Democratic Socialist Republic of Sri Lanka
Ministry of Lands
Survey Department, Ministry of Lands

CAPACITY DEVELOPMENT PROJECT FOR CREATING DIGITAL ELEVATION MODEL ENABLING DISASTER RESILIENCE

IN

THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

FINAL REPORT

December 2016

Japan International Cooperation Agency (JICA)

Pacific Consultants Co., Ltd.

Oriental Consultants Global Co., Ltd.

Nakanihon Air Service Co., Ltd.

DMS Co., Ltd.

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Acronyms

AASL	Air and Aviation Service in Sri Lanka
C/P	Counterpart
CAD	Computer Aided Design
CRIP	Climate Resilience Improvement Project
DEM	Digital Elevation Model
DMC	Disaster Management Centre
GCP	Ground Checkpoint
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GOSL	Government of Sri Lanka
GPS	Global Positioning System
GSD	Ground Sampling Distance
IGI	Integrated Geospatial Innovations
IMU	Internal Measurement Unit
IWMI	International Water Management Institute
JCC	Joint Coordination Committee
JICA	Japan International Cooperation Agency
JPEG	Joint Photographic Experts Group
JPT	JICA Project Team
LiDAR	Light Detection and Ranging
MC	Municipal Council
NBRO	National Building Research Organization
OJT	On the Job Training
PC	Personal Computer
PDF	Portable Document Format
PS	Pradeshiya Sabha
RMS	Root Mean Square
SD	Survey Department
SLD	Sri Lanka Datum
SLRC	Sri Lanka Rupavahini Corporation
TIN	Triangulated Irregular Network
TRCSL	Telecommunication Regulation Commission of Sri Lanka
UC	Urban Council
UN	United Nations
UNDP	United Nations Development Programme
UPS	Uninterruptible Power Supply
UTM	Universal Transverse Mercator Coordinate System
WGS	World Geodetic System

1 Outline of the Project

(1) Background

The Democratic Socialist Republic of Sri Lanka (hereinafter referred to as "Sri Lanka") was affected by the climate changes, and many natural disasters such as flood and landslides have affected lives and infrastructure. Floods are the major natural disasters that have caused tens of thousands of victims each year according to the records of the Disaster Management Center. In the central and southwestern areas of Sri Lanka are prone to landslides due to: topographic and geological characteristics; and development and cultivation activities in the mountainous areas. These disasters have affected human lives, destroyed houses and damaged arterial roads; they thus negatively impacted economic activities.

Under these circumstances, the Government of Sri Lanka (hereinafter referred to as "GOSL") announced a policy on disaster management triggered by the earthquake of Sumatra and tsunami in 2004 to minimize damages proactively rather than reactively. GOSL has enacted "Sri Lanka Disaster Management Act" which became a fundamental framework for activities of mitigation, preparedness, response and recovery in May 2005. The Act created Ministry of Disaster Management and Disaster Management Center to strengthen organizational structure on disaster prevention and countermeasures against calamities.

GOSL has a plan to consolidate early warning arrangements by preparing hazard maps of floods and landslides. In the process of these hazard map preparation, accurate elevation data will be required. The Laser Detection and Ranging (hereinafter referred to as "LiDAR") technology is the technology to acquire the data efficiently, but such technology is not available in Sri Lanka; therefore, conventional technologies are used.

The stated situation has led for the Ministry of Lands (former Ministry of Lands and Land Development) to make an official request to the Government of Japan to transfer the LiDAR survey technology to create Digital Elevation Model (hereinafter referred to as "DEM") that will be used for disaster prevention and related activities. Receiving the request, Japan International Cooperation Agency (hereinafter referred to as "JICA") dispatched a study team for detailed plan preparation from July 2014 to August 2014. The Survey Department of the Ministry of Lands (hereinafter referred to as "SDSL") and JICA came to agree on the contents of the Project.

(2) Objectives and Scope

(2)-1 Objectives

The objectives of the project are: 1) Preparation of DEM Data; and 2) Technical Transfer on DEM preparation and thematic map preparation.

(2)-2 Project Areas

1) Original DEM Data Production Areas

The major areas of the districts of Colombo and Gampaha, Nuwara Eliya, Kegalle, parts of Kandy, Badulla and the surrounding areas are covered as the project areas. The original project area map is shown below with classifications of DEM processing and accuracy.

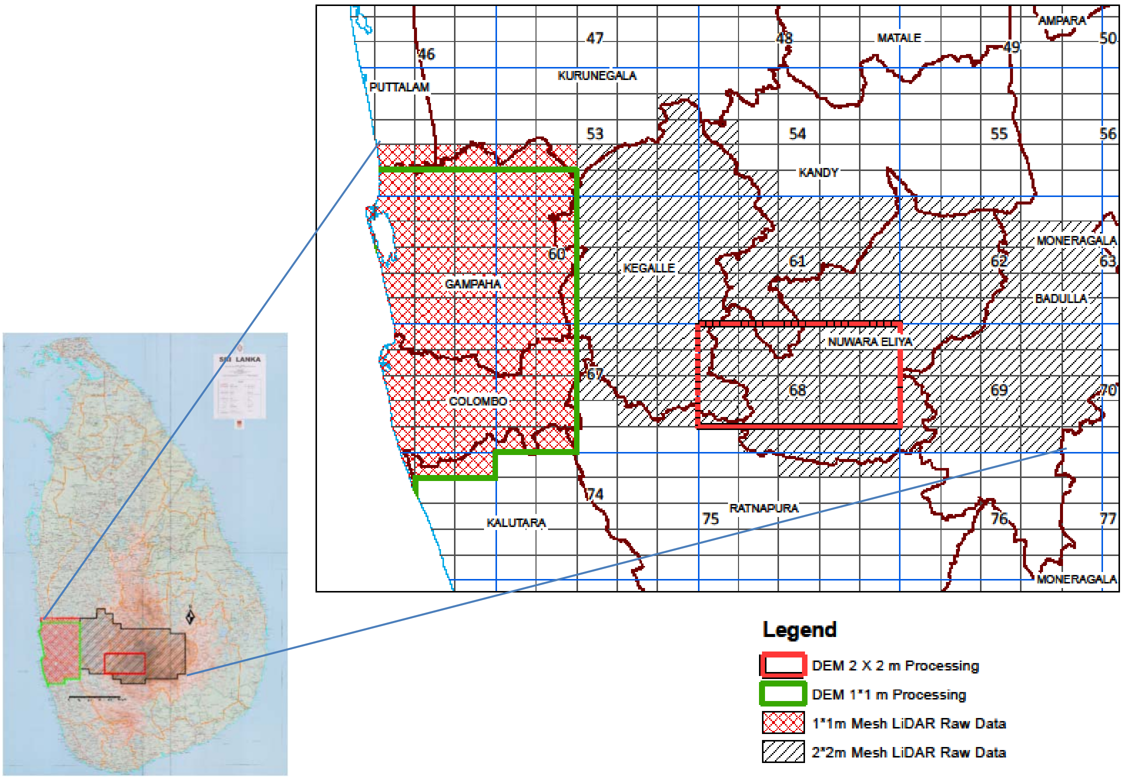

Figure 1-1 The Original Project Areas

2) Amendment to the Project Area

SDSL requested to change a part of the survey area to the Project Team on the 24th and 25th of February 2016, since any solution has not been reached over the problem of GNSS signal reception[1]. The request was reported to JICA, and JICA and SDSL has discussed over the matter, and they came to agreements as follows:

1) 2 m x 2 m mesh area

The 900 km^2 area where the LiDAR measurement could not be conducted because of the jammed GNSS signals would be shifted to the Gin Gango river mouth and surrounding area and Ingiriya area in the north-eastern area in Kalutara District.

2) 2 m x 2 m DEM Data Preparation Area

Since the eastern part of the DEM data preparation area in the 2 m x 2 m, which has 160 km^2, could not be measured, the area was shifted to westward to cover 160 km^2 equivalent to four map sheets of 1/10,000 scale map to keep the original DEM preparation area of 800 km^2.

On May 26, 2016, SDSL requested additional data to the Project Team because of the large-scale flooding caused by heavy rain in the LiDAR survey area in the 1 m x 1 m mesh area. SDSL needed to conduct a disaster survey in the area. To the planned LiDAR survey data area (2,200 km^2), additional 200 km^2 needed to be included in the LiDAR survey area. The Project Team reported the

[1] For details, refer (8)-3 Disturbance on GNSS Signal Reception.

headquarters, and the Project Team and JICA discussed the matter. On June 10, the amendment in the 1 x 1 mesh area was agreed. The areas before and after including the 2 m x 2 m mesh areas are summarized in the following tables.

Table 1-1 Original Areas for the LiDAR Survey and Data Processing

Unit: km^2

Work Item	1 m x 1 m mesh (Original)		2 m x 2 m mesh (no change)	
	SD	JPT	SD	JPT
Raw Point Clouds	200	2,200	4,600	800
Unclassified Point Clouds	200	2,200	4,600	800
Ground Data	200	2,200	4,600	800
Ortho-Photo Data	200	2,200	4,600	800
DEM Data	200	2,200	4,600	800
Contour Line Data	2,300	100	5,300	100

SD: Survey Department; JPT: JICA Project Team

Table 1-2 Amended Areas for the LiDAR Survey and Data Processing

Unit: km^2

Work Item	1 m x 1 m mesh (Changed)		2 m x 2 m mesh (no change)	
	SD	JPT	SD	JPT
Raw Point Clouds	-	2,400	4,600	800
Unclassified Point Clouds	-	2,400	4,600	800
Ground Data	-	2,400	4,600	800
Ortho-Photo Data	-	2,400	4,600	800
DEM Data	-	2,400	4,600	800
Contour Line Data	2,100	300	5,300	100

SD: Survey Department; JPT: JICA Project Team

The Contract between the Project Team and JICA was amended.

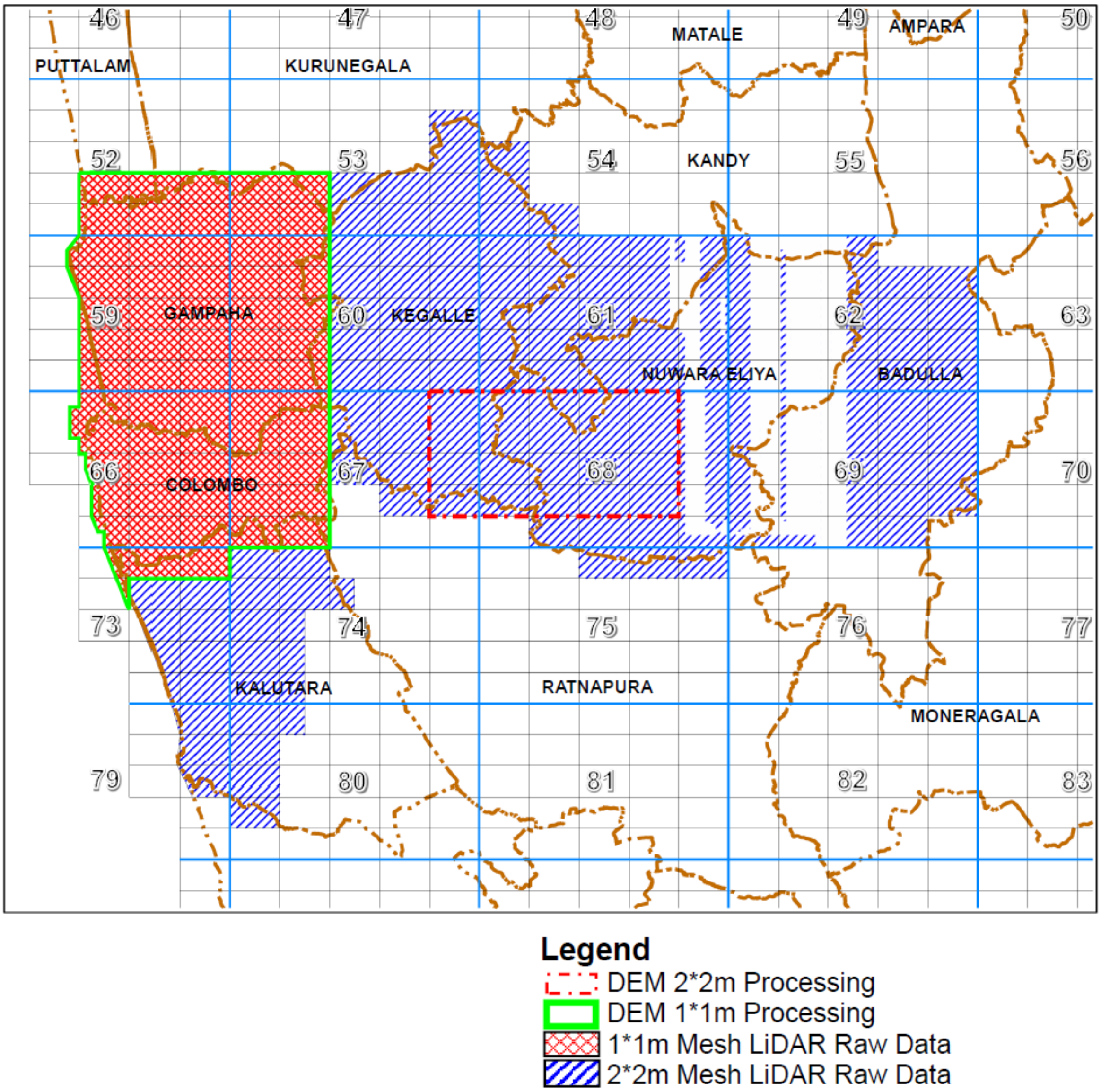

Figure 1-2 Amended LiDAR Survey Areas

After the amendment of the areas, the total LiDAR Survey area is 7,800 km^2, and the total DEM processing areas is 3,200 km^2. The areas and accuracy corresponding to the areas are summarized in the following table.

Table 1-3 LiDAR Survey and DEM Processing Areas

Locality	LiDAR Survey Area	DEM Processing Area	LiDAR Point Density	Vertical Accuracy	Ground Pixel Size on Ortho-photo image
Colombo and Gampaha districts	2,400 km^2	2,400 km^2	1 x 1 meter mesh	±30 cm	30 cm
Other than above	5,400 km^2	800 km^2	2 x 2 meter mesh	±50 cm-100 cm	50 cm

(3) Project Implementation Structure

Supported by the Secretariat of Joint Venture Enterprises in Japan, the Project Management Group, composed of the Team Leader and the Deputy Team Leader managed the Project Team. The Project Team communicated with the JICA Sri Lanka Office and the counterpart organizations to implement the project as the Project Team consults with the Joint Coordination Committee.

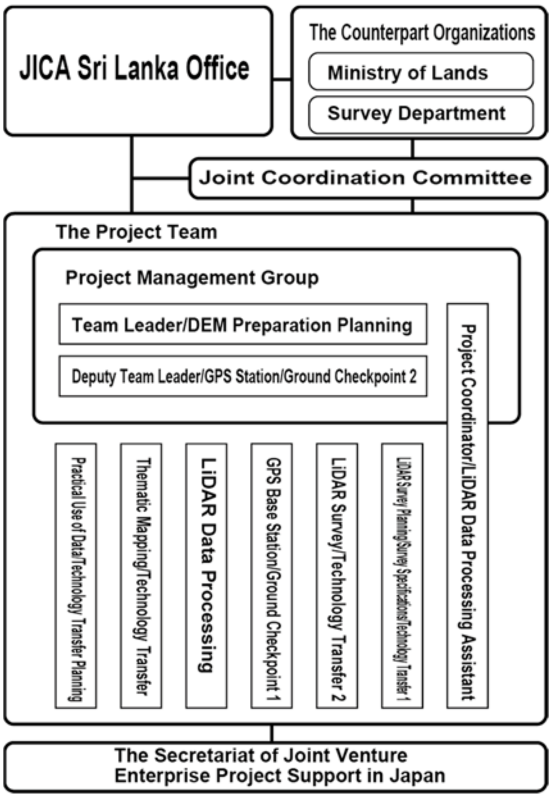

Figure 1-3　Project Implementation Structure

There were eleven members assigned for the project. Mr. Nakasha and Mr. Kitai were the supporting members have sent by Nakanihon Air Services Co., Ltd.

Table 1-4　List of Project Team Members

	Assignment	Name
1	Team Leader/DEM Preparation Planning	Dr. Yutaka Kokufu
2	Deputy Team Leader/LiDAR Survey	Mr. Koichi Kamimura
	GPS Station/Ground Checkpoint 2	Mr. Koichi Kamimura
3	LiDAR Data Processing	Mr. Reynaldo R. Adorador
4	LiDAR Survey Planning/Survey Specifications/Technology Transfer 1	Mr. Masanobu Kondo
5	GPS Station/ Ground Checkpoint 1	Mr. Kiyofumi Tamari
6	LiDAR Survey/Technology Transfer 2	Mr. Hideyuki Haijima
7	LiDAR Survey/Technology Transfer 3	Mr. Hajime Nakasha
8	Thematic Mapping/Technology Transfer	Dr. Akihiro Furuta
9	Data Use Promotion/Technology Transfer Planning	Mr. Kazunobu Kamimura
10	Project Coordinator/LiDAR Data Processing Assistant	Ms. Mary Grace Desusa
11	Project Assistant	Mr. Kazushi Kitani

(4) Joint Coordination Committee

SDSL had received DEM data requests from various agencies related to the flood after the disaster caused by the heavy rain in May, 2016. SDSL held a JCC meeting as inviting the Irrigation Department, DMC, and NBRO. The Project Team explained the progress of work regarding DEM data preparation, and data sharing in the future. It was agreed that SDSL would explain how the data would be shared among government agencies and the prices of sharing the DEM data in the seminar to be held on 11 October, 2016.

Photo 1-1 JCC

2 General Work Flow and Status

Figure 2-1 shows the general work flow of the project. This Final Report covers the contents from the beginning of the Project to the end of November, 2016. The work items are discussed in each section.

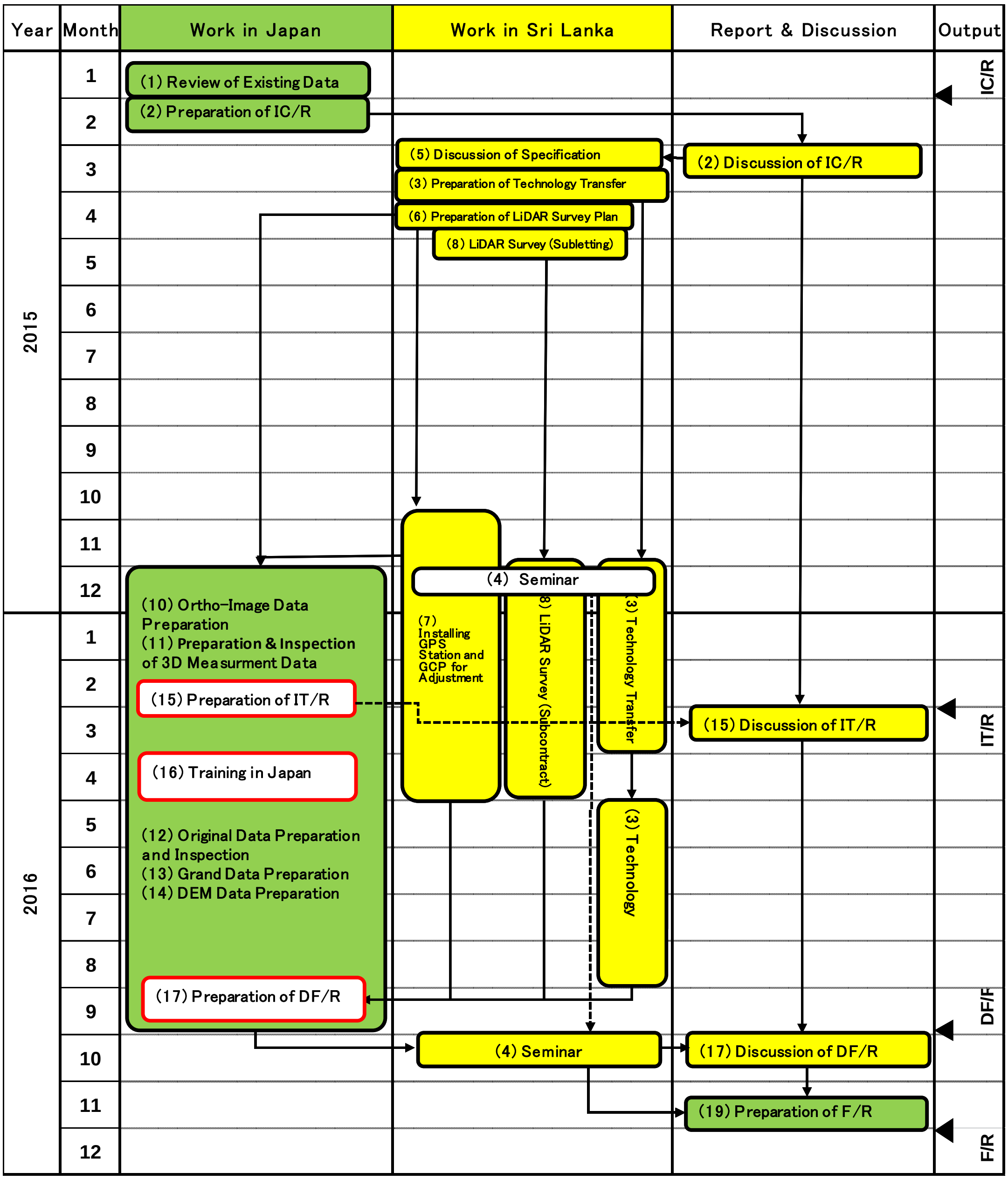

Figure 2-1 Work Flow

3 Project Implementation Results

(1) Collection and Examination of Existing Documents and Information

In Japan and Sri Lanka, following data and information were collected:

Table 3-1 List of Data and Information Collected

Name	Format
Existing Benchmark List	Kmz
Description of Benchmark	Print
Existing GPS Point List	Kmz
Topographic Map (1/50000) paper media	Print
Topographic Map (1/50000) digital data	JPEG
Road Map for Garmin GPS	img
DEPARTMENTAL SURVEY REGULATIONS	PDF

(2) Preparation of Inception Report and Discussion

On March 10, 2015, the Project Team presented the Inception Report to SDSL, and the contents were discussed. Dr. Kokufu explained three implementation schedules. After discussion, both sides agree to select Alternative C. The Minutes of Meeting is attached in the appendix.

