3-6 Pricking

3-6-1 Outline

All the ground control points, existing bench marks and other bench marks (prick points) that were required for aerial triangulation and digital plotting were pricked on the aerial photos in Ghana.

3-6-2 Pricking of ground control points (XYZ points and Z points)

For the ground control points newly and additionally installed to determine the XYZ points for aerial triangulation and digital plotting, some planimetric features that were clearly interpretable and suitable for pricking and observation were selected as eccentric points and eccentric observation was conducted. Those points were pricked on quadruple-enlarged photos. For the ground control points in the districts where aerial photography was not available, including unusable photos, ground photography was performed and detailed sketches were prepared for future use.

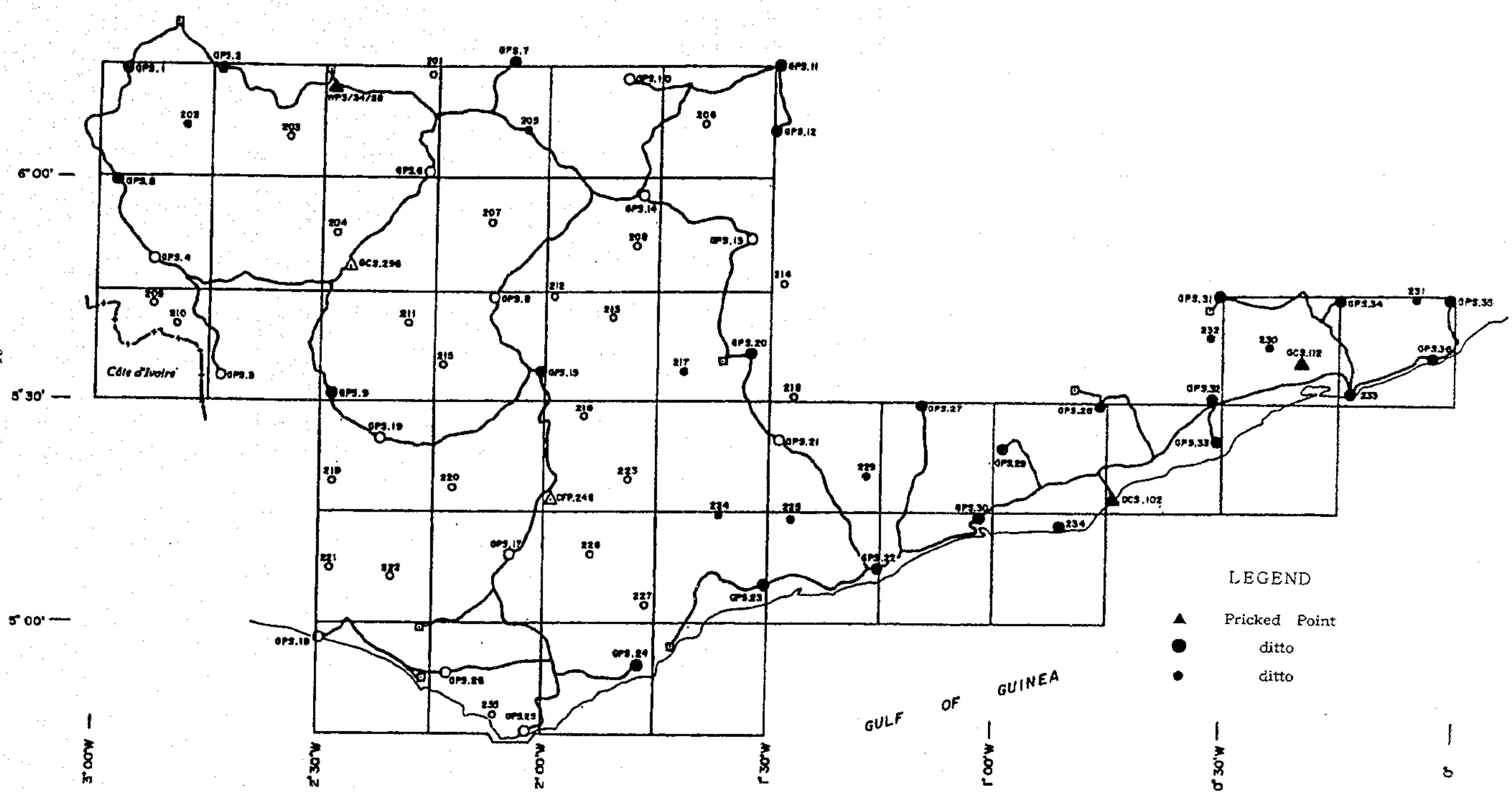
3-6-3 Pricking of bench marks

Pricking of bench marks was performed to maintain the height accuracy necessary for aerial triangulation and digital plotting. The leveling routes (approx. 1,230 km) for which leveling was conducted in this study and 102 existing bench marks installed by SDG (approx. 170 km between Accra and Cape Coast) were pricked. Each of 102 existing bench marks was surveyed on its existence or non-existence in accordance with the description of point and pricked on the double-enlarged photo.

