4 DISCUSSIONS

During the course of the Study, discussion sessions were held.   This section summarizes the results of discussions.   For details, please refer to the minutes of meetings attached to this report.

4-1 Steering Committee

A steering committee was decided to be formed during the first discussion session.   The members selected were from INETER, SINAPRED, and representatives from the Ministry of Foreign Affairs.   Representatives from Managua City, ENACAL and the Ministry of Environment were also invited to the third Steering Committee meeting. In the meeting, the Study Team reported progress, results and specifications to the committee members.   The committee was closed with the fifth meeting on the final report.

4-2 Technology Transfer

During the first discussion sessions, the OJT items and the work areas for OJT were agreed.   The Study Team proposed the equipment necessary for OJT.

The OJT items for the digital mapping (1/50,000) agreed in the first discussion were: 1) Ground control survey, pricking and Land marking; 2) Field verification; 3) Training of Stereoscope, Photo-interpretation, Handy GPS use, Fieldwork; 4) Aerial triangulation by Digital photogrammetry workstation; 5) Digital plotting for planimetric feature by Digital photogrammetry workstation; 6) DEM and contouring by Digital photogrammetry workstation; 7) Data editing; 8) Topology structuring by ArcInfo; 9) Field completion; 10) Map symbolization; 11) GIS database creation and analysis. Regarding the OJT area for topographic mapping, the two map sheets (EL TRANSITO and NAGAROTE) were decided to be mapped by INETER with supervision by the Study Team.

The OJT items for the earthquake hazard mapping were: 1) Field verification; 2) Modeling of scenario earthquake; 3) Simulation; 4) Verification of simulation using past disaster records; 5) Organizing results; 6) Hazard map legend design.

The OJT items for the Volcanic Hazard mapping were: 1) Field verification; 2) Landform analyses using aerial photographs; 3) Design of eruption model; 4) Simulation; 5) Verification of simulation using past disaster records; 6) Hazard map legend design.

The OJT items for the Flood Hazard mapping were: 1) Field verification; 2) Aerial photo interpretation for micro-landform interpretation; 3) Design of a rain fall and water level model; 4) Simulation; 5) Verification of simulation using past disaster records; 6) Hazard map legend design.

The OJT items for the Tsunami Hazard mapping were: 1) Field verification; 2) Landform studies; 3) Design of earthquake models; 4) Simulation; 5) Verification of simulation using past disaster records; 6) Hazard map legend design.

The systems for OJT were proposed as follows: 1) Digital photogrammetry workstation; 2) Data editing system; 3) GIS system for mapping and hazard simulation model; 4) Map symbolization; 5) Output device (plotter); and 6) Others (UPS network, etc). (M/M January 20, 2004)

All the equipments were installed based on the specifications which were agreed on January 2004. INETER agreed to check the quantity and working condition for all the systems together with the Study Team.   Especially for ESRI products, INETER agreed to communicate with the delivery dealer. (M/M September 9/2004)

4-3 Additional Work Items

The INETER requested: 1) Bathymetric survey in the Masachapa coastal waters for Tsunami hazard simulation; 2) Profiling of the Maravilla River for Flood hazard simulation; 3) Preparation of topographic maps (Approx.200 km^2) at a scale of 1/5,000 in Managua city for the study on Improvement of Water Supply System in Managua; and 4) Basic facility information map for natural disaster prevention for GIS application (M/M September 9th 2004).

JICA and the Study Team had discussed the matter and recognized the significance of the work items.   The four work items were decided to be conducted during the second year of the Study.

Regarding the expansion of topographic mapping at a scale of 1/5,000 for the southern part of Mountainous area, which was recommended by INETER in the Minutes of Meeting on 23rd, February 2005, the Study Team informed that the mapping of the southern part of Mountainous area was carried out in Japan to improve the accuracy of contour lines of 1/50,000 of the first year. (M/M June 24th 2004).

4-4 Specifications

(1)   Basic Agreement on Map Symbols

The details of map compilation, if not mentioned in the given document, was agreed to be decided in accordance with the "Product Specifications for 1/50,000 Scale Topographic Maps of Foreign Areas" published by NGA (National Geospatial-Intelligence Agency), then NIMA or DMA.   The compilation symbols used for the maps will basically follow the norms contained in NGA's "Manual of Conventional Symbols-On the Scale of 1/50,000."   (M/M April 1, 2004)

(2)   Map Symbols and Application Rules for 1/50,000 and 1/5,000

Since the beginning of the Study, the Study Team and INETER had intensive discussion on map symbols.   Almost two months were spent from January to March 2004 (M/M January 20, 2004).   Regarding map symbol of 1/50,000, the discussion continued in August 2004, and modified in February 2005.   In July 2005, the final map symbols for 1/5,000 were agreed between INETER and the Study Team (M/M July 24, 2005).

(3)   Marginal Information

The UTM coordinates of the four corners of each sheet was agreed to be established by INETER and the coordinate list was agreed to be provided to the Study Team in May, 2004.   (M/M April 1, 2004)   The Team prepared original design of the marginal information.   INETER proposed some modification.   Finally, the design of the marginal information was agreed. (M/M September 10, 2004)   And the actual sample was prepared and presented to the INETER side (M/M February 23, 2005).   The final version was agreed on March 16, 2005.

(4)   Specification of GIS Database

Based on the draft of specifications of GIS database prepared by the Study Team, INETER had several technical discussions with the Study Team. As a result of discussions, Specification of GIS database was agreed. (M/M February 23, 2005)

(5)   Digital Plotting Data Extraction Rule

The data format was decided to be DXF ASCII format version 12 or equivalent.   The data type must be used only Point, Line, Polyline and Single line text. The detailed table of the specifications was agreed between INETER and the JICA Study Team.   (M/M March 7, 2005)

(6)   Copyrights of Maps

About the copyright of the maps, it was discussed and agreed as follows (M/M July 24,

2005):

According to Law 312, INETER requested to the Study Team the following annotation on the Maps:

"This map belongs to INETER and it is protected by the Law 312, Law about the copyrights and Connected Rights, any reproduction, total or partial must be authorized by INETER"

"Esta obra propiedad de INETER, está protegida por la Ley 312, Ley de Derecho de Autor y Derechos Conexos, cualquier reproducción total o parcial debe ser con la autorización de esta Institución"

The Study Team explains about the copyrights as follows: INETER will manage the copyrights and Connected Rights in Nicaragua.   JICA will manage the copyrights and Connected Rights in Japan and other countries.   JICA and INETER will be able to use the products of the Study without previous mutual authorization.   To use the products of the Study, it will be necessary to refer to down the rights of both organizations on the derived products.   JICA and INETER will share the copyrights and Connected Rights. INETER will be able to update the corresponding geographical information without the previous authorization of JICA.   When the corresponding geographical information is needed for ODA (Official Development Assistant) projects of the Japanese government in Nicaragua, INETER will provide them with no charge.

INETER agreed on the above terms and conditions.

4-5 Others

(1)   Web Site

Both sides agreed to upload the JICA project information to the website of INETER. Uploading data was prepared by INETER based on the Inception Report. (M/M January, 2004)

(2)   Delivery of intermediate Results

The Study Team delivered the following intermediate results to INETER for the On the Job Training (OJT):

1)   Two (2) sets of color contact print photograph covering the volcano study (M/M 9/9/2004)
2)   One (1) set of digital ortho-photograph (black and white) at scale of 1/25,000 covering the new photographing area; (M/M 9/9/2004)
3)   One (1) set of scanned photograph covering the new photographing area (M/M 9/9/2004)
4)   One (1) set of color ortho-photographs at a scale of 1/10,000 for the Volcanic Hazard area (M/M 6/24/2005)
5)   One (1) set of ortho-photographs (Black and White) for map sheets, 2752-II (Corinto), 2753-III (León), 2853-II (La Paz Centro), 2953-III(Isla Momoto), 2952-I (Tiptapa), 2855-II (Achuapa) (M/M 7/24/2005)
6)   One (1) set of digital photographs (black and white) at scale of 1/40,000 which were scanned using existing positive films. (M/M 7/24/2005)
7)   Two (2) sets of GIS database of infrastructure for Disaster Mitigation in DVD; (M/M 11/24/2005)
8)   One (1) set of digital photographs (Color) at scale of 1/20,000 for Volcano area (M/M 11/24/2005)
9)   One (1) set of digital mapping data at scale of 1/5,000(M/M 11/24/2005)

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5 PROCESSES OF TOPOGRAPHIC MAPPING FOR 1/50,000

The existing maps of scales 1/50,000 cover the whole country with 303 map sheets. Many of these existing maps were created the 1960s, and secular-change was partially updated in the late 1980s. The target area of new topographic mapping is approx. 20,000 km^2 (60 map sheets) for the Pacific Ocean region.

The northern part equivalent to about 45% of the study area is covered with the existing aerial photographs taken in 2000 at the scale of 1/40,000, and they are under the possession of INETER. Among these, in about 35% of the study area, where the aerial triangulation had been conducted, ortho-photographs were available. The new topographic mapping was conducted using the new and existing photographs. The work started from collection of existing data in Nicaragua. The work possesses are shown in Figure 5-1.
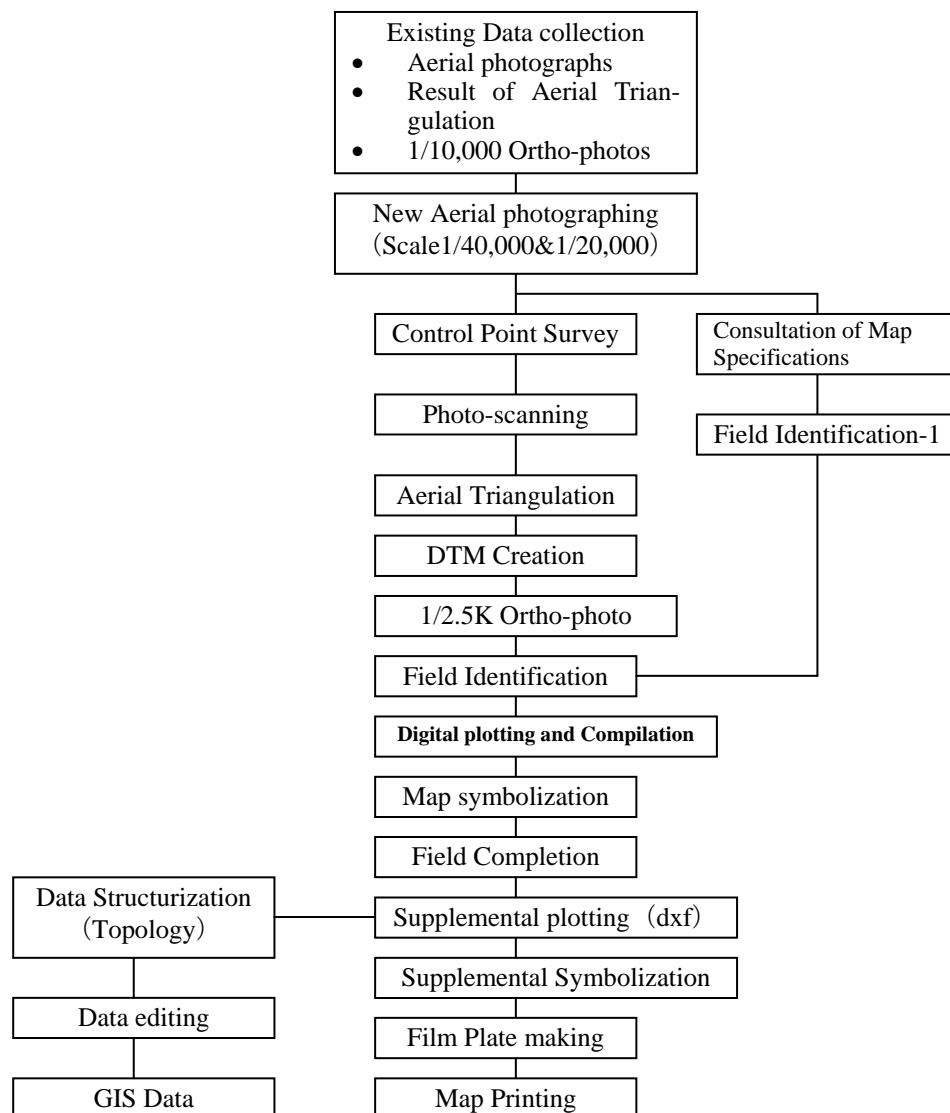
Figure 5-1   Topographic Mapping Work Flow

5-1 Data Collection

The Study Team collected existing information and materials from INETER and other organizations.   The various pieces of information and materials were used for the Study to prepare new mapping data.   The collected materials are as follows:

Table 5-1   Collected Existing Dataset

ITEM	Quantity	Format
1/50,000 scale printed maps	60 sheets	Paper, TIFF
1/10,000 scale ortho-photographs	317 output sheets	Paper
Two-time enlarged aerial photographs	94 photos	Paper
Aerial Triangulation results	1 set	Pat B Format
Existing positive films (1/40,000)	920 pieces	Film
Existing contact prints (1/40,000)	920 prints	Paper
National Borderline data	1 set	dxf
Administrative boundaries data	1 set	dxf
Annotation data for 1/50,000	1 set	dgn
Protected area	1 set	dgn
Annotation catalog for 1/50,000	1 set	dgn and Illustrator
Coordinates table for existing control points	1 set	Excel

After evaluation of the collected materials, the followings were confirmed.