(3) Preparation of Technology Transfer Plan and Implementation of the Plan

(3)-1 Skill Assessment

A skill assessment was conducted on March 23, 2015, 10:00 am to 11:00 am. Twelve persons took the test on the basic operation of MicroStation. Nine candidate participants were selected as the operators for the LiDAR data processing, and two technical leaders have been selected. The results are summarized in the following table:

Table 3-2 The Result of Skill Assessment

No	Pass or Fail	Title	First	Last	Total	Note
1	Pass	Mr.	M.N.K.	Bandara	75	Candidate Leader
2	Pass	Mr.	P.N.B.	Widanagamage	75	Candidate Leader
3	Pass	Mr.	D.	Ekanayaka	55	
4	Pass	Mrs.	D.C.S.	Jayatunga	45	
5	Pass	Mr.	M .K.J.	Wijethilaka	45	
6	Pass	Mr.	M.A.N.	Karunathilaka	30	
7	Pass	Mrs.	Y.K.	Kannangara	30	
8	Pass	Mrs.	I.S.	Welhena	20	
9	Pass	Mr.	A.G.T.P.	Weerasinghe	20	
10	Fail	Mrs.	M.M.V.U.	Silva	15	Observer
11	Fail	Mr.	W.K.C.	Madushanka	10	Observer
12	Fail	Mr.	P.S.P.	Jayatunga	10	Observer
13	Fail	Mr.	M.C.S.	Cooray	No show	

(3)-2 Technology Transfer Plan

1) Goals

- The participants will be able to prepare an airborne LiDAR survey plan.

- The participants will be able to produce DEM data from the LiDAR data.
- The participants will be able to produce thematic maps from the DEM data.
- The participants will be able to produce contour-line data from the DEM data.

2) Target Participants

As discussed with SDSL, the maximum number of OJT was nine; therefore, nine persons from the highest score were selected as the candidate for technology transfer training.

Table 3-3 Selected Nine Engineers

No	Name	Initial Text Evaluation on CAD Operation
1	Mr. M.N.K. Bandara	A
2	Mr. P.N.B. Widanagamage	A
3	Mr. D. Ekanayaka	B
4	Mrs. D.C.S. Jayatunga	B
5	Mr. M .K.J. Wijethilaka	B
6	Mr. M.A.N. Karunathilaka	C
7	Mrs. Y.K. Kannangara	C
8	Mrs. I.S. Welhena	C
9	Mr. A.G.T.P. Weerasinghe	C

For those who did not make it to the OJT candidates became observers to the OJT sessions.

Mr. Bandora and Mr. Widanagamage scored the highest among 12 test takers. They were recommended to become the candidate technical leaders in the technology transfer training and future trainers. The administrative leader was assigned to Mr. Wijiwaryanada, Superintendent of Surveys, Air Survey Branch, Survey Department.

For the LiDAR survey planning, five trainees were recommended by SDSL. They were from the Photogrammetry Branch and Photo Lab Branch.

In December 2015, SDSL requested additional 13 trainees for the LiDAR data processing. The capacity of the training facility and availability of experts were considered, and it was decided that the original trainees would train the additional trainees in the training room.

In February 2016, three trainees were added as requested by SDSL. To those three trainees, intensive training was conducted.

For the thematic mapping training, originally three trainees and three observers from the GIS Branch were planned. But SDSL requested additional trainees as the GIS Branch provided additional PCs with software licenses, the observers became the trainees. The Mapping Branch joined the training as well as nine original LiDAR survey data processing trainees. Since both ArcGIS and TerraSeries have functions to produce thematic maps and contour line data, training for both methods were provided.

Because of the flood in May, 2016, there was an additional training request from other agencies: the Irrigation Department; NBRO; and DMC. Representatives from those agencies were requested to take part in the thematic mapping training.

The names of 15 persons who took part in the training in Japan are included in the following table.

Table 3-4 Participants to the Training

Group Name	Name	Section
LiDAR Data Processing Engineer	Mr. M.N.K. Bandara	Photogrammetric Branch
	Mr. D. Ekanayake	Photogrammetric Branch
	Mrs. D.C.S. Jayatunga	Photogrammetric Branch
	Mrs. Y.K. Kannangara	Photogrammetric Branch
	Mr. M.W.A.N. Karunatilaka	Photogrammetric Branch
	Mr. A.G.T.P. Weerasinghe	Photogrammetric Branch
	Mrs. I.S. Welhena	Photogrammetric Branch
	Mr. P.N.B. Widanagamage	Photogrammetric Branch
	Mr. M.K.J. Wijayatilake	Photogrammetric Branch
Training by Survey Department	Mrs. A.K. Chandrani	Photogrammetric Branch
	Mr. M.C.S. Cooray	Photogrammetric Branch
	Ms. D.W.I.U. Gunarathna	Photogrammetric Branch
	Mrs. P.C. Guruge	Photogrammetric Branch
	Mrs. M.P.W. Jayathilaka	Photogrammetric Branch
	Mr. P.S.P. Jayathunga	Photogrammetric Branch
	Mr. W.K.C. Madshanka	Photogrammetric Branch
	Mr. A.P. Manchanayaka	Photogrammetric Branch
	Ms. P.A.C.P. Perera	Photogrammetric Branch
	Ms. A.A. Priyanthi	Photogrammetric Branch
	Mrs. M.M.V.U. Silva	Photogrammetric Branch
	Ms. L.P. Upeksha	Photogrammetric Branch
	Ms. A.M. Wickramage	Photogrammetric Branch
Contour Line Data Preparation	Mr. M.N.K. Bandara	Photogrammetric Branch
	Mr. D. Ekanayake	Photogrammetric Branch
	Mrs. D.C.S. Jayatunga	Photogrammetric Branch
	Mrs. Y.K. Kannangara	Photogrammetric Branch
	Mr. M.W.A.N. Karunatilaka	Photogrammetric Branch
	Mr. A.G.T.P. Weerasinghe	Photogrammetric Branch
	Mrs. I.S. Welhena	Photogrammetric Branch
	Mr. P.N.B. Widanagamage	Photogrammetric Branch
	Mr. M.K.J. Wijayatilake	Photogrammetric Branch
LiDAR Data Processing	Mr. P.S.P. Jayathunga	Photogrammetric Branch

Group Name	Name	Section
Engineer (Observer)	Mr. W.K.C. Madshanka	Photogrammetric Branch
	Mrs. M.M.V.U. Silva	Photogrammetric Branch
LiDAR Survey Planner	Mr. A.A.J Abaysundara	Photo Lab
	Mrs. P.C. Guruge	Photogrammetric Branch
	Mr. K.S. Gurusinghe	Photo Lab
	Mr. S.P. Meheramba	Photo Lab
	Ms. P.A.C.P. Perera	Photogrammetric Branch
Thematic Mapping for Mapping Branch	Ms. A.W. Gunawardana	Special Mapping Branch 1
	Mr. L.A.S.A. Iraj	Special Mapping Branch 2
	Ms. B.H.U. Rathnahansi	Topographical Mapping Drawing
	Mrs. R.W.G.H. Sumanasiri	Special Mapping Unit 1
	Ms. W.A. Weerasinghe	Topographical Mapping Preparation
	Ms. N.M. Withana	Special Mapping Branch 2
Thematic Mapping	Mrs. P.C. Guruge	Photogrammetric Branch
	Ms. P.A.C.P. Perera	Photogrammetric Branch
	Mr. S.M.J.S Samarasinghe	GIS Branch
	Ms. K.M. Sandaruwani	Remote Sensing Branch
	Mrs. U.K. Weerakoon	GIS Branch
	Mr. I. Welikanna	GIS Branch
Thematic Mapping for Other Agencies	Ms. Hasali Hemasinghe	NBRO
	Ms. M.H.B.C.W. Herath	Irrigation Department
	Mr. S. Jayaprakash	NBRO
	Mr. Sampath Kukulavithana	DMC
	Mrs. K.K.G.I.L. Siriwardana	Irrigation Department
Thematic Mapping (Observer)	Mr. M.N.K. Bandara	Photogrammetric Branch
	Mr. D. Ekanayake	Photogrammetric Branch
	Mrs. D.C.S. Jayatunga	Photogrammetric Branch
	Mrs. Y.K. Kannangara	Photogrammetric Branch
	Mr. M.W.A.N. Karunatilaka	Photogrammetric Branch
	Mr. A.G.T.P. Weerasinghe	Photogrammetric Branch
	Mrs. I.S. Welhena	Photogrammetric Branch
	Mr. P.N.B. Widanagamage	Photogrammetric Branch
	Mr. M.K.J. Wijayatilake	Photogrammetric Branch

Group Name	Name	Section
Trainee for Training in Japan	Mr. M.N.K. Bandara	Photogrammetric Branch
	Mr. B.C.P. Bogahawatta	Geodetic Branch
	Mr. D. Ekanayake	Photogrammetric Branch
	Mrs. D.C.S. Jayatunga	Photogrammetric Branch
	Mrs. Y.K. Kannangara	Photogrammetric Branch
	Mr. M.W.A.N. Karunatilaka	Photogrammetric Branch
	Miss Serenee Osman	Photogrammetric Branch
	Mr. G.A. Udayakumara	Geodetic Branch
	Mr. W.M.S. Weerasinghe	Geoinformatic Section
	Mr. A.G.T.P. Weerasinghe	Photogrammetric Branch
	Mrs. I.S. Welhena	Photogrammetric Branch
	Mr. P.N.B. Widanagamage	Photogrammetric Branch
	Mr. M.K.J. Wijayatilake	Photogrammetric Branch
	Mr. N.M.A. Wijerathna	Institute of Surveying and Mapping, Diyathalawae
	Mr K.S.K. Wijeyawardhana	Air Survey Branch

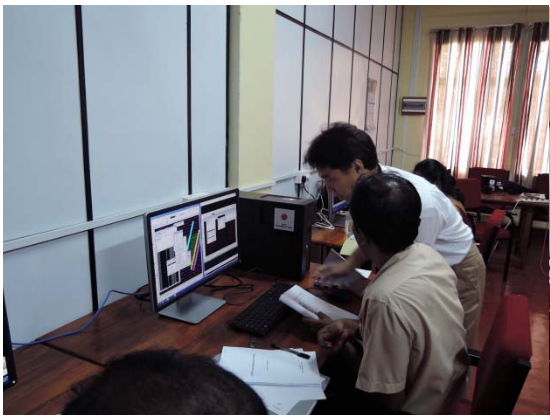


Photo 3-1　Training (OJT and Lecture)

3) Technology Transfer Results

The technology transfer sessions started on November 11, 2015 and completed on August 31, 2016. All the planned training manuals were completed, and all the 221 sessions were completed including self-learning sessions under supervision of the Project Team members.

Table 3-5　Training Implementation Summary

Code	Category	Training Type	Training From	Training To	The number of Sessions
01	LiDAR Fundamentals	Lecture	30/11/2015		1
02	Software Knowledge	Lecture	07/12/2015		1
025	Introduction to LiDAR Data Processing	Lecture	08/12/2015	15/12/2015	2
025_ Intensive	Introduction to LiDAR Data Processing (Intensive)	Lecture	16/02/2016		2
03	LiDAR Survey Planning	Workshop	24/02/2016	03/03/2016	4
04	LiDAR Measurement	Lecture	06/01/2016	02/03/2016	2
05	Raw Point Cloud	Lecture	08/03/2016		2
06	Unclassified Point Cloud	OJT	22/12/2015	24/02/2016	22
06_ Intensive	Unclassified Point Cloud (Intensive)	OJT	17/02/2016	18/03/2016	17
06_SD	Unclassified Point Cloud by Survey Department	OJT	29/12/2015	27/01/2016	6
07	Ground Data Preparation	OJT	14/03/2016	31/05/2016	35
08	DEM Data Preparation	OJT	12/05/2016	13/05/2016	4
09	Ortho-Photo Image Preparation	OJT	16/05/2016	17/05/2016	4
10	Thematic Map Preparation from DEM using TerraSeries, MicroStation	OJT	01/08/2016	30/08/2016	42
11	Thematic Map Preparation from DEM using ArcGIS	OJT	20/07/2016	28/07/2016	13
All	Review All Processes	OJT	01/06/2016	13/06/2016	17
Self	Self-Study	Self-Study	13/06/2016	15/07/2016	47
Total					221

One session was about two hours.　"Unclassified Point Cloud by Survey Department" means that the original nine trainees taught additional 13 trainees from SDSL.

The number of participants attended in one session times the number of sessions was 1994. The unclassified point cloud and ground data preparation were the two categories of the training which took time for the trainees to learn. Especially, the interactive filtering required for the ground data preparation was the hardest skill of all the processes of the LiDAR data processing.

Table 3-6 Technology Transfer Sessions Attendance Record

Code	Category	The total number of persons attended.
01	LiDAR Fundamentals	18
02	Software Knowledge	22
025	Introduction to LiDAR Data Processing	19
025_Intensive	Introduction to LiDAR Data Processing (Intensive)	6
03	LiDAR Survey Planning	22
04	LiDAR Measurement	21
05	Raw Point Cloud	26
06	Unclassified Point Cloud	189
06_Intensive	Unclassified Point Cloud (Intensive)	50
06_SD	Unclassified Point Cloud by Survey Department	102
07	Ground Data Preparation	298
08	DEM Data Preparation	36
09	Ortho-Photo Image Preparation	36
10	Thematic Map Preparation from DEM using TerraSeries, MicroStation	349
11	Thematic Map Preparation from DEM using ArcGIS	144
All	Review All Processes	139
Self	Self-Study	517
The Total		1994

4) Method of Training Record and Evaluation

For the all the OJT sessions, the following management sheet was used to monitor progress of learning. For the lecture sessions, quizzes were conducted to ensure comprehension of the trainees.

OJT Evaluation Sheet

Name: Mr. M.W.A.N. Karunatilake

VOLUME 6: Unclassified Point Cloud Preparation

Subject			Manual Page No.	Movie File No.	OJT Date			Note
2. Unclassified Point Cloud before Adjustment Preparation	2.1. DGN File Preparation	1) Coordinate Conversion on Position and Orientation Data	3	2-1-1				
		2) Preparation of Working DGN Files	8	2-1-2				
	2.2. Data Organization by Map Sheet	1) Preparation of Project Files	13	2-2-1				
		2) Organizing the Data by Map Sheet	17	2-2-2				
		3) Confirmation of the Data Files by Map Sheet	18	2-2-3				
		4) Deleting Unnecessary Flight lines and Adding Flight line Numbers	25	2-2-4				
	2.3. Adjustment to Geoid		28	2-3-1				
	2.4. Noise Removal		33	2-4-1				

Figure 3-1 OJT Evaluation Sheet

5) Achievement

Attendance, speed and accuracy of processing, and leadership during the training sessions were assessed and the trainers have evaluated the performance of training. Overall achievement was good, since most of the trainees was able to do their operation as they referred to the manuals.

Table 3-7 List of Trainees and Achievement

Group Name	Name	Section	Achievement
LiDAR Data Processing Engineer	Mr. M.N.K. Bandara	Photogrammetric Branch	A
	Mr. D. Ekanayake	Photogrammetric Branch	A
	Mrs. D.C.S. Jayatunga	Photogrammetric Branch	S
	Mrs. Y.K. Kannangara	Photogrammetric Branch	A
	Mr. M.W.A.N. Karunatilaka	Photogrammetric Branch	A
	Mr. A.G.T.P. Weerasinghe	Photogrammetric Branch	A
	Mrs. I.S. Welhena	Photogrammetric Branch	S
	Mr. P.N.B. Widanagamage	Photogrammetric Branch	S

Group Name	Name	Section	Achievement
	Mr. M.K.J. Wijayatilake	Photogrammetric Branch	A
Contour Line Data Preparation	Mr. M.N.K. Bandara	Photogrammetric Branch	A
	Mr. D. Ekanayake	Photogrammetric Branch	A
	Mrs. D.C.S. Jayatunga	Photogrammetric Branch	A
	Mrs. Y.K. Kannangara	Photogrammetric Branch	A
	Mr. M.W.A.N. Karunatilaka	Photogrammetric Branch	A
	Mr. A.G.T.P. Weerasinghe	Photogrammetric Branch	A
	Mrs. I.S. Welhena	Photogrammetric Branch	A
	Mr. P.N.B. Widanagamage	Photogrammetric Branch	A
	Mr. M.K.J. Wijayatilake	Photogrammetric Branch	A
LiDAR Survey Planning	Mr. A.A.J Abaysundara	Photo Lab	B
	Mrs. P.C. Guruge	Photogrammetric Branch	Incomplete
	Mr. K.S. Gurusinghe	Photo Lab	B
	Mr. S.P. Meheramba	Photo Lab	B
	Ms. P.A.C.P. Perera	Photogrammetric Branch	Incomplete
Thematic Mapping for Mapping Branch	Ms. A.W. Gunawardana	Special Mapping Branch 1	B
	Mr. L.A.S.A. Iraj	Special Mapping Branch 2	B
	Ms. B.H.U. Rathnahansi	Topographical Mapping Drawing	B
	Mrs. R.W.G.H. Sumanasiri	Special Mapping Unit 1	B
	Ms. W.A. Weerasinghe	Topographical Mapping Preparation	B
	Ms. N.M. Withana	Special Mapping Branch 2	B
Thematic Mapping	Mrs. P.C. Guruge	Photogrammetric Branch	B
	Ms. P.A.C.P. Perera	Photogrammetric Branch	B
	Mr. S.M.J.S Samarasinghe	GIS Branch	S
	Ms. KM Sandaruwani	Remote Sensing Branch	B
	Mrs. UK Weerakoon	GIS Branch	A
	Mr. I. Welikanna	GIS Branch	A

S: has an ability to organize training to lead training sessions.
A: has an ability to become a trainer.
B: can conduct operations using the manuals.

6) Issues and Countermeasures on Technology Transfer

It is true that all the trainees achieve the skill levels we targeted for DEM data production, but it is also true that production management skills need to be capacitated. A leader, manager, needs to know operation management to make the production smooth and efficient; also, data management skills need to be capacitated.

The Project area was 7,800 km^2, and the DEM was produced for the 3,200 km^2 area. SDSL needs to finish remaining 4,600 km^2. Current production level per person is about 3 km^2. As the operators get more experienced, the per-person production is expected to be raised to 16 km^2. With the rate, it would take about 34 months to complete the 4,600 km^2 by nine LiDAR processing engineers.

Among the processes, the ground data preparation was one of the longest processes of technology transfer. To make this process efficient is the key to make overall processes of the LiDAR data processing. Thematic Map Preparation from DEM using TerraSeris took long time. This was because the contour line production for 2,100 km^2 was included; It did not represent the length of technology transfer. Technology transfer for thematic mapping and contour-line-data preparation had been completed in one day or two.

The LiDAR survey area for this project was selected to the areas prone to landslide and flood that were prioritized in all the country area. The validity of selection of the survey area was unfortunately proven right in May 2016 when a strong tropical storm hit the area. It is highly probable that similar disaster may take place in other areas of the country. In other river basins, other donors have been conducting LiDAR surveys, and more support is call for as the efforts will be coordinated. For this purpose also, the production capacity needs to be raised.

To raise the production capacity, the production lines need to be strengthened. The training shall be continued so that more LiDAR data processing engineers will become available. With the availability of the engineers, the nine PCs will be fully utilized as two-shifts in a day operation will be implemented.

The DEM data with very high accuracy have been produced in this Project. It was mainly because the Specifications and production procedures based on the Japanese standards were used. The trade-off is the time required for the precision work. The ground data preparation required intensive interactive filtering which took most of the data processing work. In other words, it would be possible to ease the standards for quick production if the purpose and precision standards are satisfied in Sri Lanka. The Specifications and operation procedures may have to be updated in the near future.

This Project was one of the first-large-scale LiDAR project in Sri Lanka; the amount of GCP installation work was not expected for SDSL without the geoid model. Currently, in Sri Lanka, permanent GNSS stations have been installed. With this effort, various survey works will become more efficient. The establishment of the geoid model for the entire country will facilitate to the effort of installation of permanent GNSS stations as well as the LiDAR survey projects, and as a result, the model will raise capacity and efficiency of all the survey works in Sri Lanka.

(4) Seminars

The Kick-off Seminar

SDSL of Sri Lanka, Ministry of Lands, with administrative assistance from Project Team held a kick-off seminar on Capacity Development Project for Creating Digital Elevation Model Enabling Disaster Resilience in the Democratic Socialist Republic of Sri Lanka at the Galadari Hotel in Colombo, Sri Lanka on the 4th of December, 2015.

A total of 73 persons participated to the kick-off seminar. From the Japan side, Embassy of Japan, JICA Headquarters, JICA Sri Lanka, and Project Team, along with the JICA experts in the fields of disaster management and meteorology attended. From the Sri Lanka side, concerning government organizations have taken part in. They are: Central Engineering Consultancy Bureau, Central Environmental Authority, Department of Meteorology, Disaster Management Centre, Land Use

Policy Planning Department, Ministry of Disaster Management, Ministry of Lands, National Building Research Organization, National Physical Planning Department, National Planning Department, National Water Supply & Drainage Board, Urban Development Authority and SDSL. From academics, University of Colombo, University of Moratuwa and University of Peradeniya attended. International Water Management Institute (IWMI) and UNDP are the international organizations present.

The kick-off seminar was organized to share knowledge of the project and the LiDAR technology among potential data users, and to introduce activities of SDSL in Sri Lanka which is the counterpart agency for the project.