Of 263 prick points over the leveling routes of approximately 1,230km, the points pricked on aerial photos, because of pending photography, existed over a total distance of routes of about 580 km (144 points). For the leveling routes (about 650 km, 119 points) on which no pricking was performed, ground photos and detailed sketches were prepared.

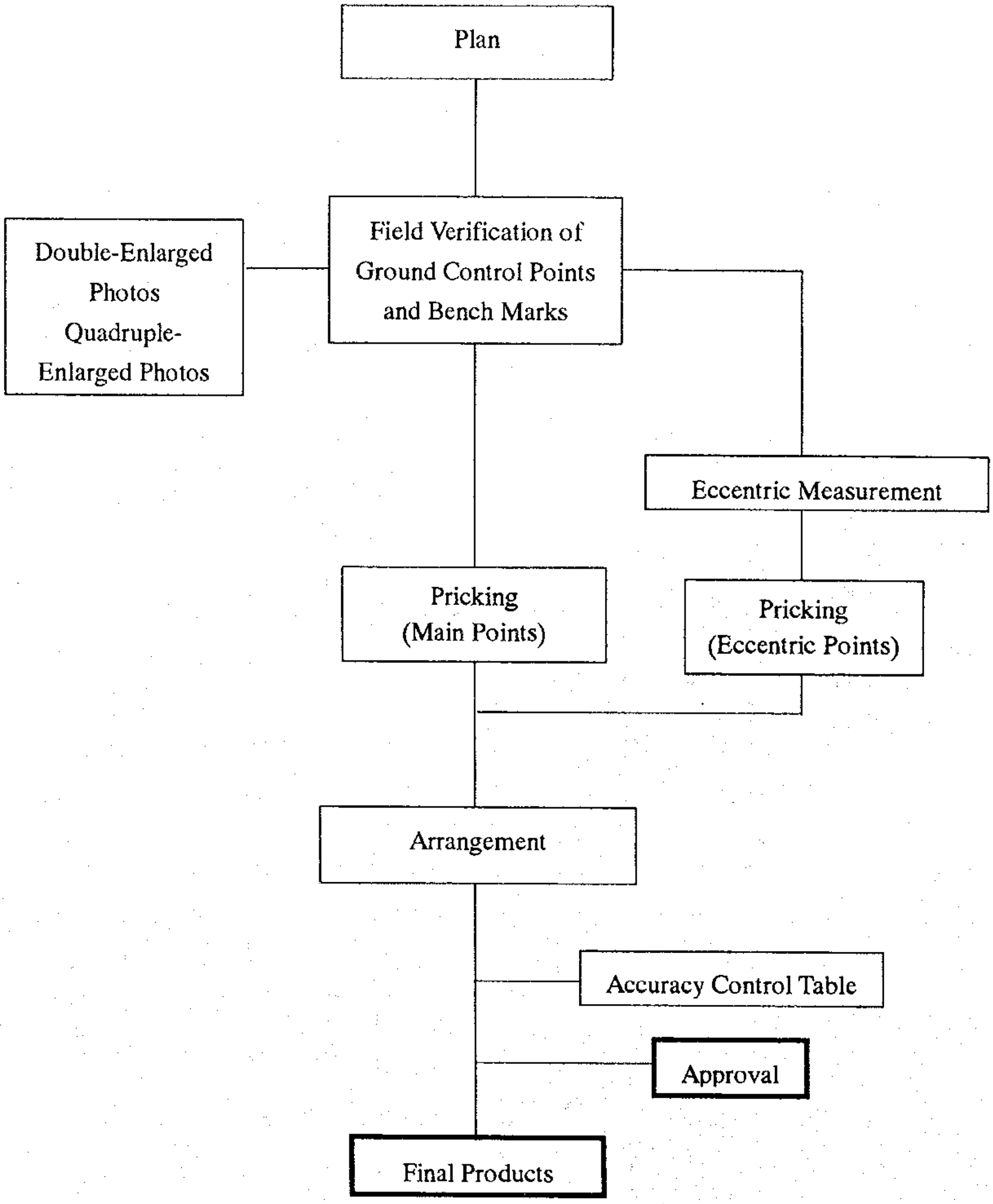
In addition, the height of bench marks (existing and new points) obtained from the leveling work were put in the double-enlarged aerial photos in which the bench marks were pricked. For the leveling routes on which additional ground control points were installed (approx. 230 km, 58 points), pricking was performed in the same specifications. (See the Prick Points Diagram on the next page.)

Pricked Points



3-6-4 Flowchart of Pricking

The flowchart of pricking work is as shown below.



