was implemented for 3 trainees and 4 observers. Each task was first carried out by the Study Team based on the manual, and were then undertaken by the trainees in a similar manner. Further, a review was held to confirm the transfer items and content at the midway stage by the trainees and Study Team.

４） Results of technology transfer

a. Tasks using LPS

The preparatory operation for creating working files and the inner orientation operation were transferred. The technology transfer of part of the operation using LPS in the aerial triangulation was completed.

b. Tasks using ORIMA

The technology for presetting by ORIMA including reading of working files and photo control point (GCP) data was transferred. Furthermore, the technologies for implementing relative orientation, successive orientation, and adjustment calculation using the bundle method, evaluating the calculation results, and establishing the final calculation results were also transferred.

（６） Digital plotting

It was clear that SDSL had sufficient experience and the capacity of digital plotting in the preliminary survey. Therefore, the technology transfer was carried out with an emphasis on adaptation to the newly introduced hardware and software, keeping in mind the need to provide efficient work schemes. The technology transfer was implemented for 11 trainees in 2 periods.

１） Equipment used

The technology transfer was carried out using the digital plotting system “LPS” and the digital plotting module “PRO600” for LPS introduced to SDSL in this Project.

２） Contents of technology transfer

The technology transfer was carried out with emphasis on operation by repeating the explanations and exercises for the following items in order to ensure the trainees gained a good familiarity with the technology:

a. Preparation before start of digital plotting

b. Digital plotting work

c. Data check

d. Automatic contour production using DEM

Picture 3-7 Training of trainees in technology transfer

３） Results of technology transfer

The results of the technology transfer were as follows:

a. Preparation before start of digital plotting

A series of technologies, covering everything from creation of the project file to creation of stereo models using the LPS, were transferred. The technologies covering the start of the plotting module PRO600 to digital plotting were transferred, including the technologies for setting various parameters and operating methods.

b. Digital plotting work

The various technologies for the digital plotting work were transferred using the stereo models of the targeted areas.

c. Data check

Preset values for data check using the functions of PRO600 and implementation of the checking, and method of correction was transferred.

d. Automatic contour production using DEM

The technology for the automatic production of contours as break lines from the plotted data was transferred.

４） Evaluation of technology transfer

The trainees were at the level at which they were capable of carrying out the photo interpretation and drawing on stereo models with no problem. In addition, through repeated exercises they became familiar with the operation for making stereo models. As a result, it can be evaluated that they will be capable of digital plotting on its own at the scale of 1/10,000.

（７） Digital compilation (including supplementary digital compilation)

The technology transfer of digital compilation was performed for 12 trainees in two periods.

１） Equipment used (software)

Technology transfer was implemented using CAD software "Microstation V8 XM Edition" and "Bentley MAP" introduced in this project.

２） Description of technology transfer

Operation-based technology transfer was implemented by repetitiously providing explanation and practice on the five items shown below in order to ensure that the trainees acquire the relevant technology:

a. Understanding of 1/10,000 map symbol specifications

b. Basic technology for operating software of an introduced digital compilation system

c. Technology for setting a digital compilation environment according to the map symbol specifications

d. Basic operations required for digital compilation

e. Quality control and data management

３） Results of technology transfer

The results of the implemented technology transfer were as follows:

a. Understanding of 1/10,000 map symbol specifications

The trainees have acquired a habit of checking the map symbol specifications as required in case they find any unknown features while proceeding with the work and have understood the importance of the map symbol specifications.

b. Basic technology for operating software of an introduced digital compilation system

All of the trainees learned the basic technologies for operating v8 without any particular problem. The new functions added in v8 (such as zooming in/out and move of the screen) were acquired as well.

c. Technology for setting a digital compilation environment according to the map symbol specifications

The technology of making symbols was acquired without any problems. The technology of making lines, which progresses from making of simple line types to making of gradually more complex line types was adopted, was acquired. Additionally, the trainees also acquired the v8 environment setup technology

d. Basic operations required for digital compilation

The tools added or upgraded in v8 required to make 1/10,000 digital topographic map were explained and demonstrated one by one. The trainees learned to use the tools through hands-on practice.

e. Quality control and data management

* Data check

Microstation v8 has a function of performing logical check of data in automatic processing. The trainees acquired the technologies of checking and correcting data using this function.