Mr. D.N.D. Hettiarachchi, Deputy Surveyor General, thanked the government of Japan, JICA Headquarters and JICA Sri Lanka, and the Project Team for supporting and implementing the project. He emphasized significance of the data not only for disaster risk reduction, but also in other sectors such as infrastructure development. He welcomed all the participants to the seminar. Mr. P.M.P. Udayakantha, Surveyor General, explained how survey and mapping functions in Sri Lanka, and stated how detailed geographical information is necessary especially in the disaster prone areas. He expected possible applications of the data in areas such as forestry and coastal zone management. Ms. Piumi Attygalle, Assistant Secretary, has delivered a message from Secretary of Ministry of Lands thanking Japan's presence in the field of disaster management in Sri Lanka.

From Embassy of Japan, Mr. Kiichirio Iwase, First Secretary, acknowledged the hardship people in Sri Lanka felt during the recent natural disaster, and sent a message that the government of Japan has been supporting disaster mitigation activities in Sri Lanka. He quoted comments of Mr. Abe, Prime Minister of Japan, when Prime Minister Wickremeshinghe has visited Japan, saying that Japan would support in the area of disaster risk reduction and meteorology. Mr. Iwase expressed gratitude to the support from Sri Lank during and after the Great East Japan Earthquake, and he hoped that the knowledge and experiences of disaster management accumulated in Japan would be shared and utilized in Sri Lanka.

Dr. Yutaka Kokufu, JICA Project Leader, explained the Project: objectives; survey area; method; and schedule after he introduced other project team members. The two objectives he mentioned were: to produce the digital elevation model and to transfer technology.

Mr. Reynald Adorador, LiDAR Survey Expert, introduced the LiDAR technology. He said that the LiDAR survey is affected by weather like the conventional aerial photography. He mentioned that there is no data reflected from water surfaces, and that it was possible that the laser beam could penetrate between leaves of trees to measure the ground height.

After the question and answer session, Mr. Kiyoshi Amano, Chief Representative of JICA Sri Lanka, concluded the meeting as introducing the Third UN World Conference on Disaster Rick Reduction held in March 2015 in Sendai, Japan to show some of Japan's international involvement in disaster management.

The program of the seminar is shown in the following table:

Table 3-8 Program (Kick-off Seminar)

Lecturer/Presenter	Agenda	From	To
-	Registration	8:30	9:00
-	National Anthem	9:00	9:10
D.N.D.Hettiarachchi	Welcome Address	9:10	9:20
Dr. I.H.K. Mahanama	Message	9:20	9:35
Mr. Kiichiro IWASE	Message	9:35	9:40
P.M.P. Udayakantha	Need of LIDAR Survey for Sri Lanka	9:40	10:00
Dr. Yutaka KOKUFU	Overview of the Project	10:00	10:30
Mr.Reynaldo R. Adorador	Presentation of Airborne LiDAR Technology	10:30	11:30
-	Discussion and Questions	11:30	12:00
Mr. Kiyoshi AMADA	Closing Remarks	12:00	12:15
-	Lunch	12:15	13:00

Photo 3-2 The Kick-off Seminar

<u>A Technical Seminar</u>

A technical seminar was held on March 21, 2016, as SDSL invited a Japanese landslide expert, Mr. Handa, who was assigned in NBRO, Ministry of Disaster Management as presenter on DEM data utilization. Dr. Kokufu, the Team Leader, explained the contents of draft DEM data during the seminar.

Photo 3-3 Technical Seminar (March 21, 2016)

Technical staff from Photogrammetry Branch, Geo-informatics Branch and Mapping Branch took part in the technical seminar.

The Final Seminar

The final seminar was held in the morning on October 6, 2016 at Galadari Hotel, Colombo, Sri Lanka.

Table 3-9 Program of the Final Seminar

Time	Agenda	Presenter
8:00 - 8:30	Registration	
8:30 - 8:45	National Anthem	
8:45 - 9:00	Welcome Address	Mr. W.M. Saman Weerasinghe, Deputy Surveyor General (Geoinformatics)
9:00 - 9:15	Message	Ms. Piumi Attygalle, Asst. Secretary, Ministry of Lands
9:15 –9:35	Need of LIDAR Survey for Sri Lanka	Mr. P.M.P. Udayakantha, Surveyor General
9:35 - 9:50	Overview of the Project	Dr. Yutaka Kokufu, JICA Project Team Leader
9:50 - 10:10	Presentation of Airborne LiDAR Technology	Mr. Reynaldo R. Adorador, Airborne Lidar Surveying, JICA Project Team
10:10 - 10:25	Presentation of Thematic Mapping using DEM	Dr. Akihiro Furuta, GIS Expert, JICA Project Team
10:25 - 10:35	Tea Break	
10:35 - 10:50	Technology Transfer	Mr. Kazunobu Kamimura, Technology Transfer Planning, JICA Project Team
10:50 - 11:20	Demonstration of LiDAR Data Processing	Mr. M.N.K. Bandara, Photogrammetric Technological officer, Survey Department
11:20 - 11:50	Demonstration of Thematic Mapping	Mr. S.M.J.S. Samarasinghe, Superintendent of Survey(GIS), Survey Department
11:50 - 12:05	LiDAR Data Sharing and Publishing	Mr. W.M. Saman Weerasinghe, Deputy Surveyor General(Geoinformatics)
12:05 - 12:15	Message	Mr. P.M.P. Udayakantha, Surveyor General
12:15 - 12:20	Discussion	
12:20 - 12:35	Awards Ceremony	
12:35 - 12:45	LiDAR Data Hand Over Ceremony	
12:45 - 13:00	Closing Remarks	Mr. Kiyoshi Amada, Chief Representative, JICA Sri Lanka
13:00 -	Lunch	

A total of 70 persons, excluding the members of the Project Team and media, participated to the final seminar. Other than 47 participants from SDSL, members from the Ministry of Lands, Irrigation Department, DMC, NBRO, the World Bank and UNDP participated.

Table 3-10 Main Participants not from SDSL

Institution	Name	Position
Disaster Management Centre	Ms Anoja Seneviratne	Director (Mitigation Research & Development)
International Water Management Institute (IWMI)	Mr. Salman Sadiquie	Senior Manager GIS/RS/Data Management Unit
Irrigation Department	Ms M.H.B.C.W. Herath	Project Director - CRIP
Land Use Policy Planning Department	Mr. H.D. Sisira Hapuarachchi	Asst. Director (Agri Economics)
Ministry of Lands	Mr. L.B.S.B. Dayaratne	Addl. Secretary (Land)
	Ms Piumi Attygalle	Asst. Secretary
National Building Research Organization	Ms Hasali Hemasinghe	Scientist
	Ms P.H.E Dulanjalee	Scientist
Sri Lanka Land Reclamation & Development Corp	Mr. T.N. Booso	Engineer
The World Bank	Mr. Suranga Kahandawa	Disaster Risk Management Specialist
UNDP	Ms Sachi Perera	DRR Specialist
JICA Sri Lanka	Mr. Hiroki Hashimoto	Representative
	Mr. Kiyoshi Amada	Chief Representative
	Ms Kishani Tennakoon	Project Specialist

As for data sharing, the following seven points were explained by Mr. W.M. Saman Weerasinghe

1. Decided at the Joint Coordinating Committee of the Project
2. Main purpose is utilization for Disaster Management
3. Consent of JICA needed during project period
4. All the transaction and sharing govern by the MOU
5. Value added products to be shared
6. Special terms of in house sharing
7. Copy right with Survey Department

The pricing of the data presented are generally classified into 1 x 1 mesh area and 2 x 2 mesh areas. The 2 x 2 mesh areas are classified into two: interactively processed and automatically processed areas. Based on the categories, prices of the unclassified point clouds, DEM data, contour line data, and quasi-ortho-photo images are tentatively prices.

Table 3-11 Tentative Pricing of Data

Category	Data Type	Unit (Rs/km^2)
1 x 1 mesh data –Interactively Processed	Unclassified Point Cloud	200
	DEM Data	100
	Contour Line Data	200
	Quasi Ortho-photo data	400
2 x 2 mesh data -Interactively Processed	Point Cloud	100
	DEM Data	50
	Contour Line Data	100
	Quasi Ortho-photo images	400
2 x 2 mesh data - Automatic Processed	DEM Data	20
	Contour Line Data	40
	Quasi Ortho-photo images	400

Mr. Bandra from the Photogrammetric Branch demonstrated the methods of LiDAR data processing, thematic mapping and topographic data preparation using the LiDAR data processing system.

Mr. Samasrasinghe, from the GIS Branch presented methods of thematic mapping and topographic data preparation using ArcGIS. His presentation included lecture materials explaining the theories behind thematic mapping.

Demonstration of Thematic Mapping and Topographic Data Preparation using ArcGIS

Demonstration of LiDAR Data Processing including Thematic Mapping and Topographic Data Preparation using LiDAR Data Processing System

Photo 3-4 Presentation by the Trainees

Dr. Kokufu, the Team Leader, submitted the LiDAR data to Mr. Amada, Chief Representative of JICA Sri Lanka Office, and Mr. Amada gave the data to Mr. Udayakantha, Surveyor General.

Photo 3-5 LiDAR Data Handover Ceremony

(5) Discussion on the Specifications

The draft of the specifications was prepared based on the Survey Operation Standards, and Amendment (partially amended (2013, Geographical Survey Institute, Ministry of Lands, Infrastructure and Transport and Tourism) and Department Survey Regulations, Fifth Edition, 2015 March (Sri Lanka Survey Department). The draft was submitted on the 16th of March, 2015. The Version 1.0 of the Specifications was presented and explained. On the 20th of March 2015, the second discussion on the Specifications was held. The Version 1.1 of the Specifications was presented and explained. The minutes of meetings including lists of attendance is attached in the appendix.

(6) Preparation of LiDAR Survey Plan

The survey plan has been designed by Survey Department and Project Team to execute the LiDAR Survey of Capacity Development Project for Creating Digital Elevation Model Enabling Disaster Resilience in Sri Lanka.

(6)-1 Specifications for the LiDAR survey

As planned at the beginning of the project, the same plan was presented and accepted. The general specifications of the LiDAR survey are summarized in the following table:

1) LiDAR survey specification

Table 3-12 LiDAR Survey Specifications

Grid size	Area	Height accuracy	Ortho Photo Image GSD
1m x 1m	2,400 km^2	S.D.30 cm	30cm
2 m x 2 m	5,400 km^2	S.D.50 to 100 cm	50 cm

G.S.D.: Ground Sample Distance

2) LiDAR Equipment

The aircraft and equipment were planned by the Project Team the required parameters of the aircraft and the equipment were accepted by the C/P.

i) Aircraft

Table 3-13 Aircraft Parameters

Item	Parameter	Unit
Type	Piper PA23 Aztec	-
Registration	PH-KED	-
Wingspan	11	m
Length	9.51	m
Power	2 motors 250	HP
Speed	90 to 150	kts
Ceiling	4,200	m
Range	850	nm

ii) Sensors

Table 3-14 Sensors

Item	Manufacturer	Type
Laser scanner	IGI	LiteMapper 6800i
Camera	IGI	DigiCam H60

Photo 3-6 Aircraft

Photo 3-7 Laser Scanner

Photo 3-8 Camera

Table 3-15 LiDAR Survey Parameters

Item	Parameters by area		Unit
	1 m x 1 m area	2 m x 2 m area	
Ground elevation	1,040	1,400	m
Ground speed	120	120	kt
Lateral overlap between swaths	40	40	%
Scan angle	60	60	degree
Pulse rate	200	70	kHz
Point density	1.9	0.5	pt/m^2
GSD of photogrammetry	17	23	cm

(6)-2 A Flight Plan

A flight plan was prepared in the 1 meter and 2 meter mesh areas. For the 1 m x 1 m mesh area, a total of 58 lines were planned, and in the 2 m x 2 m mesh area, a total of 183 lines were planned.

The GPS signal reception disturbance prevented implementation of measurement at around the center of the eastern area of 2 m x 2 m survey area since the middle of January, 2015. Because of the disturbance, parts of the project area needed to be changed. Based on the change of the survey area in the southern part of the 2 m x 2 m area (Kalutara District and others), the LiDAR measurement plan was prepared. Table 3-16 and Figure 3-2 show the final measurement flight paths of the LiDAR measurement.

Table 3-16 A Flight Plan (summary of flight line numbers)

Area	Flight line number	Number of flight lines	Note	Sub total number of flight lines
1 m x 1 m area (West area)	001 to 055	55	Main lines	64
	101 to 103	3	Across lines	
	201 to 206	6	Add lines	
2 m x 2 m area (East area)	301 to 355	55	Main lines	240
	401 to 442	42		
	501 to 524	24		
	601 to 612	12	Across lines	
	701 to 807	107	Complement lines	
2 m x 2 m area (South area)	901 to 938	38	Main lines	40
	951 to 952	2	Across lines	
Total number of flight lines				344

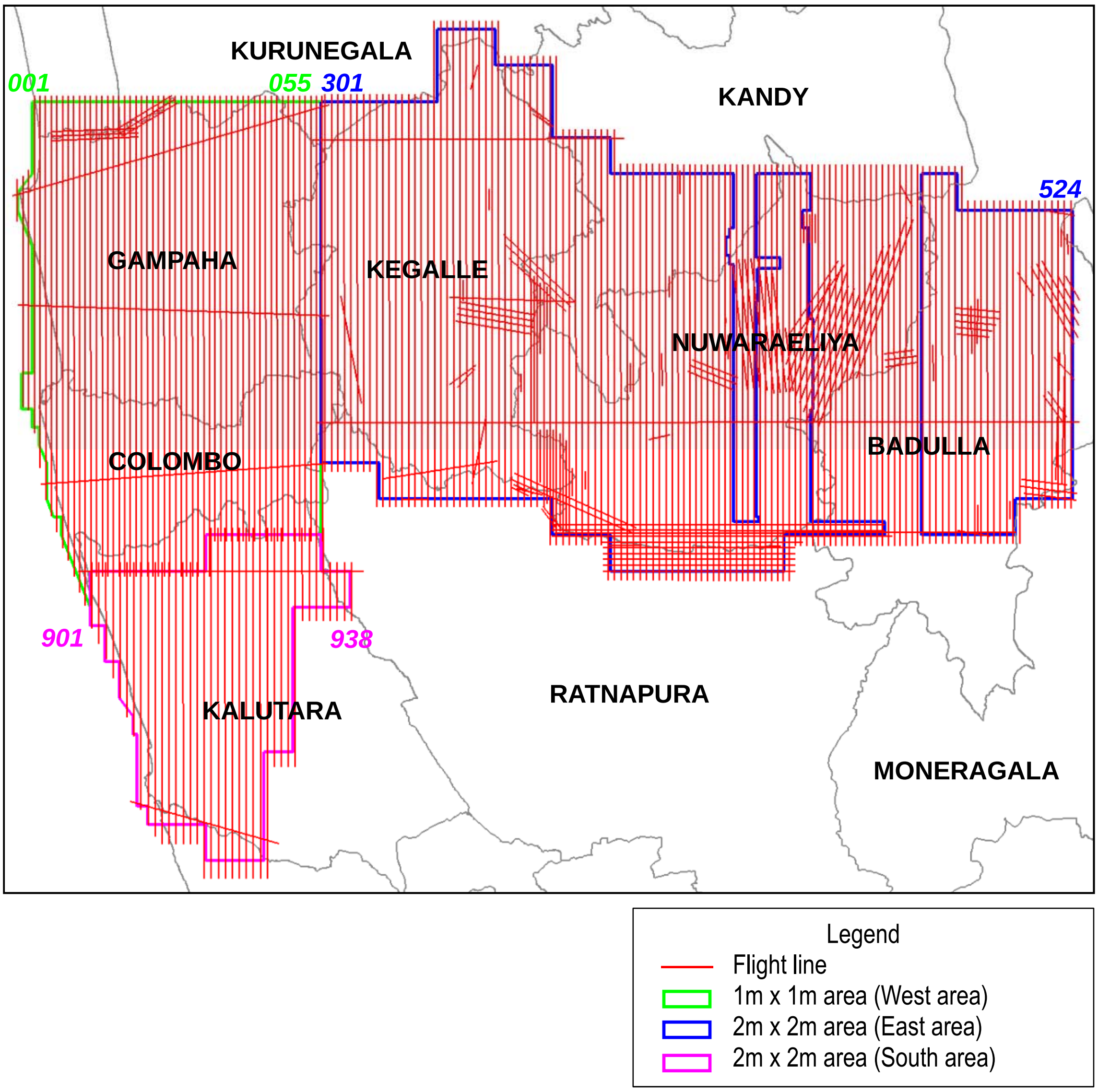

Figure 3-2 Flight Lines

(6)-3 GNSS Base Station Installation Plan

<A Plan in March 2015>

The GNSS base stations need to cover the entire survey area in addition to the 10 km areas for turning around for the aircraft. The maximum distance of one base station can cover is 50 km; preferably, the survey area needs to be with 30 km distance from the base stations. The installation plan was prepared based on the principle. Three points were planned and distributed evenly in the survey area. Additional three points for each point were planned to avoid possible reception errors. A total of six points were proposed and accepted in March, 2015.

<Revised Plan after Field Reconnaissance>

The Project Team and the C/P surveyors conducted field reconnaissance and revised the installation plan. The following matters were agreed with the C/P.

Table 3-17 Plan and Implementation of GNSS Base Stations

	Plan in March 2015	Revised Plan in December	Note (reasons for the changes)
The number of GNSS Base Stations	Three Locations ＋ Three supplemental locations＝ 6 Locations	Seven Locations ＋ Seven Supplemental Locations＝ 14 Locations	Securing electric power and assuring security
Observation Method	・ Method：GPS Kinematic ・ Reception Frequency: One second ・ Observation Period: 6:00〜18:00 (12 hours continuously)	No Change	
Equipment Used	Trimble R6 (Six sets)	Trimble R6 (Fourteen Sets)	The number of GNSS bases stations was increased.
Specifications of the GNSS Base Stations	・ Method：GPS Static ・ Classification: Secondary (B) ・ Accuracy：1/100,000	No Change	Adopted the Department Survey Regulations, Fifth Edition, March 2015

Table 3-18 GNSS Base Stations

Base station number	Location name	Note
Base 01	Gampha	
Base 02	Rewanwella	
Base 03	Nuwaraeliya	
Base 04	Budulla	
Base 05	Colombo	Survey Department of Sri Lanka
Base 06	Kegalle	
Base 07	Diyatalawa	
Base 08	Kalutara	

(6)-4 Ground Checkpoints

A total of 316 points were selected using satellite images. To inspect and adjust the raw point cloud and to prepare a geoid model, the ground checkpoints were installed.

<A Plan in March 2015>

A ground checkpoint is planned to be installed one in every square area of 25 km^2 with a 5 km side in the whole survey area with a total area of 7,800 km^2. The total number of planned ground checkpoints is 316.

<Revised Plan after Field Reconnaissance>

The Project Team and C/P conducted field reconnaissance and selection of locations. The following number of ground checkpoints, installation method and specifications of the equipment were discussed and agreed with the C/P.

Table 3-19 Ground Checkpoint Survey (Plan and Revised)

	Plan in March 2015	Revised Plan	Note
Ground Checkpoints	316	321	
Used Equipment	Trimble R6 (Tree sets)	No change	
Specifications of the GNSS Base Stations	・Method: GPS Static ・Classification: Tertiary (C) ・Accuracy: 1/50,000	No change	Adopted the Department Survey Regulations, Fifth Edition, Adapted in March 2015.

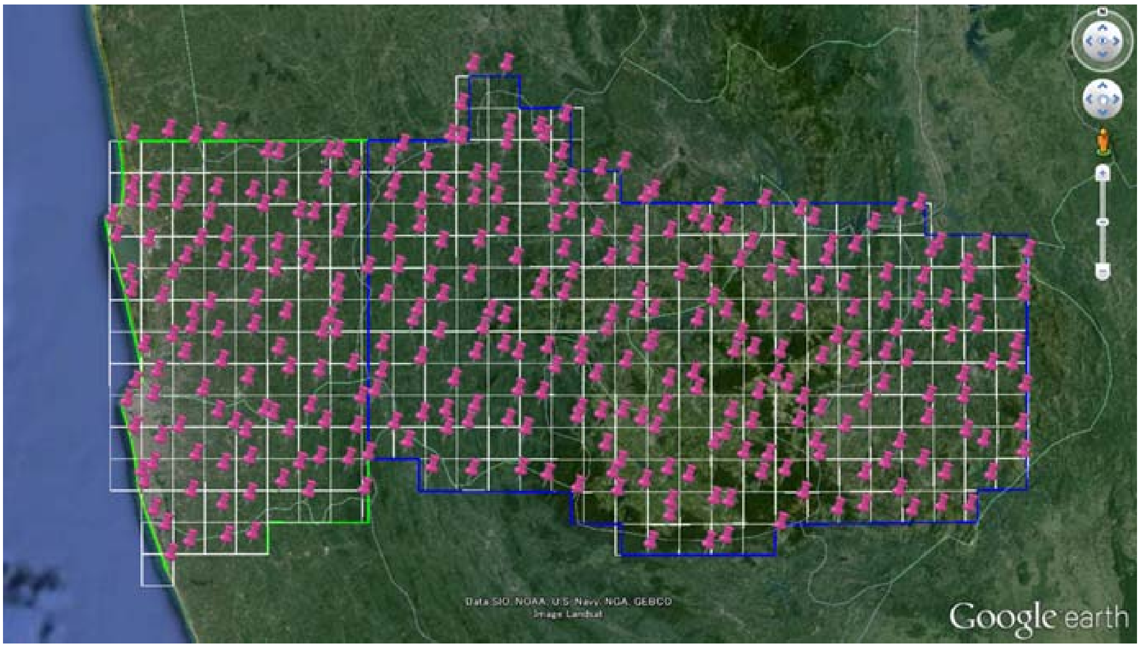

Figure 3-3 Selected Ground Checkpoints (Planned in March 2015)

(7) Installation of GNSS Base Stations and Ground Checkpoints

Based on the LiDAR Survey Plan, the Project Team and C/P surveyors commence the work installation and observation of GNSS base stations and ground checkpoints on October 28, 2015.