3-7 Aerial Triangulation

3-7-1 Outline

In aerial triangulation, the pass points and tie points selected on the contact aerial photos of 1/60,000 scale and the control points were pricked on film positives and their photographic coordinates were measured using a precision comparator. Then, block adjustment computation by the independent model method was performed based on the measured values and the results of surveys. The geodetic coordinates of all pass points and tie points in stereo models were determined. (See the diagram of Aerial Triangulation Network below.)

3-7-2 Work volumes and specifications

Item	Work volume and specifications
Photographic scale	1:60,000
Number of courses	18 courses
Number of models	323 models (incl. 147 models for the east area)
Number of blocks	3 blocks
Number of control points	Refer to Table of Control Point Residuals
Adjustment computation	Block adjustment by independent model method

3-7-3 Main equipment used

The main equipment used for aerial triangulation was as follows:

Item	Type
Pricking device	WILD PUG-4
Stereo-comparator	ZEISS JENA STECOMPUTER
Computer	LEICA DELL DIMENSION XPS
Software	PAT-M

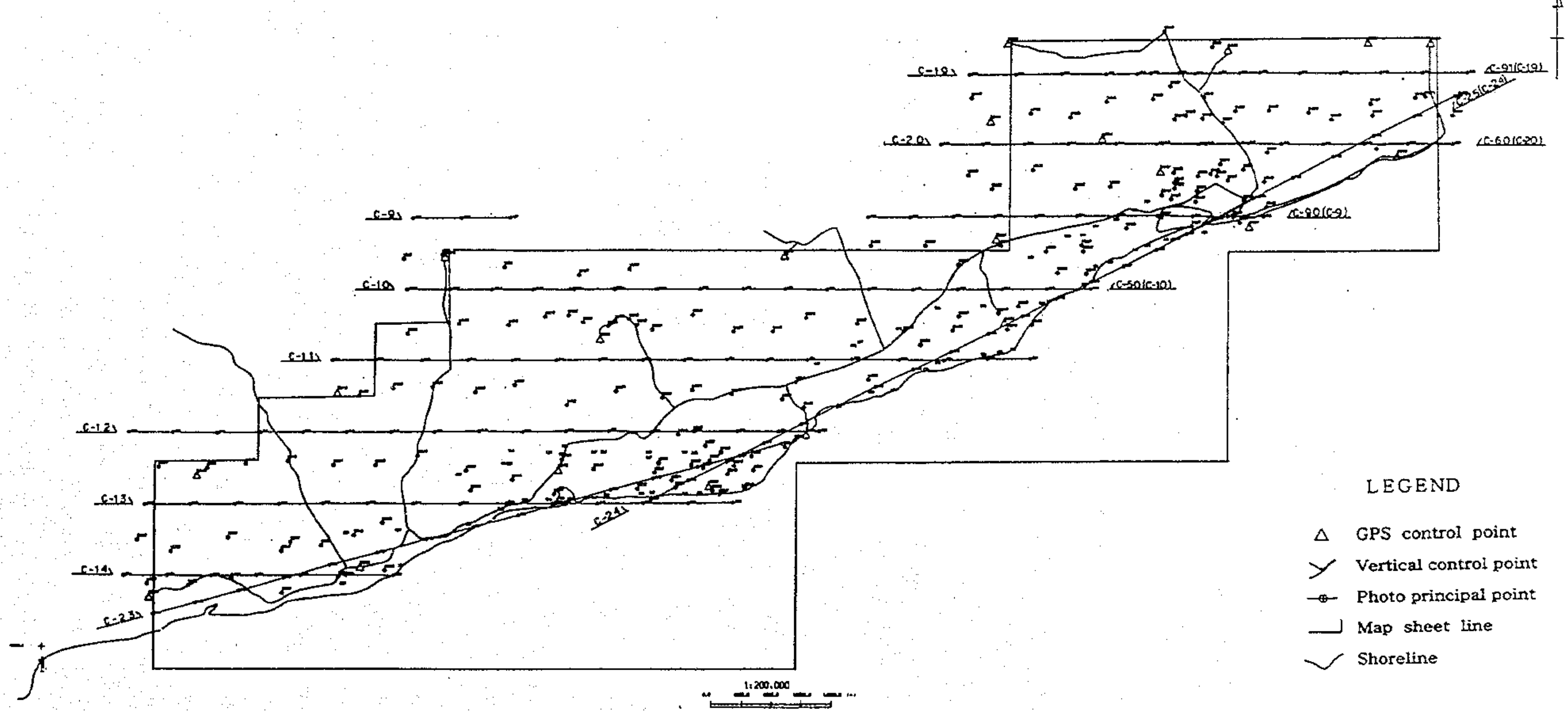
3-7-4 Point selection and pricking

In selection of pass points and tie points, the points the photographic coordinates of which could be measured on contact aerial photos clearly and accurately in accordance with the "Overseas Survey (Topographic Maps) Work Specifications of JICA (draft)" were selected on the contact aerial photos. 6 pass points for each model, one tie point for each model in a overlapped section of adjacent courses, and the ground control points referred to the pricked photos and the sketches were pricked on film positives oriented on the pricking device.