(1)   The existing ortho-photographs at a scale of 1/10,000 were very useful for the field verification of existing photographed area.

(2)   There were no aerial triangulation results in the existing photographed area. Accordingly, ortho-photographs were not available in the following area.

Map sheet: 2753-II CORINTO, 2853-III LEON, 2853-II LA PAZ CENTRO, 2953-III ISLA MOMOTOMBITO, 2952-I TIPITAPA, 2855-II ACHUAPA

(3)   An additional aerial triangulation to be conducted in Japan became necessary.

(4)   Photo control survey should be re-planned to take account for the additional aerial triangulation so that it is possible to carry out additional aerial triangulation and plotting.

The collected materials were classified by the unit of each map sheet.   The digital point data files acquired in the Excel format were converted into the GIS annotation data (ArcInfo coverage) as point data.   The scanned raster maps were given the Geo-coordinates based on the local system (Nad27, UTM 16N) and converted to a new system (WGS 84, UTM 16N).   The defective data found in the process of the classification were checked to correct them with the counterpart technician, and some data were additionally collected.

5-2 Approach to GIS Database

5-2-1   Existing Conditions of Database

The existing GIS database in the Photogrammetry Section of INETER was created from black and white aerial photographs taken in 1996 and 2000.   The workflow of its creation is presented below:

Ortho-photographs .... *Black and white photographs taken in 1996 and 2000 at 1/40,000.*

Feature Delineation and Attribute Input .... *Using the MicroStation software further customized as SPDE (Spatial Data Production System) to input attributes. Existing 1/50,000 topographic maps as the main supporting material.*

Conversion to VPF .... *Using GeoFACC customized program*

Conversion to Geo-database and Shape file .... *Using ArcEditor module of ArcGIS software*
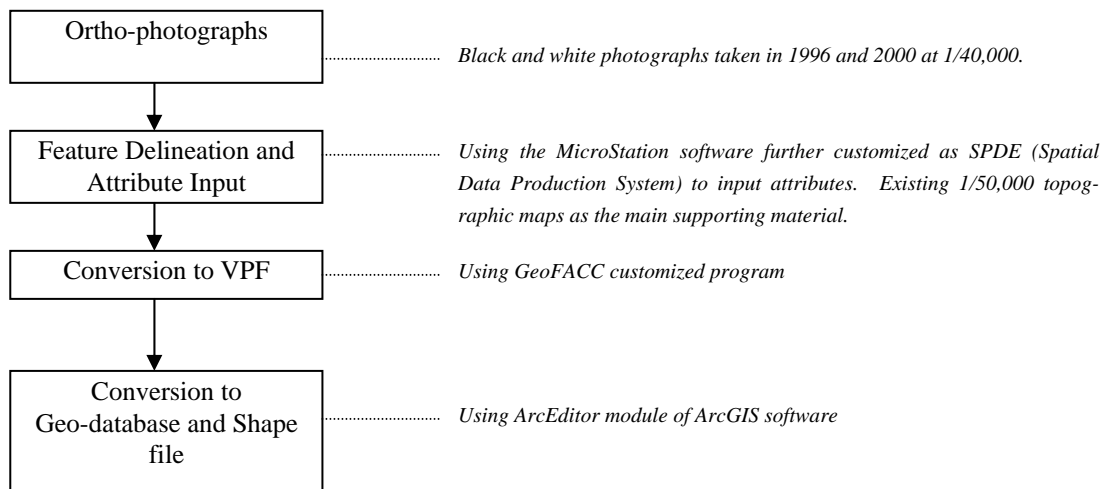
Figure 5-2   Work Flow of Digital Data Creation

For feature delineation and input of attributes, the MicroStation software was used. This software was further customized as SPDE (Spatial Data Production System) to include the database.   Then, using the customized program named GeoFACC, the files were converted to VPF (Vector Product Format), Geodatabase and the shape file format. The digital map database has been stored at all these four stages as *dgn, vpf, geodatabase* and *shp* files.

The digital database was created in six layers: 1) Administration layer; 2) `Elevation Layer; 3) Hydrology Layer; 4) Infrastructure Layer; 5) Transportation Layer; and 6) Vegetation Layer.

5-2-2   Integration of Existing and New Database

The Study Team and INETER discussed map symbols and coding system for GIS database to be prepared in this Study, especially concerning the layer codes.   It was fully considered that GIS database to be delivered would not be isolated from the existing database of INETER; rather both will be compatible to each other.

The Study Team analyzed the existing GIS database system in INETER using one of dbase files (.dbf) were provided by INETER as a part of the geographic database system of INETER.   An example of analyzed existing database is presented below:

Figure 5-3   Example of Existing GIS Database Table

Figure 5-4   Geographic Data Table

In the above table, the items are: **Shape, Objecid, Object_1, F_code, F_code_des, Nam, Wpi, Shape_length, Shape_area.**   Along with the analysis of above example of the existing INETER GIS database, the Study Team proposed the following two-step-data-creation method:

STEP 1: First, preparing the **Geographic data table** and **Attribute table** separately with one unique **ITEM** in both tables.

Figure 5-5   Attribute Table

For example, in the table above, the item **Rel_no** is same as in the both tables.   The attribute table can be prepared even using Microsoft EXCEL.

STEP 2: Joining the above two tables into one using Arc/Info and the finally, the GIS database table will look like as below:

Figure 5-6   Final GIS Database Table

During the discussion, INTER accepted the above-mentioned Method.   The new GIS database was advantageous in the following points: all the attribute data would be the integral part of Geographic Data Table all the time; and query for any of included ITEM would be possible at any time; and GIS analysis with respect to any included attribute ITEM could be easier.   The Study Team prepared sample specifications of GIS data at a scale of 1/50,000 and discussed with INETER side.   The INETER side proposed some modification and correction.   After several discussions, both side agreed to the specifications.   The specifications of GIS data is shown in Chapter 5-13 GIS Data Creation.

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5-3 Aerial Photography （1/40,000 and 1/20,000）

Aerial photography was carried out according to the Technical Specifications.   All the flight lines were planned using the Leica ASCOT flight planning software.

The aerial photography was performed only when the angle of sun with the horizon was 30 degrees or more.   The entire Pacific Ocean coastline of Nicaragua was covered with approximately 12,000 km^2 black and white aerial photography at the scale 1/40,000 and approximately 1,350 km^2 color aerial photography at the 1/20,000 scale.

The first aerial photography flight was carried out on February 5, 2004, and the entire project area was completed on February 25, 2004.   The demobilization took place on February 26, 2004 after the coverage of the aerial photography was checked.

Totally, 288 color and 814 black and white aerial photographs were taken during the aerial photography mission by the sub-contractor, FINNMAP.   The flight index map was prepared in the AutoCad format and delivered in CD.   Figure 5-7 shows the overview of the index map.
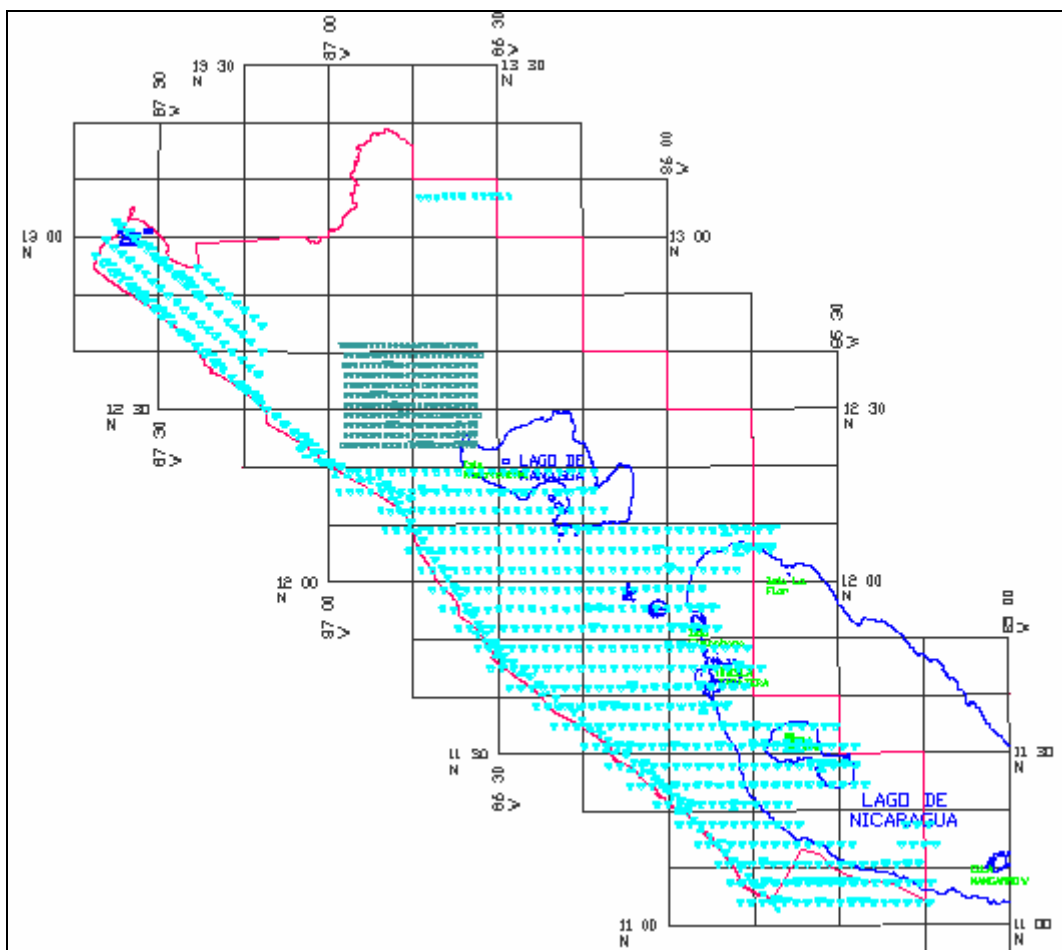

Figure 5-7   Photo Index Map

Table 5-2   Specifications for Aerial Photography

Scale of Photography	1/40,000
Type	Panchromatic
Photography Courses:	33 courses, flight length of about 2,600 km, area coverage about 12,000 km^2
Camera specifications:	LeicaRC-30 or equivalent (f= 152 mm, 23 cm $\times$ 23 cm)
Flight altitude to planned elevation:	Within 6,000 m± 5%
Overlap	Overlap 60 ± 5%
	Side-lap 30 ± 10%
Tolerable cloud cover:	Within 3% of successive 5 frames of photographs (excluding parts necessary for plotting orientation)
Condition	The coordinates of the principal points are measured using ADGPS.
Photograph processing:	Processed in the Republic of Nicaragua

5-3-1   Flight Permits

The necessary permits, to carry out the aerial photography, were applied to the concerned authorities and neighboring countries.   The following permits were applied before the commencement of the aerial photography in the Republic of Nicaragua.

Table 5-3   Flight Permit

Issuing Authority	Direccion General de Aeronautica Civil
Issuing Date:	19.1.2004, General Flying Permission
Issuing Authority:	Government of Costa Rica
Issuing Date:	11.2.2004, the permit for border crossing of the border between The Republic of Nicaragua and Costa Rica

5-3-2   Mobilization and Demobilization

The test flight of an aircraft, Cessna T310R, YS-06-N, was carried out on February 3, 2004 in El Salvador prior to the mobilization of the aircraft to Nicaragua.   The aircraft was mobilized to Managua on February 4, 2004, after the quality of the photographs was assured.   The aerial photography flights were carried out from Augusto Cesar Sandino International Airport in Managua.

5-3-3   Equipment and Materials Used

Following equipment was used for the aerial photography.

Table 5-4   Aircraft, Camera and Navigation System

Aircraft Model	CESSNA T310 R, YS-06-N
Camera Type	Leica RC 30 with PAV30 stabilized mount
Lens Type	15/4 UAG-S
No.	13260
Calibration date	15.02.2003
GPS Navigation System	Leica ASCOT
Differential GPS	TRIMBLE 4700(BASE STATION) LEICA MX9500(LEICA MX9500)

5-3-4　Technical Detail

(1)　　　Data recording interval: one second

(2)　　　Cut off angle: 10 degrees on the base station and 0 degrees on the aircraft.