(7)-1 Installation of GNSS Base Station

By November 30, 2015, all the GNSS base stations were set up, and data reception was commenced on the first of December 2016 by the C/P when the Subcontractor started the LiDAR survey. In the beginning of the Project, only three base stations were planned. But thinking of the local situations after the study, the Project Team members decided to install seven GNSS base stations. The installation was completed in the late November, 2015. Due to the change of the survey area, one additional base station was installed in on February 20, 2016. A total of eight (8) base stations were installed.

From December 1, 2015, the base stations have observed the signal from 6:00 to 18:00 every day for 12 hours continuously. One base station was added to the area in Kalutara due to the change of the measurement area.

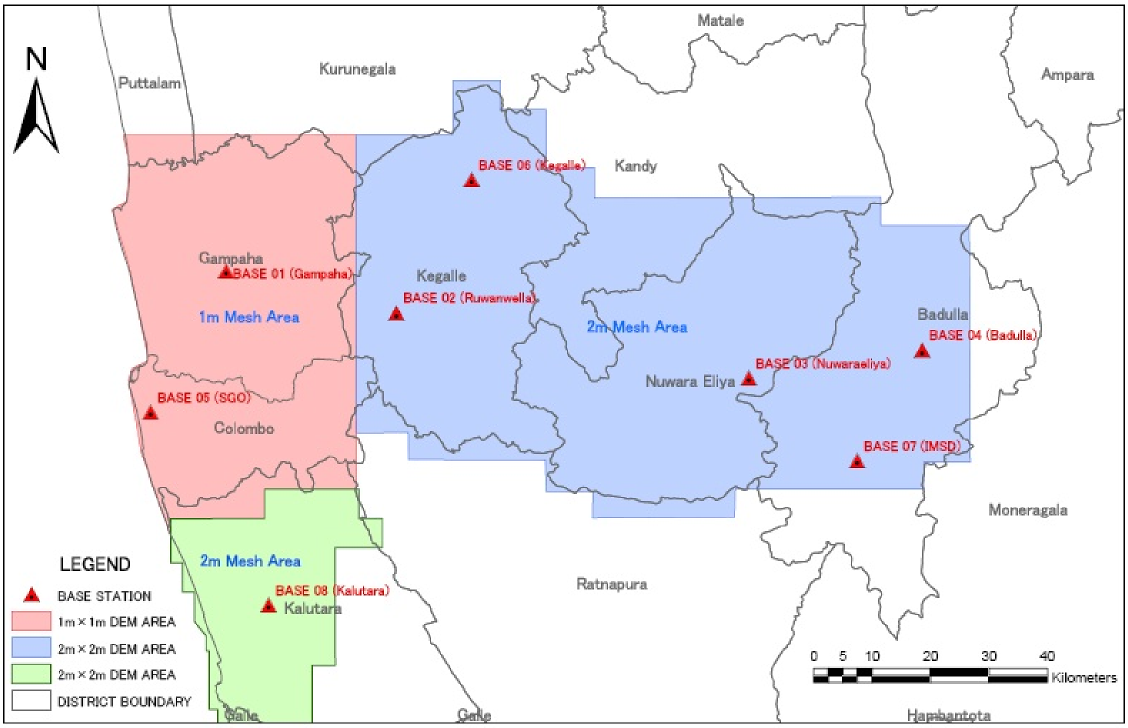

Figure 3-4 Distribution of the GNSS Base Stations

Table 3-20 Installed GNSS Base Stations

Station Name	WGS84 Latitude	WGS84 Longitude	WGS84 Ellipsoid Height (m)
BASE 01_Gampaha	N7°06'32.54633"	E79°59'24.48720"	-31.196
BASE 02_Ruwanwella	N7°02'42.09622"	E80°15'08.12071"	-75.761
BASE 03_Nuwara Eliya	N6°56'42.09006"	E 80°47'40.16113"	1771.677
BASE 04_Badulla	N6°59'16.99323"	E 81°03'41.64778"	558.295
BASE 05_Colombo	N6°53'30.92845"	E 79°52'26.21901"	-76.138
BASE 06_Kegalle	N7°15'02.25948"	E 80°22'05.01476"	9.389
BASE 07_Diyatalawa	N6°49'02.68716"	E 80°57'40.88000"	1164.366
BASE 08 Kalutara	N6°35'44.90676"	E80°03'20.27984"	-93.941

BASE 01_Gampaha

BASE 02_Ruwanwella

BASE 03_Nuwara Eliya

BASE 04_Badulla

BASE 05_Colombo

BASE 06_Kegalle

BASE 07_Diyatalawa

BASE 08_Kalutara

Photo 3-9 Installed Seven GNSS Base Stations

(7)-2 Installation of Ground Checkpoints

On March 16, 2015, the C/P and the Project Team held a coordination meeting. On June 7, 2015, the Project Team submitted an installation plan of the checkpoints. SDSL commenced the work on October 28, 2015. In the middle of January 2016, the survey area was changed because of the weak GPS signal reception in the mountainous area. On February 20, 2016 one base station was installed in the Kalutara district area, and 41 ground checkpoints were also added. By May 2016, installation of all the ground checkpoints was completed.

Table 3-21 Distribution of Checkpoints by District

District Name	Number of Installed GCP	Direct Levelling
Kandy	23	17
Nuwaraeliya	68	51
Kurunegala	5	5
Gampaha	64	62
Colombo	33	33
Kalutara	48	45
Kegalla	61	49
Rathnapura	10	5
Badulla	48	42
Total	360	309

Eight sets of Trimble R6 Receivers were used for GNSS observations and one set of Trimble Business Center software was used for GNSS data processing. The survey for the checkpoint installation was conducted based on the Specifications of SDSL: The classification is Tertiary (C); the precision is 1:50,000; the method of observation is GPS Static.

The locations of selected ground checkpionts are shown in the following diagram:

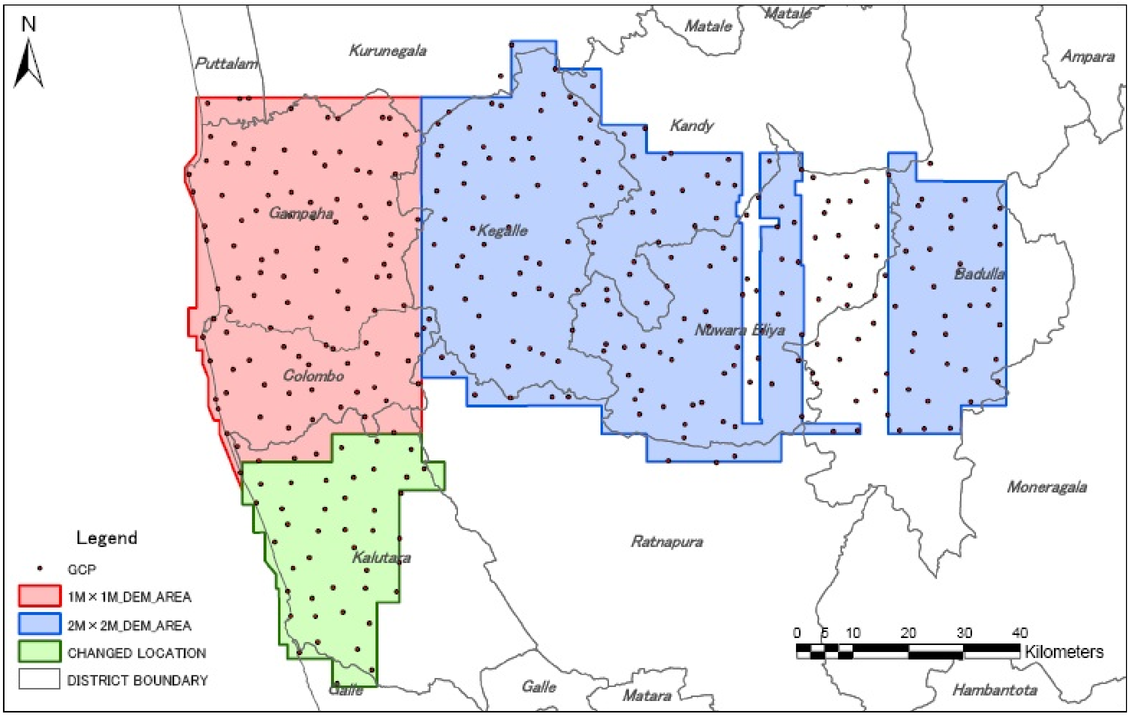

Figure 3-5 Installed Ground Checkpoints

(8) Implementation of LiDAR Survey

(8)-1 Subcontracting Work

The LiDAR survey was subcontracted and implemented since December 1, 2015 based on the agreements of: the Inception Report between the Project Team and C/P on March 10, 2015; the Specifications, GNSS base stations and ground checkpoints agreed on March 20, 2015. The contents, implementation method and procedure of the contract, supervision of subcontracting work and the outputs and inspection methods are summarized in the following table:

Table 3-22 Contents of Sub-Contract Project

1) LiDAR Survey Area (including the area for digital aerial photography)	1) 1 m x 1 m mesh:2,400 km^2 (Colombo District, Gampaha District and the surrounding areas) 2) 2 x 2 m mesh: 5,400 km^2 (Central mountainous area including Kandy District)
2) Survey Period	From December; 2015 to April 2016
3) Outputs	1) LiDAR Survey Data (GNSS, IMU, Laser Survey Observation Data) 1 set 2) 3D Survey Data (Kinematic Analysis, GNSS/IMU Analysis, BL/XY Conversion, Geoid Adjustment, Noise Removal, Data on which the rate of omission has been confirmed): 1 set 3) Digital Aerial Photographs: 1 set
4) Specifications	Public Survey—Operation Rules with Partial Amendment, 2013 (Geospatial Information Authority of Japan, Ministry of Lands, Infrastructure, Transport and Tourism)

(8)-2 Implementation Method and Contract Procedure

The subcontracting work for the LiDAR survey has started in December, 2015 and planned to be completed in April of 2016 to cover the entire project area both in 1 m x 1 x mesh area and 2 m x 2 m mesh area in accordance with the agreement on the Inception Report.

1) Procedure of the Subcontracting Work

In accordance with the "Guideline of Subcontracting Procedure in Consulting Contract" the Subcontractor has been selected.

On the 30th of March, 2015, the Project Team has explained the contents of the subcontracting work to the C/P, and discussed the details of the contents. (c.f. Coordination Meeting for Shortlisting.) Based on the past experiences of the members of the Project Team on LiDAR survey and aerial photography, five companies, that would be able to complete the work with their own LiDAR survey equipment, were shortlisted. The invitation letter was sent to those five companies. The opening of the bid started 10:00 am on the 15 of April, 2015 with an attendance of Mr. Shimano from JICA Sri Lanka Office. Out of three bidders, SKM GISAIR Oy was the lowest bidder within the planned contract amount with sufficient experience and equipment to execute the required work. The Project Team presented the technical specifications and draft contract and started contract negotiation with from 11:00 am on the same day. On May 11, 2015, the Project Team and SKM GISAIR Oy reach an agreement on the cost and the day of commencement. On the same day, the Project Team signed the contract with SKM GIAIR Oy as the Subcontractor for the work.

The process the selection is summarized it the following table.

Table 3-23 Selection of a Subcontractor

Date	Time	Procedure
March 20, 2015		Discusion on the Subcontract Work, Short-listing
April 1, 2015		Sending the Invitation Letter
April 6, 2015	17:00	Deadline for questions
April 8, 2015	17:00	Answering the questions
April 15, 2015	10:00	Reception of Bid Documents, Opening the Bid, Bid Evaluation (with representatives from JICA Sri Lanka Office)
April 15, 2015	11:00	Contract Negotiation
May 11, 2015		Singning the Contract

Photo 3-10 Selection of Subcontractor

2) Equipment and Implementation Structure of the Subcontracting Work

<Operation Structure of the Subcontractor>

The following persons are assigned for the work from December 1, 2015 to April, 2016.

Table 3-24 The Members of the Subcontractor

Role	Name
Project Manager	Mr. Inberg Jyrki Karl Olavi
Technical Manager	Mr. Kelly Neil Francis
LiDAR Survey Planning	Ms. Thebault Perrine Simone Deniise
Flight Management/LiDAR Operator	Mr. Gaillard Jean-Baptiste
Pilot/LiDAR Operator・Manager	Mr. Martinat Olivier Jean Raoul
Pilot/LiDAR Operator/Data Processing	Mr. Pain Tony Pierre
Pilot/LiDAR Operator/Data Processing	Mr. Broussouloux Eric
Pilot/LiDAR Operator/Data Processing	Mr. Ndrantomalaia Rabetrano Andrea
Pilot/LiDAR Operator/Data Processing	Mr. Beau Christophe
LiDAR Data Processing	Mr. Durand Marc Marie Noel
Airforce Security Officer/Pilot	Mr. Prasanna Kuruwita

1) The base airport of the aircraft is RATMALANA Airport.

2) LiDAR Survey Plan:

Technical Specifications included in the Contract; contract period; quantity; member; equipment used for the survey.

3) Safety Management Structure:

The contactor keeps daily report of work progress that includes weather; the report is submitted to the Project Team by email. On every Monday, progress of the work is discussed and the Project Team assures safety and makes necessary orders for safety assurance.

4) Emergency Contact and Safety Management Personnel in Colombo:

Office Address in Colombo (temporary):	Global Tower Hotel Room No.204, Marine Drive, Colombo 6, Sri Lanka
TEL:	+94-112591000
Safety Manager:	Mr. Inberg Jyrki Karl Olavi/Project Manager
Mobile Phone Number:	Number: +94-752634510
Email:	jyrki@inberg.co.th
Deputy Safety Manager:	Mr. Kelly Neil Francis/Technical Manager
Mobile Phone Number:	+94-768826517
Email:	nfk2@optusenet.com.au

5) Contact at the Air Force Security Office of at the RATMALANA Airport:

Security Officer:	Mr. Prasanna Kuruwita/CO8 Squadron
TEL:	+94-112495495
Mobile Phone Number:	+94-772229138

6) Contact in Finland

Address:	SKM GIS AIR Oy, Tehniikantie 12, 02150 Espoo, Finland
Contract:	Administration, Operation/Technology/Quality Management: Mr. Jukka Kangasmaa/Director
Mobile Phone Number:	+358-405049355
Email:	jukka.kangasmaa@skmgisair.fi
Safety Management:	Mr. Jussi Yrjola/ Managing Director
Telephone Number:	+358-44-3048175
Email:	jussi.yrjola@skmgisair.fi

3) Management of Subcontracting Work and Method of Inspecting the Outputs

The Administration Management Group, Team Leader and Deputy Team Leader of the Project Team, has managed the subcontracting work. LiDAR Measurement Planning/Measurement Specification/Technology Transfer1 and LiDAR Measurement/Technology Transfer 2 are the Project members in charge of managing the subcontracted work of the LiDAR measurement and inspection of the LiDAR measurement data. Those two members also inspects the flight line plan, measurement record, measurement daily report and monitor the progress of the subcontracted work.

Table 3-25 LiDAR Measurement Equipment and Data Inspection Item

[1] Inspection on the LiDAR Survey Equipment	・ Calibration ・ Pre-flight confirmation ・ Initialization of GPS/IMU ・ Data recording equipment
[2] Inspection of the LiDAR Survey Data	・ the data of the Kinematic Analysis and GPS/IMU analysis ・ the geodetic reference system and geoid conversion data ・ Flight paths ・ Possible omission of survey ・ Noise removal ・ Survey density (survey omission rate, survey omission rate due to waterbody polygons)

Table 3-26 List of Points

ID	Latitude (WGS84)	Longitude (WGS84)	Height (WGS84)
1	N6°50'42.28764"	E79°55' 8.79510"	-89.486
2	N 6°50'55.28234"	E 79°55' 5.60680"	-83.312
3	N 6°51' 7.71242"	E 79°55' 7.36198"	-87.412
4	N 6°51' 7.22488"	E 79°55'18.92492"	-82.859
5	N 6°50'43.80896"	E 79°55'17.06336"	-88.299
6	N 6°51' 7.62358"	E 79°55'29.39264"	-90.995
7	N 6°50'56.53039"	E 79°55'27.79507"	-77.602
8	N 6°50'39.93842"	E 79°55'33.28082"	-75.408
9	N 6°50'54.87925"	E 79°55'14.24118"	-83.931

Point Name	1		Operated by	EG.Udayalunmars
Date of Observation	27/11/2015		Checked by	
Coodinate System	WGS84			
Coordinate(m)	N			
	E			
Coordinate	Lat	6° 50' 42.28764"		
	Lon	79° 55' 08.79509"		
MSL.Height(m)			ELLIP.Height(m)	-89.486

Google Imege

Photo of Observation

Figure 3-6 Point Description

Figure 3-7 Ground Control Point Calibration Sites

Figure 3-8 Inspection of the LiDAR Measurement Data

4) Contents of the Subcontracting Work

i) Airborne-laser measurement

The measurement flight was carried out based on the LiDAR measurement plan as local weather conditions were accessed daily. Various piecies of weather information (a weather forecast, Airport METER, etc.) were used for judging implementation of the flight mission. The contents of measurement flight were reported daily to the persons concerned by evening on the same day.

ii) GNSS/IMU Processing

When the measurement data had been acquired, a GNSS baseline analysis for every flight was conducted using the receiving data of the GNSS base station uploaded and shared by the survey offices and the GNSS receiving data received from the aircraft.

The GNSS baseline analysis outputs the three-dimensional position of the aircraft in every second. Further, by conducting the integrated process of the IMU data, the flight path data, which are the basis of the laser measurement data, are acquired.

iii) The measured raw data (point-cloud data) preparation

The measured raw data were prepared using the precise time information as the distance-and-angle data were referred to make the point clouds. The measured raw data are usually prepared by flight path. The Subcontractor submitted the processed measurement raw data every week in principle to the Project Team. The Project Team members conducted inspection upon reception of the data.

(8)-3 Disturbance on GNSS Signal Reception

On January 22, 2016, the Subcontractor reported a problem of GNSS signal reception to the Project Team.

The report said that on January 15, 2016, when the LiDAR survey was conducted in the mountainous area in the middle of the survey area, the GPS receiver on board of aircraft was unable to receive the GNSS signals from the satellites in the area in the red shade. After the incident, the Subcontractor reported that they could not receive the GNSS signals as shown in the flight line chart.

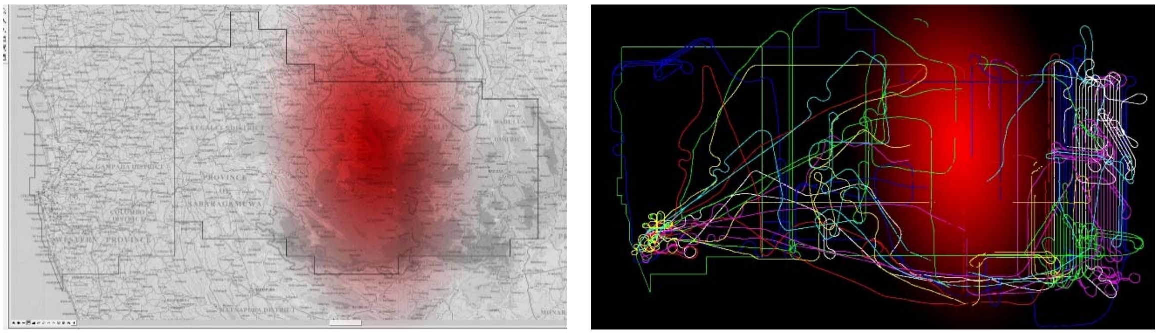

Figure 3-9 Jamming Area

The Project Team requested SDSL to investigate the cause of the wave hindrance. SDSL began investigation. The Sri Lanka Air and Aviation Service (AASL) has interrupted the service temporarily to seek the cause of the hindrance. The Subcontractor has flown the area over again, but the situation did not change. The cause has not been identified.

Photo 3-11 Telecommunication Tower

SDSL requested the Telecommunication Regulatory Commission of Sri Lanka (TRCSL) to investigate the cause of the radio wave hindrance.

The Sri Lanka Rupayahini Corporation (SLRC) has reported that they have not changed any service in January, 2016.

SDSL has been investing the cause since February 12, 2016 as requesting related agencies, but SDSL reported to the Project Team that the cause had not been identified.

(8)-4 Result of Sub-Contracting Work

The survey work by the Subcontractor started on December 1, 2015 was completed on March 11, 2016 including the addition of the LiDAR measurement plan accompanying the change of the survey area due to GPS electric wave obstacle, and a survey flight.

Form 5 Flight Operation Report of Airborne LiDAR Measurement is a list record of survey flight work. The detailed measurement flight results of each day are organized separately in Form 4 Record of Airborne LiDAR Measurement.