* Output and visual check

The compiled topographic data was outputted, and the visual check technique that compares the out putting topographic map data with a photograph of the field identification was acquired.

* Optimization of data files management

Concerning the necessity of unified management of original data and risk of data deletion, advice on making a holder per technical process, unifying the management of the data, taking a backup of holder was given and understood.

Picture 3-8 Scene practice

Picture 3-9 Scene of practice done by trainees

４） Evaluation of technology transfer

The trainees understood the importance of the map symbol specifications in producing 1/10,000 digital topographic maps and learned to perform technical operation of digital compilation according to them without problems. Additionally, they even became capable of performing limited quality control using the function of logical check of data included in the latest software package introduced in this Project.

（８） Supplementary field verification

１） Contents and Implementation of the Technology Transfer

As it is known that SDSL had knowledge and experience in field surveys before the implementation of the technology transfer, the Study Team decided to use OJT for the transfer of the following technologies to SDSL:

* How to eliminate the uncertainties identified in the digital plotting/compilation

* How to make final confirmation of administrative boundaries, road classification and annotations
* How to produce and use annotation data files
* Schedule management and accuracy control technologies
* How to prepare Supplementary Field Verification Manual

The OJT included explanation of the Work Manual and implementation of supplementary field verification work by all the trainees at a single location.

２） Evaluation of the Outcome of the Technology Transfer

The following constitute the evaluation of the outcome of the transfer of each technology.

a. How to eliminate the uncertainties identified in the digital plotting/compilation

Since the counterparts eliminated the uncertainties in accordance with the (draft) Work Manual and made few mistakes and omissions in representing the results of the elimination, the Study Team considers that they have mastered the transferred technology sufficiently.

b. How to make final confirmation on administrative boundaries, road classification and annotation

Since the counterparts made the final confirmation of each item in accordance with the (draft) Work Manual, the Study Team considers that they have mastered the transferred technology sufficiently.

c. How to produce and use annotation data files

Since the counterparts produced the annotation data files, the Study Team considers that they have mastered the technology to produce the files sufficiently. Meanwhile, it has been revealed to the Study Team that SDSL does not own sufficient number of equipment including PCs and that the number of people who can use them is thus limited.

d. Schedule management and accuracy control technologies

Since the counterparts completed the predetermined amount of works in the predetermined period, the Study Team considers that the counterparts have mastered the schedule management technology. Since the counterparts also completed the Accuracy Control Chart for each map sheet, the Study Team considers that they have mastered the accuracy control technology as well.

e. How to prepare Supplementary Field Verification Manual

Although the Study Team had taught the counterparts the method used for the preparation of the (draft) Work Manual, which was equivalent to the Supplementary Field Verification Manual, the counterparts failed to revise it by the end of the technology transfer. Therefore, it is difficult to conclude whether they have mastered the method or not.

Picture 3-10 Supplementary field verification

（９） Digital data structualization

The six SDSL trainees in the technology transfer for digital data structualization already had three to five years' work experience. Therefore, the technology transfer was carried out by focusing on the latest tools, latest technologies, and applied use of introduced software related to the digital data structualization in everyday work of the trainees.

１） Equipment used (software)

The software used in the technology transfer was ArcGIS 10.0 by ESRI of the U.S.A.

２） Details of technology transfer

The technology transfer was implemented on the following items:

a. Transformation of dgn files of Microstation to File Geodatabase of ArcGIS

b. Data structualization

c. Data compilation

d. Data projective transformation

e. Attribute search and spatial search

f. Export of a large number of maps to PDF files using Data Driven Pages

g. Production of 3D data using TIN and Terrain

h. Mutual transformation between KML files and ArcGIS data

i. Building of a road network

j. Update of Personal Geodatabase

k. Use of Bing Map data as background data

l. Utilization of mosaic datasets

m. Use of attribute domains

n. Use of the batch processing mode of ArcToolbox


Picture 3-11 Data structualization of digital data

3) Results of technology transfer

The following results were acquired by the technology transfer.

