

the GIS data were properly created

- Spelling check (the first) on the entry errors in annotations and checking, inspection and correction of their positions (overlaps on planimetric features)
- Creation of tie-strips and inspection and correction of tie points by map sheet
- Extraction and arrangement of indicated unclear points for field survey



Figure 2.1-16 Inspection map prepared in Japan

The above inspection and correction works were carried out in Japan and the output maps approximate to the final products were produced and carried out in Guatemala.

The maps prepared for this study work are as follows:

1) Maps used for inspection in Japan

- Output map from MicroStation (color maps): one copy
- Tie-strip inspection map (color maps containing polygon data on ArcInfo): one copy
- Annotation material maps (blue and black plates): one copy for each
- Annotation inspection maps (blue and black plates): one copy for each
- Mosaic photos used in the second-year field survey: one copy each
- IGN's own existing 1:50,000 scale topographic map: one copy

2) Maps prepared for inspection in Guatemala

- Output maps (imaged as final products): 2 copies (for inspection of annotation positions + shapes and types of vegetation, roads and others, and for inspection of administrative boundaries and names)
- Maps for inspection of annotations (films): one copy
- Maps for inspection of annotations (paper): one copy (for spelling check)
- 1:20,000- and 1:40,000 scale aerial photo orientation maps: one set
- Administrative boundary and name output maps + CD: one set

(8) Preliminary observation work for inspection and field completion survey

23 counterparts and 3 members of the Study Team cooperated in doing the inspection work to extract the elements for the field survey, inspect the positions of annotations and to check the spelling (the second time). The items of inspection were arranged in the map for inspection of annotations and the elements for the field survey were arranged in the final-image output maps.



Figure 2.1-17 Preliminary observation map for field completion survey

(9) Field completion survey

The field survey was made under full security control because it included some areas considered as danger zones. The concrete security control methods were made regular correspondences between groups and between IGN and each group.

The main works conducted in the field completion survey are as follows:

- Checking of unclear points
- Survey on the accurate positions of annotations
- Survey on the newly added annotations
- Corrections of any secular changes to road attributes and planimetric features (bridges, public buildings, etc.)



Photo 2.1-5 Field survey

(10) Re-acquisition of materials from IGN

1) Review of road attributes

The data on road attributes was provided by IGN in the second-year field survey. However, some data errors and secular changes were found out during the Work in Japan. These were pointed out at the meeting of discussions with IGN and the review was requested to IGN. IGN checked on these data errors and changes and corrected the data. Then, IGN presented the final correction materials to the Study Team.

2) Re-acquisition of national border data and others

The problem that the form of the river along the national border was largely different from the form of the national border in the provided data was caused by the national border data owned by the SUNIL. The national border data was developed on the basis of the 1:250,000 scale topographic map of IGN. Therefore, IGN created the digital data in the 1:50,000 scale again. The correction of the national border data caused some discrepancies between the national border data and the provincial border data, which were corrected by the tie-strip processing at IGN.

On the municipal boundaries, which included some undefined points, it was discussed and decided that those boundaries remained in the GIS data by IGN's request, but that those were not represented in the printed maps. (Refer to the Memorandum as attached hereto.)

2.1.6 Production of spatial information database (Digital plotting of modifications and digital compilation)

(1) Basic Policy on Digital Plotting of Modifications

Originally, it was intended to extract the temporal changes by comparison with the existing maps and aerial photos and to conduct digital plotting of the models containing such temporal changes through map indexing.

However, when the corrective plotting was started, it was found that there were many temporal changes scattered over the entire map sheet and it was decided that map indexing of all models containing temporal changes to be updated was not realistic from the viewpoint of efficiency and accuracy. Therefore, the entire area was divided into several blocks and aerial triangulation was carried out in each block in order to enhance efficiency and ensure uniform accuracy.

(2) Positive Film Scanning of Aerial Photos

In the digital plotting of the modifications, general digital plotting using an analyzing plotter was not used, but the digital photogrammetric system was adopted, and scanning of the positive films of the 1/40,000-scale aerial photos was conducted.

The digital photogrammetric system was selected for the following reasons:

- ① It was possible to output orthophotos.
- ② The same method was used for making the 1/10,000-scale orthophotos, so the data ensured compatibility for easy use of both data.
- ③ In this Study, the existing national base maps were vectorized before digital plotting of the modifications. In the digital photogrammetric system, the vector data could be superimposed on a scanned photo on the display monitor in the digital plotting process, ensuring enhanced accuracy in the extraction and updating of temporal changes.

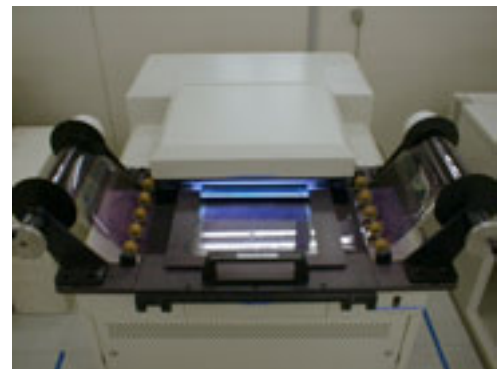


Photo 2.1-6 Special scanner dedicated to aerial photography

The Study Team conducted tentative scanning to extract samples of each typical terrain such as city area, grassland, mountainous area and bare land before data acquisition and collected the setting values for brightness and contrast. The data was acquired with a resolution of 30 μ m per pixel, 256 monochrome gradation levels and the original image data was

saved separately from the work data file.

After the end of the scanning, accuracy control of each photo was conducted regarding the following items to confirm that there would be no problem in subsequent work:

- Resolution
- Brightness
- Contrast
- Noise (flaws and folds)
- Normalized processing (correction of mechanical errors)
- Data acquisition range (whether indexes are included or not)
- Possibility of index observation (whether in an observable condition or not)
- Image rotation
- Format (TIFF, uncompressed, 256 monochrome gradation levels)
- File name (whether data and file names coincide or not)

(3) Aerial Triangulation

This process is corrective plotting, but aerial triangulation was carried out in order to secure uniform accuracy. The elements necessary for aerial triangulation were selected from the control points installed for preparation of the 1/10,000-scale orthophotos and definite planimetric features on the existing 1/50,000-scale maps. These elements were digitized and the points whose coordinate values had been acquired were also adopted as control points. In addition, the aircraft GPS data acquired when the photos were taken were also used as control points.

Accuracy control was conducted of the following items per block and it was confirmed that there would be no problem in subsequent work:

- Number of horizontal control points
- Number of elevation control points
- Number of canceled horizontal control points
- Number of canceled elevation control points
- Residuals of horizontal control point (standard deviation and maximum value)
- Residuals of control point elevations (standard deviation and maximum value)
- Residuals of bundle crossings (standard deviation and maximum value)
- Residuals of horizontal positions in aircraft GPS data
- Residuals of elevations in aircraft GPS data

(4) Preliminary Examination of Linear Planimetric Features (Roads and rivers)

Preliminary examination of the temporal changes in polygonal features was completed in the process of “Photo Interpretation/Temporal Change Detection”. Temporal changes in linear planimetric features such as roads and rivers which were not covered in “Photo Interpretation/Temporal Change Detection” were examined in this process.

(5) Digital Plotting

Digital plotting of the temporal changes based on the preliminary examination was conducted using an analyzing plotter capable of overlay display and a digital plotter. Basic spatial information data was acquired of all the items necessary for topographic maps including the GIS database. The operators paid special attention to acquisition of elements with orientation (schools and hospitals).

After completion of the digital plotting, accuracy control of the following items per model was conducted to correct errors:

- Number of faulty entries and omissions of codes (Faulty entries include faulty attributes and inaccurate shapes.)
- Number of edge mismatching points



Photo 2.1-7 Digital plotter

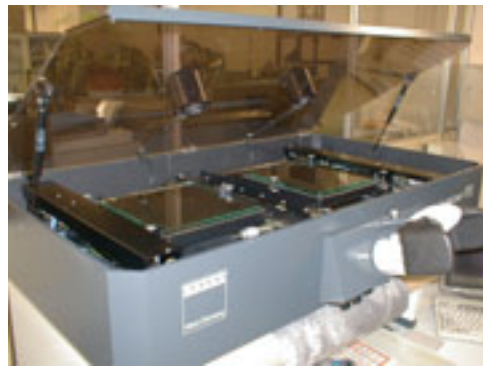


Photo 2.1-8 Analyzing plotter

(6) National base maps: Merge modified plotted data with existing data

The basic spatial information data which had been digitized and vectorized was overlaid on the temporal change data to delete the older data. In this process, the operators paid special attention to ensure that the road network, small objects and symbols were not disconnected or deleted.

After merging both data, the operators edited the basic spatial information data as a database.

In the editing process, the layer items for the GIS database and those for the printed map data were checked and corrected for errors such as overshoots and undershoots, and processing for adjoining map sheets was performed.

In addition, the data processing necessary for representation of topographic maps such as double lines for roads and arrangement of map symbols was performed. These work processes were controlled per map sheet and the basic spatial information database was configured.

After the editing work was completed, accuracy control per map sheet was conducted by the following items to correct any errors:

- Number of faulty entries and omissions of codes (including marginal information data)
- Number of edge mismatching points
- Number of errors such as overshoots and undershoots

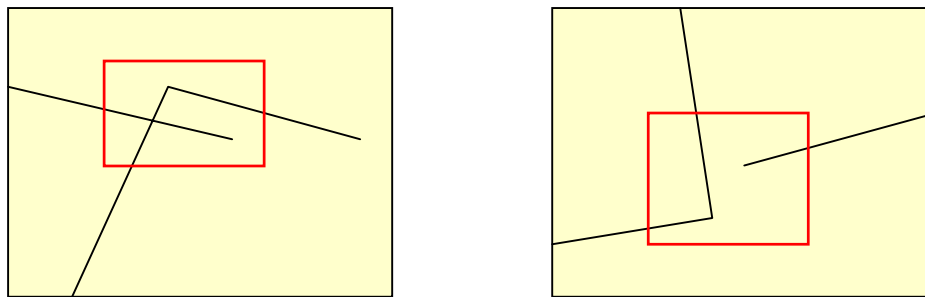


Figure 2.1-18 Example of overshoot and undershoot

(7) National base maps: Creation of DEM

TIN models were created using the layers with 3-dimensional attributes (contours, elevation points and control points) from the data acquired as the basic spatial information database. DEMs in meshes of 40m intervals were created from these TIN models. The operators stored these DEMs as part of the basic spatial information database. In this work, data of the duplicate parts of adjacent sheets was also stored in the basic spatial information database to cover all the map sheets which are its unit components.

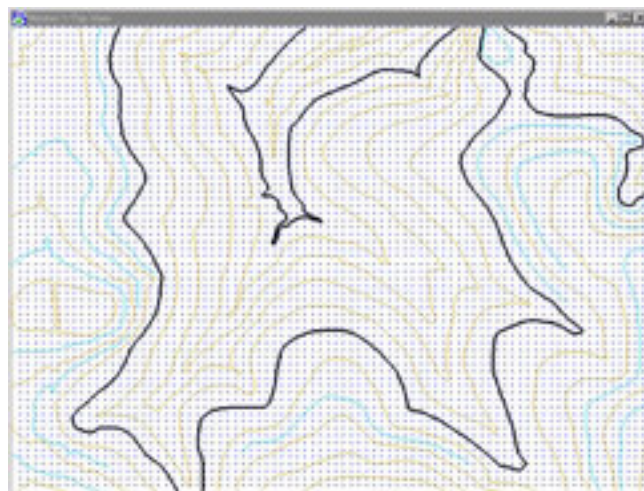


Figure 2.1-19 Creation of DEM

If the DEM data structure was not standardized for each map sheet, it was anticipated that it would hinder effective use of the DEM data in future. So even if the map sheets covered the

areas other than the study area, the elevation values in the other areas were also acquired as dummy data.

(8) Digital Compilation

The skeleton data to be converted into GIS data and printed maps was configured in the DGN file format unique to MicroStation.

Prior to the creation of the data, the points to consider in determining the data structure were the classification of planimetric features and annotations to be represented on the topographic maps and to bring the data structure as close as possible to that of the DGN file. This made possible the effective conversion of the skeleton data into printed maps and a GIS database.

In creating the data, the point to consider was to create the data based on the common points and differences between the topographic map data and the GIS database. A map is a model of the real world and a medium to provide information on material bodies existing on the surface of the ground. Therefore, topographic map data and the GIS database are often deemed to be similar to each other, and they do have many common points. In practice, however, there are some obvious differences in the information interpreted by human beings and that interpreted by a computer. This is because things that pose no problem to human interpretation cannot be interpreted at all by the computer unless an accurate model of the real world is available.

In digital compilation the digital plotter used to create the skeleton data on the actual conditions does not support the function of adding topological structure, from the nature of the software. In addition, the functions of the plotter and its software are specific to topographic map production. This means that these functions are designed to operate to create data with a level of accuracy that can be interpreted by a human.

When data for the production of printed maps and building of the GIS database is created under these conditions, the computer may not be able to interpret the planimetric features correctly. Below are given some examples of these problems, with a description of the points considered in the digital compilation.

1) Graphic intersections are not interpreted correctly

a) When a line is not properly connected (Undershoot)

In a case like this, a person will recognize that the lines are connected, but the computer cannot make this interpretation.

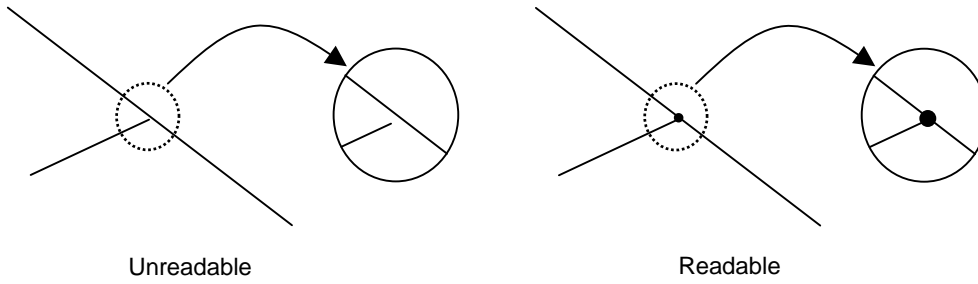


Figure 2.1-20 Failure to connect

b) Lack of intersection data (node)

In a case like this, a person will recognize that the two lines intersect each other, but the computer make this interpretation.