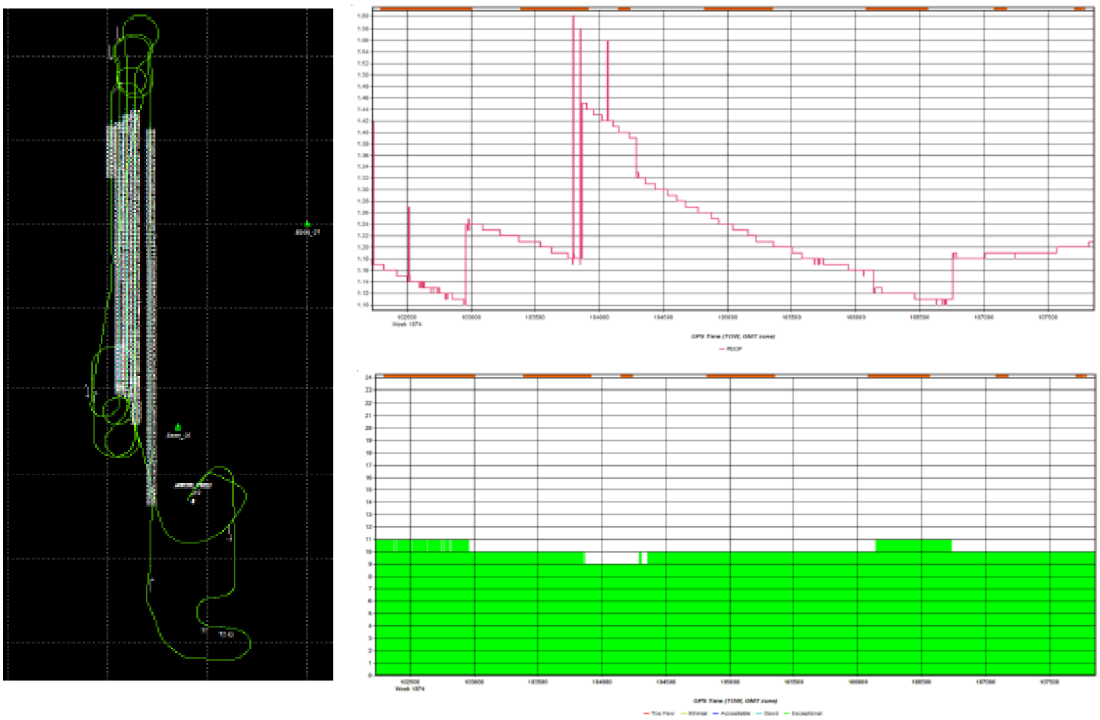

Figure 3-10 An Example of FORM4 Record of Airborne LiDAR Measurement

The Subcontractor conducted the calibration flight every two weeks to adjust the equipment to the precision levels required. The required boresight areas were independently setup; within the boresight, night control points were setup and marked. The aircraft flew over the area the same way for calibration. The following table shows the dates when the boresight calibration was conducted:

Table 3-27 Dates of Boresight Calibration Implementation

Year	2015			2016			
Flight Date	Dec 1	Dec 2	Dec 19	Jan 2	Jan 18	Feb 3	Feb 19

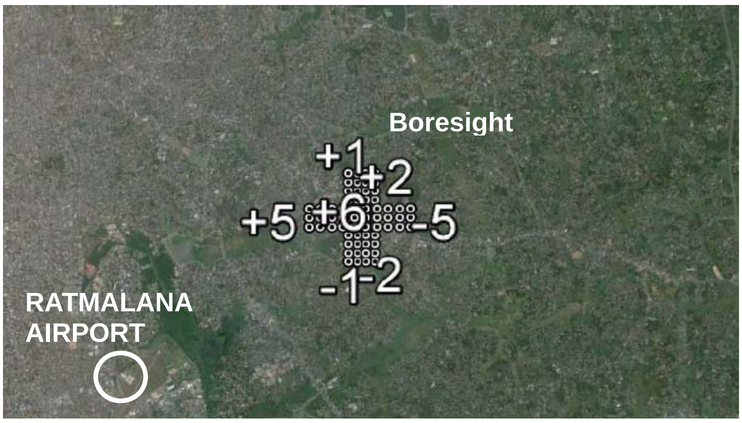

Figure 3-11 The Boresight Calibration Area (North-East of the Ratmalana Airport)

The Subcontractor inspected the measurement raw data and submitted to the Project Team every week. The Project Team members inspected the contents and area coverages every week. After receiving all the data, the Project Team inspected all the data, and the Contract work was completed in the middle of March 2016.

Table 3-28 The Final Result of the Contract Work

Area	Target Areas of LiDAR Measurement	Measurement Raw Data Completion Area
1 m x 1 m area (West area)	2,400 km^2	2,400 km^2
2 m x 2 m area (East area)	4,500 km^2	4,500 km^2
2 m x 2 m area (South area)	900 km^2	900 km^2
Total area	7,800 km^2	7,800 km^2

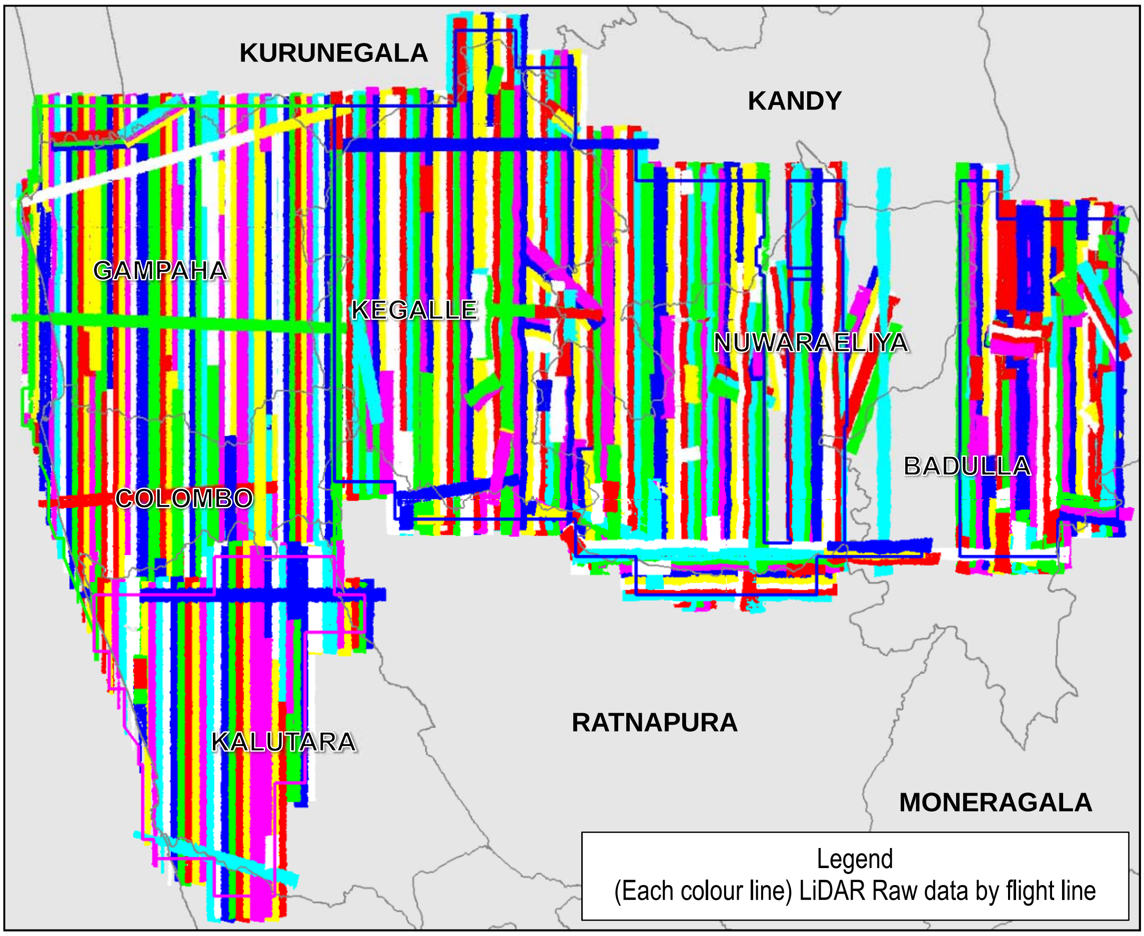

Figure 3-12 The Results of the Subcontract Work (LiDAR Measurement Raw Data)

(9) Preparation of Ortho-Photo Data

The ortho-photo data were created as satisfying the requirement shown in Table 3-29 using: (1) The digital aerial images captured, simultaneously with the LiDAR measurement, using the camera on-board of the aircraft; (2) the position-and-orientation information; and (3) the raw point clouds

For the areas other than the planned areas within the Project period, all the data acquired during the measurement have been ready for SDSL to produce ortho-photo data as reviewing the manual provided during the training. The Project Team has confirmed that all the data required for ortho-photo production have covered the entire LiDAR survey areas.

Table 3-29 Result of Ortho-Photo Data Preparation

Area	LiDAR Measurement Target Areas	Ortho-Photo Data Preparation Areas	GSD of Ortho-Photo Data
1 m x 1 m area (West area)	2,400 km^2	2,400 km^2	25 cm
2 m x 2 m area (East area)	4,500 km^2	800 km^2	50 cm
2 m x 2 m area (South area)	900 km^2	0 km^2	-
Total area	7,800 km^2	3,200 km^2	25 cm/50 cm

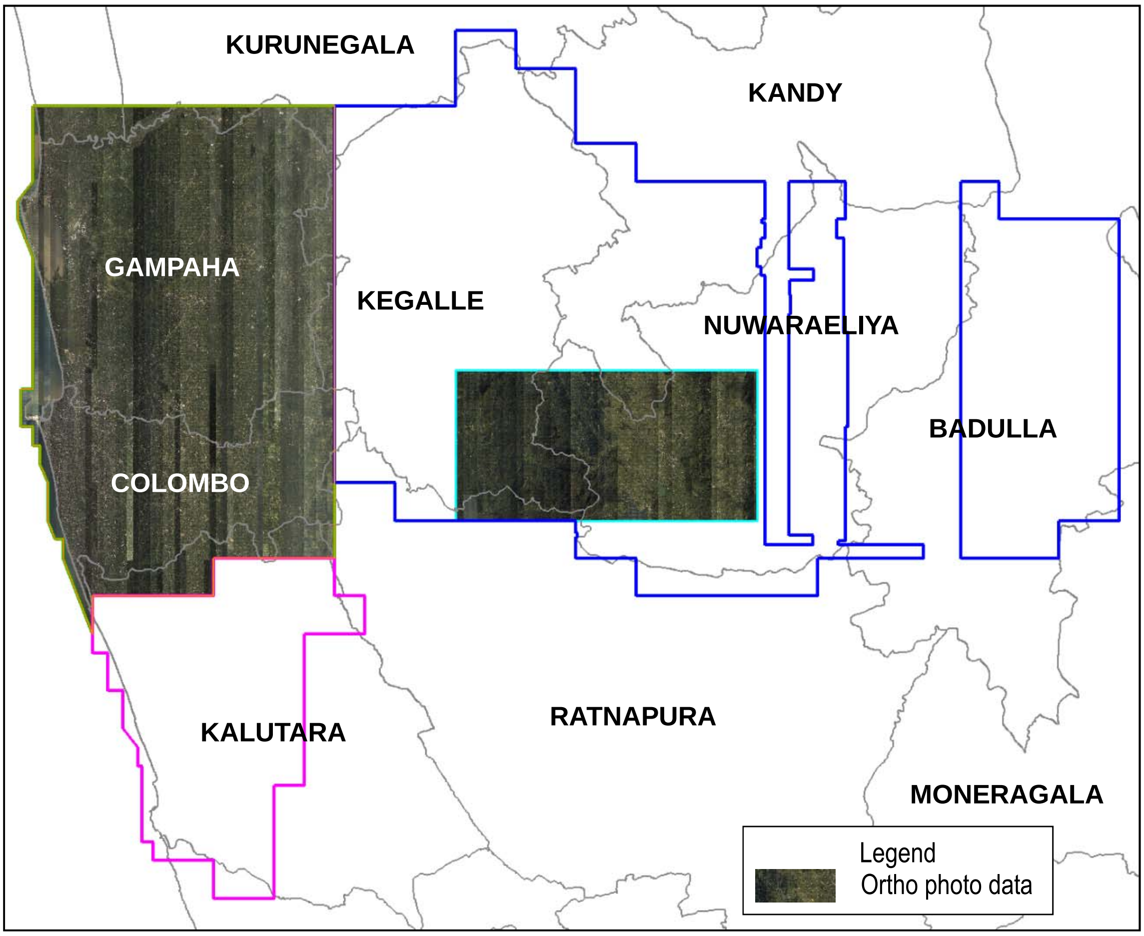

Figure 3-13 Ortho-Photo Data Preparation Areas

(10) Preparation and Inspection of 3D Measurement Data (Raw Point Cloud)

The raw point clouds have been prepared from the raw LiDAR measurement data received from the Subcontractor. Various inspection works have been conducted.

The raw point clouds have been prepared in the entire survey area, since the data processing has been conducted by measurement lines and inspection works needed to be conducted.

Table 3-30 Result of Raw Point Cloud Preparation

Area	LiDAR Measurement Target Areas	Areas for Raw Point Cloud Preparation	Note (Actual Areas of Raw Point Cloud Data Preparation)
1 m x 1 m area (West area)	2,400 km^2	2,400 km^2	
2 m x 2 m area (East area)	4,500 km^2	800 km^2	4,500 km^2
2 m x 2 m area (South area)	900 km^2	0 km^2	900 km^2
Total area	7,800 km^2	3,200 km^2	7,800 km^2

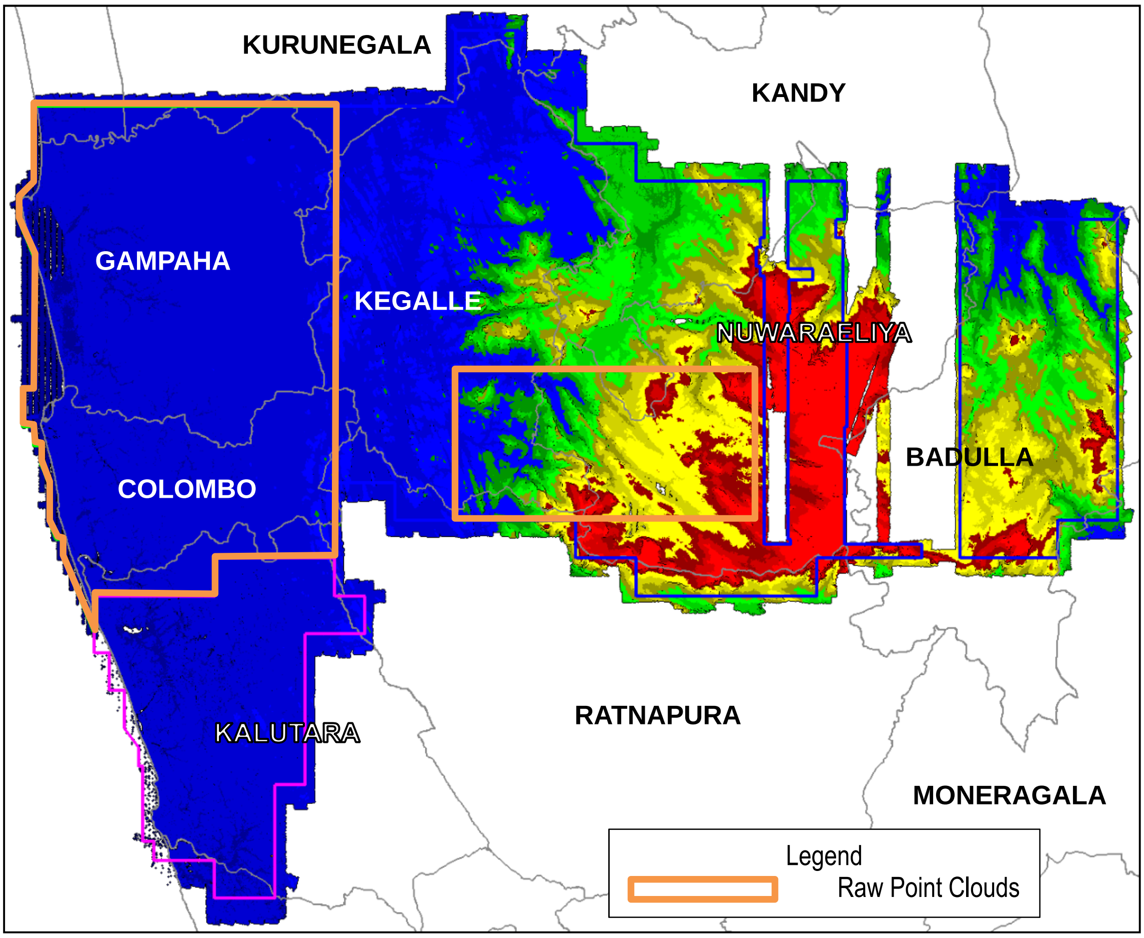

Figure 3-14 Areas of Raw Point Cloud Preparation

Tentatively, the raw point clouds with the UTM Zone 44N coordinates and the WGS84 ellipsoid were produced from the raw measurement data. The coordinates of the point clouds are converted from UTM44N to SLD99. The heights are both the heights from the ellipsoid.

Since the data of the point clouds became too large to be handled using a personal computer, the data were divided to the size of a 1/5,000 map sheet which is a fourth of the 1/10,000 map sheet which is the basic scale of SLD99.

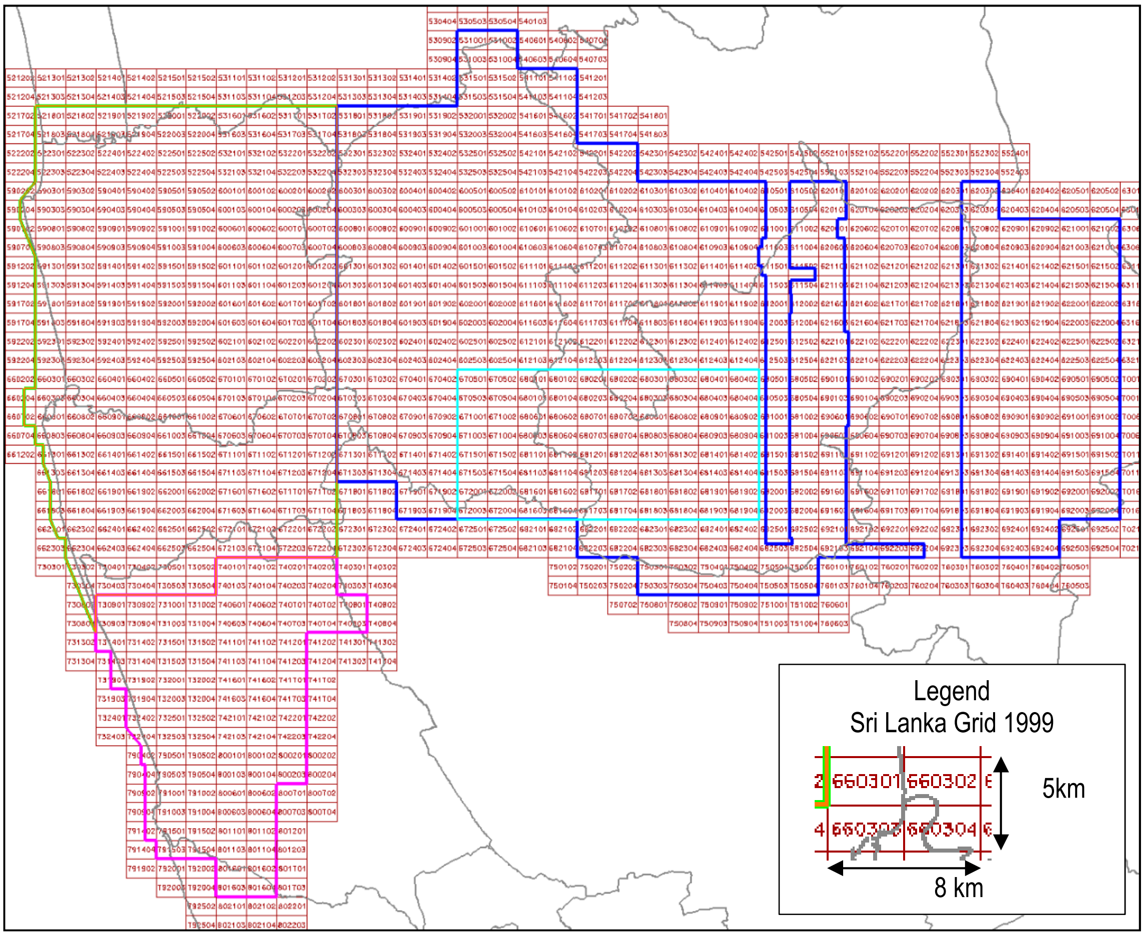

Figure 3-15 LiDAR Data Management Sheet (based on Sri Lanka Grid 1999)

(11) Post-Processing of Raw Point Cloud

(11)-1 Verification of Elevation (Ellipsoid Height)

Since in the beginning of the Project, the geoid model was not available; therefore, the geoid adjustment could not be conducted to the raw point clouds.

Because of the difficulty, a comparative adjustment was conducted using the ellipsoid heights of the checkpoints and the ellipsoid heights of the raw point clouds. The results of the adjustment are shown in Table 3-31.