* Acquired the technology of manual and automatic transformation of topographic map dgn data to ArcGIS data.
* Acquired the technology of putting together topographic map data transformed to file geodatabases into feature classes to build a topology and searching for and correcting errors.
* Can detect attribute and spatial arrangement errors using the attribute search and spatial search functions of necessary features during the compilation.
* Can use the latest background data with importing ArcGIS Online data such as Bing Maps Aerial and Bing Maps Road.
* Acquired the technology of mutual transformation between KML files of Google Earth and ArcGIS data.
* Learned how to export a large number of maps based on Data Driven Pages to PDF files with ease. It is improved the efficiency to produce the output of the topographic map data.
* Acquired the technology of processing a large volume of data using the batch processing mode of ArcToolbox.
* Can perform high-speed display and search of a large volume of raster and ortho data by using the mosaic data set. It is easy to use the ortho data as a background data.
* Successfully performed automatic update of ArcGIS data already managed in Personal Geodatabase to the latest format, File Geodatabase.
* Learned how to produce 3D Surface data as well as contour lines, DEMs, and shaded relief maps based on the establishment of TIN and Terrain.
* Improved the efficiency of input for the attributes using the domain of attribute.

4) Evaluation of technology transfer

From the above technology transfer results and the results of the pilot operation involving making of dgn files of topographic maps to making of GIS data implemented by the trainees, it can be evaluated that SDSL is capable of producing structurized GIS data using ArcGIS on its own.

（１０） Map symbolization

The technology transfer on map symbolization was performed for 12 trainees divided into 4 groups, in order to allow SDSL to produce data for printed topographic maps on its own.

１） Equipment used (software)

The technology transfer on map symbolization was performed using Adobe Illustrator, a graphic software introduced in this Project.

２） Contents of technology transfer

The following technologies of map symbolization using actual data acquired in supplementary digital compilation were transfered.

a. Setup of print environment

b. Basic operations of Adobe Illustrator CS5

c. Preparation for map symbolization operations

d. Map symbolization operations

e. Production of topographic map data files for printed maps through composition of topographic map data and marginal data

f. Data correction (including correction of secular changes)

Picture 3-12 Map symbolization

３） Results of technology transfer

a. Setup of print environment

After we explained the fact that the print film output was different from the conventional plotter output (RGB), the counterpart understood the overall concept of printing digital data.

b. Basic operations of Adobe Illustrator CS5a.

As a result of explanation using an original basic operation manual and technology transfer through training using assignments, the counterpart mostly learned the operations of Adobe Illustrator required for map symbolization.

c. Preparation for map symbolization operation

The trainees learned to create the registered colors (Swatch Colors) to be used in map symbolization, palette files, vegetation patterns, symbol brushes, and line brushes (such as depressions, artificial slops and etc.) required for symbolization according to the map symbol specifications.

d. Map symbolization operation

The following technologies were acquired

＊Scale-down transformation of DXF data to 1/10,000 scale

＊Management of hierarchical relationships of layers

＊Transformation of objects according to the map symbol specifications (transformation of polygon colors, embedding of patterns, transformation of line types, line colors, and line gauges, and transformation of fonts, sizes, and colors of annotations)

＊Correction of inconsistencies

When the attributes of features are transformed in batch processing, inconsistencies occur in some of the parts. The counterpart learned to use commands to fix them.