(3)　　　The base station for entire aerial photography mission was the existing geodetic station INETER 3 (INE3) at the INETER office site in Managua.

(4)　　　The Continuously Operating Reference Station (CORS) MANA, which was located also at the INETER office, was as back-up base station.

(5)　　　All the data was processed daily after the aerial photography flights by Ashtech PNAV(Precision Navigation) –software using the backward and forward processing method.

(6)　　　The processed data and final coordinates of each photo center, were stored in CD and delivered to the client.

(7)　　　The eccentricity components between camera perspective and the aircraft antenna phase center were follows:

Table 5-5　Aircraft, Camera and Navigation System

	X (m)	Y(m)	Z(m)
CESSNA T310 R YS-06-N	+0.210 (forward positive)	-0.057 (starboard positive)	+1.182 (up positive)

5-3-5　Aerial photography Film

KODAK AERO MX 2407, Agfa Aviphot PAN 80 black and white and KODAK 2444 color aerial photography film was used for the project.

5-3-6　Photographic Processing

(1)　　　Development of films

The film was developed at the FINNMAP's laboratory.　AGFA Gevatone 66 film processor and AGFA AVIPHOT 7C and AGFA G333c chemistry were used for the film processing.　The quality of film developing was monitored during the entire process using the Techkon T112 densitometer.

(2)　　　Making of prints

All prints were produced in the same laboratory, using the SPEK 3030 automatic dodging contact printer.　AGFA Gevatone 65c and AGFA G333c chemistry and Tetenal TT Vario Ultra paper were used for printing the contact prints.

5-3-7　Film Annotation

Film annotation was carried out with the NC-Scriper CS110 automatic annotation machine in accordance with the Technical Specifications and the instruction from the Client's Engineer.　The annotation includes the following data: JICA Nicaragua Project Scale of photography 1/40,000 or 1/20,000; Flight course number; Serial number of camera & lens; Flight altitude; and Photo number.

5-3-8　Quality Control of Photographs

The Study Team members carried out a quality control of the photographs using the rush prints.　The parts of photo- image, which had been covered with clouds, haze and shadows, were founded.　The amounts of the overlap and side-lap were measured from the contact prints in accordance with the Map Specifications.　The following aerial photographs were adopted as final results.

Table 5-6　　Volume of Checked Photographs

Run No.	Counter Nos.	No.　of Photos
Color		
R101	0176--0152	25
R102	0178--0201	24
R103-1	0210-0202	9
R103-2	0217-0231	14
R103-3	0443-0446	4
R104	0255-0232	24
R105	0471-0447	25
R106-1	0256-0278	23
R106-2	0442-0438	5
R107-1	0494-0504	11
R107-2	0564-0550	15
R108-1	0493-0482	12
R108-2	0534-0549	16
R109-1	0472-0481	10
R109-2	0533-0517	17
R110	0304-0281	24
R111-1	0025-0001	26
R111-2	0437-0434	4
	TOTAL	288 PHOTOS

Run No.	Counter Nos.	No. of Photos
B&W		
R1	0131-0141	11
R2	0391-0414	24
R3-1	0390-0369	22
R3-2	0418-0415	4
R3-3	0811-0809	3
R3-4	0979-0981	3
R4	0346-0367	22
R5-1	0775-0787	13
R5-2	0828-0841	14
R5-3	0982-0988	7
R5-4	1155-1151	5
R5-5	1156-1160	5
R6-1	0798-0788	11
R6-2	1001-0989	13
R6-3	0849-0841	9
R6-4	1093-1090	4
R6-5	1164-1161	4
R7-1	0799-0808	10
R7-2	1075-1062	14
R7-3	0850	1
R7-4	0851-0857	7
R8-1	0689-0701	13
R8-2	0741-0729	13
R9-1	0688-0674	15
R9-2	0860-0858	3
R9-3	1013-1002	12
R10-1	0661-0673	13
R10-2	1014-1025	12
R10-3	1258-1256	3
R11-1	0593-0617	25
R11-2	1259-1261	3
R11-3	0728-0727	2
R12-1	0640-0618	23
R12-2	0863-0862	2
R13-1	0641-0652	12
R13-2	1286-1293	8

Run No.	Counter Nos.	No. of Photos
R13-3	0868-0864	5
R14-1	0660-0653	8
R14-2	1285-1276	10
R14-3	0869-0871	3
R14-4	1096-1094	3
R15-1	0711-0726	16
R15-2	0899-0907	9
R15-3	1252-1253	2
R16-1	0706-0710	5
R16-2	1269-1275	7
R16-3	1251-1247	5
R16-4	0915-0908	8
R16-5	0879-0888	10
R16-6	1302-1304	3
R17-1	1268-1265	4
R17-2	0955-0945	11
R17-3	0898-0889	10
R17-4	1307-1305	3
R17-5	0873-0872	2
R19-1	1176-1169	8
R19-2	1301-1294	8
R19-3	1130-1135	6
R20-1	1165-1168	4
R20-2	1053-1061	9
R21-1	1147-1136	12
R21-2	1243-1241	3
R22	1121-1239	19
R23-1	1129-1126	4
R23-2	1120-1115	6
R23-3	1224-1209	16
R24-1	1097-1101	5
R24-2	1106-1114	9
R24-3	1200-1208	9
R25	0130-0122	9
R26-1	0058-0044	15
R26-2	0314-0323	10
R27	0101-0120	20
R28-1	0059-0083	25

Run No.	Counter Nos.	No. of Photos
R28-2	0324-0345	22
R29	0967-0978	12
R30	0774-0754	21
R31-1	0575-0592	18
R31-2	1184-1177	8
R32-2	1105-1102	4
R33	0938-0940	3
R34	0943-0941	3
	TOTAL	**814 Photos**

5-4 Control Point Survey and Pricking

5-4-1   Existing Geodetic Control Point Information

The World Bank has provided funds to Nicaragua for development of a land management program.   The initial phase of the project was establishing a new primary geodetic control network.   In response to a request for assistance from the World Bank and the government of Nicaragua, DMA started the GPS Network survey in 1996.

A Global Positioning System (GPS) geodetic control network survey was performed in Nicaragua during January and February 1996.   Personnel from the Defense Mapping Agency and INETER accomplished the fieldwork for this survey.   The survey established GPS absolute position on six station and relative positions on an additional 44 station, all in the World Geodetic System 1984(WGS 84) reference frame.

In 1999, the Vertical Datum P2000 Project funded by the World Bank was started in the Republic of Nicaragua.   The National Imagery and Mapping Agency (NIMA: former DMA) of the United States of America carried out the project from February - June 2000.   NIMA was to use GPS and the WGS84 (EGM96) geoid to develop a vertical control network.   361 new stations were established, and twenty-six stations surveyed by NIMA in 1996 were incorporated.   Orthometric heights for each station were computed with the ellipsoid height and the WGS 84 (EGM 96) geoid height.

Figure 5-8   Geodetic Network in Nicaragua

5-4-2 Operation

According to the initial plan of control point survey, it was projected that the pricking would be done over the aerial photographs, once these are taken and processed. Nevertheless, the counterpart agency solicited training in what refers to the installation of land markings and acquisition and the calculation of eccentric elements. Therefore, land markings were installed in the 35 control points to follow the original plan. The work covered much of the area where the new aerial photographs were taken, which made up part of the designed area for the elaboration of the topographic maps at a scale of 1/50,000.

Six additional control point survey were carried out because aerial triangulation was not yet done in some area in the existing photographed area (Figure 5-9). Therefore, 41-ground control point survey was implemented in the study area.

Selection of Points and Land Markings

It was suggested to establish a link between the photo control points and the primary control point network established by Defense Mapping Agency in 1996. This became the information which had been provided by INETER. The land markings were installed by selecting the nearest control points to the indicated sites on aerial photographs. When a primary control point was not available or it had become difficult to mark due to obstacles like trees and buildings, a new point was installed.

The land marking consisted of three wings. Each wing dimension was 0.6m x 2.3m. These marks were installed on the primary control point and newly established photo control points, once the existing control point was confirmed thru field recognition and verified the adequate open sky for taking the aerial photographs. With regard to each of the observation points, the eccentric elements were obtained by using the "Solar Method" or the "Magnetic method". Out of the 41 points, 17 points were obtained using the "Solar Method" and 24 points were obtained using the "Magnetic method".

Photo 5-1   Land Marking Training in INETER

5-4-3 Results of Land Marking and Pricking

Out of the 41 points, 10 points were not visible on the photographs. As for that, there may be a cause in the defect of the setting of the land marking. However, it was judged that 31 points were enough the number of control point for the bundle adjustment of the aerial triangulation.

Table 5-7   Results of Land Marking

NO	Station Name	Visibility	Status for aerial Triangulation
1	2754-3-1	No	No use
2	2851-2-1	OK	Used
3	2852-1-1	OK	Used
4	2852-2-3	No	No use
5	2951-2-1	No	No use
6	2951-3-1	No	No use
7	Mateare	OK	Used
8	2953-4-1	No	No use
9	3049-1-1	OK	Used
10	3050-1-1P	OK	Used
11	3052-3-1	OK	Used
12	BMS1	No	No use
13	CN10P2 (Pricking point)	OK	Used
14	CN12	No	No use
15	CN33	OK	Used
16	INETER	OK	Used
17	MN04	OK	Used
18	2951-1-5	No	No use
19	NI01	OK	Used
20	NI02	OK	Used
21	NI03	OK	Used
22	NI04	OK	Used
23	NI12	OK	Used
24	NI13	OK	Used
25	NI14	No	No use
26	NI15	No	No use
27	NI16	OK	Used
28	NI17	OK	Used
29	NI18	OK	Used
30	NI19	OK	Used
31	NI20	OK	Used
32	NI21	OK	Used
33	NI22	OK	Used
34	NI23	OK	Used
35	NI24	OK	Used
36	NI25	OK	Used
37	NI26	OK	Used

NO	Station Name	Visibility	Status for aerial Triangulation
38	NI27	OK	Used
39	PB03	OK	Used
40	PB17P	OK	Used
41	PB18	OK	Used

New Control Pints: N01-N127

5-4-4   GPS Observation

According to the original plan on the control point survey, 41 control points were to be observed by the GPS receivers with dual frequency.   Totally 14 sessions of GPS observation were carried out.

(1)   Observation method

The observation was carried out by means of the Static Observation Method, using two receptors with two frequencies Trimble 4700 and two receptors with two frequencies Leica SR399.   INETER provided the equipment.   The average time for the synchronized observation was two hours.