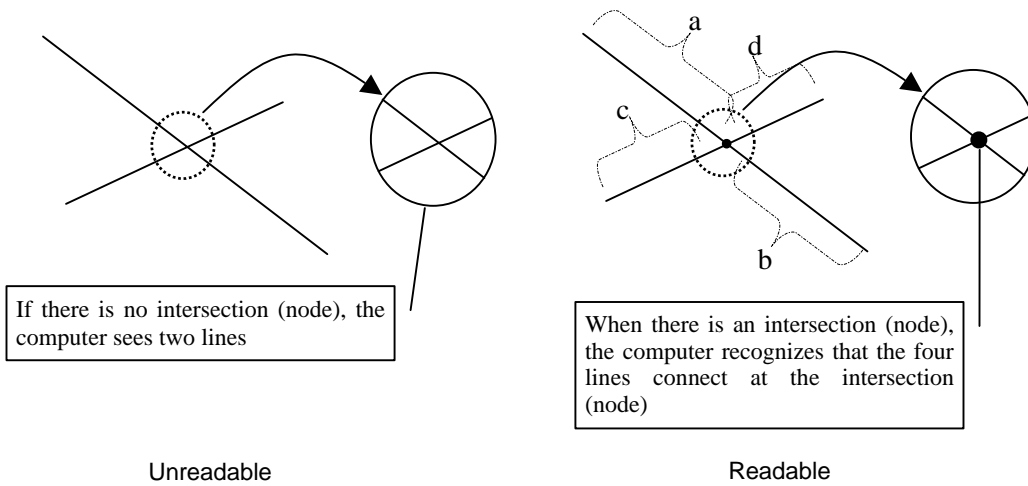


Figure 2.1-21 Missing node

c) Closed figure that is not closed

In a case like this, a person will recognize that this represents an area, but the computer cannot make this interpretation.

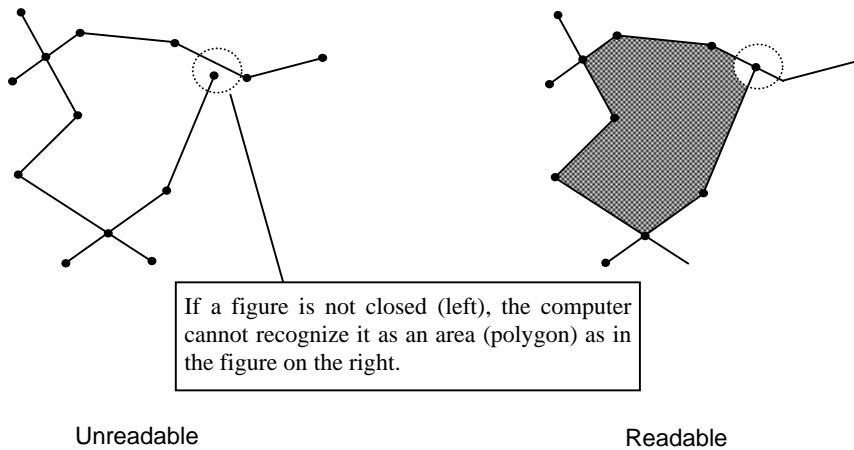


Figure 2.1-22 Gap in closed figure

The following three GIS software functions for correcting connections are considered effective in cases like those given above:

- Function to generating a point of intersection when one line stretches over another line;
- Function to connecting all points existing within a given (adjustable) range;
- Function to remove lines below a given distance (trimming)

However, when automatic connecting correction is done, the coordinate values are also corrected, resulting in incompatibility between the national base maps and the GIS database. Thus, every effort should be made to avoid the repeated use of these functions. In addition, when using MicroStationJ for digital compilation, the functionality of the software means that the relationships between figures have to be defined visually. This means that in practical terms it is very difficult to create data with accurate connections; undershoots and overshoots, as illustrated below, are the result.



Figure 2.1-23 Examples of errors

In view of these technical limitations, it was decided to draw the lines configuring a feature basically as overshoots, in order to avoid as far as possible the deformation of figures caused by automatic connecting correction by GIS software after structuralizing. This method allowed the computer to recognize a closed figure by adding a point of intersection and trimming the unnecessary line (overshoot). This had a huge effect on the reduction of the volume of correction work and accuracy enhancement.

When using the automatic connecting correction function using GIS, it is first of all necessary to perform structuralization, the details of which are described in (10). “Structuralization”.

2) Polygon type cannot be recognized

To represent planimetric features (such as buildings, roads and railways) using points and lines, the features are classified into different types according to attribute values (by color, level and line type) defined in MicroStationJ and converted into those symbols, so that their topological structures can be built and they can be identified relatively simply. However, with regard to areas, there are several different types of line that make up an area, and their

combinations are not standard, so that it is very difficult indeed to identify a polygon configured by conversion, leading to a need for repeated interpretation of the topographic features. Since the work of interpreting the topographic features has already been carried out when the data was created using MicroStationJ, re-interpreting the topographic features again after the topological structuralizing would be a duplication of the work. Therefore, the special features of the software used to create the skeleton data and the software used to create the GIS database were utilized as described below with the aim of creating polygons effectively.

The software for CAD systems has a special data structure to represent a symbol, called a cell. as shown in the example below, this is used to represent features such as houses or churches by a common pattern for each type of feature. To represent an area such as a forest or a field, a cell corresponding to the feature is placed within the closed figure making up the area (one cell to each closed figure).

Note: The figure below is different from the cell used in the Project.

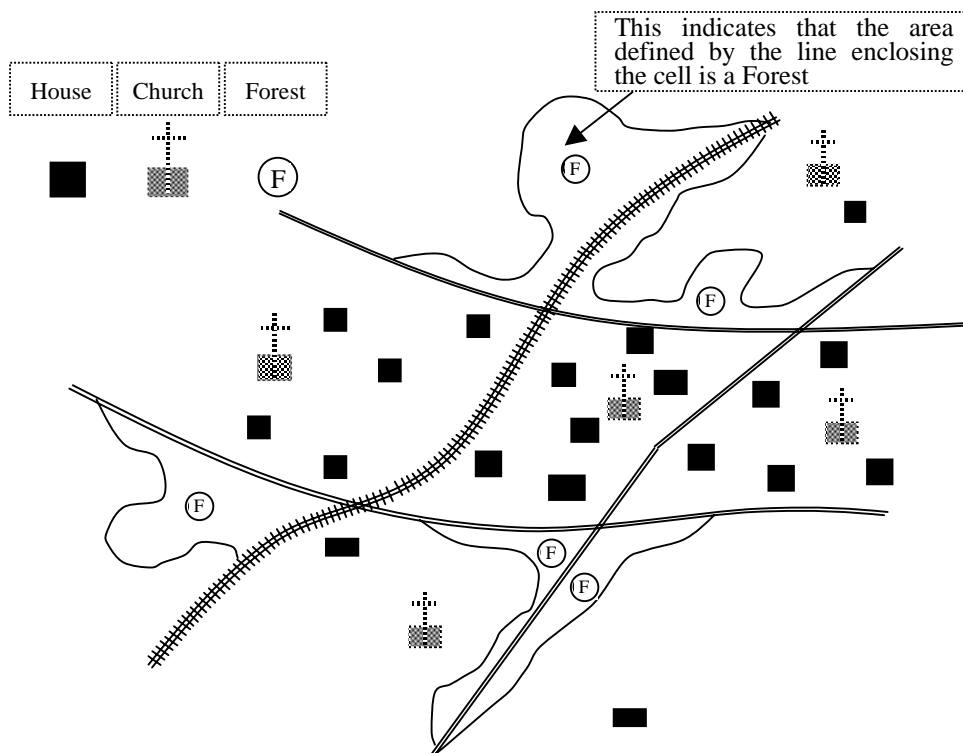


Figure 2.1-24 Relationship between polygons and symbols

A cell is made up of the position information (coordinates) and graphic data indicating a pattern. In practice, the patterns (cell source) exist as a library. When a cell is added to a figure, it consists of the coordinate values (as a point, the cell number, and a link to the figure indicated by the cell number. To represent a church for example, the data contains the position information (coordinate) on where the church stands and the information showing the link to the cell indicating the church. In addition, the attribute information for level, color, etc., is maintained unchanged as the attribute value.

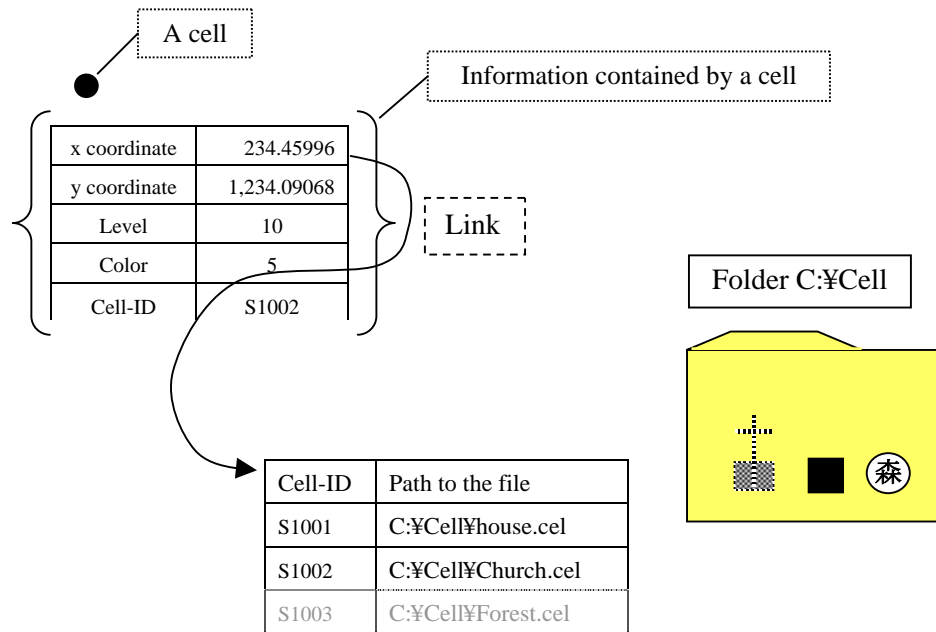


Figure 2.1-25 Data structure of MicroStation

When a cell that has been added as described above is converted into GIS data (by Arc/Info Coverage), the cell's attribute data (such as level, color and cell number) maintained on the design file are inherited even after conversion within Coverage as an external attribute table.

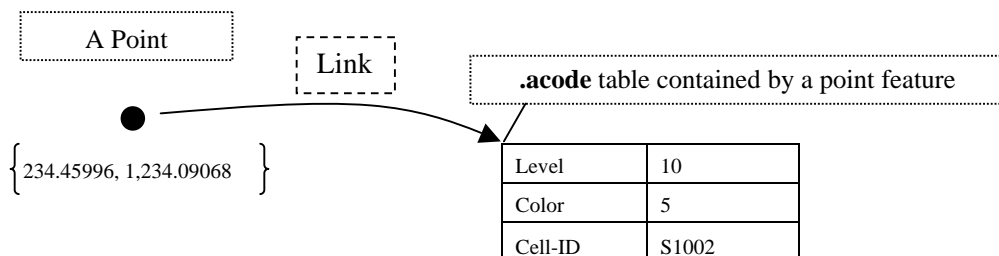


Figure 2.1-26 Data structure of Arc/Info

Similarly, when a closed figure is converted into GIS data (by Arc/Info Coverage), a polygon feature is formed. At this stage, however, the software configures a polygon in the area recognized as a closed figure, but does not link it with the existing cell. This means that a

polygon configured by a closed figure does not maintain the above information.

In digital compilation, therefore, a cell is placed within an area where a polygon should be formed and after structuralizing, the cell's attribute table (.acode) is linked with the polygon attributes, thereby allowing the type to be assigned to the polygon automatically. This process carried out after structuralizing is described in (10) "Structuralization".

(9) Data Export

In order to create the GIS data and the printed map data from the spatial basic information database prepared in the DGN file format, the following points were taken into consideration for exporting the data to various file formats:

1) Annotations and symbols

Annotations and symbols are indispensable information for the production of printed maps; the font type and size, as well as the symbols, must meet the IGN specifications for printed maps. Therefore, the data input of annotations and symbols was carried out in accordance with the IGN specifications for digital compilation of the spatial basic information database using MicroStation.

It is important that the information should finally be reproduced accurately with AdobeIllustrator even after having been subjected to data format conversion. Here the compatibility of the fonts used by MicroStation with the fonts used by ArcInfo and AdobeIllustrator was a problem. It became clear from verification of all these applications that by exporting the data in the EPS format from MicroStation directly into AdobeIllustrator, it was possible to ensure accurate reproduction of the information.

In addition to the problem of the fonts, another problem was that the lines and texts imported into AdobeIllustrator were not smooth. This problem was solved by exporting the information from MicroStation at four times actual size and reducing it back to actual size in AdobeIllustrator.

2) Polygon (land use)

The line elements forming a land-use feature do not necessarily form a closed figure in the DGN file. Therefore, a cell was placed inside the figure as described in (8) Digital Compilation, and the cell data and the line data forming the polygon were input simultaneously into ArcInfo.