＊Trimming of maps

Objects close to the neat lines in a topographic map may encounter loss or excess of data. The counterpart acquired the technology for fixing the loss or excess of data

e. Production of topographic map data files for printed maps through composition of topographic map data and marginal data

The counterpart also learned how to compose the basic marginal files and the produced topographic map data and add information such as a drawing number, attainment, and title to the resultant data to produce topographic map files for printed maps.

f. Data correction (including correction of secular changes)

The counterpart also learned the procedure for correcting the map symbolization data if the data acquired in supplementary digital compilation needs to be corrected

４） Evaluation of technology transfer

The counterpart of SDSL learned fairly well the production of objects to be used in topographic maps and the processes from input of data acquired in supplementary digital compilation to map symbolization. From this fact, we can evaluate that the trainees' understanding and acquisition has reached a level at which they can produce map data for printing.

3.3 Other Works

3.3.1 Seminar/Workshop

（1） Holding Seminar/Workshop

The Seminar/Workshop was held on November 4th 2011 at Water Edge with approximately 150 participants, including the Deputy Minister and the Secretary of the competent ministry of SDSL.

The addresses of the guests of honour were followed by presentations on the outline of the Project and public dissemination of the project outputs and a presentation on its future activity plan formulated by SDSL on the basis of the outcome of this Project. There was also a presentation on the specifications of the project outputs and some presentations by the Study Team and SDSL on the outcome of the technology transfer.

Digital plotting, one of the outputs of the technology transfer was demonstrated and some of the participants practiced digital plotting.

In the closing stage of the Seminar/Workshop, guidelines for construction of GIS database and construction of various geospatial data sets expected to be implemented by SDSL were presented as a recommendation. At the closing, a question-and-answer session for the entire Seminar/Workshop was held. Then the participants were asked to fill in a questionnaire asking their requests to SDSL on use and dissemination of the digital topographic maps produced in this Project and production of digital topographic maps of the Northern Region.

3.3.2 Reports

（1） Production of Inception report (IC/R)

The Inception Report was produced by compiling the basic policies, procedures, implementation system, schedule and so on.

（2） Explanation of and Discussion on Inception report

The explanation and discussion of the IC/R was held on 4th March 2010. Present on the Sri Lankan side were nine members of SDSL management, and four members of the study team and one person from the JICA Sri Lanka Office.

The content of the project including its purpose, target, basic policy, procedures, schedule, and outputs, were explained based on the report. During the discussion after the explanation, there were some questions and answers.

With those questions and answers, the Inception Report was approved. The above details were compiled in the Minutes of Meeting and both parties signed it.

（3） Production of Interim report (IT/R)

The Interim Report was produced detailing the progress of the project and evaluation of its implementation as of the end of September 2010, and how and when the rest of the project will proceed.

（4） Explanation of and Discussion on Interim report

Explanation of and discussion on Interim Report was held at the SDSL office on September 28th, 2010. Participating were six staff of SDSL, four members of the Study Team, and one from the JICA Sri Lanka office.

In the explanation the implementation status of each component of the project up to the end of September 2010 was explained according to the Interim Report. The mid-term results of the project and their evaluation were also explained. Furthermore, the policies and plans for the remaining operations were explained. The discussion after the explanation involved some questions and answers.

With the discussion results, the questions and answers, the Interim Report was approved.

The above content was compiled in the minutes of meeting and signed by both parties.

（5） Production of Draft final report (DF/R)

The Draft Final Report covering the results and implementation status of the whole project has been made. In addition, two guidelines (work manuals) were made, one so that SDSL can independently produce, update and manage various data (geographic spatial data) in future, and another for establishing the database and designing the system for a GIS.

（6） Explanation of and Discussion on Draft final report

Explanation of and Discussion on the Draft Final Report was held on November 1st 2011 at the SDSL Office. Nine SDSL staff members, including the Surveyor General, five Study Team members and one staff member of JICA Sri Lanka Office attended the Explanation/Discussion.

In the Explanation/Discussion, the Study Team explained the outline of the Project, implementation of the Project, the outcome of the project implementation and production of digital topographic maps in future in accordance with the Draft Final Report. After the explanation, discussion was held on the addition of the description of the changes made in the original plan to the Report, attachment of reference data required for future activities to the Report, a future plan to produce digital topographic maps of the Northern Region and problems expected in the implementation of the plan. Discussion was also held on lessons learned by the Study Team and SDSL from the project implementation.