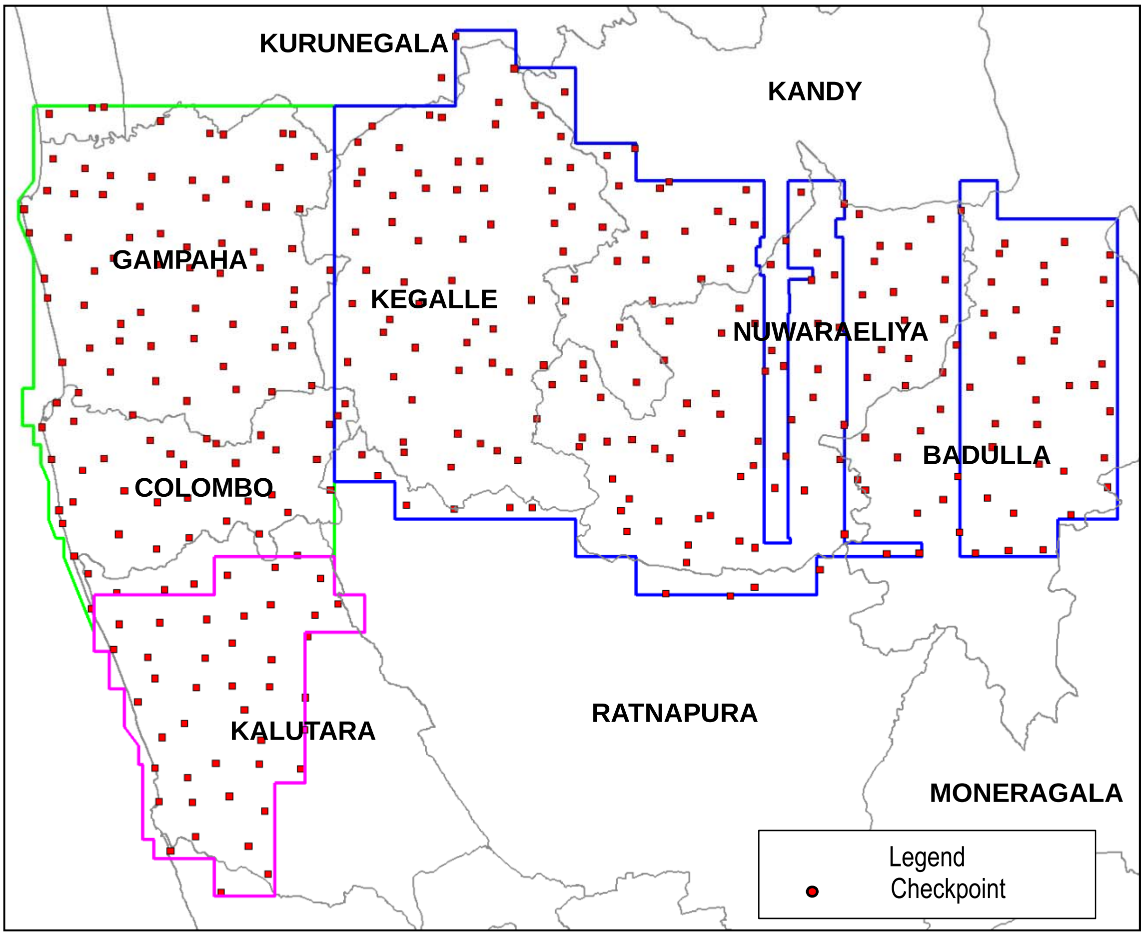

Figure 3-16 Verification Points of Checkpoints

Table 3-31 Differences from the Ellipsoidal Heights of the Final Checkpoints

dZ	West area	East area	South area
Mean	0.105 m	0.006 m	0.025 m
Standard deviation	0.077 m	0.136 m	0.118 m
Min	-0.174 m	-0.286 m	-0.278 m
Max	0.378 m	0.309 m	0.290 m
Shift applied	-0.120 m	-0.250 m	0.000 m

(11)-2 Verification of Elevation between Flight Paths

Inspection of differences to the height direction was conducted to the raw point clouds where the data were overlapped parts.

Excluding the mountainous areas where appropriate points could not be found, one point was selected at an interval of approximately 10 km of a flight path on a flat area.

The locations of the verification points are shown in Figure 3-17. The exact values of the differences are recorded using Form 11.

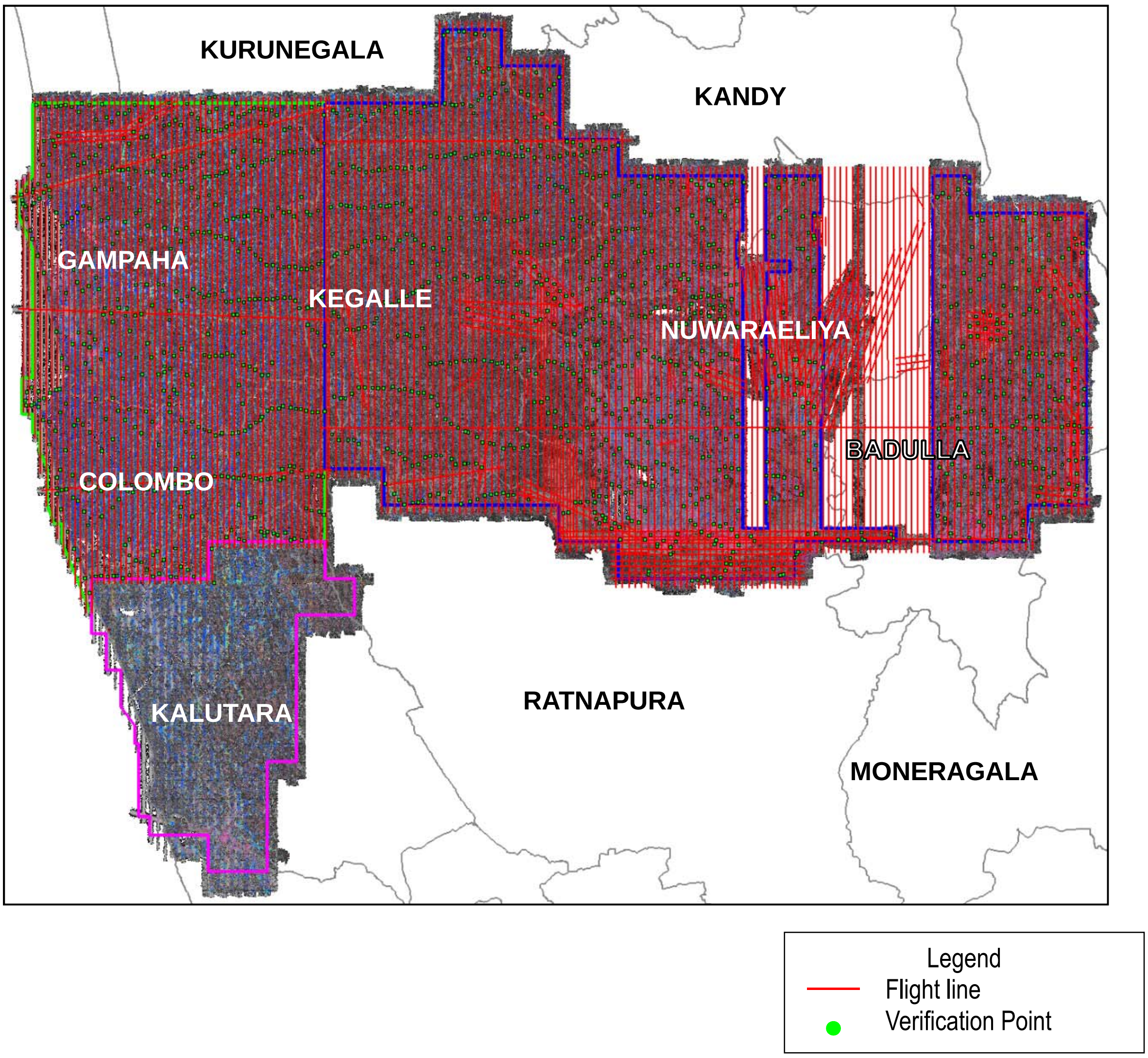

Figure 3-17 Verification Points of Differences between the Flight Paths

(11)-3 Verification of Possible Omission of Measurement

All the raw point cloud data in the survey areas were extracted and inspected visually on missing data or omission of measurement. The basic work areas excluded the areas where the GPS signal disturbance. Water bodies and shade areas where the laser reflection could not be received are not included as inspection areas.

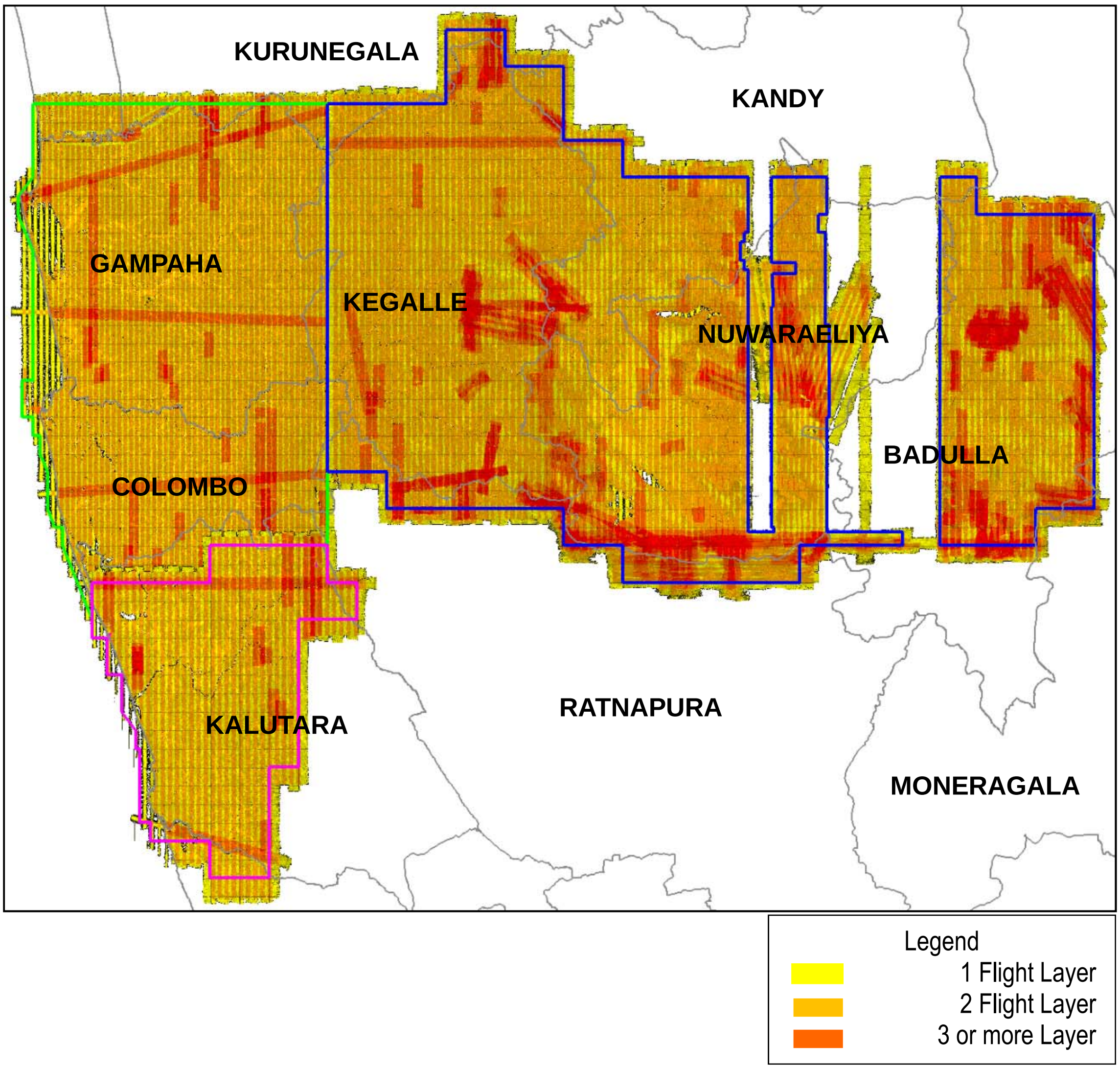

Figure 3-18 Inspection of the Measurement Omission

(11)-4 Calculation of the Measurement Loss Ratio

The Project Team has calculated the laser measurement point densities in the survey areas to verify if the densities satisfied the Specifications. The measurement-loss ratios were calculated by a map sheet unit. The point density of the LiDAR measurement was inspected within the measurement areas. The inspection was conducted in a way to confirm the range of the measurement loss ratios which needed to be within the tolerance levels in accordance with the Specifications. The measurement loss ratios were calculated by a map sheet within the DEM preparation areas; in this process, water areas were excluded from the calculation.

The maximum values and the values in the Specifications by areas based on the grid intervals are listed in Table 3-32.

Table 3-32 Measurement Loss Ratios (values in the Specifications and the Maximum Value)

Area Grid Interval (DEM)	Measurement Loss Ratio calculated area	Measurement Loss Ratio (Specification)	Measurement Loss Ratio (Max result)
1 m x 1 m area (West area)	2,400 km^2	15% or less	8.7%
2 m x 2 m area (East area)	800 km^2	10% or less	0.7%
2 m x 2 m area (South area)	0 km^2	10% or less	-

(11)-5 Preparation of the Geoid Model

A new geoid model was prepared in the Project using the differences between the SLD99 ellipsoid heights and values from leveling of each checkpoint values. Outliers in the results of checkpoint values were excluded in developing the model as the points were interpolated.

(11)-6 Geoid Adjustments

The geoid-adjustment model was prepared from the geoid model prepared above. Using the model, the geoid adjustment was performed to the three-dimensional survey data of SLD99 ellipsoid height. The final results of the raw point clouds with the SLD99 values have prepared.

(11)-7 Verification of Elevation

All the leveling results of the final checkpoint data and the raw point data after the geoid adjustments were compared and verified. The results of the comparative verification for each checkpoint were recorded to Form 9, and the all the results of checkpoints were organized in Form 10. If the differences between the GCP heights above from the sea level and the laser leveling heights exceed one meter, the values are judged as errors, and they were excluded. The errors are colored in red in Form 10.

Table 3-33 Verification of Elevations

Area Grid Interval (DEM)	Verification of Elevation area	Vertical Accuracy RMS (Specification)	Vertical Accuracy RMS (Max result)
1 m x 1 m area (West area) DEM Processing Area	2,400 km^2	0.3m or less	0.12m
2 m x 2 m area (East area) DEM Processing Area	800 km^2	1.0m or less	0.34m
2 m x 2 m area (East area)	(4,600 km^2)	1.0m or less	(0.19m)
2 m x 2 m area (South area)	(900 km^2)	1.0m or less	(0.19m)

(12) Unclassified Point Cloud Preparation and Inspection

The raw point cloud data are divided, organized and saved by a map sheet unit. After noise removal, the unclassified point clouds were prepared.

The unclassified point clouds are randomly distributed point data of all the planimetric features on the ground. Using the data, the ground data are prepared that are require for DEM data production.

Table 3-34 Results of the Unclassified Point Cloud Preparation

Area	LiDAR Measurement Target Areas	Areas for Unclassified Point Cloud Preparation
1 m x 1 m area (West area)	2,400 km^2	2,400 km^2
2 m x 2 m area (East area)	4,500 km^2	800 km^2
2 m x 2 m area (South area)	900 km^2	0 km^2
Total area	7,800 km^2	3,200 km^2

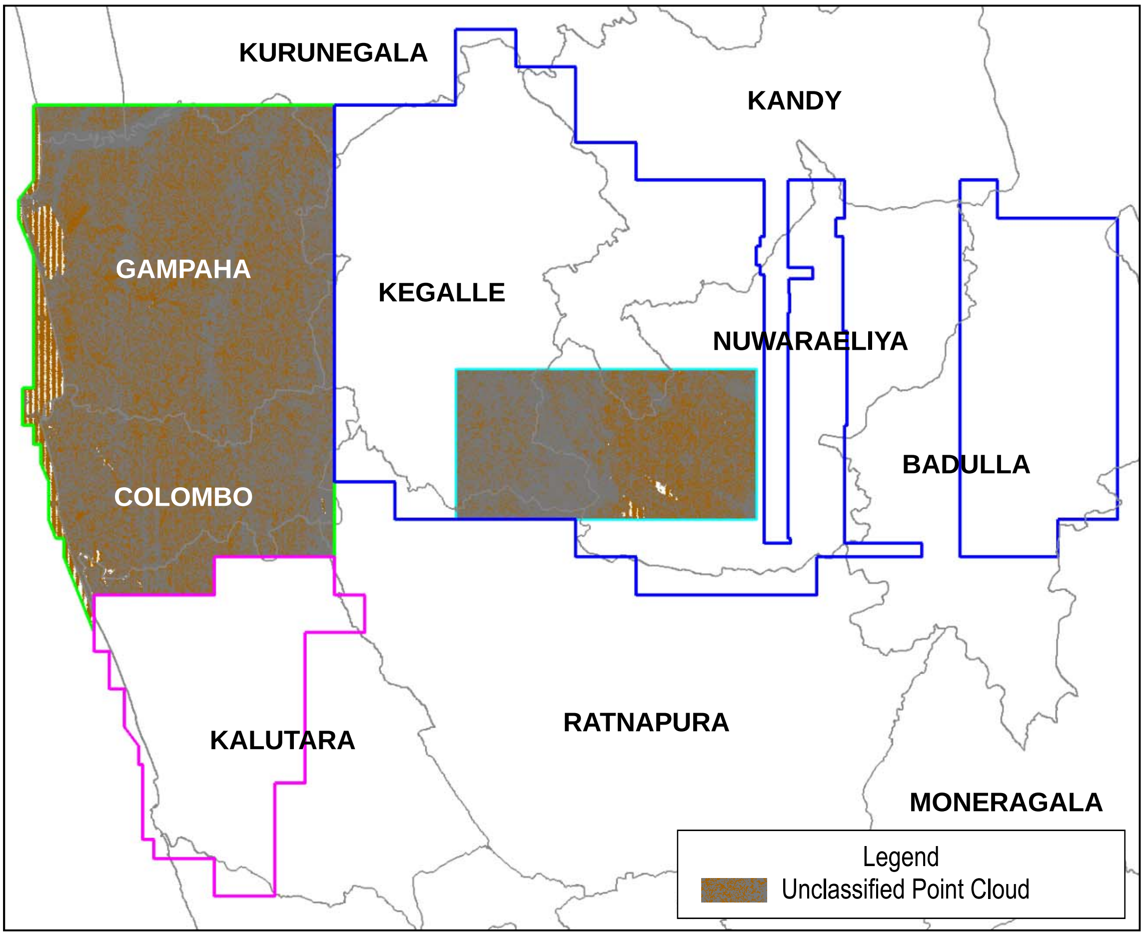

Figure 3-19 Areas for Unclassified Point Cloud Preparation

Figure 3-20 An Example of Unclassified Point Clouds (Birds' Eye View)

(13) Ground Data Preparation

Automatic filtering processing and interactive-filtering processing were performed to the prepared unclassified point cloud, and the ground data was prepared. The results were visually verified by a data processing engineer. When an error is found, the engineer interactively edits the data to finalize the ground data preparation.

Table 3-35 Results of Ground Data Preparation

Area	LiDAR Measurement Target Areas	Ground Data Preparation Areas
1 m x 1 m area (West area)	2,400 km^2	2,400 km^2
2 m x 2 m area (East area)	4,500 km^2	800 km^2
2 m x 2 m area (South area)	900 km^2	0 km^2
Total area	7,800 km^2	3,200 km^2

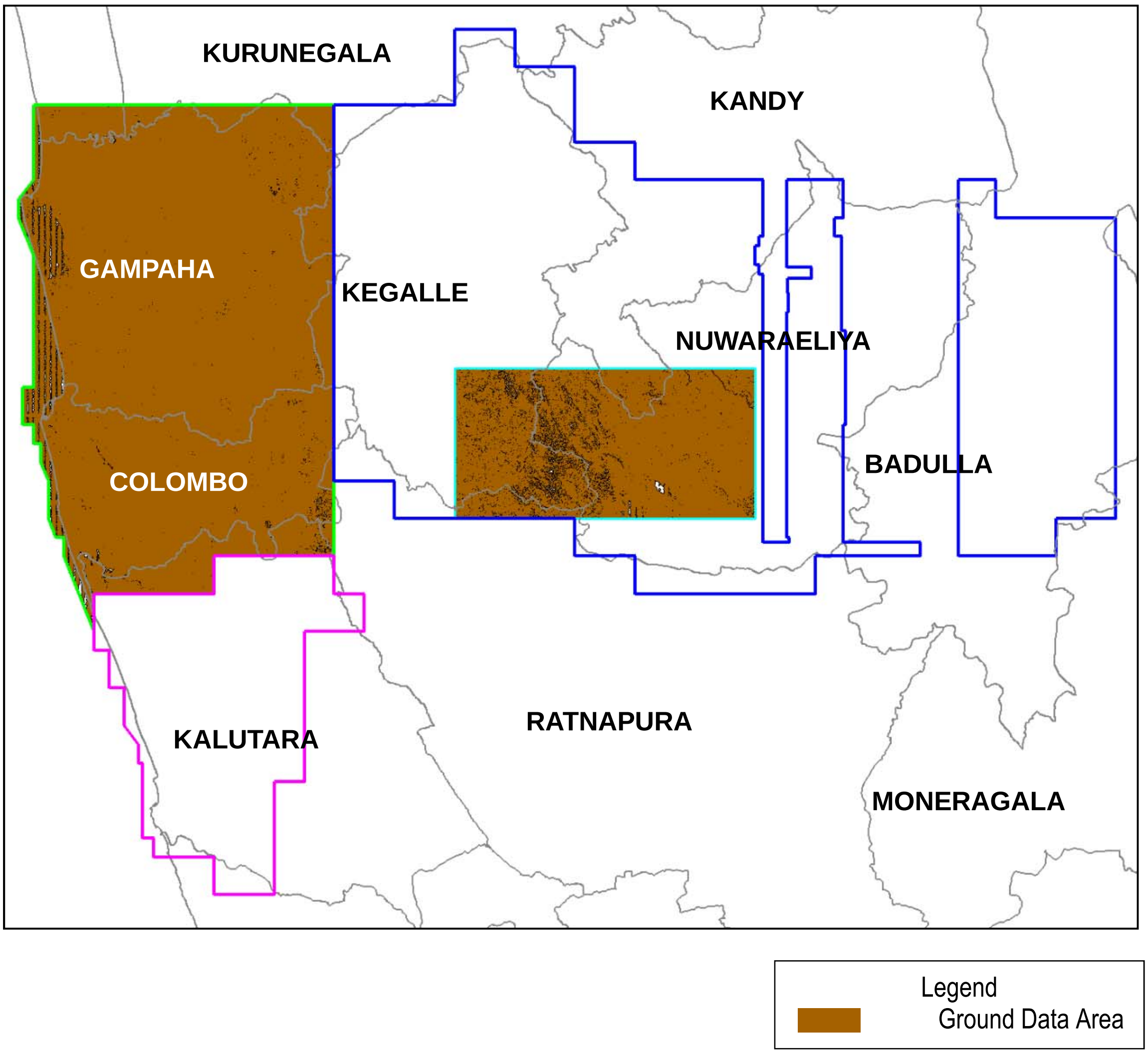

Figure 3-21 Ground Data Preparation Areas

Figure 3-22 An Example of Ground Data (Birds' Eye View)

The ground data after interactive filtering were visually inspected. Further, relief maps for verification have been prepared to inspect a large area in three dimensional viewing. The results of correction have been organized using Form 14. Figure 3-23 shows an example of ground data inspection using a relief map:

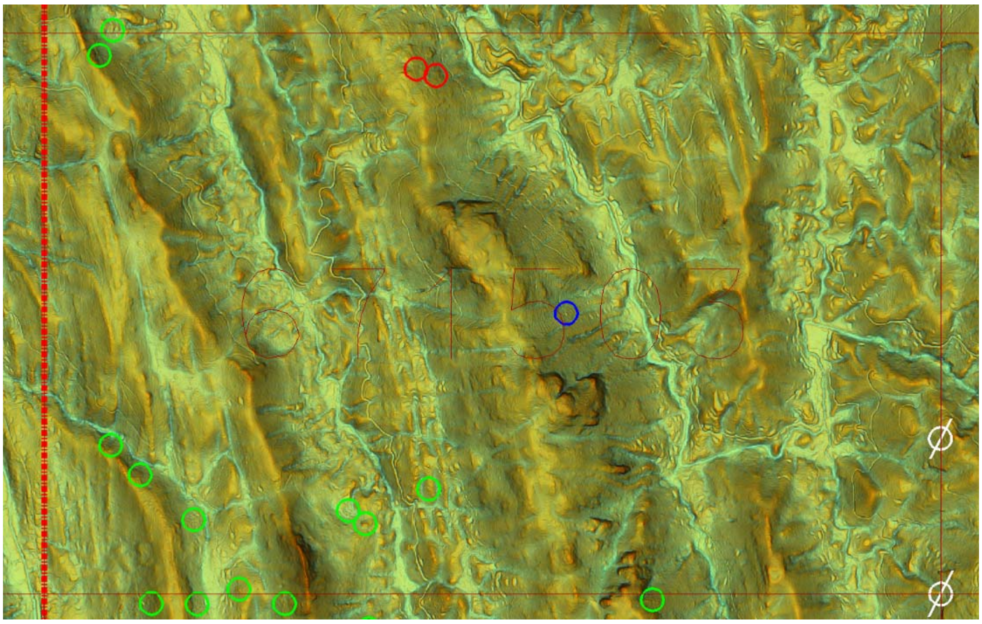

Figure 3-23 An Example of Ground Data Inspection Work using a Relief Map

(14) DEM Data Preparation and Utilization

(14)-1 DEM Data Preparation

Using the ground data, the DEM data, the elevation data of a mesh, were prepared as utilizing the TIN interpolation method.