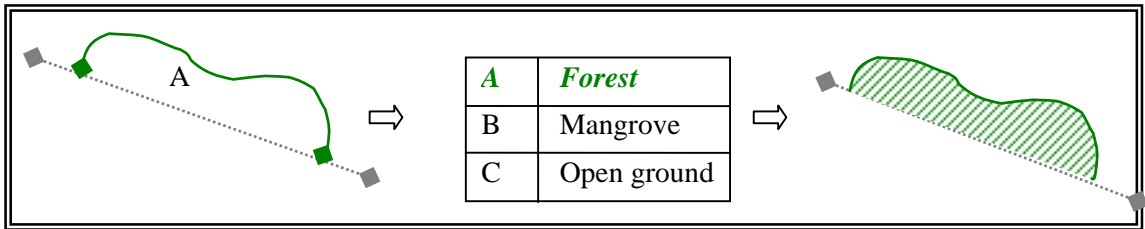


Figure 2.1-27 Formation of a land-use polygon

3) Polygons (others), lines and points

Planimetric features forming polygons other than for land use (such as built-up areas, wide rivers, lakes and swamps, features with shape) which are always closed figures, features with linear form (roads, railways, narrow rivers, administrative boundaries, power transmission lines and other infrastructure), and features forming points (such as buildings and land marks) were exported in the DXF format from MicroStation to ArcInfo.

(10) Structuralization

The DGN data created in MicroStation was converted into the ArcInfo Coverage format in order to add the topological structure to the data.

When producing the printed maps using graphic software, the addition of topological structure to the data was essential to provide the simple lines and polygons with the line types and patterns in conformity with topographic map representation.

This structuralizing process prepares the data for the production of the printed maps and at the same time adds the structure for the GIS database. At this point, the data does not yet conform with “PAABANC”, the IGN-established specifications, so the data was not complete as a GIS database, but it can be used as the data source when the GIS database comes to be built later on.

First of all the data is rectified through the correction of diagrammatic errors and supplementation of incorrect or incomplete attribute input. Then so that it can be edited as a database for printed maps in the graphics software AdobeIllustrator it was converted from the GIS data format (Coverage) via the ArcInfo external conversion file format (E00 format) to the AdobeIllustrator format (AI).

In fact, because of the need to process a huge amount of data – 74 maps covering one-third of the land area of Guatemala – a program was written for the above format conversion work, and the processing was done automatically.

1) Polygon (land use)

With the ArcInfo application used for this Project, it is possible to add an arbitrary user ID (or arbitrary information) by inserting a representative point when a polygon is created. When a polygon is created, a check is made for the presence within the polygon to be created of a representative point (label feature), and if there is a representative point the polygon is created with the information contained in the point as the user ID.

In the ArcInfo Coverage conversion work, after conversion the cell was converted as a point, and the attribute information (level, color, cell name etc.) held maintained through the data structure was held as an attribute table (.acode table). Using this function, when the skeleton data was created the polygon information was arranged as a cell.

In this Project, by converting these cells as points and using them in place of label features, some data attributes were maintained even after conversion. Thus in the part representing the area a cell with a unique ID number was conferred on each planimetric feature. After conversion of the GIS data, this ID number was used as an indicator to identify each planimetric feature.

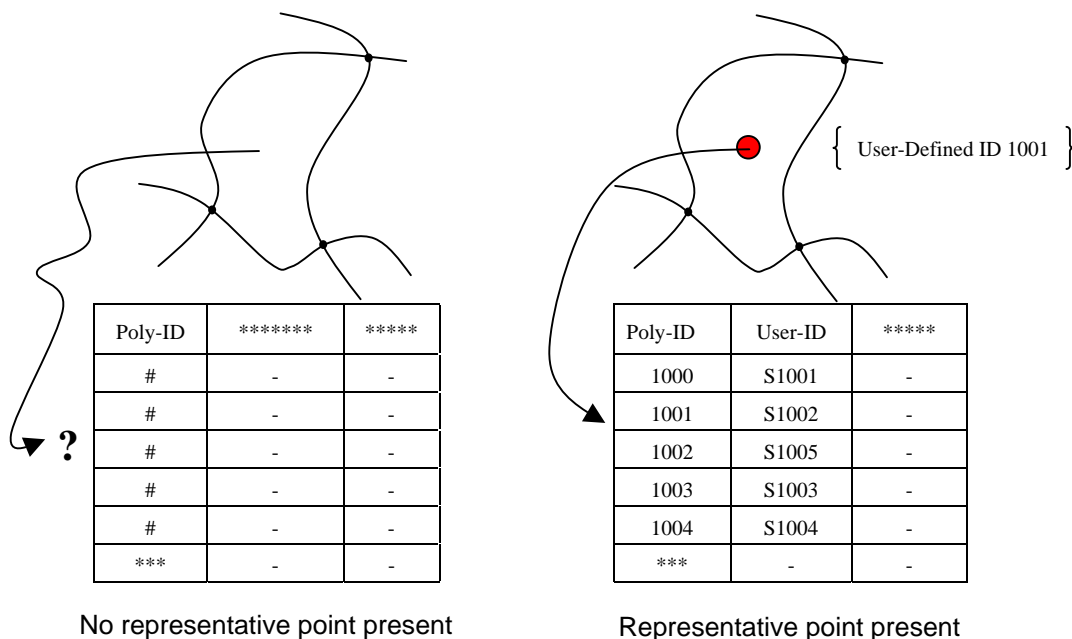
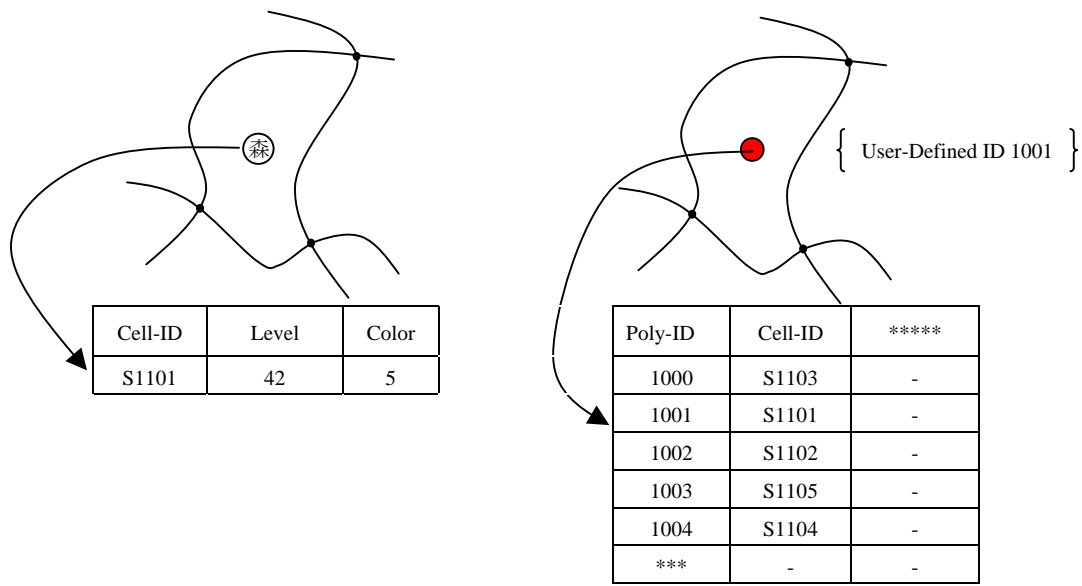


Figure 2.1-28 Contents of Arc/Info data

Using this procedure it became possible to configure the GIS data effectively while maintaining the information available from the interpretation of the topographic maps carried out when the skeleton data was created. To process the large volume of data, land-use polygons were created automatically by batch processing using the macros in ArcInfo. A later inspection found some instances of polygons that had not been created properly because of undershoots and representative points that had been left out, so the work of inspection and

correction was carried out repeatedly.



In MicroStation

After conversion to Arc/Info (Coverage)

Figure 2.1-29 Creation of a polygon other than for land use

2) Polygons (others)

The DXF format data was converted into the ArcInfo Coverage format. At this point, the Coverage file contained all the lines forming polygons, other lines and points. Of these, only the lines needed to create polygons were extracted and the polygons created with referral to the layer numbers in the DXF data. These polygons represented the planimetric features other than for land use, which always form closed figures.

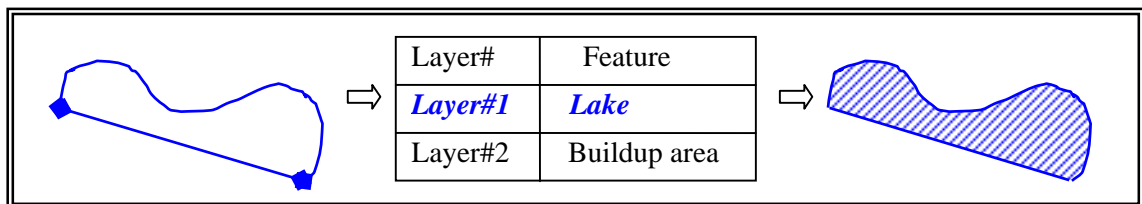


Figure 2.1-30 Contents of MicroStation and Arc/Info data

3) Lines

The lines used for polygons were deleted from the data converted to the ArcInfo Coverage format, and the line data representing linear planimetric features only was extracted.

Then automatic connecting correction was carried out using the functions of ArcInfo described below. Remaining errors that could not be corrected automatically were corrected manually

a) When a line does not properly connect to another (undershoot)

Within a certain distance (tolerance), lines that do not join up are automatically corrected so that they connect.

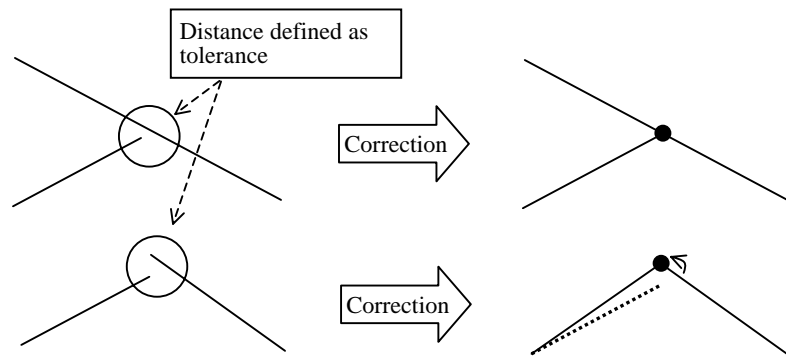


Figure 2.1-31 Correction of undershoot using Arc/Info

b) When the intersection data (node) is missing

When two lines cross or touch each other (i.e., the tip of one line lies on another line) a node is generated at the intersection to show that the two lines are connected.

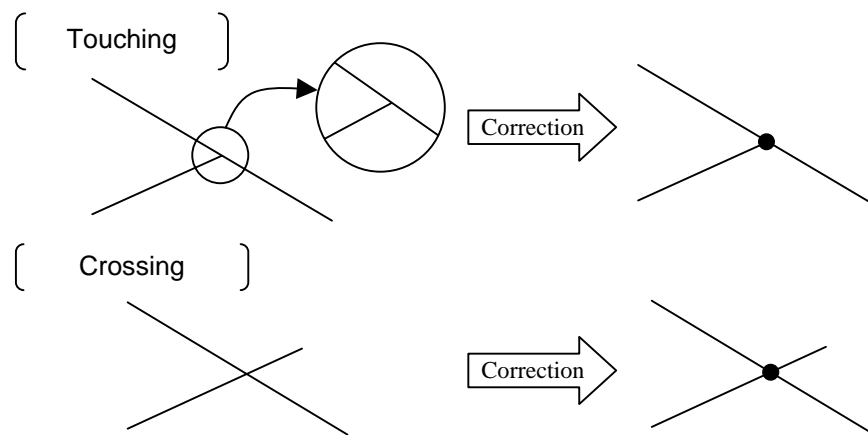


Figure 2.1-32 Creation of node using Arc/Info

c) When lines do not connect exactly (overshoot)

Lines under a certain length are automatically (or manually) erased (trimming)

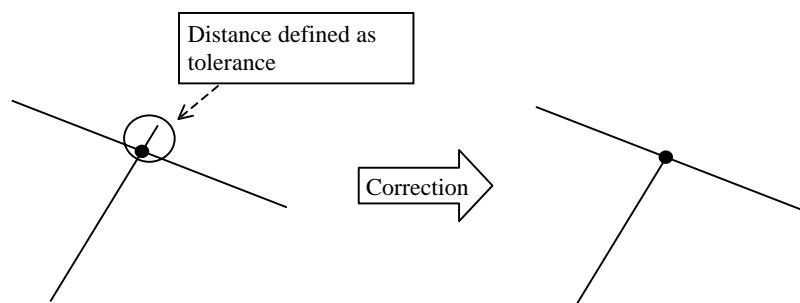


Figure 2.1-33 Correction of overshoot using Arc/Info

(11) Corrective entry 1

The corrective entry of the annotations for which the checking and correction was deemed to be necessary in the stage of work in Japan prior to the inspection work and the field completion survey in Guatemala were made using the digital compilation system as one item of study equipment and MicroStation after confirmation by the IGN side and in the cooperation between the Study Team and the counterparts.



Photo 2.1-9 Inspection by IGN staff member

This problem often came out in the course of the work of updating secular changes, which were caused by the changes in village forms to be annotated, the newly formed villages and other changes of various planimetric features. These changes were correctively entered referring to the existing topographic maps and new photos and with the counterparts' confirmation.

(12) Corrective entry 2

The corrective entry was made on the basis of the inspected contents arranged in the annotation inspection map (paper) using the digital compilation system and the digital plotter as procured as the study equipment and in the cooperative work of the Study Team and the counterparts.

- The changes to annotations were corrected with the digital compilation system and MicroStation.
- The line data that might be omitted in plotting were additionally plotted using the digital plotter as one item of the study equipment, on the basis of the prepared correction-indicating map. The main line data as corrected included the data of lakes, roads, rivers, Cem (cemeteries), Corral (fences) and local runways.
- The corrections in GIS data were made by redrawing polygons using ArcInfo.
- After completion of the correction work on all changes, the data was output again and the final inspection on the spelling of annotations, updating errors and others was made in the cooperative work with the counterparts.



Figure 2.1-34 Compilation of 1:50,000 scale topographic map using MicroStation

(13) Inspection, correction and processing in Japan

The inspection on the following items that could not be made in the fourth field survey was carried out in the Work in Japan and the data were corrected.