After the question-and-answer session and discussion, the Draft Final Report was approved.

The minutes of the meeting describing the explanation and discussion mentioned above were prepared and approved by the parties involved with the signatures of the authorized personnel of the respective parties.

（7） Production of Final report (F/R)

The Study Team produced the Final Report by making revisions and additions to the Draft Final Report as required by the outcome of the Explanation of and Discussion on the Draft Final Report and the progress and outcome of the works implemented after the completion of the Draft Final Report.

3.4 Lessons Learned During the Implementation of This Project and from the Results of the Implementation

3.4.1 Lessons Learned During the Implementation of This Project

（1） Aerial Photography

a. We became keenly aware of the importance of not only organizational relationships but also personal relationships with the relevant personnel in facilitating the acquisition of permits during the process of obtaining the various permits for the implementation of aerial photography.

b. From the experience of the engine trouble of the aircraft to be used for the aerial photography, we recommend that the contractor for aerial photography should at least have the capacity to make arrangements for a replacement aircraft and that arrangements for a replacement aircraft should be confirmed or specified in the contract concluded with the contractor.

（2） Procurement of Equipment to be Used in the Project

a. With regard to the procurement of equipment for the project (including that for the technology transfer), the required equipment (with specifications, brand names, quantities, etc.) and the locations at which such equipment can be procured need to be clarified at the start of the project. The equipment (specifications, brand nemes, quantities and composition), especially equipment that the operability and sustainability of techniques are different based on the past experience, must be discussed and decided upon with the C/P institution.

3.4.2 Lessons Learned from the Results of the Implementation of This Project

（1） Specifications for the Digital Topographic Maps to be Produced

Since a digital topographic map is viewed as a form of geospatial data, the map symbol specifications will have to be converted to specifications for topographic maps which incorporate the concept of a topographic map database in the GIS. Needless to say, the above-mentioned argument is based on the assumption that the purposes of use of the GIS have been clearly established.

（2） Aerial Photography

Taking into account increasingly abnormal weather conditions these days, this type of project must be start before the dry season, which is the best time for aerial photography and the appropriate resposes must be taken for the wether condition.

（3） Procurement of Equipment for the Project

Project components in which procured equipment is to be used should be highly independent of other components and involve project team members and C/Ps who are not involved in any other project component. Even within a limited project implementation period, the project implementation schedule should allow some extra time.

（4） Technology Transfer

The fruits of the technology transfer are intangible. However, the output maps of the digital plotting, the digital compilation and the map symbolization produced by the C/Ps using the transferred technologies in the parts of the technology transfer are represented, albeit indirectly, the outputs of the technology transfer.

Chapter 4 Efforts toward the Development of Digital Topographic Map

4.1 Effective Use of the Project Outputs

4.1.1 Effective Use of the Digital Topographic Maps

（1） Publication of Digital Topographic Maps and Their Specifications

The digital topographic maps and their specifications shall be made public. At the same time, measures will be taken to make the relevant government offices and the general public widely aware of the publication of the topographic maps and their specifications, including the conditions for their use.

（2） Awareness Creation Activities to Promote Use of the Digital Topographic Maps

Awareness creation activities customized mainly for relevant government offices, local authorities and donor organizations shall be conducted

（3） Supply System of the Digital Topographic Maps

A decision shall be made on copyrights, supply methods (supply points, supply media, etc.), prices and etc. which are to be established.

4.1.2 Effective Use of the Outputs of the Technology Transfer

The Study Team is evaluating the output of the implemented technology transfer. SDSL is required to evaluate the technology transfer themselves as a recipient organization of the implemented technology transfer and to propose actions to be taken on the basis of the evaluation results. Such evaluation shall be the first step for SDSL toward effective use of the output of the technology transfer.

4.2 Tasks Based on the Results of Technology Transfer

4.2.1 Summary of the Technology Transfer

In the project, the following technologies to be applied to making of 1:10,000 scale digital topographic maps were transferred:

Photo Control point survey: Installation of air-photo signals, GPS survey, leveling, and pricking

Field identification: Field identification (using aerial photos) and supplementary field verification.