Photo 5-2   GPS Receiver Setting

5-4-5   GPS Baseline Analysis

According to the map specifications, the missclosure of each session was less than 10 ppm of the base line.   All of the base lines were calculated using the GPS analysis program "Trimble Total Control" of the Trimble Co.   Control points were adjusted, dividing the area in four blocks using the data of 14 sessions.   A diagram of the net adjustment is shown in Figure 5-9.   The loop closure value is shown in Table 5-8.   All loop closure was less than three PPM.   This meant that each ground control had higher accuracy than required.   Adjusted coordinates are shown in Table 5-9, 5-11, 5-12, and 5-13.
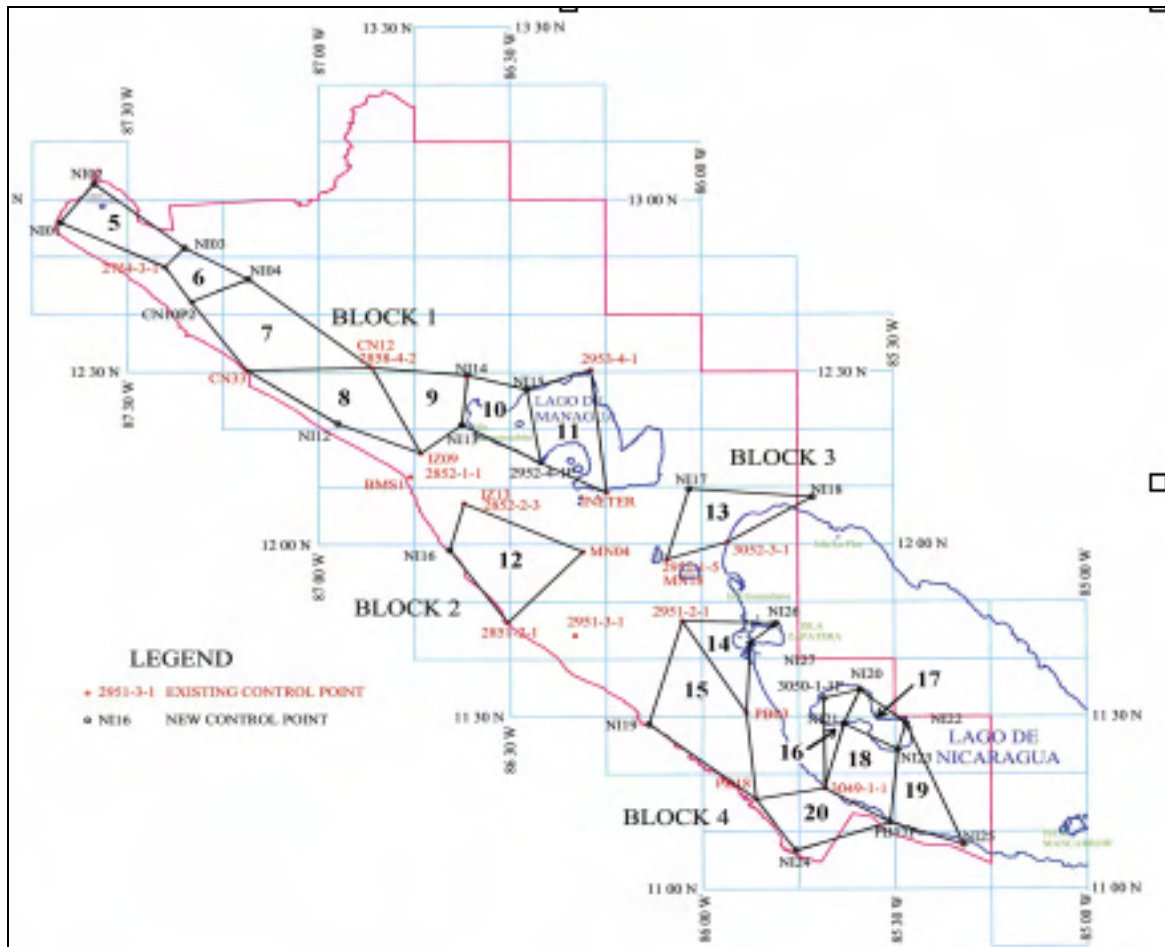
Figure 5-9　GPS Net Adjustment Diagram

Table 5-8   Loop closure of each session

Session No	Closure Error			Mis Closure	Total Length	Precision
	N (m)	E (m)	H (m)	(m)	(m)	(PPM)
5	0.0060	0.0480	-0.2530	0.2575	89,827.0679	2.867
6	-0.0010	0.0000	0.0040	0.0038	60,454.6067	0.062
7	0.0020	-0.0010	0.0060	0.0064	125,632.8369	0.051
8	-0.0030	-0.0080	0.0180	0.0199	122,816.9199	0.162
9	0.0590	-0.0310	0.2800	0.2882	88,578.4385	3.253
10	0.0000	-0.0010	0.0010	0.0013	82,968.4958	0.016
11	-0.0200	-0.0740	0.2030	0.2170	104,043.1805	2.086
12	-0.0010	-0.0020	-0.0030	0.0038	112,388.1505	0.033
13	0.0020	-0.0010	-0.0010	0.0026	117,902.6746	0.022
14	0.0880	-0.0810	-0.0660	0.1369	99,776.9128	1.372
15	0.0250	-0.0410	0.0270	0.0552	135,653.0268	0.407
16	0.0440	-0.0340	-0.1610	0.1705	72,822.4516	2.342
17	0.0040	-0.0060	-0.0250	0.0264	54,844.0905	0.482
18	0.0020	0.0040	0.0010	0.0040	83,916.5749	0.048
19	0.0110	0.0690	-0.0040	0.0704	96,375.3916	0.073
20	0.0020	0.0040	0.0040	0.0040	83,916.5749	0.048

(1)   Adjusted Results for Block I

Table 5-9   Adjusted Results for Block I

Número del punto (Nombre)		Valor aproximado de la coordenada	Valor de ajuste	Valor más probable de la coordenada	Declinación estándar
					m
285121 (MASACHAPA)	B=	11°46′23.5486″	0.0000″	11°46′23.5486″	0.0000
	L=	-86°30′23.2365″	0.0000″	-86°30′23.2365″	0.0000
	Altura elipsoidal=	13.636m	-0.0000m	13.6360m	0.0000
	Altura geoidal=			1.5954m	
	Elevación=			12.041m	
2852-2-3(IZ13)	B=	12°07′06.9842″	0.0000″	12°07′06.9842″	0.0000
	L=	-86°37′14.7607″	-0.0000″	-86°37′14.7607″	0.0000
	Altura elipsoidal=	80.000m	0.0000m	80.0000m	0.0000
	Altura geoidal=			2.0200m	
	Elevación=			77.980m	
2951-4-1(MN04)	B=	11°58′43.4179″	-0.0000″	11°58′43.4179″	0.0000
	L=	-86°18′38.0514″	-0.0000″	-86°18′38.0514″	0.0000
	Altura elipsoidal=	909.120m	0.0000m	909.1200m	0.0000
	Altura geoidal=			3.7639m	
	Elevación=			905.356m	
NI16	B=	11°59′01.1173″	-0.0001″	11°59′01.1172″	0.0841
	L=	-86°39′29.4627″	-0.0034″	-86°39′29.4661″	0.1043
	Altura elipsoidal=	4.332m	0.0128m	4.3444m	0.1688
	Altura geoidal=			1.2143m	
	Elevación=			3.130m	

(2)   Adjusted Results for Block II

Table 5-10   Adjusted Results for Block II

Número del punto (Nombre)		Valor aproximado de la coordenada	Valor de ajuste	Valor más probable de la coordenada	Declinación estándar
					m
3052-3-1	B=	12°00′21.0160″	-0.0000″	12°00′21.0160″	0.0000
	L=	-85°56′01.2657″	0.0000″	-85°56′01.2657″	0.0000
	Altura elipsoidal=	40.110m	-0.0000m	40.1100m	0.0000
	Altura geoidal=			5.9545m	
	Elevación=			34.156m	
2951-1-5	B=	11°57′23.1695″	0.0000″	11°57′23.1695″	0.0000
	L=	-86°05′29.3702″	-0.0000″	-86°05′29.3702″	0.0000
	Altura elipsoidal=	295.518m	0.0000m	295.5180m	0.0000
	Altura geoidal=			5.1413m	
	Elevación=			290.377m	
NI17	B=	12°09′38.4621″	0.0004″	12°09′38.4626″	0.1580
	L=	-86°02′00.4878″	-0.0065″	-86°02′00.4943″	0.1666
	Altura elipsoidal=	39.809m	0.1086m	39.9176m	0.3651

	Altura geoidal＝			5.7074m
	Elevación＝			34.210m
NI18	B=	12°08′13.0994″	0.0004″	12°08′13.0998″	0.1278
	L=	-85°42′41.3134″	-0.0074″	-85°42′41.3207″	0.1306
	Altura elipsoidal＝	47.901m	0.1528m	48.0543m	0.2757
	Altura geoidal＝			6.7494m
	Elevación＝			41.305m

(3)　　　Adjusted Results for Block III

Table 5-11　Adjusted Results for Block III

Nombre		Valor aproximado De la coordenada	Valor de ajuste	Valor mas probable de la coordenada	Declinacion estandar
					m
2951-2-1	B=	11°46′39.7614″	0.0000″	11°46′39.7614″	0.0000
	L=	-86°03′06.9155″	0.0000″	-86°03′06.9155″	0.0000
	Altura elipsoidal＝	167.217m	-0.0000m	167.217m	0.0000
	Altura geoidal＝			5.0084m	
	Elevacion＝			162.209m	
3049-1-1	B=	11°17′31.5756″	0.0000″	11°17′31.5756″	0.0000
	L=	-85°40′53.1205″	0.0000″	-85°40′53.1205″	0.0000
	Altura elipsoidal＝	47.273m	-0.0000m	47.2730m	0.0000
	Altura geoidal＝			6.5453m	
	Elevacion＝			40.728m	
3050-1-1P	B=	11°33′10.9416″	0.0005″	11°33′10.9421″	0.0936
	L=	-85°41′05.8225″	0.0023″	-85°41′05.8201″	0.1396
	Altura elipsoidal＝	112.292m	-0.0683m	112.2239m	0.1774
	Altura geoidal＝			6.2955m	
	Elevacion＝			105.928m	
NI19	B=	11°28′41.7634″	-0.0021″	11°28′41.7613″	0.0682
	L=	-86°08′22.2790″	-0.0010″	-86°08′22.2800″	0.0816
	Altura elipsoidal＝	8.655m	0.0689m	8.7236m	0.1426
	Altura geoidal＝			3.9915m	
	Elevacion＝			4.732m	
NI20	B=	11°34′39.9239″	0.0005″	11°34′39.9244″	0.0819
	L=	-85°35′23.6103″	0.0023″	-85°35′23.6080″	0.1257
	Altura elipsoidal＝	57.947m	-0.0741m	57.8731m	0.1599
	Altura geoidal＝			6.5770m	
	Elevacion＝			51.296m	
NI21	B=	11°28′47.3479″	-0.0002″	11°28′47.3477″	0.0805
	L=	-85°37′57.6603″	-0.0013″	-85°37′57.6616″	0.1199
	Altura elipsoidal＝	44.009m	0.0461m	44.0547m	0.1538
	Altura geoidal＝			6.4758m	
	Elevacion＝			37.579m	

Nombre		Valor aproximado De la coordenada	Valor de ajuste	Valor mas probable de la coordenada	Declinacion estandar
NI22	B=	11°28′50.4303″	-0.0003″	11°28′50.4301″	0.1136
	L=	-85°28′14.6655″	-0.0012″	-85°28′14.6667″	0.1432
	Altura elipsoidal=	59.670m	0.0558m	59.7259m	0.2530
	Altura geoidal=			6.9536m	
	Elevacion=			52.772m	
NI23	B=	11°24′16.0351″	-0.0005″	11°24′16.0346″	0.1191
	L=	-85°29′32.6846″	-0.0019″	-85°29′32.6865″	0.1469
	Altura elipsoidal=	44.372m	0.0031m	44.3753m	0.2618
	Altura geoidal=			6.9402m	
	Elevacion=			37.435m	
NI24	B=	11°06′43.6601″	0.0014″	11°06′43.6615″	0.0545
	L=	-85°45′30.3314″	0.0080″	-85°45′30.3234″	0.0707
	Altura elipsoidal=	11.590m	-0.3862m	11.2037m	0.1129
	Altura geoidal=			6.7748m	
	Elevacion=			4.429m	
NI25	B=	11°07′44.8157″	-0.0003″	11°07′44.8153″	0.0657
	L=	-85°19′19.0558″	-0.0002″	-85°19′19.0560″	0.0864
	Altura elipsoidal=	47.689m	0.0098m	47.6990m	0.1272
	Altura geoidal=			7.7713m	
	Elevacion=			39.928m	
NI25P	B=	11°07′44.3709″	-0.0003″	11°07′44.3706″	0.0798
	L=	-85°19′42.6181″	-0.0002″	-85°19′42.6183″	0.0984
	Altura elipsoidal=	57.929m	0.0098m	57.9384m	0.1590
	Altura geoidal=			7.7600m	
	Elevacion=			50.178m	
NI26	B=	11°46′15.6543″	0.0010″	11°46′15.6552″	0.0499
	L=	-85°48′29.8294″	0.0029″	-85°48′29.8265″	0.0574
	Altura elipsoidal=	97.438m	-0.0835m	97.3543m	0.1346
	Altura geoidal=			6.0713m	
	Elevacion=			91.283m	
NI27	B=	11°42′50.7139″	0.0014″	11°42′50.7153″	0.0481
	L=	-85°52′30.9493″	0.0029″	-85°52′30.9464″	0.0578
	Altura elipsoidal=	40.379m	-0.0993m	40.2799m	0.1394
	Altura geoidal=			5.7598m	
	Elevacion=			34.520m	
PB03	B=	11°30′35.4872″	-0.0000″	11°30′35.4872″	0.0000
	L=	-85°53′07.5387″	-0.0000″	-85°53′07.5387″	0.0000
	Altura elipsoidal=	70.583m	0.0000m	70.5830m	0.0000
	Altura geoidal=			5.5253m	