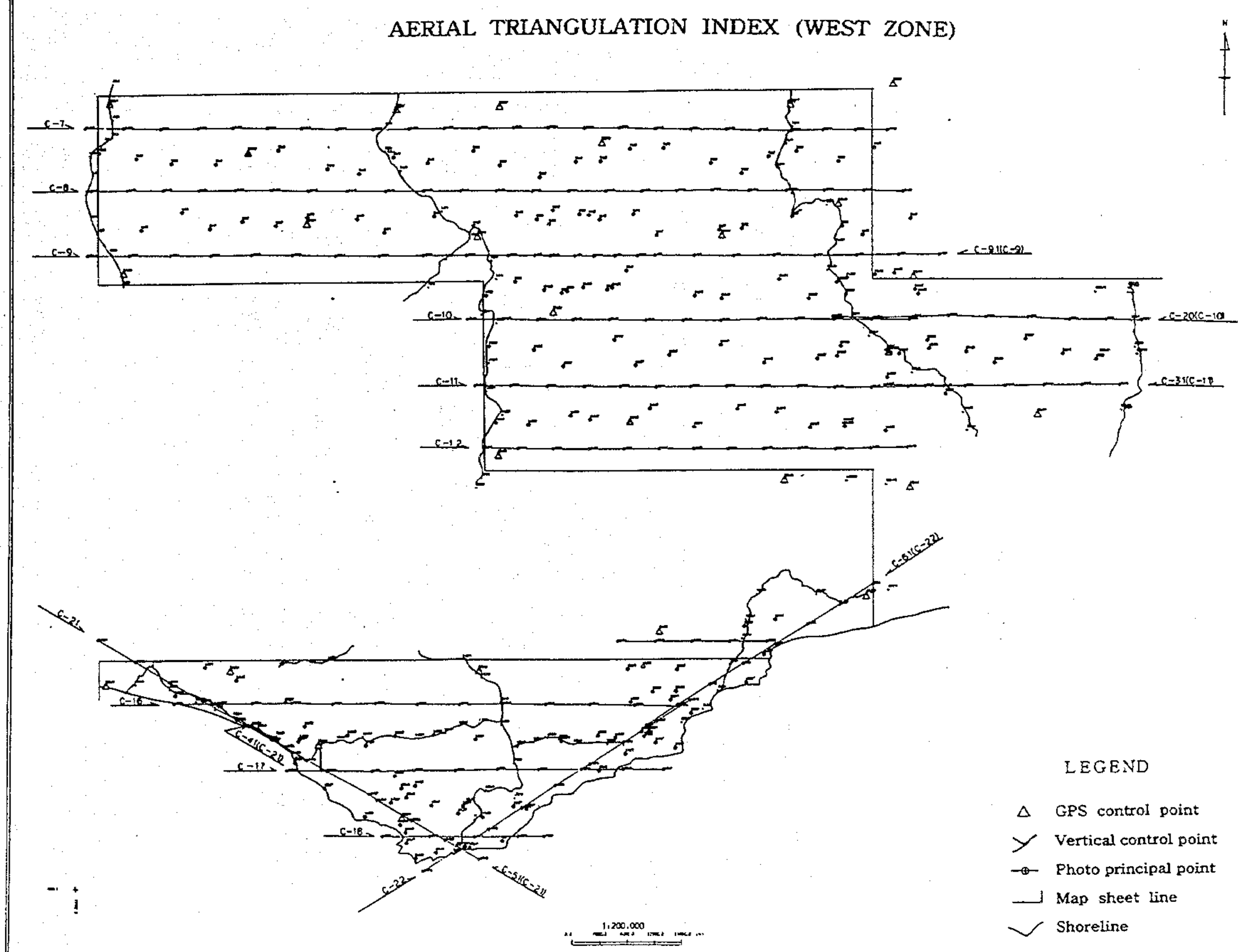
3-7-5 Measurement of photographic coordinates

The pricked pass points, tie points, control points and bench marks (normally not pricked) as well as the indexes on the aerial photos were measured with an accuracy of 1 micron by a precision stereo-comparator. The average values in two times of measurements were adopted normally. If there is a difference exceeding a limit value between two values, however, one more measurement was made to adopt the average value of all measurements.