- The annotations (in grouping) in which each character was separated from another were detected in the batch processing on ArcInfo and corrected to the normal style.
- The position of any building symbol protruded into a road for which the width was expanded was corrected by manual processing using MicroStation.
- The processing to delete any symbol protruding outside the neat line (into the margin) in the printed map data was executed.
- The logical check on contours and elevation points, and the checks and correction on whether there were the highest elevation points or not were executed using MicroStation.

(14) Structuralization of GIS database: Addition of projected information

The spatial basic information data was required to be under data control per neat line while the entire area had to be handled as seamless data for the GIS database. In this work, the special basic information data divided by neat lines was adjusted to be adjoined and integrated into an entire map. All the planimetric features in the GIS database were reconfigured in accordance with the PAABANC data specifications.

The spatial basic information data had existing coordinate values because it was built on MicroStationJ in the setup conforming to the ellipsoidal projection method as specified by IGN.

On the other hand, for processing various types of data as the GIS database, it was necessary to register the ellipsoidal and coordinate systems of the data on the GIS software. Therefore, the projection information was added to various types of data in ArcInfo Coverage format in accordance with the following specifications:

- Reference ellipsoid: WGS84 (a=6,378,137.0 f=1/298.257223563)
- Projection method for topographic maps: Horizontal Mercator's projection (GTM)
- Position of origin: Meridian direction=Long. 90°30' west
- Latitudinal direction=the equator
- Coordinates of the origin: X (N-S)=0, Y (E-W)=500,000m, scale factor=0.9998

(15) Adjoining of map sheets

Through the process of "Digital compilation of basic spatial information database", the following five types of data were created for each of the 74 sheets of the 1:50,000 scale topographic maps under the study: ① EPS file for symbols and annotations; ② ArcInfo Coverage file for polygons (for land use); ③ ArcInfo Coverage file for polygons (for other planimetric features); ④ ArcInfo Coverage file for lines; and ⑤ ArcInfo Coverage file for points. The file ① contained the data used only for creating the data for printed maps, which was not adopted in the GIS database. The file ⑤ contained the data on the points created to complement the symbols that were not filed in ①, but it held the annotation texts as attributes. These annotation text attributes were converted into the attributes of the corresponding features in reconfiguring all the polygon, line and point data as the GIS database, thereby avoiding the overlap of work.

The continuous figures, such as polygons and lines, had to be adjusted to adjoin the map sheets. These corresponded to the data in the above files ②, ③ and ④, the figures and attributes were adjoined and the data separated by neat line was integrated using the processing procedures as described below.

1) Preparation of figures (edge matching <node to node and arc to arc> and reconfiguration of topology)

Before adjoining multiple map sheets in practice, the compilation work that would enable the figures to be adjoined had to be done, as described in detail below.

a) Edge matching

There were deviations in the figures to be adjoined, which could not be visually determined. There were two main causes for such deviations: one case was, when acquiring data, the coordinates of a figure existing across the neat line were not matched in both map sheets. The other case was when the acquired figure data adjoined on the same coordinates was deformed in the automatic phase structuralizing process, thereby causing a deviation. The deviations to be corrected in this

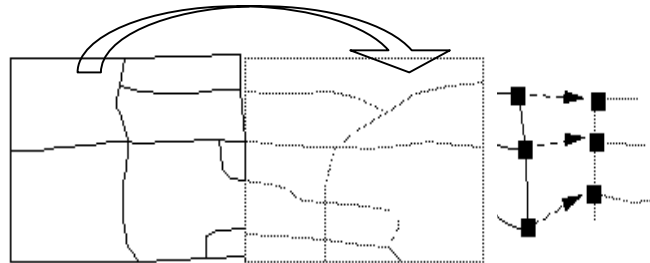


Figure 2.1-35 Edge matching

work corresponded to the latter case. The coordinates were matched in digital compilation on MicroStationJ, but some figures were deformed and deviated in adding the phase structure on ArcInfo. To correct these deviations, the maximum value (threshold value) to allow the automatic adjoining was preset, and the figures deviated within the threshold value were automatically adjoining node to node or arc to arc. If the figures that greatly deviated were forced to be adjoining, the shape of the figures would be largely changed, resulting in the lower accuracy of the data acquired on MicroStationJ. Thus, the threshold value was minimized.

b) Reconfiguration of topology

The figures were compiled by edge matching. Then, the topology was reconfigured to update the connecting relations of adjacent figures, while the attribute data of the figures were also automatically updated. In this case, some figures, which remained erroneous because the topology could not be configured, had to be subject to human judgment and they were manually corrected through visual check.

2) Preparation of attributes (deletion of unnecessary items → all items with the same attribute)

To adjoin map sheets, the figures had to be adjoining while the attribute items for the figures had to be the same. Therefore, the unnecessary items such as the attributes automatically generated in the previous work processes were deleted to standardize the attribute data.

3) Adjoining of map sheets (74 sheets in one coverage by item by map adjoining/appending)

In the previous work, the figures and attributes were standardized. Then, the data for three themes of polygons (for land use), polygons (for other planimetric features) and lines (such as rivers and roads) that was divided into 74 sheets according to the neat lines of the 1:50,000 scale topographic maps were integrated into one data file.

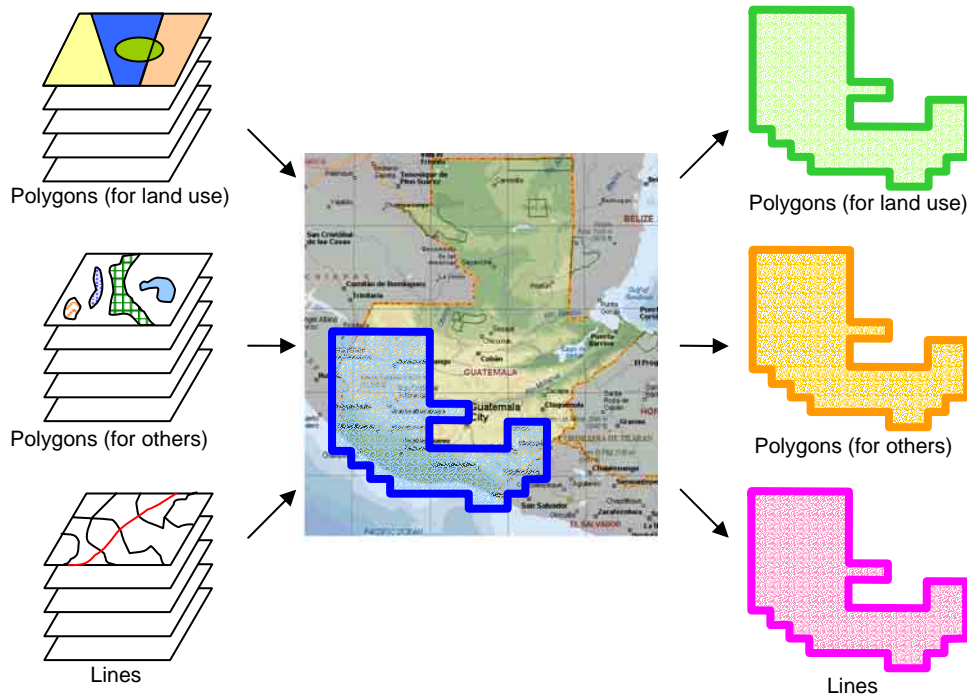


Figure 2.1-36 Integration of map sheets

4) Processing after adjoining (Removal of sliver polygons and dangling arcs and topology reconfiguration → Connecting adjacent features with the same attribute by dissolving)

a) Removal of sliver polygons

In the case where the figures of a feature in adjoining map sheets are not completely matched though they are matched as a feature, a small polygon might be automatically generated at the adjoining part. This is called a sliver polygon, which is automatically generated as a result of data

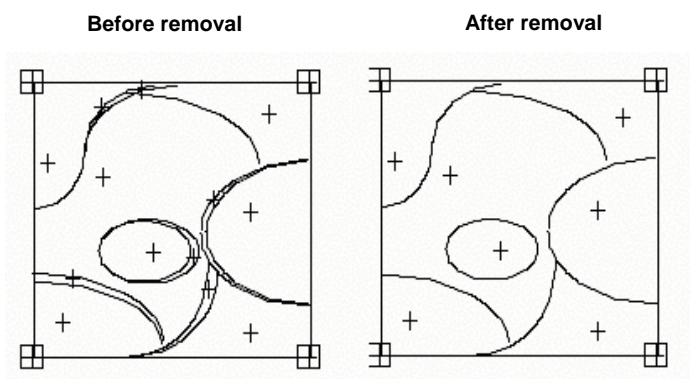


Figure 2.1-37 Removal of sliver polygons

processing, not through the acquisition of data. To remove sliver polygons, polygons that were smaller than a certain area were processed to automatically be adjoined with the adjacent polygon.

b) Removal of dangling arcs

An arc that is very short and not used as a side forming a polygon is called a dangling arc. There are two causes of this: acquisition of overshoot data and adjoining of data. To remove them, arcs that were shorter than a certain length, and of which the polygons on both the left and the right sides were the same, were automatically processed to be deleted.

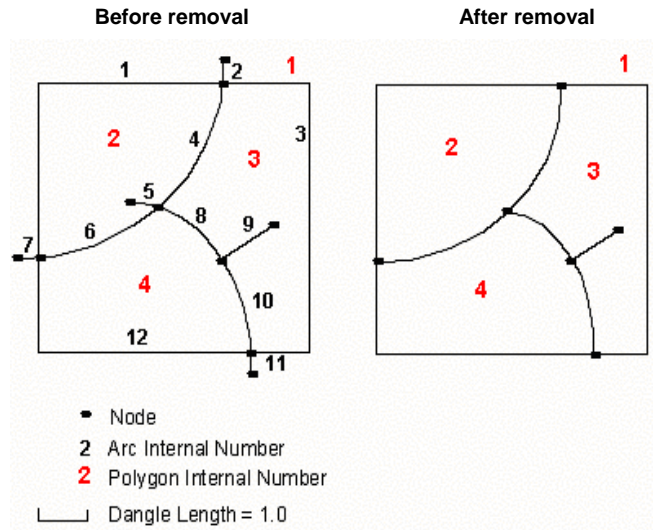


Figure 2.1-38 Removal of dangling arcs

c) Topology reconfiguration

The topology was configured again based on the compilation of figures after adjoining the map sheets, and the connection of adjacent features was updated while their attribute data was also automatically updated.

d) Connecting adjacent features with the same attribute by dissolving

The final process in the adjoining work was the integration of the adjacent features having the same attribute. For example, in the case where the polygons of the same vegetation type were adjacent, there existed two polygons having their figure and attribute information. By handling these polygons as one polygon (in the dissolving process), the information could be halved, ensuring the enhanced data operability in feature compilation and retrieval of attribute information.

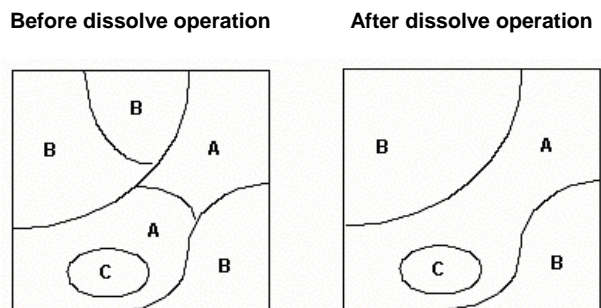


Figure 2.1-39 Dissolve operation

(16) Exporting to PAABANC Specifications

1) Arrangement of PAABANC specifications

The GIS database covering 22 sheets of 1:50,000 scale topographic maps was developed under the assistance of France in 1998. The GIS database specifications applied to this database were PAABANC. The final form of the GIS database as the product of this Project was required to conform to these specifications. PAABANC was specified to create the data in ArcInfo Coverage format and to categorize it into 10 thematic maps.

Table 2.1-11 PAABANC specifications

| Coverage name | Theme | Phase structure type |
|---------------|-------------------------|----------------------|
| RCA | Road network | Arc |
| RFE | Railway network | Arc and nodes |
| HIL | River | Arc |
| DAD | Administrative boundary | Arc and polygon |
| OCS | Land use | Arc and polygon |
| TSI | Flooded area | Polygon |
| ACM | Facility (line) | Arc |
| TOP | Facility (point) | Point |
| PTC | Control point | Point |
| ALT | Elevation | Arc and point |

The PAABANC data covered many planimetric features represented by vector figures such as points, lines (arcs), nodes and polygons in the 1:50,000 scale topographic maps. The detailed types by theme (such as, for example, an arterial road in a road network, a sidewalk) were categorized by the data attributes. The features with proper names were configured to hold vector figures having names as attribute values. In comparison between the printed maps of the 1:50,000 scale topographic maps and the PAABANC data, it was found that the categories of features represented in the topographic maps were more detailed, while all the features could not be represented under the PAABANC specifications. Therefore, these attribute items were added in the work process of this Project through discussions with IGN and the PAABANC standard of data acquisition was modified accordingly.

2) Arrangement of GIS data specifications established so far

The digital compilation of the spatial basic information database was executed and the ArcInfo Coverage data was created to be used as the data source for the GIS database and the printed map database. In the subsequent work of the process of "Structuralization of GIS database", the data divided into 74 sheets was integrated by theme, and its features and attributes were compiled for use as data covered in each of the 74 sheets.

Table 2.1-12 GIS database built from basic spatial information database

| Coverage name | Theme | Phase structure type |
|---------------|---|----------------------|
| line | All linear features | Arc |
| poly | Polygonal features except those for land use | Polygon |
| vegeta | Land use | Polygon |
| point | All point features, annotations and symbol points | Point |

The coverage created were as shown in the above table and categorized into vector figure types such as point, line (arc) and polygon. For example, all the features represented as lines (such as roads, rivers and contours) were included in the line coverage, while the features except those for land use (such as lakes or swamps, buildings with actual forms, and building-settled areas) represented as polygons were in the poly coverage.