Nombre		Valor aproximado De la coordenada	Valor de ajuste	Valor mas probable de la coordenada	Declinacion estandar
	Elevacion=			65.058m	
PB17P	B=	11°11′33.1526″	-0.0001″	11°11′33.1525″	0.0466
	L=	-85°30′43.9531″	-0.0001″	-85°30′43.9532″	0.0629
	Altura elipsoidal=	50.773m	0.0045m	50.7778m	0.0869
	Altura geoidal=			7.2371m	
	Elevacion=			43.541m	
PB18	B=	11°15′39.2977″	-0.0000″	11°15′39.2977″	0.0000
	L=	-85°51′39.4961″	-0.0000″	-85°51′39.4961″	0.0000
	Altura elipsoidal=	13.570m	0.0000m	13.5700m	0.0000
	Altura geoidal=			5.9047m	
	Elevacion=			7.665m	

(4)   Adjusted Results for Block IV

Table 5-12   Adjusted Results for Block IV

Nombre		Valor aproximado De la coordenada	Valor de ajuste	Valor mas probable de la coordenada	Declinacion estandar
					m
2754-3-1	B=	12°48′19.6554″	0.0000″	12°48′19.6554″	0.0000
	L=	-87°24′15.3348″	-0.0000″	-87°24′15.3348″	0.0000
	Altura elipsoidal=	25.308m	-0.0000m	25.3080m	0.0000
	Altura geoidal=			1.2320m	
	Elevacion=			24.076m	
2953-4-1	B=	12°30′20.1781″	0.0000″	12°30′20.1781″	0.0000
	L=	-86°17′19.6950″	0.0000″	-86°17′19.6950″	0.0000
	Altura elipsoidal=	55.055m	-0.0000m	55.0550m	0.0000
	Altura geoidal=			5.2185m	
	Elevacion=			49.837m	
CN10P1	B=	12°42′11.9497″	0.0001″	12°42′11.9498″	0.0196
	L=	-87°20′01.4874″	0.0008″	-87°20′01.4866″	0.0240
	Altura elipsoidal=	19.169m	-0.0226m	19.1468m	0.0423
	Altura geoidal=			1.1415m	
	Elevacion=			18.005m	
CN10P2	B=	12°42′12.5276″	0.0000″	12°42′12.5276″	0.0239
	L=	-87°20′06.2714″	0.0002″	-87°20′06.2712″	0.0333
	Altura elipsoidal=	17.766m	-0.0066m	17.7592m	0.0495
	Altura geoidal=			1.1345m	
	Elevacion=			16.625m	
CN12	B=	12°30′43.4101″	-0.0000″	12°30′43.4101″	0.0000
	L=	-86°51′39.1377″	0.0000″	-86°51′39.1377″	0.0000

Nombre		Valor aproximado De la coordenada	Valor de ajuste	Valor mas probable de la coordenada	Declinacion estandar
	Altura elipsoidal=	127.707m	-0.0000m	127.7070m	0.0000
	Altura geoidal=			2.7737m	
	Elevacion=			124.933m	
CN12P	B=	12°30′39.1303″	-0.0010″	12°30′39.1293″	0.0111
	L=	86°51′36.5938″	0.0037″	-86°51′36.5901″	0.0129
	Altura elipsoidal=	129.578m	-1.1786m	128.3991m	0.0163
	Altura geoidal=			2.7705m	
	Elevacion=			125.629m	
CN33	B=	12°30′19.1536″	-0.0000″	12°30′19.1536″	0.0000
	L=	-87°11′19.3270″	0.0000″	-87°11′19.3270″	0.0000
	Altura elipsoidal=	5.217m	0.0000m	5.2170m	0.0000
	Altura geoidal=			0.9697m	
	Elevacion=			4.247m	
INETER3	B=	12°08′55.6058″	-0.0000″	12°08′55.6058″	0.0000
	L=	-86°14′53.3377″	0.0000″	-86°14′53.3377″	0.0000
	Altura elipsoidal=	69.526m	-0.0000m	69.5260m	0.0000
	Altura geoidal=			4.6026m	
	Elevacion=			64.923m	
IZ09	B=	12°15′53.2569″	0.0000″	12°15′53.2569″	0.0000
	L=	-86°43′59.9061″	0.0000″	-86°43′59.9061″	0.0000
	Altura elipsoidal=	22.452m	-0.0000m	22.4520m	0.0000
	Altura geoidal=			2.0408m	
	Elevacion=			20.411m	
Mateare	B=	12°14′10.5270″	-0.0023″	12°14′10.5247″	0.0283
	L=	-86°25′11.5977″	0.0013″	-86°25′11.5963″	0.0362
	Altura elipsoidal=	50.184m	-0.0604m	50.1232m	0.0704
	Altura geoidal=			3.8122m	
	Elevacion=			46.311m	
NI01	B=	12°55′56.8347″	-0.0002″	12°55′56.8346″	0.1407
	L=	-87°40′39.7249″	-0.0007″	-87°40′39.7256″	0.3364
	Altura elipsoidal=	90.627m	0.1114m	90.7384m	0.2986
	Altura geoidal=			0.4539m	
	Elevacion=			90.284m	
NI02	B=	13°02′41.3388″	-0.0005″	13°02′41.3383″	0.1416
	L=	-87°35′20.8191″	-0.0021″	-87°35′20.8212″	0.3367
	Altura elipsoidal=	8.624m	-0.0703m	8.5534m	0.3002
	Altura geoidal=			1.4899m	
	Elevacion=			7.064m	
NI03	B=	12°51′34.1361″	0.0000″	12°51′34.1361″	0.0304

Nombre		Valor aproximado De la coordenada	Valor de ajuste	Valor mas probable de la coordenada	Declinacion estandar
	L=	-87°21′04.1075″	0.0000″	-87°21′04.1075″	0.0355
	Altura elipsoidal=	10.781 m	-0.0011 m	10.7803 m	0.0644
	Altura geoidal=			1.8174 m	
	Elevacion=			8.963 m	
NI04	B=	12°46′09.2770″	0.0006″	12°46′09.2775″	0.0266
	L=	-87°11′03.0151″	0.0021″	-87°11′03.0131″	0.0325
	Altura elipsoidal=	38.197 m	-0.0447 m	38.1523 m	0.0567
	Altura geoidal=			2.3646 m	
	Elevacion=			35.788 m	
NI12	B=	12°21′00.6751″	-0.0009″	12°21′00.6741″	0.0159
	L=	-86°56′59.1069″	0.0025″	-86°56′59.1044″	0.0172
	Altura elipsoidal=	13.249 m	0.0204 m	13.2698 m	0.0371
	Altura geoidal=			1.3560 m	
	Elevacion=			11.914 m	
NI13	B=	12°20′48.6590″	-0.0020″	12°20′48.6571″	0.0240
	L=	-86°37′33.5022″	0.0015″	-86°37′33.5007″	0.0277
	Altura elipsoidal=	81.809 m	-0.0600 m	81.7487 m	0.0635
	Altura geoidal=			3.0949 m	
	Elevacion=			78.654 m	
NI14	B=	12°29′25.5799″	-0.0015″	12°29′25.5784″	0.0499
	L=	-86°36′43.1043″	0.0006″	-86°36′43.1036″	0.0453
	Altura elipsoidal=	106.965 m	-0.5847 m	106.3798 m	0.1159
	Altura geoidal=			3.9053 m	
	Elevacion=			102.475 m	
NI14P	B=	12°29′00.6432″	0.0005″	12°29′00.6438″	0.0285
	L=	-86°36′49.4983″	-0.0026″	-86°36′49.5009″	0.0334
	Altura elipsoidal=	101.130 m	0.0936 m	101.2238 m	0.0565
	Altura geoidal=			3.8625 m	
	Elevacion=			97.361 m	
NI15	B=	12°27′01.3327″	-0.0011″	12°27′01.3316″	0.0252
	L=	-86°27′24.2869″	0.0003″	-86°27′24.2866″	0.0336
	Altura elipsoidal=	47.409 m	-0.0532 m	47.3558 m	0.0664
	Altura geoidal=			4.4172 m	
	Elevacion=			42.939 m	

(5)   Description Sheet

The coordinates of land markings and pricking points were recorded in a description sheet so that the results of the calculations would serve as photo control points for the aerial triangulation.   A sample of the description of photo control point is shown Figure 5-10.
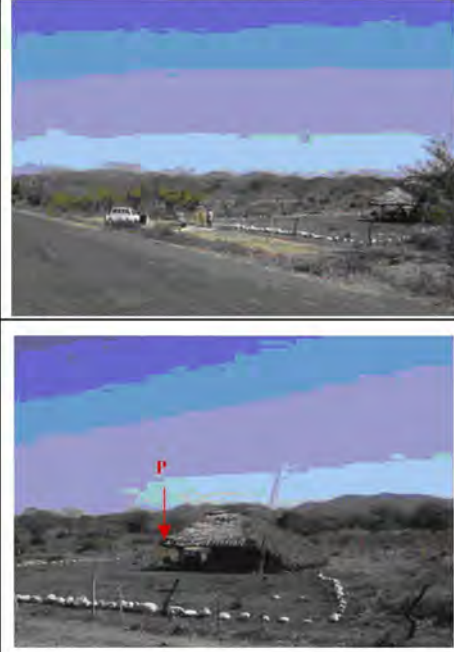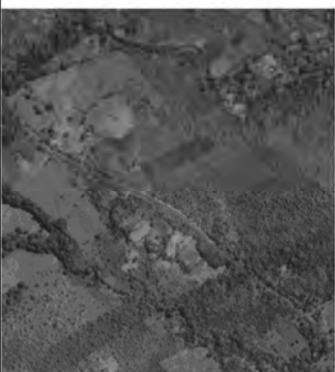
STATION NO,			Operated by	REONEL
2754-3-1			Checked by	K.Tamari
			Date	31-Jan-04
Zone No		UTM16 W		
	N	W		H
Main Point	1,415,656.72	456,127.31		24.08
P1	1,415,663.90	456,142.51	Ground	23.82
Supplementary Point			Roof	25.55

Sketch-Map of Station and Neighborhood	Photograph of Station

Aerial Photograph LEFT RUN-27 2710	Aerial Photograph RIGHT RUN-27 2711

Figure 5-10 Description of Photo Control Point

5-4-6   Pricking of the GPS Leveling Points

To secure the precision of the elevation (Mean Sea Level) for the succeeding aerial tri-angulation process, a pricking work of the GPS/leveling points was conducted.

(1)   Methodology of orthometric height calculation

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The existing GPS/leveling points, which were set by the Vertical Datum Project established in 2000, had only ellipsoidal heights. Therefore, the geoid height of GPS/leveling points in the study area was required so that it could be converted to the orthometric height from the ellipsoidal height. The geoid height with 1 km grid that corresponded to the study area was generated by EGM96 using Trimble Total Control software. Based on the geoidal grid, 1m-geoid contour line was delineated by the TIN model. After creating a local geoid model and contour lines, the orthometric heights of each point were calculated by the interpolation method.
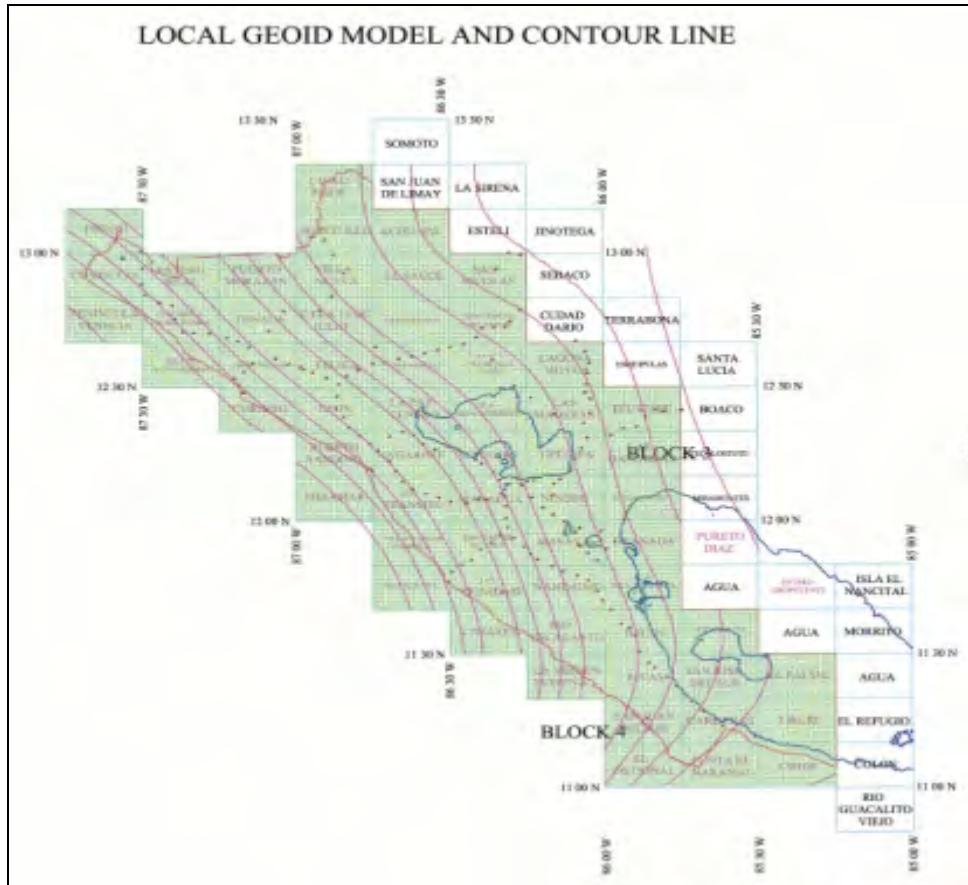

Figure 5-11 Local Geoid Model and Contour Line

(2)   Pricking on the Photos

Since it was difficult to prick the points directly onto the photos, the calculated orthometric heights of each point were transferred by the direct leveling to the places that could be seen clearly on the aerial photographs such as intersections of the road and bridges. Then those points were pricked. To avoid errors, the UTM coordinates of the pricking site were registered using the portable GPS receivers.