Table 3-36 Results of DEM Data Preparation

Area	LiDAR Measurement Target Areas	DEM Data Preparation Areas	Note (mesh size)
1 m x 1 m area (West area)	2,400 km2	2,400 km2	1 m mesh
2 m x 2 m area (East area)	4,500 km2	800 km2	2 m mesh
2 m x 2 m area (South area)	900 km2	0 km2	
Total area	7,800 km2	3,200 km2	

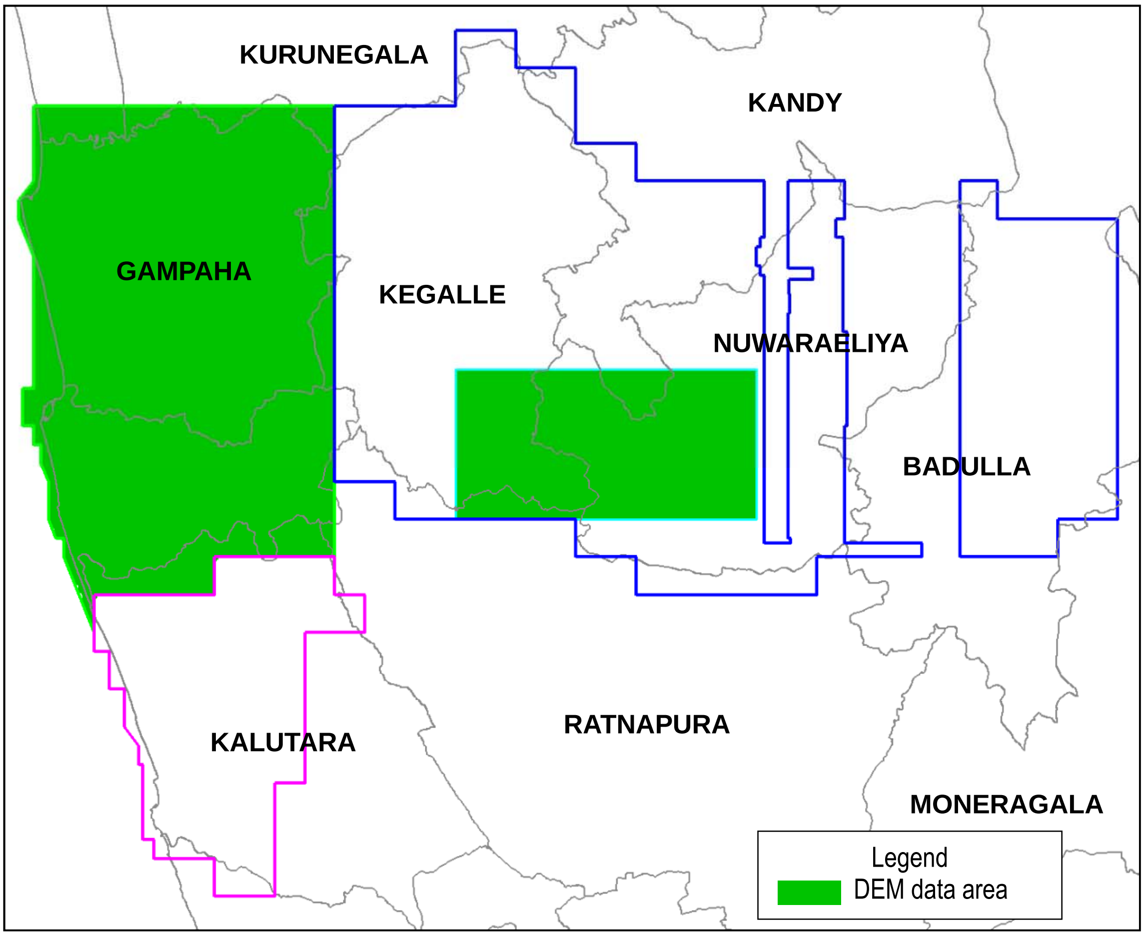

Figure 3-24 DEM Data Preparation Areas

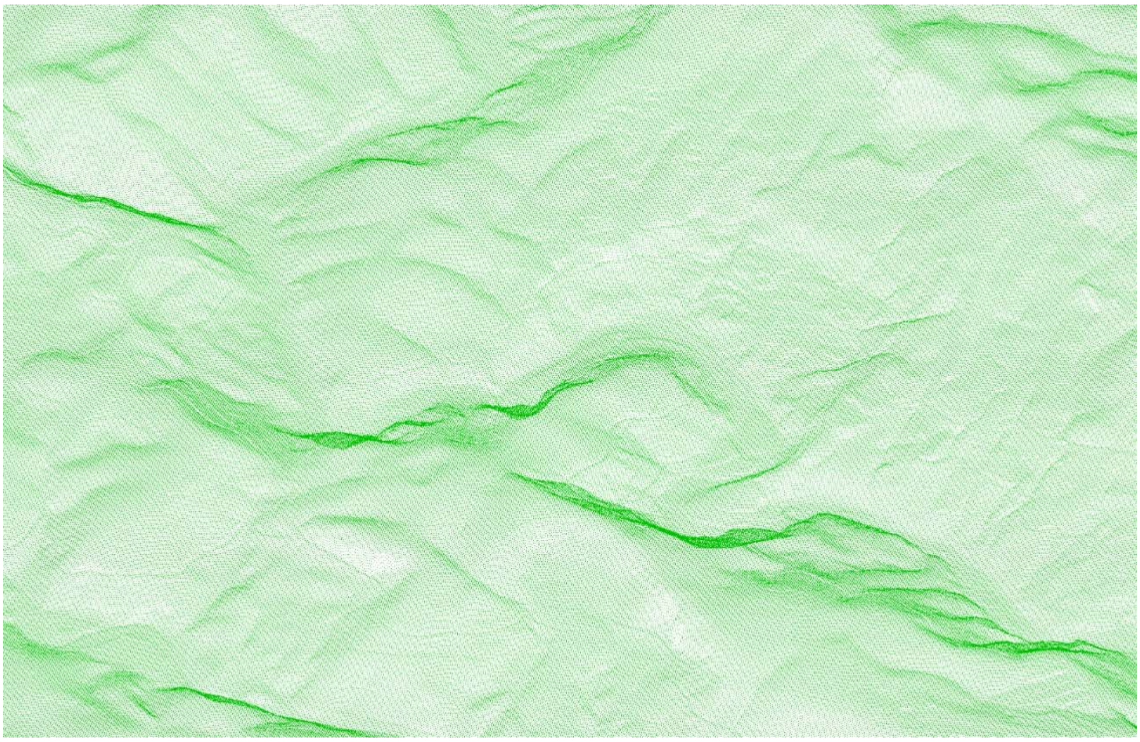

Figure 3-25 An Example of DEM Data (Birds' Eye View)

(14)-2 Verification of the DEM Data Precision by SDSL

In accordance with the agreement during the discussion of the Interim Report, the Project Team has submitted the draft DEM data of four areas in the 1 m x 1 m mesh area on 21 March, 2015. SDSL examined the data as it compared with the leveling data at corresponding locations. SDSL reported that the DEM data satisfied the precision stated in the Specifications as submitting a verification report.

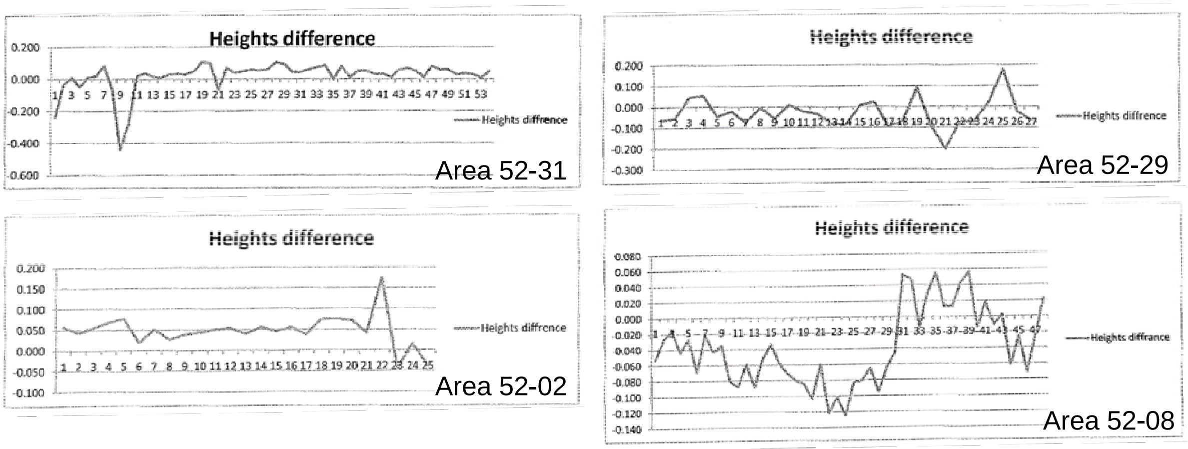

Figure 3-26 Results of Verification of the DEM Data Precision

Table 3-37 Results of Verification of the DEM Data Precision

Draft DEM Data	Validation Point	Heights RMS Error	Specifications
Area 52-31	54 points	0.09 m	0.30 m or less
Area 52-29	27 points	0.08 m	
Area 52-02	25 points	0.06 m	
Area 52-08	48 points	0.06 m	

(14)-3 DEM Data Utilization

1) Department of Survey

SDSL updated 1:5,000 town maps in 17 urban municipalities as requested by DMC. In 2016, in 22 urban municipalities, town maps at a scale of 1:5,000 will be prepared and updated. Within 22 urban municipalities, in seven municipalities, the DEM data prepared in the Project are planned to be used. Low land areas are prioritized, since the request was from DMC.

Table 3-38 Updating the Contour Lies for the Town Maps (1:5,000)

No	Council Name	District	DEM
1	Moratuwa MC	Colombo	2015 (New) 2016 (Update)
2	Kolonnawa MC	Colombo	2016 (New)
3	Kaduwela MC	Colombo	2016 (New)
4	Negambo MC	Gampaha	2016 (New)
5	Gampaha MC	Gampaha	2016 (New)
6	Homagama PS	Colombo	2016 (New)
7	Kaluthara UC	Kaluthara	2015 (New) 2016 (Update)

MC: Municipal Council
UC: Urban Council
PS: Pradeshiya Sabha (a local government unit)

2) DMC (Disaster Management Center)

A Risk Profiling Project will be implemented budgeted domestically. The purpose is risk assessment that unifies information on risks on development activities. More specifically, it is to carry out the national risk assessment strategy, identification of hazards and risk assessment using scientific methods at the national and local levels of governments. The projects to be implemented from 2016 are flood risk profiling in six river basins, and multi-hazard risk profiling in 22 urbanized areas. The base maps to be used in these projects are the topographic maps at the scale of 1/10,000. In urbanized areas, 1/5,000 scale topographic maps are planned to be used. The DEM data will be utilized for updating the contour lines for 1/5,000 topographic maps.

3) Irrigation Department

With the financial assistance from the World Bank, Irrigation Department has started the Comprehensive Climate Resilience Improvement Project (CRIP). The work in Component 1 will prepare investment plans in ten river basins; in the Component 2, a public education regarding climate risk. The LiDAR data, produced in the Project, are planned to be used for two river basins among ten river basins (Catchment areas: Kelani Ganga and Attanagalu Oya; and Maha Oya and Mahaweli Ganga). The DEM produced in the Project will be used in hydrology and hydraulic models. In other eight river basins, the DEM data from a LiDAR project implemented by the World Bank are planned to be used.

4) NBRO（National Building Research Organization)

NBRO is planning to use the DEM to identify hazard areas as it is planning to use the DEM data to be prepared in all the LiDAR measurement areas, but specific areas have not been prioritized. A specific data use from the Project was for the analysis of the landslide areas cause by heavy rain in the early May, 2016.

(15) Contour Line Data Preparation

Using the DEM data, contour line data are generated using a function of software. The areas and contour intervals for each area are summarized in the following table.

Table 3-39 Results of Contour Line Data Preparation

Area	LiDAR Measurement Target Areas	Contour Line Data Preparation Areas	Note (Contour Line Interval)
1 m x 1 m area (West area)	2,400 km^2	300 km^2 (2100 km^2)*	Intermediate 1m; Index 5m
2 m x 2 m area (East area)	4,500 km^2	100 km^2	Intermediate 2m; Index 10m
2 m x 2 m area (South area)	900 km^2	0 km^2	
Total area	7,800 km^2	400 km^2	

* SDSL produced the contour line data in 2,100 km^2 within the 1 m x 1 m mesh area, after the technology transfer was completed.

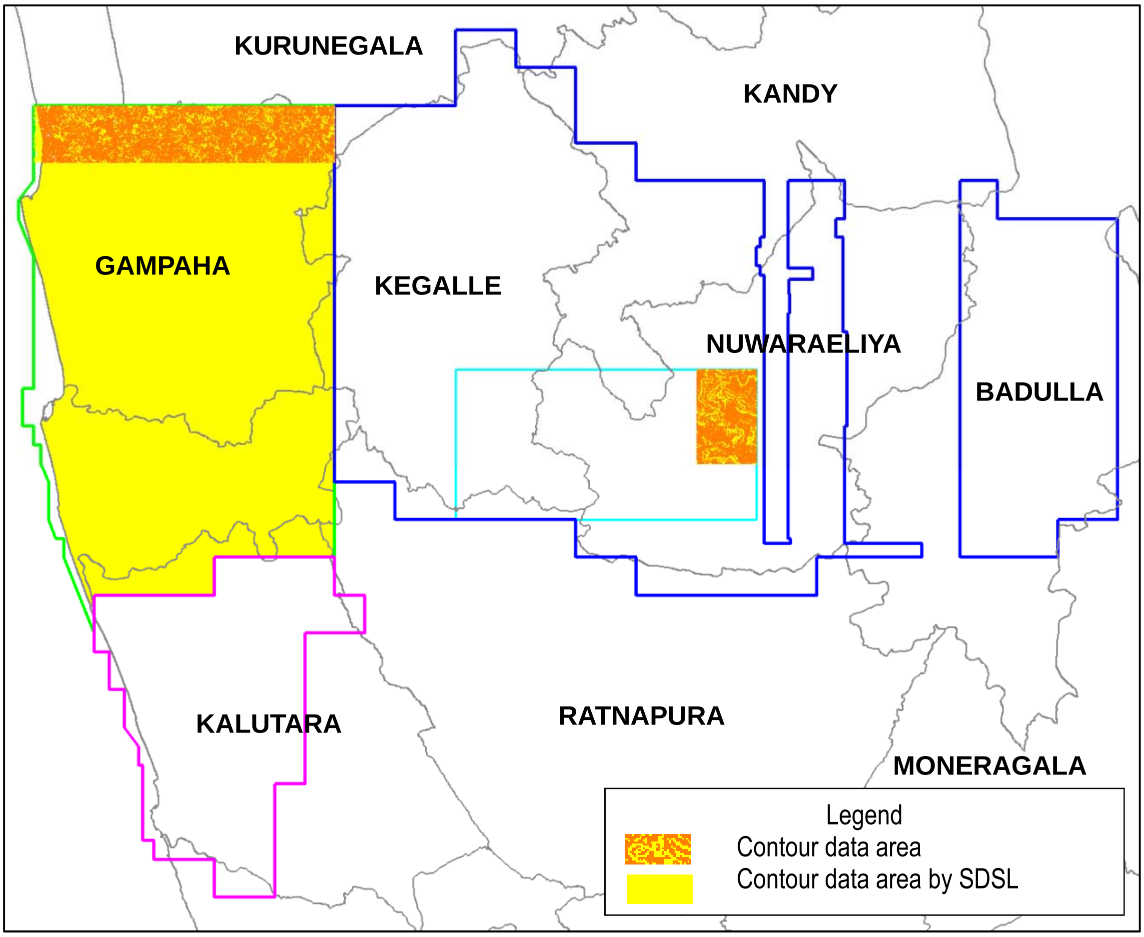

Figure 3-27 Contour Line Data Preparation Areas

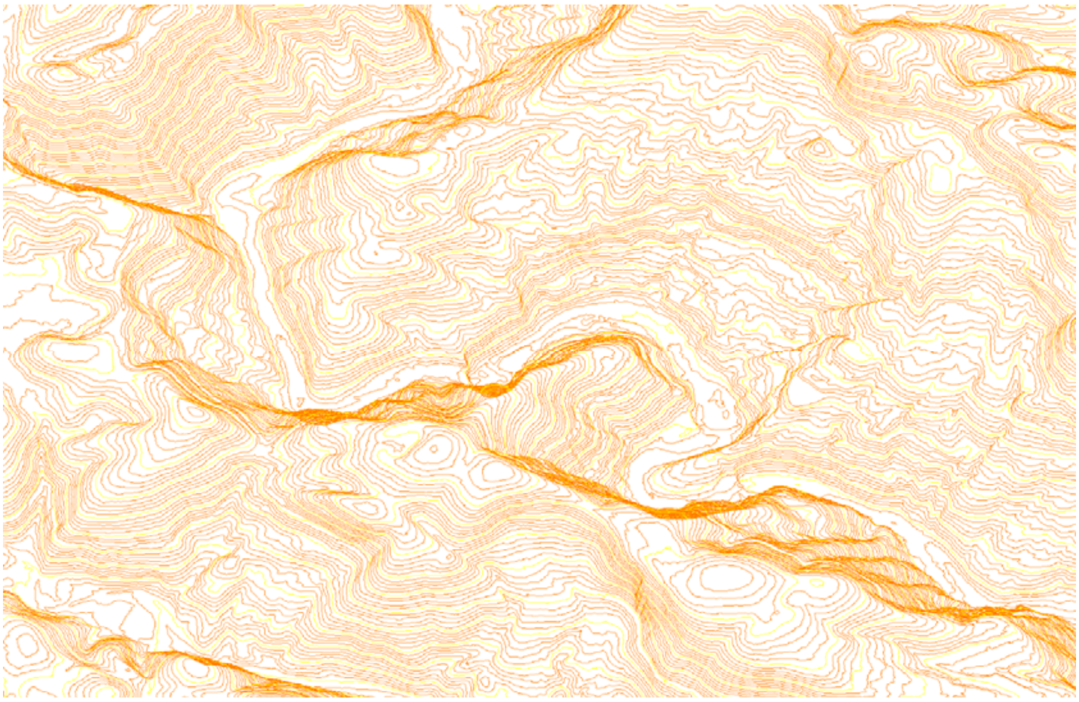

Figure 3-28 An Example of Contour Line Data (Birds' Eye View)

(16) Preparation of Interim Report and Discussion

The Interim Report was prepared and the contents were discussed with the C/P. The report was submitted to JICA and the C/P. The results of the discussion were recorded in the minutes of meeting.

(17) Training in Japan

The training in Japan was conducted in April, 2016 with three objectives:

1. To learn activities, roles, and technologies of the Geographical Survey Institute, private corporation and other entities in disaster mitigation and management;

2. To learn the latest LiDAR survey method and DEM data processing to harness LiDAR survey data in Sri Lanka in the future;

3. To learn practical uses of DEM data in Japan to promote uses of the data in Sri Lanka.

With the objectives, the training program was designed and implemented.

The period of the training in Japan was from April 4, 2016 to April 23, 2016. The beginning of the training was allocated to: 1) practical training for LiDAR survey; 2) Airborne LiDAR measurement data processing; 3) Airborne LiDAR Equipment Operation (Field Trip); and 4) Airborne LiDAR Data Processing.

The following training was performed in Nakanihon Air Service Co., Ltd.:

1) Plan preparation of an actual airborne LiDAR survey;
2) Field identification for an airborne LiDAR survey;
3) Downloading and processing of airborne LiDAR measurement data.

Technology transfer on downloading and processing of airborne LiDAR measurement data could not be done because the data were dependent to the equipment on board of the aircraft.

In the Asian Disaster Prevention Centre, mainly following matters have been explained in detail:

(1) Activities of the Asian Disaster Prevention Centre for disaster prevention;
(2) Training records and cases of the trainees from Sri Lanka; and
(3) Methods of analyses and practical uses of the LiDAR data.