The detailed types by theme were categorized by the attribute of the data. The data attributes were represented as a combination of level and color values used in data acquisition on MicroStation, which was largely different from the attribute items under the PAABANC standard.

3) Exporting method

The PAABANC specifications as described above were different from the GIS database built in this Project in the coverage categories and attribute items. As the PAABANC standard categorized the features into detailed themes, it was necessary to assign level and color attribute values to the database built in this Project. The combinations of levels and colors were assigned uniquely to the features represented in the topographic maps in accordance with the combinations of attribute items and values as specified in the PAABANC standard.

The flow in Figure 2.1-40 shows the process of the work to create the RCA coverage (road network) under the PAABANC standard from the GIS database of lines created in this Project.

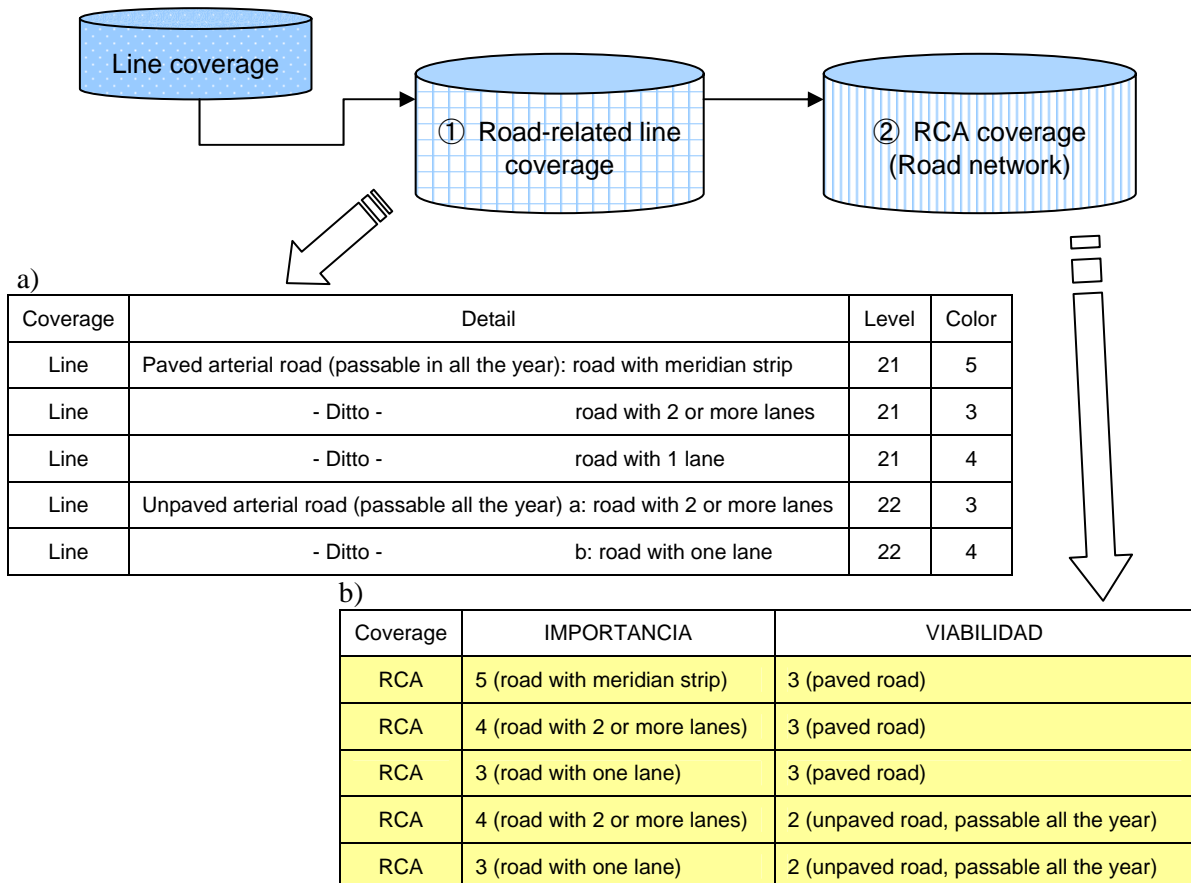


Figure 2.1-40 Flow of data export into PAABANC

a) Extract only road-related features from the line coverage including all linear features

In the line coverage, the level values of road data were 21 and 22, which were combined with color values to categorize the road types. Only the data having the level and color values in the table a) was extracted from the line coverage to create a new coverage for that combination.

b) Shift the coverage including only road-related features created in a) above to the PAABANC standard

Separately from the data a), the idle RCA coverage having the data structure in conformance to the PAABANC standard was created. The data created in a) was copied in this idle coverage by road type unique to the level and color combination. For example, the data a) for the paved arterial road (passable in all the year) with meridian strip had the level value of 21 and the color value of 5. These values were selected and copied. The copied data was stored in the idle RCA coverage. These values in the RCA coverage under the PAABANC standard were the attribute items IMPORTANCIA=5 and VIABILIDAD=3.

2.1.7 Production of printed map data (digital compilation)

After digital compilation the spatial basic information data was converted into printed map data. This was digitally compiled and structuralized in AdobeIllustrator to reproduce the data for representation as the topographic maps. These parts are indicated in blue and pink in the flowchart in Figure 2.1-41 below.

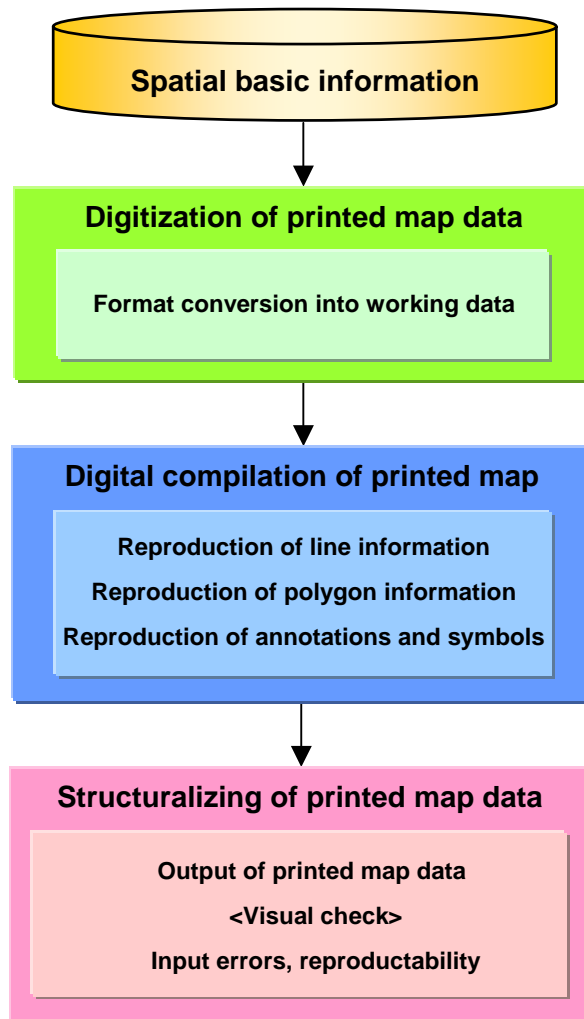


Figure 2.1-41 Data flow

(1) Data format conversion

In accordance with the specifications for printed maps determined through discussions with IGN, including the fonts, symbols, sizes, shapes and colors of the annotations, the representation of topographic features (such as double-line depiction of roads, railways, houses, etc.), line thickness and patterns, it was arranged so that polygons, lines, points, symbols and annotations would be automatically reproduced when the conversion to AI format was carried out.

The automation was mainly done by program, but specifically, the methods described below were used to represent lines, polygons, annotations and symbols on the topographic maps.

(2) Reproduction of topographic map representations

Prior to the production of the printed maps, first of all output maps for field survey to be used in the process of “Supplementary survey in the field for basic spatial information database” were prepared.

These output maps were prepared by creating the data for printed maps using the same procedure as that used for producing printed maps and outputting it on an ink-jet plotter. As

the specifications for the topographic map representations for printed maps (such as the fonts, sizes, colors of annotations, representation of planimetric features, etc.) had not been determined, the specifications for field survey output maps were tentatively determined separately from those for printed maps, and these were used for reproduction.

There were two types of data for printed maps converted from the spatial basic information database; an AI file of the polygons and lines converted via ArcInfo, and an EPS file of annotations and symbols converted from MicroStation. Each of these files is in a format that can be edited in Illustrator.

Because the ink colors for the four specific colors (blue, brown, green and black) used in printed maps were not clear, the CMYK process colors were specified for the reproduction of the colors on the field survey output maps. On printed maps only lighter and darker shades of the specific colors are used, with no color combinations; but on the field survey output maps, unlike on printed maps, different colors were used in a variety of combinations in order to facilitate the field survey.

1) Reproduction of line information

The spatial basic information database converted from ArcInfo into the AI format was only the data that could be edited in Illustrator, not the data reproducing the specifications for printed maps such as line widths and line types.

The reproduction of line information begins by determining what planimetric feature the lines represent. The key items specifying the type of feature is the combination of level and color input into MicroStation. In ArcInfo the level and color are held as line attributes, but in the AI format there is no line attribute that can be assigned freely. When the data was converted into the AI format, therefore, the level and color values were added to the CMYK values for line colors.

In Illustrator, the lines were classified by their CMYK value and divided into layers, and the type of planimetric feature was managed by layer. By managing the types of feature by layer, it became easy to carry out the continuous processing of overlapping contour lines, roads and rivers. It also becomes possible to reproduce line information layer by layer.

In addition to the line reproduction method in which line widths and line types are specified, another method of reproducing lines in Illustrator is the application of a brush. For example, there are two methods of reproducing a railway line; one is the combination of a bold line with broken lines, and the other is to apply to the line a brush representing the shape of a railway line. However, when a railway line in the spatial basic information data is drawn with a brush, the Tics around the anchor points may be deformed or the tic intervals may be unequal. So the tic size and form could not be reproduced as specified. Therefore, a brush was not used to represent lines; instead the method of combining line elements was adopted.

a) Reproduction of double-line roads

The outer lines (to indicate the road width) of a double-line road and the colored part within the double lines were represented on different layers, so that the joint parts (road indicating lines at road intersections to be blanked) are not closed by another road drawn in later. The problem of the joints was solved by drawing the outer lines of all the double-line roads before coloring in the road part.



Figure 2.1-42 Intersections are closed off

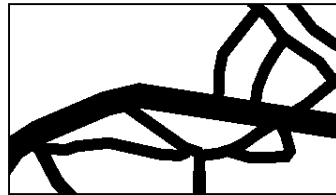


Figure 2.1-43 Draw in outer lines

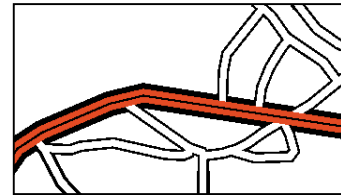


Figure 2.1-44 Colour in road part

b) Reproduction of narrow-gauge single-line railway

The Tics on a narrow-gauge single-line railway are represented by parallel broken lines to left and right on a centre line. As the length of the inner line differs from that of the outer line at a curve, it was necessary to adjust the spacing of the broken lines to left and right (Figure 2.1-46).

c) Reproduction of electric line (high-voltage) and enclosure/iron-wire enclosure

As the symbols in the spaces of broken lines cannot be represented by line elements, only the broken lines were reproduced, with no symbol. On the printed maps, the problem was solved by outputting the symbols from MicroStation to EPS in the same way as for the reproduction of annotations.

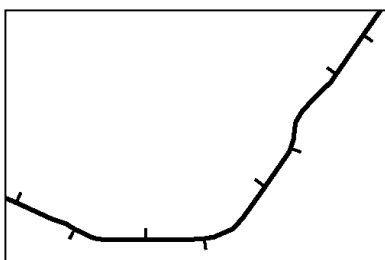


Figure 2.1-45 Tics unevenly spaced to left and right

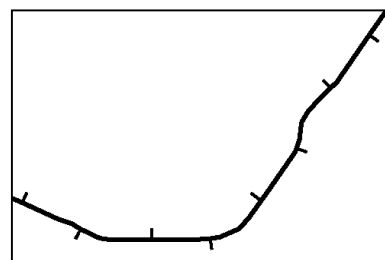


Figure 2.1-46 Tics evenly spaced to left and right

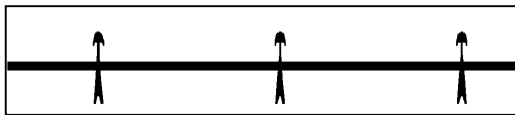


Figure 2.1-47 High-voltage line

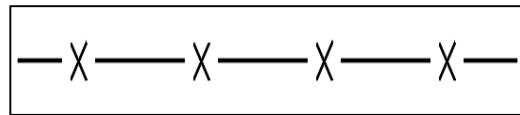


Figure 2.1-48 Enclosure/iron-wire enclosure

2) Reproduction of polygon information

Like the line information, polygon information was divided into layers and the polygon information was reproduced layer by layer.

However, the key items to specify polygon type are different for 'land-use' polygons and 'other' polygons. For 'other' polygons the key items are, as for line information, a combination of Level and Color; but for 'land-use' polygons, as Level and Color are not unique, cell names were the key items. The key items are not line colors but polygon colors.

The polygons on the field survey output maps were not represented by patterns, but block color. On the printed maps, polygons are represented by patterns, which if registered in Illustrator can be handled in the same way as block colors. The types of pattern were determined through consultation with the engineers of the IGN Cartography Division.

For 'other' polygons it should be noted that there are polygons for which not only the inside pattern but also the boundary lines are reproduced.

3) Reproduction of annotations and symbols

The annotation and symbol data were used only for printing after preparation in MicroStation; the data was not converted into the GIS database. This meant that the data was imported from MicroStation directly into Illustrator. The data conversion format used was the EPS format, using the print function of MicroStation. If the print function of MicroStation is used, the annotation data are outlined, and cannot be handled as text in Illustrator. The annotations cannot be corrected in Illustrator; the correction of annotations can be done only in MicroStation, which means that the data source is centralized. In addition, the use of the print function in MicroStation allows the font, size, position, slope and character spacing to be reproduced accurately. However, EPS output at full size lowers the resolution so that smooth curves cannot be represented. Therefore, the annotations and symbols were output at four times the size and reduced to 25% in Illustrator.