AERIAL TRIANGULATION INDEX (EAST ZONE)



AERIAL TRIANGULATION INDEX (WEST ZONE)



3-7-6 Internal orientation

In internal orientation, corrections of distances on display by extension and contradiction and corrections of distortions in the aerial camera were added to the photographic coordinates of all indices on film positives that were measured by the stereo-comparator. Then, coordinate conversion computation was performed with the origin at the principal point. The tolerance of the residual error of the indices was set to 0.03 mm or less.

3-7-7 Relative orientation

In relative orientation, all the points in the models were used and the model coordinates for which the effect of refraction in the atmosphere were corrected were computed. The residual vertical parallax was designated 0.03 mm or less on the film positives.

3-7-8 Adjustment computation

In this study, there were some districts where aerial photography was not finished. Therefore, adjustment computations were performed for three blocks of the districts where aerial photography was completed. The block adjustment using the independent model method (simultaneous in the successive relative orientation) was adopted. All the results of ground control point surveys, leveling, pricking and eccentric observation were good and the results of adjustment computation was also highly accurate.

Table of control point residuals

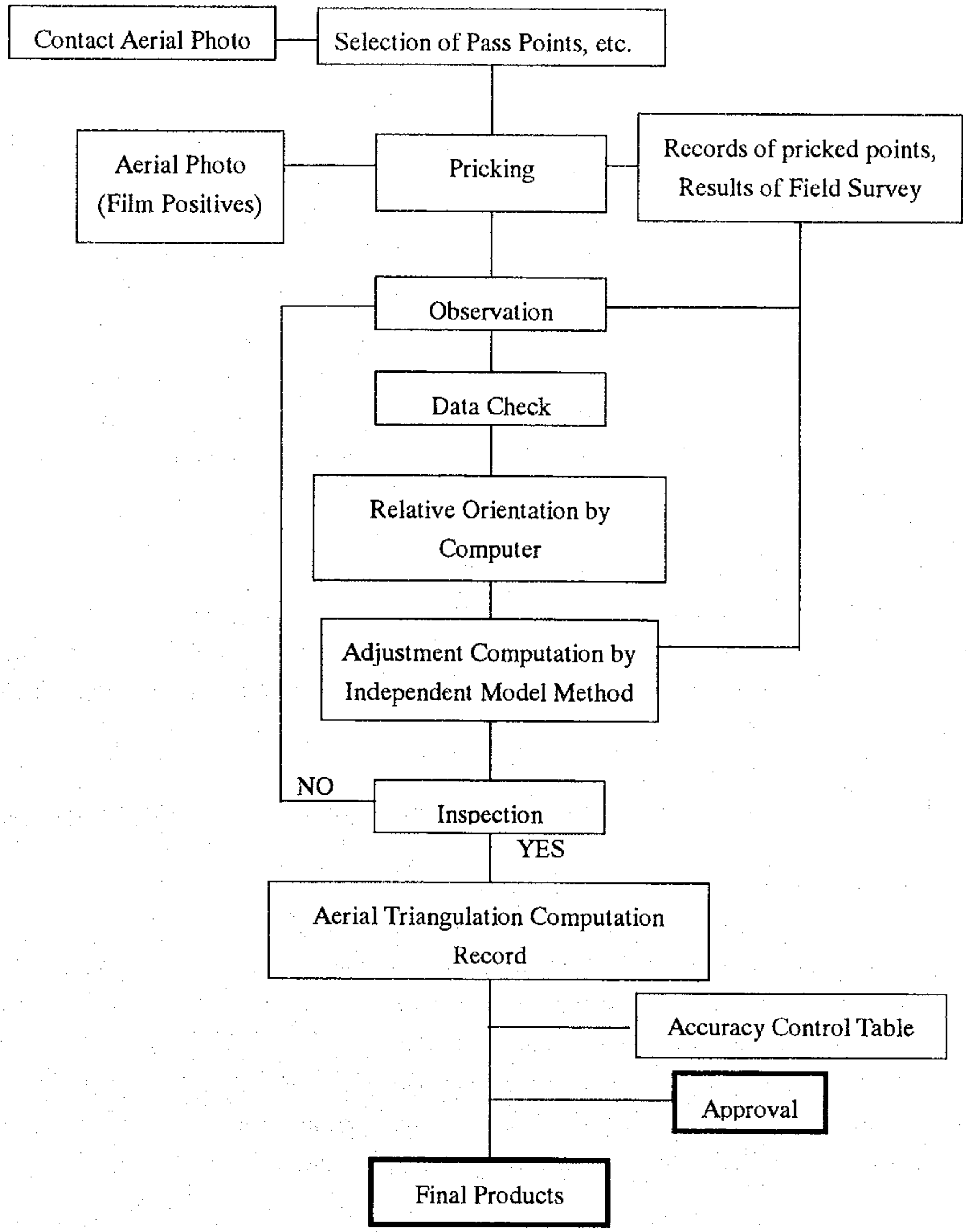
Block & Models	Number of control point		Horizontal residuals		Vertical residuals	
	Horizontal	Vertical	S.D.	Max	S.D.	Max
East 147md	18 points	143 points	1.09m	2.14m	0.43m	0.99m
West1 119md	25 points	82 points	1.09m	1.94m	0.38m	1.42m
West2 57md	9 points	62 points	1.00m	1.51m	0.32m	0.68m