(3)   Review of orthometric height and Mean Sea Level height

In the GPS campaign, the photo control points were leveled from the old benchmarks that were installed in the 1960s in Corinto, Masachapa and San Juan del Sur (Datum: M S N M M). The orthometric heights and Mean Sea Level heights of the existing control points were compared to the results through the direct measurements of the leveling points. The results are shown in Table 5-13.

Table 5-13   Comparison of Orthometric Height and MSL Height

Area	Observation Point	GPS Elevation			MSL Height	Difference
		Ellipsoid Height	Geoid Height	Orthometric Height		
Corinto	CN-33	5.217	0.970	4.247	3.303	0.944
	CBM-4	4.179	0.930	3.249	2.335	0.914
Puerto Sandino	BMS-1	7.088	1.520	5.568	4.651	0.917
Masachapa	2851-2-1	13.263	1.600	11.663	11.454	0.209
San Juan del Sur	PB-18	13.570	5.890	7.680	7.328	0.352

According to the result of comparison in Masachapa and San Juan del Sur, it was esti-mated that the accuracy of EGM96 (Global) in Nicaragua was the same, and could be 20 cm to 30 cm.

In such a way, the calculated orthometric height of GPS/leveling points had errors, but it had enough accuracy for the preparation of topographic maps at a scale of 1/50,000.

Nonetheless, in the northern part of Nicaragua such as Corinto, Puerto Sandino, the value exceeds the margin.   One of the causes is the sinking of the ground due to earth-quakes, etc., since the leveling points of the MSNMM Datum where installed more than 40 years ago.

Therefore, in some places of Nicaragua there's a difference between the geoidal height and the real value.   This phenomenon is more noticeable from the Pacific coast where there's a lot of seismic activity.   The geoidal model used currently was made 10 years ago.   Taking into account the earthquakes that have occurred in the years that followed the creation of the geoidal model, an actualization of the geoidal data is recommended.

5-5 Aerial Photograph Scanning

The aerial negative film used was black and white for the scale of 1/40,000 and color for the scale of 1/20,000.   The photos were taken in 2004 using the Leica RC30 camera. The images were scanned using the Vexcel UltraScan5000 Photogrammetric scanner. Before the scanning work both radiometric and geometric calibration was performed. The scanning resolution was 20 microns and the process was as in the following flow diagram.
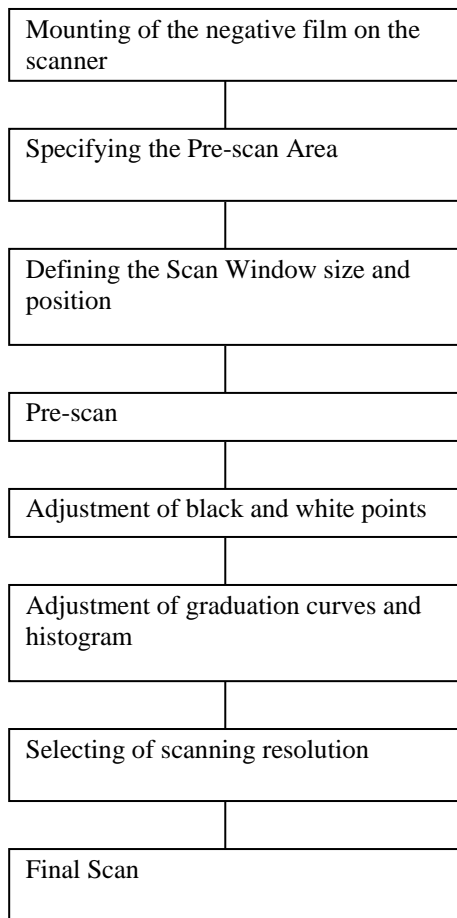
```
┌─────────────────────────────────────┐
│ Mounting of the negative film on the │
│ scanner                              │
└─────────────────────────────────────┘
                  │
┌─────────────────────────────────────┐
│ Specifying the Pre-scan Area         │
└─────────────────────────────────────┘
                  │
┌─────────────────────────────────────┐
│ Defining the Scan Window size and    │
│ position                             │
└─────────────────────────────────────┘
                  │
┌─────────────────────────────────────┐
│ Pre-scan                             │
└─────────────────────────────────────┘
                  │
┌─────────────────────────────────────┐
│ Adjustment of black and white points │
└─────────────────────────────────────┘
                  │
┌─────────────────────────────────────┐
│ Adjustment of graduation curves and  │
│ histogram                            │
└─────────────────────────────────────┘
                  │
┌─────────────────────────────────────┐
│ Selecting of scanning resolution     │
└─────────────────────────────────────┘
                  │
┌─────────────────────────────────────┐
│ Final Scan                           │
└─────────────────────────────────────┘
```

Figure 5-12 Work flowchart of Photo scanning

Photo 5-3   Vexcel UltraScan5000 Photogrammetric Scanner

Totally, 288 colors and 814 black-and-white aerial photographs covering the study area were stored in HDD as a backup data.

File names of each scanned image were put as AA_BBBB.   AA is the course number and BBBB is the photo number.   A file saving work was done with care not to put wrong file names and sample extraction checks were carried out several times.   First delivery to INETER was August 2004 in HDD for OJT.   The final scanned data was delivered in 2006.

5-6 Aerial Triangulation

5-6-1 Aerial Triangulation Area

In the beginning of the Study, the Study Team collected existing photographs and the results of aerial triangulation for the plotting process. The Study Team found the some area had no results of aerial triangulation in the existing photographed area. Therefore, additional ground control survey was conducted for additional aerial triangulation. The Study Team carried out additional aerial triangulation as Block 4 (Map sheet number: 2743-2, 2853-3, 2853-2, 2953-3), Block 4B (2952-1) and Block 5 (2855-2).

Block1, Block2 and Block3 are original plan of aerial triangulation area in new photographed area. After all, aerial triangulation divided 6 Block as shown in Figure 5-13.
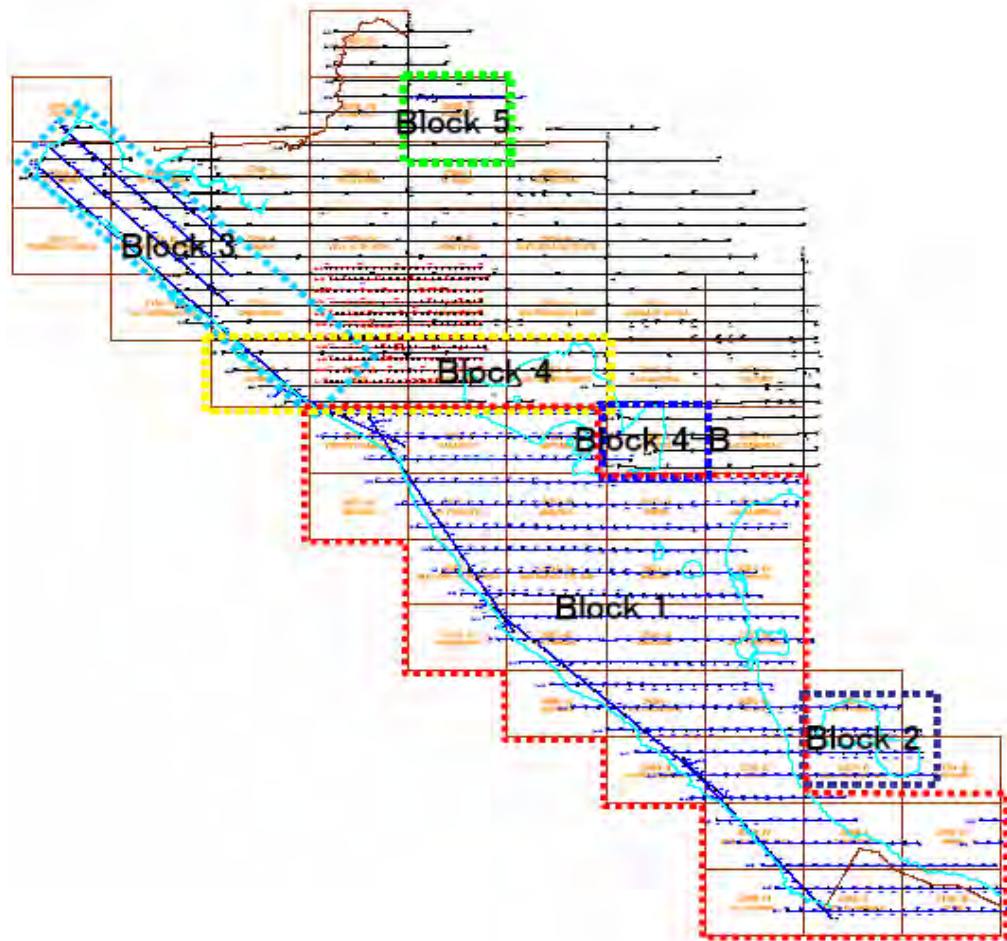
Figure 5-13 Aerial Triangulation Blocks

5-6-2 Introduction of Software

Fully digital photogrammetric ("Softcopy") approach of Aerial triangulation was selected for several reasons: It is the most modern, accurate and fastest method compared with older method of analytical photogrammetry. Therefore it is not necessary to make any mechanical point marking ("Pugging") on diapositives and all manual work phases were minimized. Also manual marking of the pass/tie points on paper prints was not necessary.

The software used in Aerial Triangulation was Match-AT, an automatic aerial triangula-

tion software by Inpho GmbH, Stuttgart, Germany.   (For more details please see http://www.inpho.de).   The main features of the software are:

(1)   Pass point/tie point selection, point transfer and block adjustment is integrated into one process without user interactions.

(2)   Tie points are automatically selected in so called "tie point areas" which are user adjustable in case of incomplete (partly water) models.   The default setting of the tie point areas are so called Von Gruber's position where the software will automatically measure and transfer a group of points on each photo.

(3)   The automatic AT procedure combines sophisticated image matching techniques with an integrated robust approach.

(4)   Results can directly be used for model setup in stereo plotter.   Various analytical and digital plotters are supported.

(5)   Interior orientation is fully automatic, with a manual option for checking and possible re-measurement.

(6)   No restriction for processing a block of any size (amount of photos) and taken with any overlap.

(7)   Fully supports Differential GPS data and GPS/INS from Applanix (POSEO) and CCNS4 / AERO control-II (FOG-IMU) systems by IGI.

5-6-3   Input files and data

The following files and data are required for performing Aerial Triangulation with Match-AT:

(1)   xxx.tiff files

The scanned image files.   Tiff format is the preferable with Match-AT.

(2)   xxx.gps file

xxx.gps is the aircraft GPS antenna position file having Easting, Northing, Elevation and the time tags for each exposure.

(3)   xxx.GCP file

The xxx.GCP file is the ground control point coordinate file.   The format is Easting, Northing and Orthometric height.

(4)   Camera file

Camera file is including camera calibration data for the particular camera used in photography.   The camera template file contains descriptions of the shapes of the fiducial marks of specific cameras.   In Match–AT, there exist default templates for Wild/Leica RC cameras, RMK, LMK and UMK.

Other Additional data

The following additional data was given in the Match-AT Project file:

(a)   Mean terrain height
(b)   Photo scale
(c)   A priori standard deviation of ground control points
(d)   Scan position and resolution of the images

5-6-4   Steps through Aerial Triangulation

Aerial Triangulation was carried out divided in 3 Block.   For a project creation, folders and paths were prepared.   A project file was created in Match-AT Project folder; all

necessary input files are copied to the same folder; and the path for obtaining the scanned images is created.

(1)	Processing of image pyramids.

In Match-AT it is necessary to create image pyramids in order to find iteratively solution from coarse to fine.   During this stage of image processing seven new different resolution levels were derived for the digital images.