The layers for annotations and symbols were separated not by type but by color. This is because in Illustrator colors only were reproduced and there was no need to set detailed parameters for each type. Again, as annotations and symbols do not overlap, there is no up-down relationship between the layers. However, the frame symbol for each road number

was put onto a separate layer because it had to be drawn beneath the annotation.

Four EPS format files were created on MicroStation; three files classified by color (blue, brown and black) and one file for road number frames. The four files (one layer per file) were imported into Illustrator with one layer per file and the color setting done. In this case, it was necessary to convert from the RGB color mode to the CMYK mode.

To represent annotations for linear features such as roads, rivers and railway lines, the data prepared in MicroStation was used unchanged. Therefore, each annotation was not placed along the linear feature as in the analogue method: instead, each word was rotated.

The road number frame symbols were drawn in black lines, with the space within them colored white, which meant that they had to be formed as closed figures. However, as frame symbols other than circles were not closed figures, closed figures had to be substituted for them in Illustrator. In the future, it will be necessary to correct the data in MicroStation, so that the frames will be closed figures.

4) Future tasks

- * Determine the order of layers

In Illustrator the order in which layers are arranged allows continuous processing when planimetric features overlap to be handled easily, but it is necessary to determine how the overlapping features should be represented on the printed maps.



Figure 2.1-49 Examples of overprinting

- * Overprint settings

At the stage when the specifications for the printed maps are determined in the future, it will be determined through consultation with IGN for the following year, whether overprinting should be done on thin lines in colors other than black, such as single-line rivers, contour lines, etc..

- * Overlapping polygons

As there are cases in which a vegetation polygon may overlap a polygon created from line data, it is necessary to correct the special basic information database.

(3) Printed map data and supplementary digital compilation

1) Supplementary digital compilation of annotations

In regard to annotations, the Study Team lent the prepared output maps to IGN and requested the checking of the font types and sizes. As a result, it was pointed out that the font

sizes were too large in general regardless of annotation types.

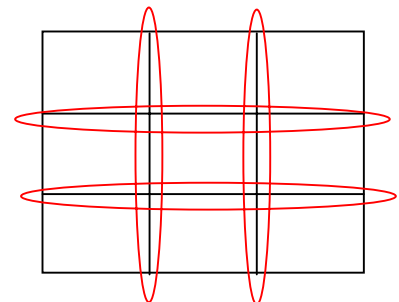
The annotation sizes were entered in accordance with the materials prepared by IGN (in which all the annotations in the annotation block of the existing map sheets were numbered and the annotation codes, font types and sizes were typed in the Excel file). It was unlikely that the font sizes in the annotations were different from the specified ones, but the detailed examination made clear that the parameter to use for conversion of a point number into mm was different for the Japanese and the IGN modes. Therefore, one map sheet was produced using the newly preset conversion rate and IGN was requested to recheck it. Separately, the list of annotations of all types (Figure 2.1-50) was prepared. This list was created to grasp the image of printed maps in using MicroStation to output the annotations in the actual process of producing printed maps. The font types and sizes of all types of annotations were checked on this list and agreed upon by the counterparts.

Figure 2.1-50 Example of list of annotations

| Code | Size(Pt) | Size(mm) | Font | Example |
|-------|----------|----------|------------------------|------------------|
| 80100 | 18 | 3.55 | Helvetica Bold Cond. | GUATEMALA |
| 80200 | 12 | 2.88 | Helvetica Bold Cond. | GUATEMALA |
| 80300 | 12 | 2.88 | Helvetica Bold Cond. | Guatemala |
| 80400 | 12 | 2.88 | Helvetica Medium Cond. | Guatemala |
| 80500 | 10 | 2.22 | Helvetica Medium Cond. | Guatemala |
| 80600 | 8 | 1.33 | Helvetica Light Cond. | Guatemala |
| 80807 | 7 | 1.55 | Helvetica Light Cond. | Guatemala |
| 80800 | 10 | 2.22 | Helvetica Light | Guatemala |

Parallel with the above checking work on the font types and sizes of annotations, IGN was requested to check and verify spelling errors and arrangements.

Similar to the existing maps, the grid lines per 1km were drawn on the 1:50,000 scale national base maps in order to arrange the coordinate values on the grid lines near three divided sections of the vertical and horizontal lines of the neat lines. (See Figure 2.1-51.)



The positions for arranging these

Figure 2.1-51 Coordinate values on grid lines and their positions on printed map

values and the font types and sizes were also determined through discussions with the counterparts.

The font types and sizes of annotations in all the map sheets were changed by batch processing by the use of MicroStationJ as one item of the procured study equipment.

Once the font sizes of annotations were changed, it was also needed to check the arranged position of each annotation because the position of the origin on MicroStationJ was set at the center of the annotation to be arranged. Changing the font size in reference to this origin resulted in the unmatched position of the annotation arranged in two lines, the overlap with the corresponding feature and the overlap of the grid line value with the grid line. Therefore, the work of correcting these unmatched or overlapped positions was conducted. (See Figure 2.1-52, Figure 2.1-53) The arranged positions conformed to the order of arrangement in the NIMA standard. At the same time, all the results of the spelling check and field survey that were requested the counterparts were reflected on the data.

In the stage of exporting data, there was a problem that the lines and texts imported in AdobeIllustrator were not smooth. This problem was solved by exporting the font size in 4 times as large as the actual size from MicroStationJ and reducing it to the actual size on AdobeIllustrator in the work of “Digital compilation of basic spatial information database”. During the work in the fourth survey, however, it was made clear that the curves and texts were not smoothly drawn because the original data was produced with low resolution.

Therefore, the resolution parameter was adjusted by the used output driver file to ensure the smooth lines and texts to be properly exported from MicroStationJ without enlarging the size of the original data to 4 times the actual size.

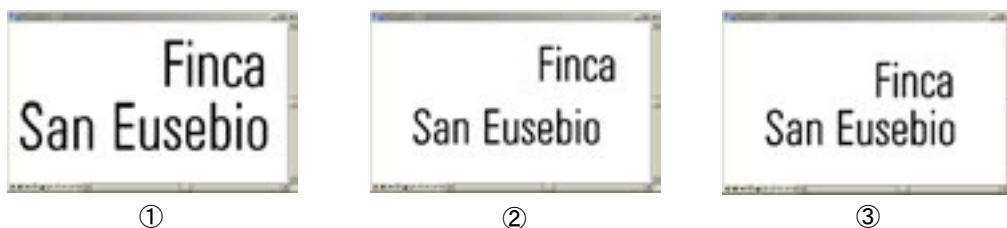


Figure 2.1-52 Example of annotation font size reduction and rearrangement

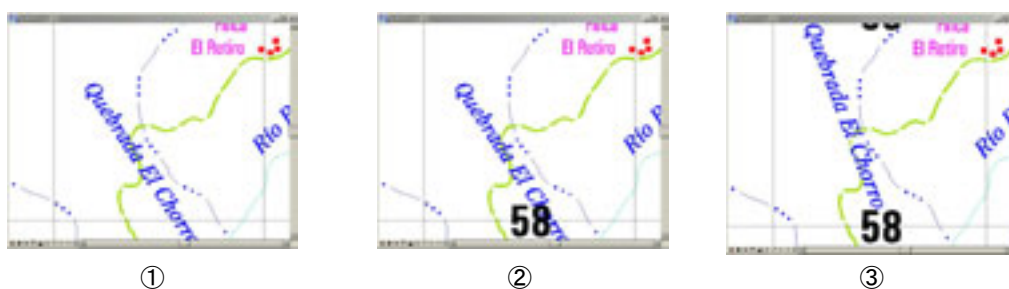


Figure 2.1-53 Example of annotations rearranged to avoid the overlaps with grid line values

2) Supplementary digital compilation of administrative boundaries

In the inspection stage of “Digital compilation/structuralization”, it was made clear that the administrative boundary data provided by IGN was unmatched with the topographic and planimetric features in which the secular changes were corrected. In the fourth field survey, this fact was explained to IGN and IGN was requested to re-create the data.

The administrative boundary data provided by IGN included the national borders, the department boundaries and municipality boundaries.

The Study Team converted the new administrative boundary data file provided by IGN into the Design File and replaced the old data with the new administrative boundary data on all 74 map sheets in order to correct the positional relations of topographic and planimetric features. (See Figure 2.1-54)

However, all the municipality boundaries in the entire country of Guatemala had not clearly been defined, so that the administrative boundaries were not represented on the printed maps but only the administrative names were indicated, although all the administrative boundaries were included in the GIS database.

The unmatched points with annotations that newly appeared due to changes of some administrative boundaries were corrected by changing the arranged positions of the annotations.

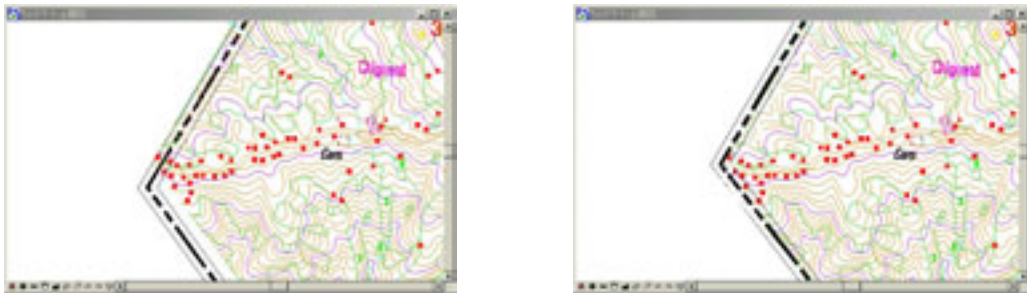


Figure 2.1-54 National border lines with some deviations corrected

3) Supplementary digital compilation of topographic and planimetric features

With the planimetric features such as vegetation, there were some problems that “no divisional lines were entered” and that “there were some errors”, though the polygonal shapes were proper. Thus, it was necessary to additionally plot the lacking divisional lines and correct the errors. The former problem was solved in the compilation by changing the attributes in the Coverage data (ArcInfo) after structuralizing the data. The latter problem was solved by additional plotting with the digital plotter to create the data file containing only the additional data. Further, the data was exported from MicroStationJ and structuralized again on ArcInfo in the same way as the work process of “Digital compilation of basic spatial information database”. Then, the additional data was integrated with the polygon (land use) data created in the process of “Digital compilation of basic spatial information database” and the integrated

data was used as the final data source for producing GIS database and printed maps.

Then, the data in ArcInfo Coverage format was converted into the AI format on AdobeIllustrator in order to produce the printed maps. In the case that there were some changes in division lines of the features such as vegetation, the line data was acquired using the digital plotter. Further, the digital compilation of the data was performed on MicroStationJ in the way that no discrepancies were caused with the surrounding polygons, and the polygonal shapes were corrected on ArcInfo. It was not needed to newly acquire the line data such as the divisional lines of vegetation, but the corrections to change only the attributes were also made directly on ArcInfo as described above.

In the correction work for these linear planimetric features such as divisional lines, roads and water systems, the digital plotter VirtuoZo procured as the study equipment was used to build stereo models for digital plotting.

In the work of correcting the national topographic maps in this Project, the aerial triangulation of the entire study area was implemented, but not the orientation per model of the map sheets. Thus, the orientation was conducted by the use of the adjustment computation results of the aerial triangulation, so that the additional digital plotting could be achieved with high efficiency.

The correction of the planimetric features such as buildings to be represented with symbols was carried out by adding, deleting or moving the symbols on MicroStationJ based on the field completion survey made by the IGN side.

4) Supplementary digital compilation of road attributes

The road types were entered in accordance with the materials provided by IGN (the main roads were numbered in the black plates of the existing map sheets and the road types were typed in an Excel file). However, some points provided with the attributes of clearly different types were found in comparison with the 1:40,000 scale aerial photos and the past field survey results. So, IGN was requested to survey the road attributes again. The Study Team changed the road attributes on MicroStationJ referring to the new materials provided by the IGN side.

At the same time, it was needed to make additional plotting of the data on the basis of the changes of the road attributes as clarified in the field survey and the results of inspection of the output maps. The data was acquired on the digital plotter and MicroStationJ before it was structuralized on ArcInfo. Then, the structuralized data was integrated with the entire data created in the stage of third work in Japan (2002).

(4) Checking and accuracy control

The attributes and arranged positions of annotations, the continuity of line data and layer

architecture were inspected by each neat line and arranged in the quality control sheet. The processes of digital plotting and compilation were repeatedly executed as required.

(5) Output of printing positive films and production of CD-ROM

1) Printing data output

① Printing data output and visual check

The processed data were outputted in color and an inspection has been made visually and on a display screen to know whether the data were created as indicated in the Specification.

In the visual check, the data were compared with the simple output maps in the spatial infrastructure database in order to check up on whether the database contents are reflected properly on the data output, whether no picture is blurred and whether each of the data is reproduced as mentioned in the Specification.

For the inspection on a display screen, a checking has been made to know whether the colors, line sizes and the overlapped data points were processed properly. This inspection was repeated several times until the complete data output could be obtained.

② Production and inspection of positive films

The completed data were converted into the EPS format (a format to output positive films). Then, the resolution of the image setter (dedicated output equipment) EPS-formatted data was preset to about 2,400 dpi and 175 lines, and the EPS-formatted data were outputted to prepare 4 positive films in 4-color separation per map sheet.

A visual check was performed to know whether the positive films with the right contents were outputted as color-separated blocks was made and obtained as final products.