Table of discrepancy between of tie points

Block & Models	Horizontal		Vertical	
	S.D.	Max.	S.D.	Max
East 147md	0.58m	1.94m	0.37m	1.50m
West1 119md	0.63m	1.50m	0.37m	1.11m
West2 57md	0.50m	1.19m	0.29m	0.78m

3-7-9 Flowchart of aerial triangulation

The flowchart of aerial triangulation is as shown blow.



3-8 Field Verification

3-8-1 Outline

Based on the map symbols used in the existing 1/50,000-scale topographic maps as well as the code table of the Ghana Environmental Resources Management Project (GERMP), and in accordance with the map symbols and application rules as agreed between the study team and SDG (Appendix 1.), various existing materials such as materials of administrative boundaries necessary for topographic mapping were collected, the planimetric features and geographic names were checked in field work, and the results of survey and collection of interpretation keys for digital plotting and compilation were inscribed and arranged on the double-enlarged aerial photos. The progress of aerial photography delayed very much due to the bad weathers in the study area. Therefore, the field verification was conducted in two phases. In the first phase, the eastern part (about 4,270 km^2) was surveyed where aerial photography was finished before the field verification in the third year, and in the second phase, the central and southern parts (about 6,830 km^2) where aerial photography was finished in the third year were verified.

3-8-2 Field verification (first phase)

The field verification in the first phase was performed by three groups of members in the eastern part (about 4,270 km^2). Each group includes one counterpart considering smooth communications with the local inhabitants in hearing survey and his experience in grasping the points of the survey.

The verification survey was made on the following items using the double-enlarged aerial photos:

- Field check of the results of reconnaissance
- Collection of interpretation keys for interpretation of aerial photos for plotting
- Check of unclear matters and small objects on aerial photos
- Check of sections of roads and railways and related structures
- Check of other linear objects (such as power lines)
- Check of public buildings such as schools and churches
- Check and collection of geographic names and administrative names
- Check of other matters to be represented on topographic maps

3-8-3 Field verification (second phase)

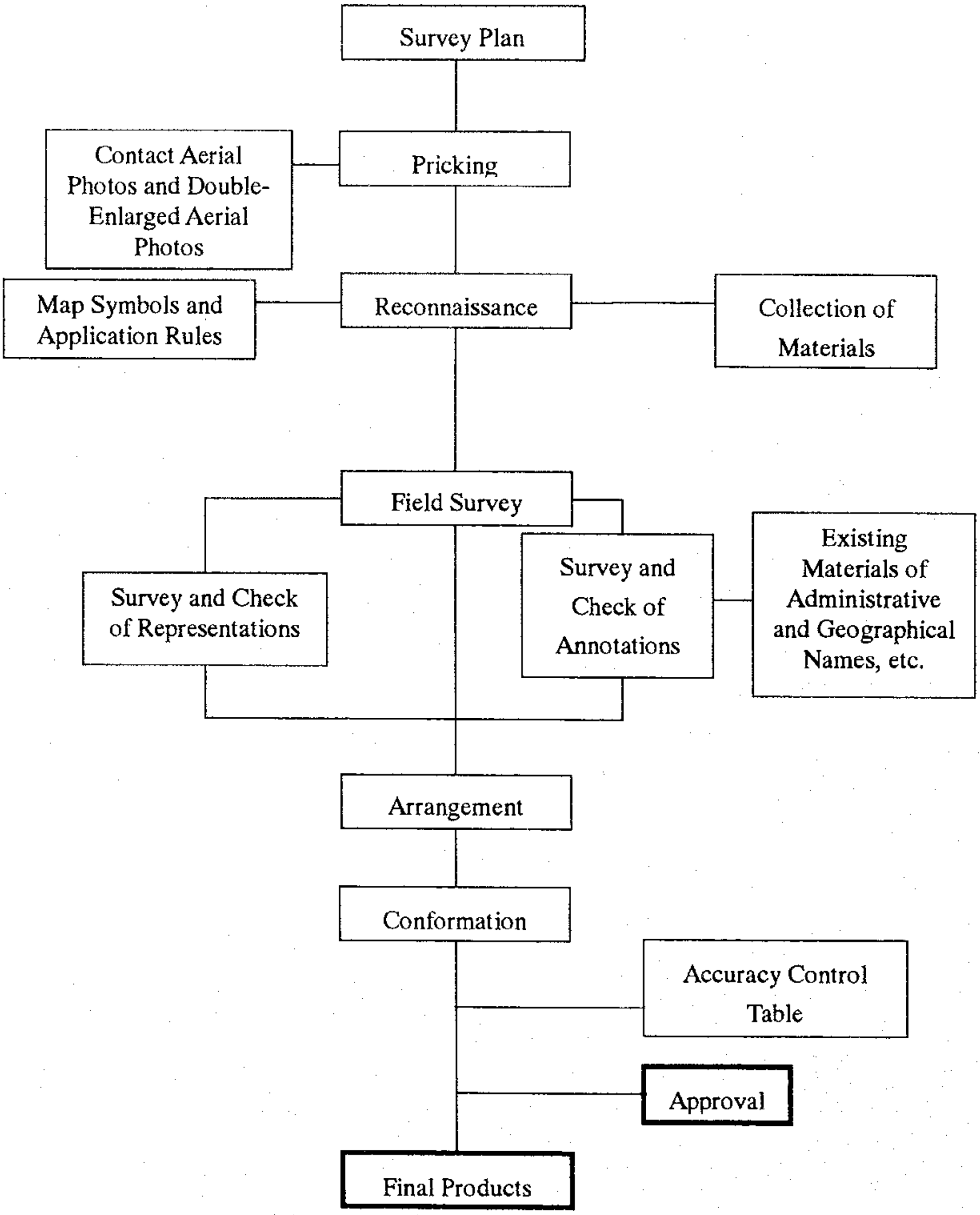
The field verification in the second phase was conducted by 4 groups of members in the central and southern parts (about 6,830 km^2).