During the computation a temporary file <image>.PYRTMP was generated to be able to restore the original data.   The pyramid levels and corresponding resolutions were:

Pyramid level 6 (pixel size 1344 microns)
Pyramid level 5 (pixel size 672 microns)
Pyramid level 4 (pixel size 336 microns)
Pyramid level 3 (pixel size 168 microns)
Pyramid level 2 (pixel size 84 microns)
Pyramid level 1 (pixel size 42 microns)
Pyramid level 0 (pixel size 21 microns = original resolution)

(2)	Running of interior orientation

The "Interior Orientation" module of Match-AT combines automatic, semi-automatic and manual interior orientation approach.   An automatic (AIO) process was used, but all measurements were checked and manual process used in order to improve some measurements.

(3)	Measuring the ground control points

The ground control points were measured in "Photo Measurement" mode.   Each point is measured manually on one image only and the automatic correlation will measure the same point on each other image it appears.

The leveled points which had approximate XY coordinates were imported in Match-AT using the coordinates.   After importing the points, exact location of each point was measured using field descriptions.   The approximate XY GPS coordinates were not used in adjustment

(4)	Running Automatic Aerial Triangulation

After the necessary matching parameters were set, the automatic AT was started.   An Online Monitor reports the current status of the AT run.   Information like elapsed time, estimated time etc. will be displayed.   The process also includes automatic bundle block adjustment.

(5)	Inspecting of the results in Analysis mode

The results were inspected in analysis mode using the Graphical Block Analyzer of Match-AT.   It offers operator guidance of defective or poorly connecting image block areas.

(6)	Correcting bad connections and deleting bad points

After the analyzing, the bad connections were corrected by introducing manual observation.   This was necessary on some incomplete (water) models and on the swamp.

(7)	Post processing

The final block adjustment was done in three steps with different modes.   The first method "with blunder detection" was run in order to remove any points having cross errors.   The second method was "with no blunder detection."   The third method was the final adjustment.

5-6-5   Summary of Aerial Triangulation Results

Number of photographs, point measurements and accuracy are summarized in Table 5-14.

Table 5-14   Aerial Photographs and Accuracy for All Block

Block no	Sub_Block	No of photos	No of strips	No of point measurements	Sigma naught
1	1	200	9	22830	6.08 micron
	2	169	9	20426	7.08 micron
	3	186	13	19095	5.00 micron
2		27	4	3393	5.92 micron
3		89	5	20085	5.66 micron
4		106	4	15203	6.8 micron
4B		22	4	4848	4.50 micron
5		66	7	17699	8.22 micron

The summary of residuals at control points and tie points for each block is shown in Table 5-15, 16.

Table 5-15   Residuals at Control Points Used for Each Block

BLOCK_1	RMS control points Standard deviation	MAX. Residuals
Sub block-1		
X	0.422 m	0.770 m
Y	0.277 m	0.495 m
Z	0.627 m	0.928 m
Sub block-2		
X	0.212 m	0.265 m
Y	0.212 m	0.296 m
Z	0.287 m	0.347 m
Sub block-3		
X	0.202 m	0.360 m
Y	0.229 m	0.366 m
Z	0.319 m	0.383 m
BLOCK_2		
X	0.316 m	0.515 m
Y	0.468 m	0.804 m
Z	0.510 m	0.941 m
BLOCK_3		
X	0.331 m	0.566 m
Y	0.175 m	0.281 m
Z	0.599 m	0.826 m
BLOCK_4		
X	0.636 m	1.156 m
Y	0.474 m	0.877 m
Z	0.549 m	0.553 m
BLOCK_4B		

X	0.226 m	0.498 m
Y	0.343 m	0.715 m
Z	0.393 m	0.958 m
BLOCK_5		
X	0.672 m	0.987 m
Y	0.536 m	0.942 m
Z	0.731 m	0.984 m

Note: Specified standard deviation is 0.2‰ x Flight altitude (6000m) Maximum residual is 0.4‰ x Flight altitude.

Table 5-16   Residuals at Tie Points Used for Each Block

BLOCK_1	Residuals at tie points
Sub block-1	
X	4.6 micron
Y	4.9 micron
Sub block-2	
X	5.4 micron
Y	5.6micron
Sub block-3	
X	4.6 micron
Y	4.9 micron
BLOCK_2	
X	4.9 micron
Y	4.5 micron
BLOCK_3	
X	4.2 micron
Y	4.4 micron
BLOCK_4	
X	5.2 micron
Y	5.2 micron
BLOCK_4B	
X	3.3 micron
Y	3.3 micron
BLOCK_5	
X	6.4 micron
Y	5.7 micron

Note: Specified residuals is less than 20 micron

According to the specifications, which were agreed between the Study Team and INETER, the standard deviation of at control point residuals should have been less than 0.2 ‰ of the flight height.   The maximum should have been less than 0.4 ‰of the flight height.   Also, the residuals at pass points used for block adjustment should have been less than 20 microns.   Therefore, the result of aerial triangulation fully satisfied the specifications.

5-7 Preparation of Ortho-photographs for Field identification

Ortho-photographss at a scale of 1/10,000 were available in the existing photographed area.   The Study Team decided to use ortho-photographs for the field verification.   And also new or-

tho-photographs was required to prepare for new photographed area.

5-7-1 DTM Generating

(1)   Introduction of the Software Match-T by Inpho

Match-T is highly automated DTM generation software using feature-based matching techniques.

The main features of the software are:

Derives DTM   from aerial and satellite images
Automatic adaptive DTM grid width depending on the surface curvature
Handling of poorly textured areas by auto-optimization of adaptive parameter settings
Elimination of outliers, e.g. trees, houses, by robust finite element interpolation
Internal quality control
Several DTM exchange formats

(2)   DTM generating and Quality Check

The procedure of DTM generation with Match-T is straight forward and is done by simply importing the Inpho Project file created during the aerial triangulation with Match-AT and defining the path for image files and the terrain type.   The grid interval was set to be 50 m and the terrain type "flat/hilly".   The DTM generation process was done fully automatically.

The correctness of the generated DTM was checked using interactive DTM Merge software module integrated in Match-T which allows perspective viewing of the generated point clouds and eliminating of unsuitable terrain points.   The generated DTM was saved both in Geo-Tiff and .txt (ASCII) format.

5-7-2 Rectifying

(1)   Introduction of the Software OrthoMaster by Inpho

Software used for rectifying the ortho-photographs was Inpho's OrthoMaster software. The benefit of this is that the entire rectification procedure is very straightforward and fully automated.   Typically all photos, orientations, elevation models etc. can be imported within a couple of minutes and block wide rectifications can be performed as a batch process in a fully automatic way.

Orthorectification with OrthoMaster is extremely straightforward and automated the process.   The main steps to work through are the following:

(a)   Project generation

In Inpho's OrthoMaster this means importing the Match-AT project file, which takes couple of seconds.

(b)   Orientations

This process is not necessary, because all the orientations are read in, when the Match-AT project file is imported.

(c)   DTM import

It is fast and easy to perform by just defining the file(s) to be imported.   OrthoMaster supports various DTM formats, e.g. ASCII XYZ and AutoCAD dxf.

(d)   Setting parameters

The following parameters need to be set.

Output filenames and directory path
Output ground resolution (pixel size)

Resampling method to be used
Rectification method: Two selectable methods fast or precise

    (e)   Defining ortho areas

OrthoMaster can generate ortho areas automatically leaving a user-defined overlap area between adjacent ortho-photographs.   Of course, the entire photos can also be rectified, when necessary.

    (f)   Selecting photos to be rectified

In some software packages this is done by selecting desired files manually from the list. In OrthoMaster selecting is performed by dragging a square or digitizing a polygon around the area of interest with a mouse.

    (g)   Running the rectification

The rectification itself is completely automatic batch process, running on background.

(2)   Rectifying the B/W aerial photographs

The following parameters and input files were used:

The generated DTM file with 50 m spacing was imported in OrthoMaster in the ASCII
       zyx- format.
The bi-cubic resampling method was used in rectification as it gives the best quality
       output image.
Images were rectified in three sub-blocks corresponding to the aerial triangulation
       blocks.
The output ground resolution (pixel size) was selected to be 80 cm.
The rectification method "precise" was selected.

5-7-3   Mosaicing and Color Balancing

(1)   Introduction of the Software OrthoVista by Inpho/Stellacore

The OrthoVista software uses advanced image processing techniques to automatically adjust and combine ortho-photographs of any source to one single seamless mosaic. The main features are:

Automatic mosaicing and color balancing
Automatic single image correction
Automatic seam line detection
Interactive seamline editing
Supports multichannel imagery

(2)   Mosaicing and Color Balancing of the images

Mosaicing of the b/w aerial images was performed automatically using OrthoVista. The following parameters were set:

Hot spot removal
Global tilting adjustment
Adaptive feathering

The final quality checking of the ortho-photographs was completed with the ER Mapper software and the data was saved in the Tiff format.

(3)   Slicing the data in map sheets

In order to slice the data according to the final map sheet division the data was first converted to the Grid format using ArcInfo.   After slicing, the ortho-photographs were saved by map sheet in the Tiff format.
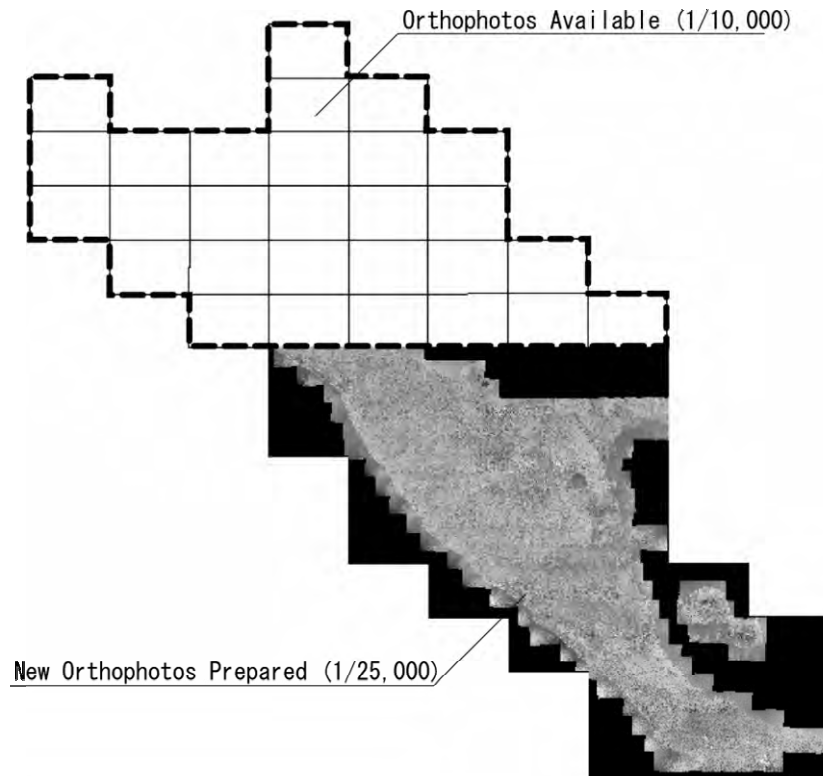
Figure 5-14 New Ortho-photographs in the Study Area

5-8 Field Identification

The work area of the field identification was divided into two areas with existing photo area and new photographed area.　The existing photo area was carried out from January to March 2004 by the four field teams.　The new photographed area was carried out from July to August 2004. The Study Team provided guidance and supervision to the counterpart in conducting the work.