2) Production of CD-ROM

The spatial infrastructure information database and other data including those concerning all map sheets were compressed and stored in a CD-ROM. The recording format was standardized as follows:

- Spatial infrastructure information data format: ZIP self-decompression format (MicroStation dgn file)
- GIS data format: same as above (Arc/Info coverage file)
- Printed map data format: Same as above (Adobe Illustrator ai file)
- Storage format: CD-ROM (CD-R)

2.2 Production of 1/10,000-scale Orthophoto Maps

2.2.1 Ground control point survey (in technical cooperation with IGN)

This work is carried out to obtain the XY coordinates and elevation values of control points to be used in the subsequent automatic aerial triangulation. The work specifications and required accuracy that were decided in the process of “Discussions on GIS/printed map specifications, about OJT scope and investigation of existing conditions” were adopted for this work.

For the basis of horizontal position and elevation, the following control points were placed.

- Control point : G = 25 points (plan=20 points)
- Pricking of existing triangulation point : 7 points (plan=10 points)
- GPS bench mark : L = 34 points (plan=25 points)
- Pricking of existing bench mark : 184 points (plan=175 points)

As this work was carried out with technical cooperation, the study team furnished sufficient guidance to ensure thorough schedule management and accuracy management.

The control point survey, which is preparatory work of 1/10,000 orthophoto production, was carried out with IGN and three supervisors from the JICA study team. This cooperative effort was very significant in terms of transferring technology. Based on the mutual understanding of the importance of technical transfer, IGN and the study team cooperated through all of the work procedures (information collection, survey planning, survey implementation, data analysis, calculating output) during the two months of field survey.

(1) Discussions about production plan: Investigation of existing conditions

The survey standards, work specifications and the map description to be displayed on each 1/10,000 orthophoto map, will be the same as for the 1/50,000 national base maps.

The digital symbols were decided through discussions between the study team and the Guatemala side. The specifications for orthophoto maps (neat lines, marginal information, etc.) were also decided after discussion.

The study team collected additional materials such as results on control points and bench marks, sketches and network maps that were insufficient in the materials collected and organized in the preparatory work in Japan and the first field survey (2000), and conducted a review of the survey plan.

(2) Risk management

1) Discussions with the Japanese embassy, JICA office, and related organizations

At the beginning of the field survey, the JICA office in Guatemala and Japanese embassy informed us of security problems in Guatemala. Therefore the study team raised safety as the first priority and also made IGN aware of this situation.

The study team prepared an emergency communication network for the members staying in Guatemala City. Also, the study team prepared a weekly fieldwork schedule of the members working outside of the city so that communications among the members were secured. This information was reported weekly to the JICA office in Guatemala and the Japanese embassy.

On February 14th, the JICA office requested the study team to enforce security control. Hence the study team requested IGN to cooperate in changing survey points in (Totonicapan) and forming an advance mission. The advance mission consisted of two groups (8 engineers from IGN).

2) Formation of the advance mission

The role of the advance mission was to arrive to the survey area earlier than the survey group, check the local security, and escort the survey group members while they were surveying.

In fact, the advance mission interviewed local policemen, city hall, neighboring stores, gas stations, and local people so that the study team and IGN would be aware of the local conditions. Information collected was shared with survey group members at the hotel.

While surveying, transceivers and mobile phones were used for communication between the advance missions and also with the survey groups. Consequently all the surveys were completed safely.

3) Securing communication lines

In Guatemala, the mobile phone network is developed along the main roads. In order to conduct the GPS surveys, two mobile phones and two satellite telephones were supplied for communication. With these, survey teams could exchange with each other information about survey progress and transportation and also establish the emergency communication network with the study team office in Guatemala City. As a result, all the tasks were finished safely and efficiently.

(3) Survey preparation

1) Adjustment of equipment

The followings are the equipment used for this survey. All equipment were examined, and adjustments made in Japan were reconfirmed before using.

- Trimble 4000SSE, Ssi GPS receiver (double frequency) : 4 sets
- Topcon Total Station GTS-3 : 1 set
- Nikon Autolevel AE-5 : 4 sets

2) Preparation of topographic maps (1/50,000)

Prior to field surveys 74 printed maps (1/50,000) which cover the study area were prepared and all of the control point, benchmarks, and benchmark networks were marked on the maps for each survey group. This preparation effectively facilitated the field survey.

3) Preparation of benchmark descriptions

Each survey team prepared and brought the information about benchmarks descriptions and location information to the field. This preparation facilitated the process of finding existing benchmarks.

4) Personnel assignment

The staff for the survey formed in technical cooperation of IGN is as follows:

- Survey supervisor (JICA study team) : 3 persons
- Survey engineer (IGN) : 8 persons

(4) Survey

1) Control point survey (simplified static GPS survey)

At the request of IGN, the study team changed from photo control point survey to ground control point survey. Accordingly, the accuracy of the survey was increased.

The control point survey was conducted using GPS, including area triangulation, and 25 new control points were created. Eight existing control points in Guatemala were used as existing points. The survey was implemented by following the survey specifications decided in “Discussions on GIS specifications”. The control point survey plan is shown in Figure 2.2-1.

The details of the work are as follows:

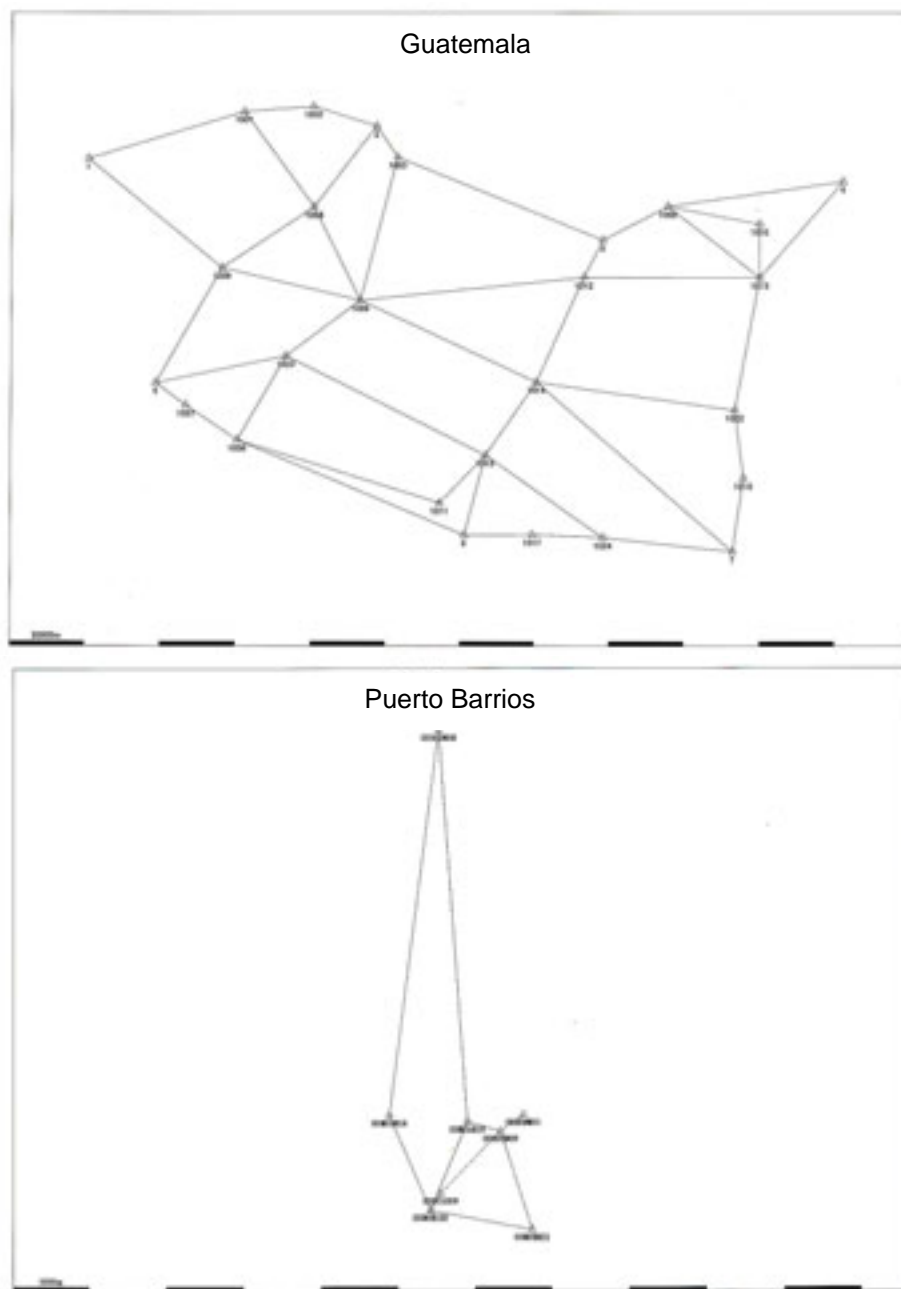


Figure 2.2-1 Control point survey

a) Point selection

The final observation positions for the new control points and triangulation points were determined with consideration given to radio interference, aerial visibility and the distribution of the points in the network adjustment computation. The survey supervisor for each team selected and examined all of the points based on the control point survey plan. It was very important to select the positions of existing triangulation points and new control points that facilitate pricking on aerial photographs. Therefore the study team, together with IGN, selected known points as the control points and buried metal tablets at the sites.

For each control point, the study team pricked the position on a pair of stereo aerial photographs and also prepared a description with the following information.

- Name of the control point
- Name of conducted survey supervisor
- Date of setting
- Diagram of the point location
- Two digital pictures that contain the point
- Profile of the point
- Number of the stereo aerial photographs and of the flight course pair

b) Observation

As a rule one or more sessions of simplified static observation (one session = 2 hours, observation at 15-sec intervals) were conducted using a dual-frequency GPS receiver. When making a prick point eccentric, an azimuth marker was set up using GPS positioning when necessary (only one azimuth marker, EL_SITIO, was set). Observation in this case was carried out as sessions of simplified static observation (one session = 1 hours, observation at 15-sec intervals).

Prior to the GPS survey, the study team prepared a survey network plan. Since all four survey groups had to complete the task individually, the observation time was preset everyday. Based on the satellite information acquired in Guatemala, two survey sessions were set between 8:30 to 16:30 per day.

By providing all the survey groups with weekly schedules, each group was informed of the location of the others and able to retain perfect overlapping time of the surveys.

The following items were recorded in GPS survey sheet.

- Display of points
- Type of GPS antenna
- Drawing of points
- Starting / Ending time

c) Base line analysis

In order to decide length of the base line and to guarantee that the closure error of vectors is tolerable, the survey team applied a GPS base line analysis everyday.

The procedure was as follows:

- WGS84 was applied as a map plane for GIS vector computation.
- Information of antenna height etc. was compared and examined with survey records, in order to find data input error.
- Prior to adjustment computation, irregular data and degraded data with cycle strip were deleted.

- Using broadcast satellite coordinates, data about base line length was analyzed, and a tentative base line network was created.
- RMS value calculated by the base line vector was examined.
- In order for the computation result not to be influenced by systematic error, the coordinates of existing triangulation points were fixed during the process of base line analysis.
- Created the network with several traverse nets and analyzed the closure error of the lines. Regarding overlapping base lines, the difference in X, Y, Z values were compared. With all networks, closure error was within the tolerance value of $45\text{mm} \sqrt{N}$ (N=numbers of sides).

d) Adjustment computation

After the GPS survey and base line analysis, all networks were integrated into one (except Puerto Barrios). The coordinate and elevation for each ground control point was determined after analysis of analysis and adjustment computation application. For this adjustment computation, “TRIMNET” was used.

The results of analysis are as follows and are within the horizontal accuracy limit of 150mm and the vertical accuracy limit of 300mm.

Maximum error is:

Guatemala area: $\Delta B(X)=24\text{mm}$, $\Delta L(Y)=29\text{mm}$, $\Delta H=200\text{mm}$

Puerto Barrios area: $\Delta B(X)= 3\text{mm}$, $\Delta L(Y)= 4\text{mm}$, $\Delta H=18\text{mm}$

To determine the elevation of each control point, an interpolation program was used. But if the evaluated point was near a standard line the elevation was determined by direct leveling. In this survey, the elevation of 13 points were determined by direct leveling and 12 points were by computation.

e) Organization of the results

The coordinates and elevation values of the evaluated points that had been determined through adjustment computations were collected and sorted. An accuracy management table was also prepared.

f) Technical transfer

The study team instructed four IGN engineers about the process and methodology of downloading GPS survey results, analysis, and adjustment computations with the use of field data.

2) Pricking of existing bench marks

There are standard lines already set up throughout Guatemala, with approximately 700 km of the standard lines within the range of the 1/20,000 aerial photography. Benchmarks were

pricked on these existing standard lines (184 points at approx. 4 km intervals). The prick points were selected in clear places on the aerial photos by the study team and IGN survey engineers and the difference in elevation measured from the benchmark by direct leveling.

The content of the work is as follows:

a) Point selection

The positions and status of existing bench marks that will become known points were checked against the collected and sorted materials (description of points, network diagram).

b) Observation

Double running leveling observation was carried out. The survey standards determined in “Discussions about orthophoto mapping plan” were applied.

c) Checking

The reciprocal difference obtained in the field survey calculations was checked. All surveys were below the limit value of $20\sqrt{s}$ (s=distance km) and eligible.

d) Organization of the results

The determined elevation values were sorted and matched to the pricked aerial photos. The results were organized into field notebooks.

3) GPS leveling (simplified static GPS observation)

GPS leveling was carried out over a distance of about 100 km along a road with no fixed benchmarks at intervals of about 4 km. Using GPS, it was leveled by forming traverse routes and setting 34 GPS leveling points. Control points, with accurate elevations derived from direct leveling, were used as existing points. Surveys followed the survey specifications determined in “Discussions on GIS specifications”. Figure 2.2-2 shows the GPS leveling survey plan.