Digital photogrammetry: Digital aerial triangulation, digital plotting and compilation, digital data structurization, map symbolization

As a result, the proficiency levels and remaining tasks for various transferred technologies have been discovered through the evaluation of technology transfer. The following table shows the evaluation results:

Transferred Technology	Proficiency Level	Remaining Task
Control point survey	Trainees became sufficiently proficient in the technologies practiced repetitiously in the technology transfer (installation of air-photo signals and making of description of photo control points). They did not acquire sufficient experience in some of the technologies required from the viewpoint of implementing aerial triangulation.	Improvement of skills for applying the acquired technologies under changed conditions, increase of experience, and improvement of productivity of each technology shall be the tasks to be carried out.
Field identification(Including the supplementary field verification)	Trainees acquired high proficiency in technologies for implementing the indoor operation. However, they did not acquire sufficient proficiency in technologies for implementing the outdoor operation, especially using the aerial photography.	Reconsideration and improvement of the field identification method to be adopted by SDSL shall be the task to be carried out.
Digital photogrammetry	Trainees acquired all the technologies for using new functions of the latest introduced equipment (hardware and software). However, they did not have sufficient repetitive learning and therefore did not acquire sufficient proficiency. On the other hand, they have high proficiency of a basic digital photogrammetry technologies.	Increase of repetitive learning and acquisition of more experience are the tasks to be carried out. At the same time, improvement of productivity in various technical fields is also a necessary task.

4.3 Production of Digital Topographic Maps for the Remaining Unmapped Areas in the Northern Province

4.3.1 Improvement of Technical Abilities for Making Digital Topographic Maps

The core technologies for making digital topographic maps are digital photogrammetry and field identification that have been covered in the technology transfer.

From this viewpoint, it is necessary to conquest the aforementioned tasks for complete development of digital topographic maps of the Northern Region and to improve the comprehensive technical abilities for making digital topographic maps in consideration of the following points:

* Promotion and ensuring of understanding of the digital map specifications of the parties concerned

* Effective utilization of the project outputs
* Propagation of technologies acquired in the project

4.3.2 Formulation of a Project to Produce Digital Topographic Maps of the Remaining Unmapped Areas in the Northern Region

A project for production of digital topographic maps for the remaining unmapped areas in the Northern Region shall be formulated taking into consideration the available technical capacities and the issues mentioned below:

* To establish the priority order for digital map production within the unmapped areas
* Human and material resources of SDSL which can be mobilized for mapping
* Per-unit production at each technical stage

4.3.3 Project to Produce Digital Topographic Maps of the Remaining Unmapped Areas in the Northern Region

（1） Gathering of Information Required for the Map Production Project

Regarding the formulation of a project to produce digital topographic maps of the remaining areas, Information needs to be gathered on priority areas, human and material resources available for map mapping and per-unit production.

（2） Formulation of the Map Production Project

On the basis of the information gathered as mentioned above, a map production project shall be formulated taking into consideration the needed periods and the degree of overlap with each process involved in the project.

（3） The Map Production Project for the unmapping areas in the Northern Region by SDSL

SDSL has formulated plans to produce digital topographic maps with a priority order for the areas to be mapped based on the requests of relevant government offices.

In these plans, SDSL has formulated two options: an ordinary plan aiming at completion of map production by June 2014 and a fast track plan aiming at completion of map production by March 2013. In the formulation of the plans, SDSL used design figures of production per unit period in the major processes for the formulation of map production schedules.

Regardless of whichever plan is adopted, securing necessary budget and human resources, in addition to mapping productivity improvement will be vital to achieving the plan.

4.3.4 Project to Produce Digital Topographic Maps of the Remaining Unmapped Areas in the Northern Province

Once the implementation of the digital topographic map production project in accordance with the formulated map production project has begun, accuracy control measures will have to be carried out at each process to maintain the product quality. At the same time, project implementation will need to be constantly monitored in order to prevent any delays.