    (1)　　　Methodology

    Methodology of the field identification consisted of two methods.　One was a conventional method using two-time enlargement of aerial photography and existing maps. Another way was to use existing and new ortho-photographs together with Handy GPS receivers.　Two-time enlargement method was used for CORINTO, LEON, LA PAZ CENTRO, ISLA MOMOTOMBITO, TIPITAPA, and ACHUAPA since ortho-photographs were not available during the field identification.　Except those six (6) map sheet, GPS and ortho-photographs were used as modern technique.　In the existing ortho-photographs area, ortho-photographs at a scale of 1/10,000 were used and ortho-photographs at a scale of 1/25,000 were prepared and provided for the new photographed area.　Ortho-photographs with coordinates were very useful to identify small ground objects by Handy GPS.　Preliminary-photo interpretation was conducted using ortho-photographs, contact prints and existing maps prior to the fieldwork.　Based on the preliminary-photo interpretation, objects were verified in the field in accordance with the map specifications.　The field verification method for each map sheets is shown in Figure 5-15.
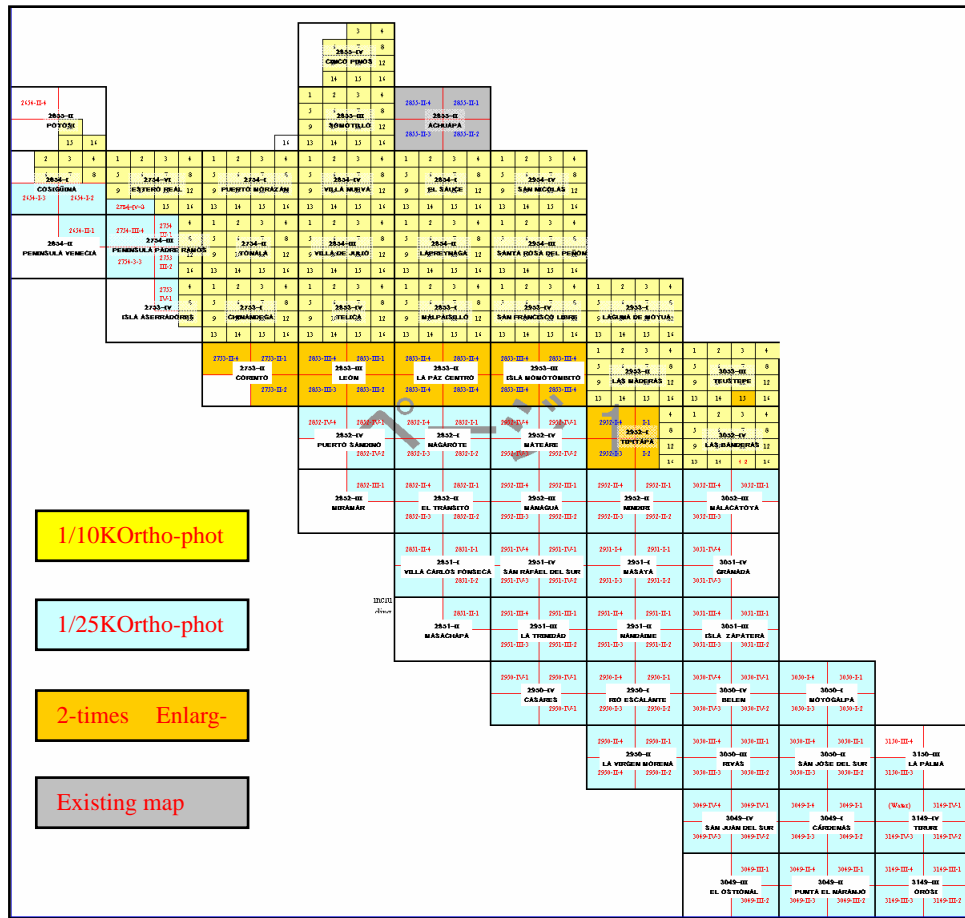
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Figure 5-15 Field Verification Method for Each Map Sheets

Photo 5-4   Field Identification   Photo 5-5   Ortho-photographs

(2)   Preparation of Orthophoto and two-time enlarged photograph

The existing ortho-photographs at a scale of 1/10,000 were printed by plotter for the field verification of existing photgraphed aera.   For the new photographed aera , the

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new ortho-photographs were prepared in Japan.   Digital data (22GB) was stored in DVD and provided to the Cartography Section of INETER.   It was very useful to make new images printed at a scale of 1/25,000 using ArcView for built-up areas for field verification.

The two-time-enlarged photograph at a scale of 1/20,000 were prepared using the scanned photographs for the map sheets: 2753-II CORINTO, 2853-III LEON, 2853-II LA PAZ CENTRO, 2953-III ISLA MOMOTOMBITO, 2952-I TIPITAPA, and 2855-II ACHUAPA.

(3)   Photo-interpretation before the fieldwork

Before the fieldwork, photo-interpretation work was carried out using the ortho-photographs, two-time-enlarged photograph and the existing maps.   The field teams had mutually confirmed the photo-interpretation keys, which made differences among shapes, reflected features, shades and tone patterns on the photographs prior to their photo-interpretation work.   The Study Team gave instructions to the field teams to pay their full attentions to the followings during the field activity:

1)   To understand map symbol for the field identification and to recognize the information required from a shape, shade, tone and pattern on the photographs;
2)   To use existing materials such as topographic maps and contact print for photo-interpretation;
3)   To identify special objects which exists only in the specific areas; and
4)   To identify objects for which the photo-interpretation is difficult;

In the office work of photo-interpretation, the field verification symbols were marked on two-time enlargement, ortho-photographs for the features, which could be verified basing on the existing maps.   The areas having secular changes remarkable in the past such as built-up areas and vegetation boundaries were marked on the photos.   In the classification of vegetation, features, which could not be verified by a single photograph, were verified using stereoscopes.   Finally, the results of the photo-interpretation were put on the photographs (enlargement and ortho-photographs) by using color pencils and graphic pens for the actual fieldwork.

(4)   Field identification

Field verification of existing photographed area was implemented from February to March, 2004 using the existing ortho-photographs in total of 317 sheets which covered the northern part of the project area and two-time-enlarged photograph in a total of 94 sheets were used for the areas where ortho-photographs were not available.   The new photographed area was implemented using the new ortho-photographs from July to August, 2004.

The four field teams were deployed at each phase under the supervision of the Study Team.   Following instructions were given to the field team:

1)   To make the interpretation-key using a digital camera and aerial photographs for succeeding plotting work;
2)   To collect all the small ground features and their location information by Handy GPS;
3)   To put attribute code to classify of the small ground feature when GPS was used;
4)   To use more than five satellites for fixing locations by GPS;
5)   To interpret objects from photo images when GPS did not work well in forested areas; and
6)   To describe the results of field identification on the photographs using red, blue, green drawing pen.

Table 5-17   GPS Attribute Table

No	Código	Ingles	Español	Código de Punto	Número de Punto
1	227	Bridge	Puente	P	001
2	231	Culvert	Alcantarilla	AL	001
3	320-1	School	Escuela Primaria	EP	001
4	320-2	High School	Escuela Secundaria	ES	001
5	320-3	Technical School	Escuela Técnica	ET	001
6	320-4	University	Universidad	U	001
7	322	Health Center	Center de Salud	CS	001
8	321	Hospital	Hospital	H	001
9	408	Antenna	Antena	AT	001
10	401	Tower	Torre	T	001
11	416	Elevated Tank	Tanque Elevado	TA	001
12	415	Ground Tank	Tanque Basado	TB	001
13	649	Well	Pozo	PO	001
14	405	Windmill, Pump	Molino de Viento	MV	001
15	238	Ford small	Vado Pequenó	V	001
16	239	Ford	Vado Grande	VA	001
17	652	Spring	Manantial	M	001
18	410	Power Station	Subestación Eléctrica	SE	001
19	232	Power Plant	Planta Eléctrica	PE	001
20	402	Chimney	Chimenea	CH	001
21	403	Lighthouse	Faro	F	001
22	428	Cemetery	Cementerio	C	001
23	454 and 459	Mine	Mina	MI	001
24	308	Shrine	Santuario o Altar	S	001
25	306	Church	Iglesia	IG	001
26	327	Hut	Choza	CHO	001
27	648	Pool	Piscina	PI	001
28	608	Resorvoir	Embalse	E	001
29	468, 469 and 470	Dam	Presa	PR	001
30	647	Sewage Disposal Land	Pila Séptica	PS	001
31	407	Monument	Monumento	MN	001
32	425	Re-creative Area	Complejo Recreativo	CR	001
33	330	Area of Ruins small	Ruina o Sitio Arqueologico	SA	001
34	331	Area of Ruins Big	Ruina o Sitio Arqueologico	SAG	001

(5)   Arrangement of the field results

For the succeeding plotting work, the field results were checked and arranged in office. It was necessary to edit the location data of several objects which were collected by Handy GPS in the field.　The editing process was done to compare the point coordinate and background image (ortho-photographs) using by MicroStation software in office. Classification of symbols were inspected and corrected in accordance with the instruction sheets of the map symbols and the application rules.

(6)   Check and inspection

The results of the field verification were checked and inspected based on the quality control and discussed within the field identification teams.

The technology transfer of the method of the quality control including the check and the inspection of the results of field identification was conducted by Ing. Nestor Rodriguez who was the person in charge of check and the inspection of the results of field verification.

The quality control table was used for the description of the vague and uncertain matters found in the investigated process and the map symbol names which were not able to be investigated.

The field team had several meetings during the fieldwork to manage the quality control as follows:

(a)   All bridges shall be investigated.　(The range of the investigation is not bound by the size of the bridge.)
(b)   High-pressure power lines to be investigated do not have the limitation by the voltage.
(c)   The notes on the map which have not already been used shall be described by X sign to the corresponding note by a red ballpoint pen
(d)   The annotation newly found in the field shall be described in the existing printed map by a red ballpoint pen.
(e)   Black is not used excluding the symbol of the road type
(f)   The color of the symbols shall refer to the colors described in "Clasification de Campo"
(g)   The characters shall be used by the same characters as in the printed map.
(h)   The characters shall be described clearly in the results.
(i)   The road shall be investigated by the sign with the circle is added to the figure based on the road classification.　The road should painted out.
(j)   The symbols described by abbreviated sentences are assumed to be the same characters described in "Clasification de Campo".
(k)   Because the Japanese judges annotation excluding the character described in the field classification symbols, "Clasification de Campo", characters other than annotation shall not be described on the photographs.
(l)   An X sign is described for annotation which has been described on ortho-photographs and does not expressed on the map prepared this time.　The necessary one is rewritten again with a red ballpoint pen.

(7)   Sample of the field verification results

The results of the field identification are all recorded onto ortho-photographs and enlarged photographs.　Symbols to be written down on the photographs are specifically guided by the Study Team in accordance with the specifications for map symbols and its application rules.　A sample of a field verification results is shown in Figure 5-16.
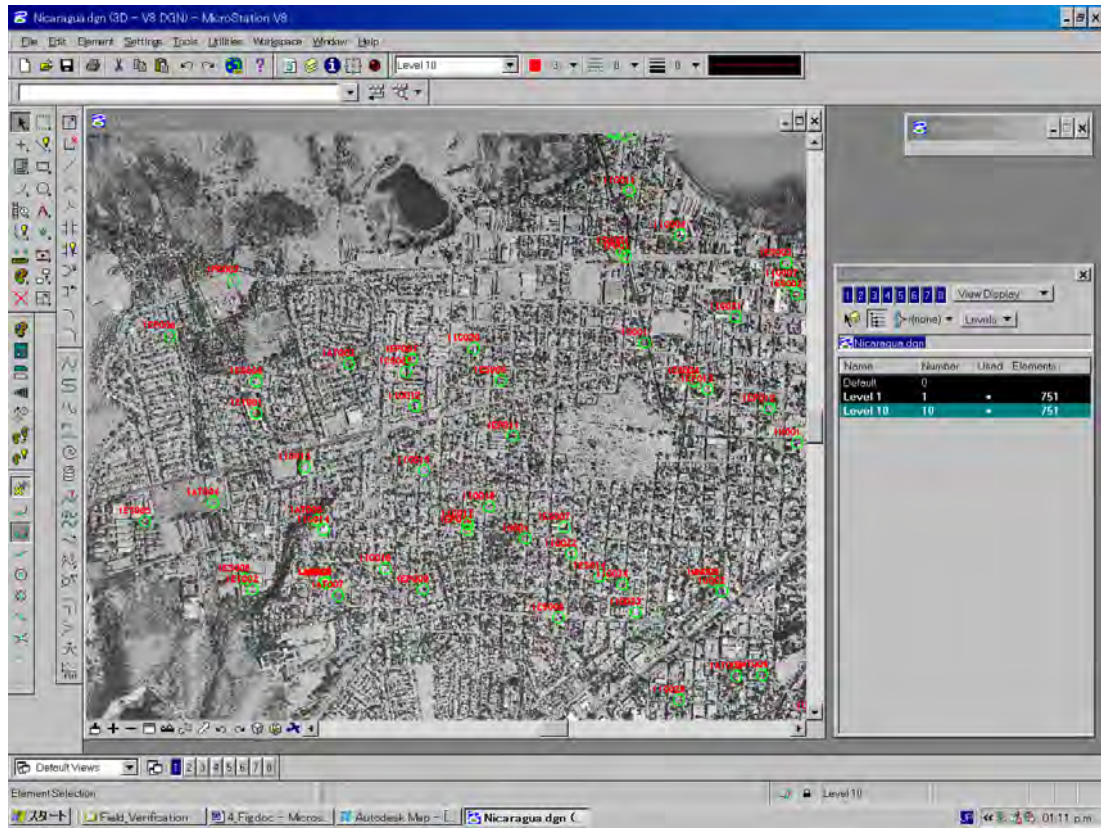
Figure 5-16 Notes on a Double-Enlarged Photograph