The work content was as follows:

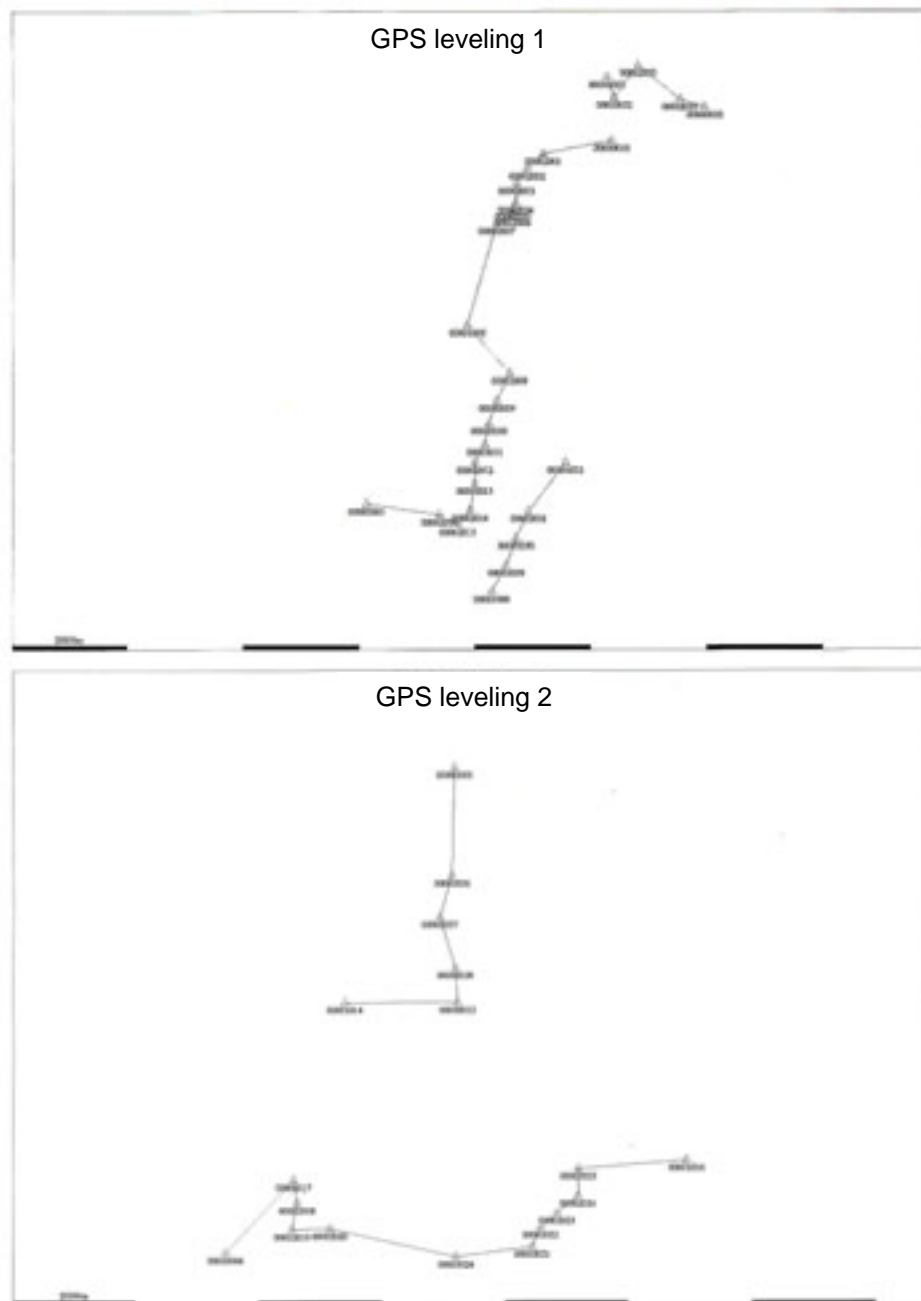


Figure 2.2-2 GPS leveling survey

a) Point selection

Due consideration for selecting was given to radio interference, aerial visibility and the distribution of the points in adjustment computation. The survey supervisor for each team selected and examined all of the points based on the ground control point survey plan. The study team, together with IGN, selected verified points for the GPS leveling points and buried metal tablets at the sites. For each GPS leveling point, the study team pricked the position on a pair of stereo aerial photographs and also prepared a description with the following information.

- Name of the GPS leveling point
- Name of survey supervisor
- Date of setting
- Diagram of the GPS leveling point location
- Two digital pictures that contain the GPS leveling point
- Profile of the GPS leveling point
- Number of stereo aerial photographs and of the flight course pair

b) Observation

As a rule, one or more sessions of simplified static observation (one session = 1 hours, observation at 15-sec intervals) were conducted using a dual-frequency GPS receiver. Prior to the GPS survey, the study team prepared a survey network plan. Since all the four survey groups had to complete the task individually, the preset time overlapped the survey sets everyday. Based on the satellite information acquired in Guatemala, three survey sessions were set between 8:30 to 16:30 per day.

The following items were recorded in GPS survey sheet.

- Display of points
- Type of GPS antenna
- Drawing of points
- Starting / Ending time

c) Base line analysis

The base line analysis was carried using the observed data to determine the base line between measured points, and to determine differences in elevation as well as the XY coordinates. Methods of analysis followed those of the control point survey.

d) Checking

As the GPS standard lines are closed, a check was made of the closure error. All closure errors were within the tolerable range of $45\text{mm}\sqrt{N}$ (N=numbers of sides).

e) Organization of the results

Closure error was averaged, and the GPS leveling elevation was determined. The elevation values were sorted and matched to the pricked aerial photos. In addition to the sorting of the results, an accuracy management table was prepared.

2.2.2 Production of orthophoto maps

(1) Negative film scanning of aerial photos

Before scanning aerial photo films for data acquisition, tentative scanning of each typical terrain such as city area, grassland, mountainous area and bare land was conducted to extract samples and collect the setting values for brightness and contrast. The data was acquired with a resolution of 20 μ m per pixel and in 256 monochrome gradation levels, and the original image data acquired was stored as an archive in a universal TIFF format separately from the work data file.

After completion of the scanning process, accuracy control of the following items per orthophoto was conducted to confirm that no problems would be caused in subsequent work:

- Resolution
- Brightness
- Contrast
- Noise (flaws and folds)
- Normalized processing (correction of mechanical errors)
- Data acquisition range (whether indexes are included or not)
- Possibility of index observation (whether in an observable condition or not)
- Image rotation
- Format (TIFF, uncompressed, 256 monochrome gradation levels)
- File name (whether data and file names coincide or not)

(2) Orthophoto maps: Automatic aerial triangulation

Automatic aerial triangulation can yield stable results using a number of tie points. 649 photos for the west area, 1,070 photos for the central area and 18 photos for the east area were subjected to automatic aerial triangulation using the bundle adjustment method. In this process, batch processing and automatic processing were used extensively to ensure higher work efficiency. This work was performed in the following steps:

- ① Confirmation of control points: Each control point was confirmed on an image and the position of any control point that was unclear due to photo quality was rescanned to maintain accuracy.
- ② Creation of initial data: The aircraft GPS data was analyzed in advance before the rough XYZ values of each photographed point were acquired. By entering these values into a digital plotter, the volume of operations in subsequent work was substantially reduced.

- ③ Internal indexing: The photo indexes were automatically measured to calculate the coordinates of the main points and the rate of expansion and compression and amount of rotation of each photo.
- ④ Tie-point observation: Using the initial data that was obtained through analysis of each photo for which internal indexing had been performed and the GPS survey data, the same point in adjacent photos was defined as a tie point, and the coordinates of the tie point were measured and recorded. As the success rate of automatic processing was low for some forest areas, the tie points in such areas were not automatically defined, but additionally measured through stereoscopic viewing by the operator.
- ⑤ Control point survey: Automatic processing for extraction of the control points installed in the first year of this Study was so difficult that the control points were measured through stereoscopic viewing by the operator on the digital plotter.
- ⑥ Adjustment calculations: The accurate photographic position and inclination of each photo and the UTM coordinate values of each tie point were calculated by the aerial triangulation program using the bundle method, with reference to the UTM coordinate values of each control point and the photographic coordinate values of the tie points and control points measured on the digital plotter. The calculated aerial triangulation results were entered into the digital plotter as external indexed elements to create stereo models.
- ⑦ Arrangement of the results: After checking the results of the adjustment calculations, the results were output and arranged, and an accuracy control table was prepared.

After the completion of aerial triangulation, accuracy control of the following items for each block was conducted to confirm that no problems would be caused in subsequent work:

- Number of horizontal control points
- Number of elevation control points
- Number of canceled horizontal control points
- Number of canceled elevation control points
- Residuals of control point horizontal positions (standard deviation and maximum value)
- Residuals of control point elevations (standard deviation and maximum value)
- Residuals of bundle crossings (standard deviation and maximum value)
- Residuals of horizontal positions in aircraft GPS data
- Residuals of elevations in aircraft GPS data

(3) Creation of DEM

Automatic DEM extraction is the work of searching for and determining stereo pair points. The DEM interval was set to 40m, equivalent to 4mm on a 1/10,000-scale map, and it was confirmed that this value was appropriate for topographic representation at this scale, the generation of contour lines and the creation of orthophotos.

The work was carried out in the following steps:

Creation of working images and hierarchical images to reduce the volume of operations:

① In automatic processing to search for pair points, in order to reduce the volume of arithmetic operation, the work of creating the working images from which the vertical parallax at the stereo pair points was removed and creating hierarchical images using the working images was performed by batch processing.

② Optimization of automatic DEM extraction parameters:

The output of the automatic DEM extraction process is controlled by a large number of parameter sets. The window size of the search range is particularly important. Therefore, typical topographical features such as grassland, forests and urban areas were classified and extracted. A trial automatic DEM extraction was carried out to optimize the parameter set for the window size (the work of determining the parameter values to remove the noise from each typical shape of the ground surface).

③ Image correlation (stereo matching)

The hierarchical images created from the images from which the vertical parallax at stereo pair points had been removed were used in the pair point search process, and random pair points were obtained through batch processing.

④ DEM output

The pair points obtained were arbitrary random point groups that were obtained with software, so the pair points were interpolated onto the grid points at intervals of 40m on the geodetic coordinate system and output through batch processing as DEMs in a text form that was easy to handle in subsequent processes.

⑤ Manual addition and corrective measurement of DEMs

DEM were checked through stereoscopic viewing for each stereo pair, and any points containing major errors were subjected to corrective processing or re-measurement in terms of area.

(4) Generation of Contour Lines

As for contour lines, it became apparent that if intermediate contours of 5m and index contours of 25m were drawn as originally planned, the intervals between the contours in mountainous terrain became particularly narrow, hiding the image data in the background. The Study Team therefore held discussions with their counterparts in both IGN and INSIVUMEH and determined that the interval would be 50m for index contours and 10m for intermediate contours. However, it was determined that the supplementary contours would be drawn at intervals of 5m on flat terrain.

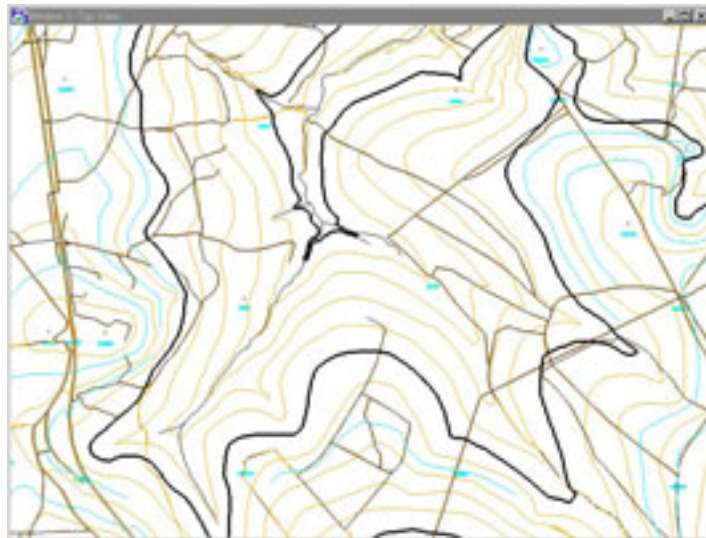


Figure 2.2-3 Generation of Contour Lines

(5) Contour Data Plotting

To draw the contour lines, the method of creating TIN models to generate contours based on the DEMs at 40m intervals created in the above-mentioned work was used in conjunction with the method of acquiring some contour lines through stereoscopic viewing by the operator on the digital plotter.

For forest areas in which the error between the contour lines based on DEMs and the plotted contour lines exceeded 2.5m, the operator extracted the area and performed the plotting manually. The forest areas occupied approximately 40% of the Study Area, so it was more desirable and efficient to acquire the contour data by direct plotting than to perform processing to lower the DEM for each forest area by the tree height.

(6) Creation of Final DEMs

A TIN model was created based on the contour data acquired in direct plotting. DEMs at 40m intervals were created from the TIN model in this area and matched with the DEMs acquired in the above automatic processing, until the DEMs at 40m intervals were completed for the entire area.

(7) Checking and Correction

For the contour data that was created, accuracy control of the following items for each model was conducted to correct any errors:

- Technique (automatic generation method and contour line drawing method)
- Number of major errors (mismatching) only in automatic generation
- Number of features (trees, houses, etc.) requiring manual correction only in automatic generation
- Number of points joining adjacent models to be corrected

Accuracy control of the following items when creating DEM data (per model) was conducted to correct any errors:

- Data sequence
- Format errors
- Number of points

(8) Plotting of Planimetric Data

Planimetric features were plotted using a digital plotter. The main items plotted are shown in Table 2.2-1. As a rule, data was acquired and compiled in 3 dimensions.

Table 2.2-1 Items for plotting planimetric features

| | Point | Line | Poligon | Annotation |
|--------------------------------|-------|------|---------|------------|
| Center line of roads | | ○ | | |
| Center line of railways | | ○ | | |
| Center line of rivers | | ○ | | |
| Lakes and marshes | | | ○ | |
| Center line of road tunnels | | ○ | | |
| Center line of road bridges | | ○ | | |
| Center line of railway tunnels | | ○ | | |
| Center line of railway bridges | | ○ | | |
| Points of altitude | ○ | | | ○ |
| Contour lines | | ○ | | |
| Values of altitude | | | | ○ |