3-8-4 Arrangement of results of field verification

The results of field verification were arranged by color classification on the double-enlarged photos in accordance with the standard established to enable the operators in charge of digital plotting and mapping compilation to judge them accurately. Inspection was made in the field to check that all the connections of adjacent aerial photos were not imperfect.

3-8-5 Flowchart of field verification

The flowchart of field verification is as shown below.



3-9 Digital Plotting

3-9-1 Outline

Originally, the analog plotting system was planned, but SDG's request for changing it to the digital plotting system was accepted by JICA. Digital plotting requires enormous work compared with analog plotting. However, once the symbols are structuralized, the work volume to update secular changes regularly can be reduced. The change of plan was very significant in providing the important base maps that can be effectively utilized in various types of GIS (geographic information system) and for other many purposes such as preparation of various kinds of theme maps. In the original plan, aerial photography in the five mine districts with remarkable secular changes was planned for partial digital plotting of those districts. However, it was confirmed that there were existing aerial photos of the five districts. Therefore, it was decided to adopt these photos because they were deemed to be fully usable. Of the entire study area of 25,500 km^2 (a total of 40 maps), digital plotting was performed for the area of approx. 11,100 km^2 where aerial photography was finished based on the results of leveling and aerial triangulation, and the photo materials from field verification. In the partial digital plotting of the five districts using existing aerial photos, only pricking (of pass points and tie points) was performed because there were few stereo models of each district available. No aerial triangulation was performed, but digital plotting was performed based on map orientation method.

The specifications for digital plotting are as shown below.

Item	Specifications of Digital Plotting
Photographic scale	New aerial photos (Scale 1:60,000) Existing aerial photos (Scale 1:50,000; 1:20,000; and 1:60,000)
Plotting scale	1/50,000
Area	Approx. 11,100 km^2 (3 districts). Partial digital plotting of 5 districts
Number of map sheets	20 map sheets
Contour line intervals	Intermediate contour lines 10 m (20 m in steep slopes)
Projection	Ghana Modified Transverse Mercator
Neatlines	15' x 15'

3-9-2 Major equipment used

The major equipment used for digital plotting are as follows:

Item	Type
Analytical plotter	CARL ZEISS PC-3, LEICA DRS-2000, etc.

3-9-3 Orientation

In relative orientation, 6 pass points were used and the residual vertical parallax was specified as 0.02 mm or less on film positives. In absolute orientation, the pass points, tie points, ground control points and bench marks that were determined by aerial triangulation were used and the tolerance error was 0.3 mm for XY on the map and 1/4 of a contour line interval for Z. The orientation record was prepared for later re-orientation. The absolute orientation for partial locations of the mine districts was conducted relative to the heights in the existing topographic maps.