They have visited the Great Hanshin-Awaji Earthquake Memorial Museum. They have experienced the movie at the 1.17 Theater that showed the earthquake disaster of Hanshin-Awasji in 2D, and saw a documentary file of the East Japan Earthquake. The volunteers in the Museum explained disaster prevention situation in Japan, and the participants from Sri Lanka exchanged their opinions.

At the Disaster Prevention Research Institute, Kyoto University, iRIC, the stream flow and river bed fluctuation software, was distributed with DEM to all the participants. They have experienced the software using the DEM data. In the demonstration, the instructor instructed the use of software to the participants. The software has been used in institutions of higher learning and government institutions in the following countries: Japan, United States, Canada, China, South Korea, Chili, Nepal, Myanmar, Thailand, India, Pell, Indonesia, Bhutan, Vietnam, Egypt, Russia, and Taiwan.

During the visit to the Geographical Survey Institute (Headquarters), and the Japanese Association of Surveyors, the participants have learned: sales and management of sheet maps, GIS data management; equipment testing, current situation of NSDI and roles of institutions in NSDI in Japan. The participants were interested in the permanent GNSS stations, and asked questions regarding the technologies used to install and manage the permanent GNSS stations.

In the Japan Aerospace Exploration Agency, JAXA, uses of the satellite images were the topic covered; at the exhibition area, where the rockets and satellites were displayed, the participants observed the exhibitions carefully.

At Pacific Consultants Co., Ltd. lectures on LiDAR data usage were given, and at the Technical Research Center of Pacific Consultants Co., Ltd. in Tsukuba, a method of hazard map preparation was lectured. Also, applied research on river, water and sewer and environment conducted by private company was introduced, and the participants actually visited the sites for technology development.

At Remote Sensing Technology Center of Japan, a technology transfer session was conducted on the remote-sensing technology, and a method of producing DEM using satellite images. At NTT DATA, the NSDI project of the Yen Loan was presented in details.

The program of the training in Japan is summarized in the following table.

Table 3-40 Schedule of Training in Japan

Date	Day	Program	Venue
April 10	Sun.	Colombo to Nagoya	
April 11	Mon.	Briefing, Courtesy Call	JICA Chubu
		General Orientation	JICA Chubu
April 12	Tue.	Introduction, Airborne LiDAR Survey	Nakanihon Air Service Co., Ltd.
April 13	Wed.	Airborne LiDAR Survey Data Processing - Hands-on Session (site visit)	Nakanihon Air Service Co., Ltd.
April 14	Thur.	Airborne LiDAR Survey Data Processing - Hands-on Session	Nakanihon Air Service Co., Ltd.
April 15	Fri.	Airborne LiDAR Survey Data Processing - Hands-on Session (site visit)	Nakanihon Air Service Co., Ltd.
April 16	Sat.	Airborne LiDAR Survey Data Processing - Hands-on Session	Nakanihon Air Service Co., Ltd.
		Move from Nagoya to Kyoto	
April 17	Sun.	History of Disaster and Disaster Management	Asian Disaster Reduction Centre
April 18	Mon.	Disaster Research	Disaster Prevention Research Institute, Kyoto University
		Move from Kyoto to Tokyo	
April 19	Tue.	Introduction, Lecture on LiDAR Data Usage	Pacific Consultants Co., Ltd
		Hazard Mapping Methodology	Japan Association of Surveyors
April 20	Wed.	NSDI and National Control Point System in Japan, Discussion, Facility Visit in Geo Spatial Information Authority of Japan	Geospatial Information Authority of Japan
		Use of Satellite Images	Japan Aerospace Exploration Agency
		Disaster Management: River flood, Sabo and Tsunami in Japan	Pacific Consultants Co., Ltd.
April 21	Thur.	DEM from Satellite Images	Remote Sensing Technology Centre of Japan
		Cases of Geographic Information System Development	NTT Data
April 22	Fri.	Meeting with the Project Team and Preparation of Report and Presentation Materials	Pacific Consultants Co., Ltd.
		Reporting the Results of the Training (Presentation of an Action Plan*)	JICA Tokyo
April 23	Sat.	Narita →Colombo	

A total of 15 participants was selected and taken part in the training in Japan.

Table 3-41 Participants to the Training in Japan

No	Name	Title	Branch
1	Mr. M.N.K. Bandara	Photogrammetric Technological Officer	Photogrammetric Branch, Survey Department
2	Mr. P.N.B. Widanagamage	Photogrammetric Technological Officer	Photogrammetric Branch, Survey Department
3	Mr. D. Ekanayake	Photogrammetric Technological Officer	Photogrammetric Branch, Survey Department
4	Mrs. D.C.S. Jayatunga	Photogrammetric Technological Officer	Photogrammetric Branch, Survey Department
6	Mr. M.W.A.N. Karunatilaka	Photogrammetric Technological Officer	Photogrammetric Branch, Survey Department
7	Mrs. Y.K. Kannangara	Photogrammetric Technological Officer	Photogrammetric Branch, Survey Department
8	Mrs. I.S. Welhena	Photogrammetric Technological Officer	Photogrammetric Branch, Survey Department
9	Mr. A.G.T.P. Weerasinghe	Photogrammetric Technological Officer	Photogrammetric Branch, Survey Department
10	Miss Serenee Osman	Photogrammetric Technological Officer	Photogrammetric Branch, Survey Department
11	Mr. W.M.S. Weerasinghe	Deputy Surveyor General	Geoinformatic Section, Survey Department
12	Mr. B.C.P. Bogahawatta	Government Surveyor	Geodetic Branch, Survey Department
13	Mr. K.S.K. Wijayawardhana	Senior Superintendent of Surveys	Air Surveys Branch, Survey Department
14	Mr. G.A. Udayakumara	Government Surveyor	Geodetic Branch, Survey Department
15	Mr. N.M.A. Wijerathna	Lecturer, Senior Superintendent of Surveys	Institute of Surveying & Mapping, Diyatalawa

Survey Department: Survey Department of Sri Lanka

(18) Preparation of Draft Final Report and Discussion

The Draft Final Report was prepared in September 2016. The contents were discussed with the C/P.

(19) Preparation of the Manuals

When the technology transfer plan was prepared, draft of the technical manuals on data preparation, maintenance and management was prepared as the Project Team members had discussions with the C/P. During the technology transfer, as the instructor found it was necessary, the manuals were revised. The final version of the manuals were submitted as supplemental documents to the DF/R.

As explained, for the lectures of the training, the PowerPoint presentation materials were used as the training materials. All the manuals and training materials have been completed. :

Table 3-42 Manuals

Cat_Code	Subjects	Type	Status
00	First Seminar	PPT	Completed
01	LiDAR Fundamentals	PPT	Completed
02	Software Knowledge	Manual	Completed
03	LiDAR Survey Planning	Manual	Completed
04	LiDAR Measurement	Manual	Completed
05	Raw Point Cloud	Manual	Completed
06	Unclassified Point Cloud	Manual	Completed
0708	Ground Data Preparation/ DEM Data Preparation	Manual	Completed
09	Ortho-Photo Image Preparation	Manual	Completed
10	Thematic Mapping using Tera Series from DEM	Manual	Completed
11	Thematic Mapping using ArcGIS from DEM	Manual	Completed
12	Equipment Management	Manual	Completed

During the Inception Report meeting, the following matters have been discussed and changed.

Table 3-43 Organization of the Technical Manuals: Proposed vs Completed

No	Proposed in the Inception Report	Amended in the Inception Report meeting	Status
1	LiDAR Survey Operation Rules	The Specifications	Completed as in the Specifications
2	DEM Product Specifications	Included in the Specifications	Completed as in the Specifications
3	Manual of Pre-Processing of DEM Observation Data in LiDAR Survey	Manual of Pre-Processing of DEM Observation Data in LiDAR Survey	Completed as in the manuals of 05, 06, and 0708.
4	DEM Data Preparation Manual	DEM Data Preparation Manual	Completed as it the manual of 0708 Ground Data Preparation/ DEM Data Preparation
5	Quality Control Manual	Included in the Specifications	Completed as in the Specifications
6	Thematic Map Preparation Manual	Thematic Maps from DEM	Completed as in the manual 10 and 11.
7	Equipment Operation Management Manual	-	Completed

"2 DEM Product Specifications" is decided to be included in t the Specifications for the LiDAR Survey. The Specifications also includes 1. LiDAR Survey Operation Rules and 5 Quality Control Manual.

(20) Preparation of the Final Report

Reflecting the comments from the C/P on the Draft Final Report, the Final Report was prepared and submitted to the C/P and JICA.

(21) Outputs

Following outputs were submitted to the Sri Lanka side during the course of the project.

Table 3-44 Outputs

	Output	Submission (Deadline)	Quantity
[1]	Reports		
1)	Inception Report (IC/R)	at the commencement of the project	10 copies
2)	Interim Report (IT/R)	Fifteen (15) months after the commencement (August 2015)	10 copies
3)	Draft Final Report (DF/R)	Twenty-two (22) months after the commencement (Sept. 2016)	10 copies
4)	Final Report (F/R)	Within one month after receiving comments from the Sri Lanka side	15 copies
[2]	Outputs of Technical Cooperation		
1)	LiDAR Survey Rules	at the submission of the DR/R	1 set each
2)	DEM Product Specifications		
3)	DEM Observation Data Pre-Processing Manual for LiDAR Survey		
4)	DEM Data Preparation Manual		
5)	Quality Control Manual		
6)	Thematic Mapping Manual		
7)	Equipment Operation Management Manual		
[3]	Data and Other Reports		
1)	Results of Field Identification	at the submission of the F/R	1 set
2)	Digital Data Files		1 set
I	3D Survey Data		1 set
ii	Original Data		1 set
iii	Ground Data		1 set
iv	DEM Data		1 set
v	Ortho-photo Data		1 set
vi	Contour Data		1 set
vii	Specifications		1 set
viii	Manuals for technology Transfer		1 set
3)	Report on Quality Management		1 set
4)	Others (Equipment Procurement Documents)	at the end of the project	1 set
[4]	Monthly Work Report	15th day of the following month	All the copies
[5]	Collected Information	at the submission of the F/R	1 set
[6]	Promotion Material (Response to the Disaster)	at the submission of the DF/R	190 copies
	Promotion Material (Project Brief)	at the submission of the F/R	150 copies
[7]	Digital Image Data (to JICA)	at the submission of the F/R	One CD-R
[8]	Others		
1)	Minutes of Meeting (to JICA)	as soon as it is prepared	All the copies
2)	Letters to the Government of Sri Lanka (photocopies) (to JICA)	as soon as it is prepared	All the copies

Because of urgency of the use of the data due to the disaster in May, 2016, the Project Team has submitted the following DEM data and contour line data to JICA and SDSL before the end of the Project:

Table 3-45 Advance Data Submission

Date	Mesh Area	Data Type	Area	Submitted to
17 June, 2016	1 m x 1 m	DEM Data	2,200 km^2	JICA
17 June, 2016	1 m x 1 m	Contour Line Data	100 km^2	JICA
22 June, 2016	1 m x 1 m	DEM Data	2,200 km^2	SDSL
22 June, 2016	1 m x 1 m	Ortho-Photo Data	2,200 km^2	SDSL
22 June, 2016	1 m x 1 m	Contour Line Data	100 km^2	SDSL
23 September, 2016	1 m x 1 m	DEM Data	200 km^2	JICA
23 September, 2016	1 m x 1 m	Contour Line Data	200 km^2	JICA
28 September, 2016	1 m x 1 m	DEM Data	200 km^2	SDSL
28 September, 2016	1 m x 1 m	Ortho-Photo Data	200 km^2	SDSL
28 September, 2016	1 m x 1 m	Contour Line Data	200 km^2	SDSL

The rest of the data were submitted on December 16, 2016 when the Final Report was submitted.

(22) Operation Schedule

During the discussion on the Inception Report, the Project Team presented alternative plans. After discussion with consideration of weather condition of Colombo and surrounding areas, one of which the LiDAR survey had been scheduled start in November 2015 was selected.

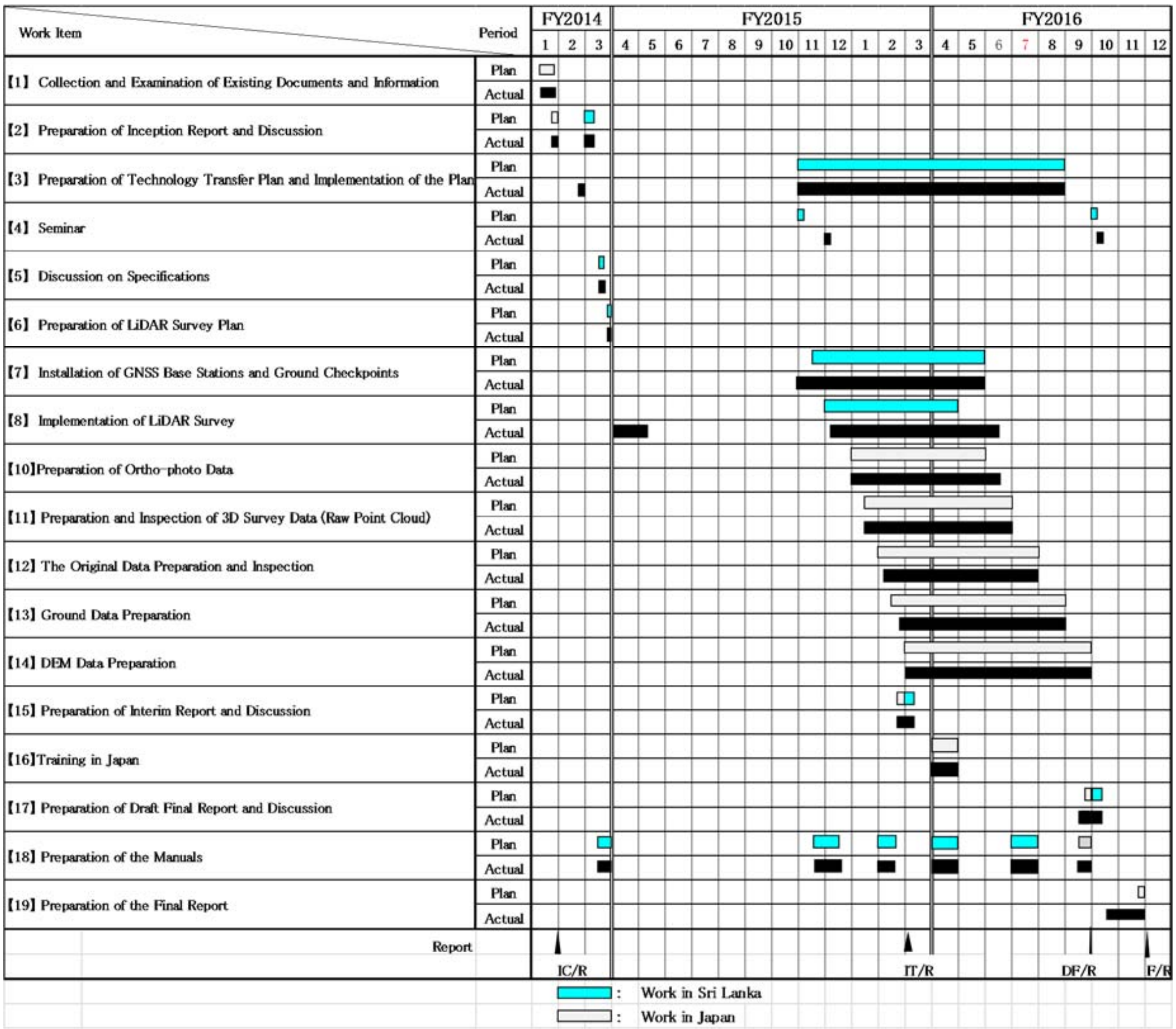

Figure 3-29 Operation Schedule Chart

There was an additional LiDAR data processing and additional training for contour line preparation; Mr. Hajima's assignment was added for two months from July, 2016 to August, 2016. There is no significant change of the operation schedule.

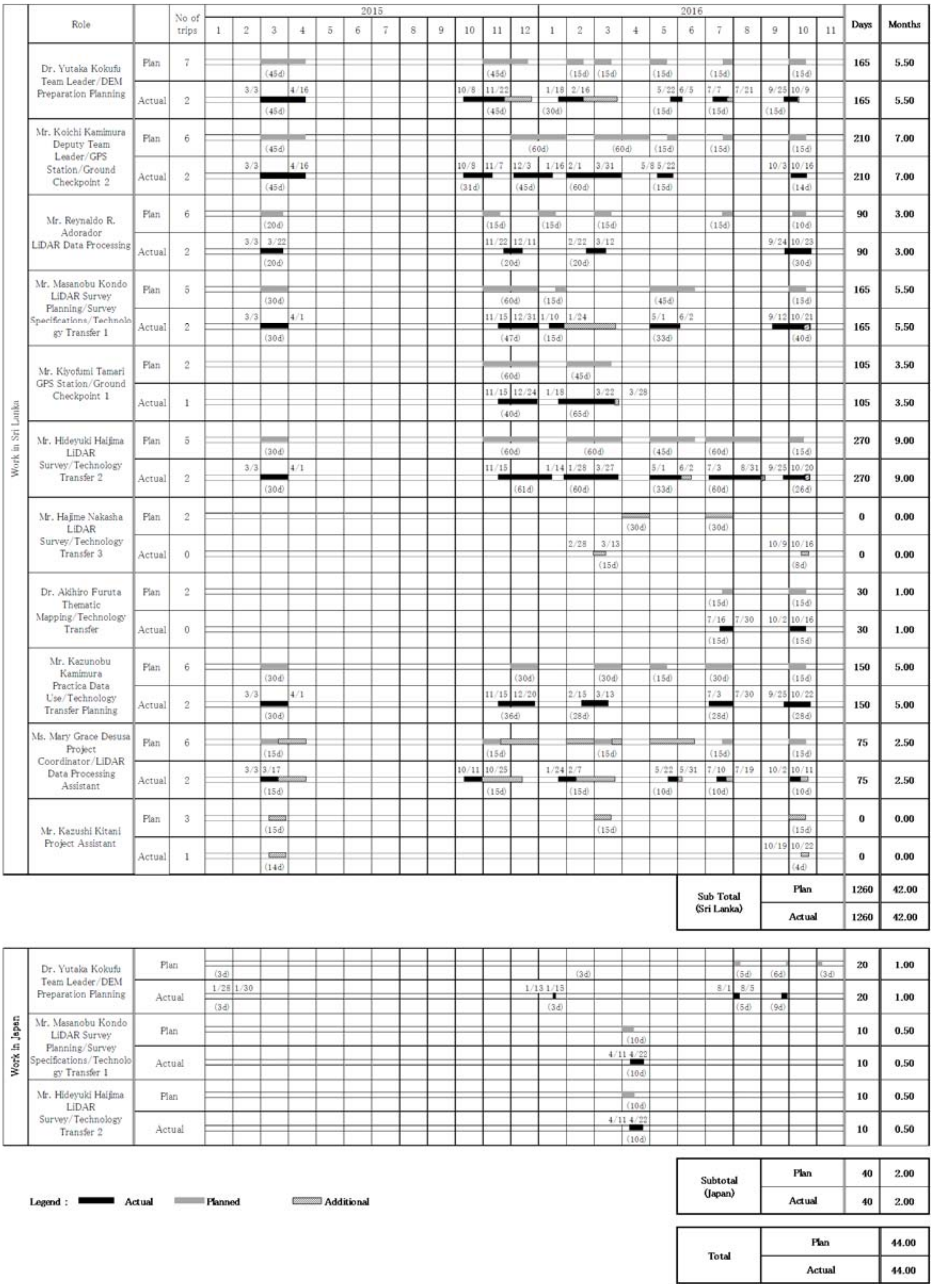

Figure 3-30 Planned Assignment and Actual Days Spent by the Project Team Members

(23) Equipment Installed in the Survey Department

PCs and software and other pieces of equipment are installed in the training room of SDSL. The items and date of installation are summarized in the following table.

Table 3-46 Equipment Procured in Sri Lanka

No.	Item	Software Type	Procured by	Date of Installation	Quantity
(1)	Elevation Discrepancy Adjustment between Flight Courses of Laser Survey and Sensor 3 Axes Calibration Adjustment Software	Base	Project Team	Dec. 8, 2015	1
		Add-on	Project Team	Dec. 10, 2015	
(2)	Automatic Filtering (Automatic Classification) Processing Software for Laser Survey Data	Base	Project Team	Dec. 8, 2015	1
		Add-on	Project Team	Dec. 10, 2015	
(3)	Image Processing for Laser Survey Point Group and Data	Base	Project Team	Dec. 8, 2015	1
		Add-on	Project Team	Dec. 10, 2015	
		Base	JICA	Dec. 15, 2015	2
		Add-on	JICA	Dec. 18, 2015	
(4)	Three-Dimensional Modelling (TIN Model, Surface Generation) Software for Laser Measurement Point Groups	Base	Project Team	Dec. 8, 2015	1
		Add-on	Project Team	Dec. 10, 2015	
(5)	Manual Filtering and Data-Quality-Control Software of Laser Survey Point Group Data	Base	Project Team	Dec. 8, 2015	1
		Add-on	Project Team	Dec. 10, 2015	
(6)	ArcGIS with Extensions	-	JICA	Dec. 16, 2015	3
(7)	Display of Laser Survey Point Group, 3-Dimensional CAD Modelling Software	Base	JICA	Dec. 15, 2015	1
		Add-on	JICA	Dec. 18, 2015	
(8)	Laser Survey Point-Group-Data Processing for Civil Design (Earth Quantity Calculation) Software	Base	JICA	Dec. 15, 2015	1
		Add-on	JICA	Dec. 18, 2015	
(9)	Desk top PC	-	Project Team	Dec. 4, 2015	9
(10)	UPS	-	Project Team	Dec. 4, 2015	9
(11)	External Hard Disk	-	Project Team	Dec. 4, 2015	2

Figure 3-31 Photos of New Equipment for Training