3-9-4 Digital plotting

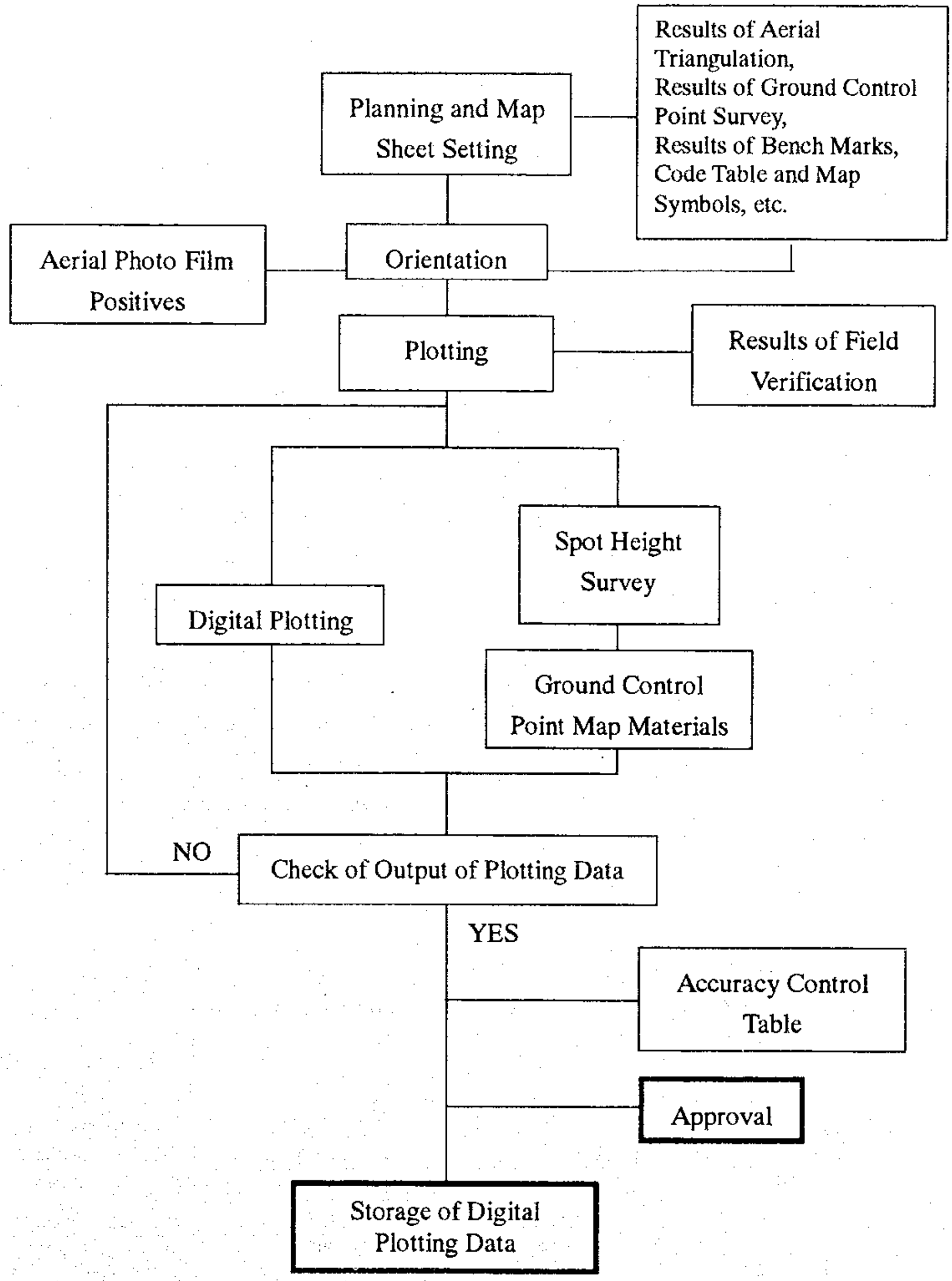
The study team explained all the plotting operators about the map symbols, application rules and detailed measuring method as well as the work specifications using the instruction manual, in order to avoid inconsistent, unequal understanding among the operators. The measurements were made in the order of roads, rivers, railways and other linear objects, buildings and other planimetiric features, and lastly contour lines. As to the spot heights, the average values of two measurements in 1m steps were adopted.

3-9-5 Check after digital plotting

After completion of the digital plotting, the results of plotting were verified with the double-enlarged photo materials and collected materials made available from the field verification and checked on the conformity to map symbols. Some plotting omissions and errors were corrected. The matters that were left as questions in digital plotting and should be checked in the field completion were also arranged. The inspection was conducted based on these results.

3-9-6 Flowchart of digital plotting

The flowchart of digital plotting is as shown below.



3-10 Satellite Image Processing

3-10-1 Outline

Aerial photography was conducted once in the first year, twice in the second year and once in the third year, 4 times in total. The work was incomplete each time due to bad weathers. As a result of discussions, aerial photography was suspended only for the coverage of about 11,100 km^2 (20 map sheets) of the entire study area of about 25,500 km^2 (40 map sheets). For the remaining coverage of 14,400 km^2 (20 map sheets), however, it was decided to employ the existing SPOT satellite images (photographed during the period of January 1994 to February 1995 by Spot Image Corp., France). Then, Ortho images were created.

3-10-2 Major equipment used

The major equipment used for image processing is as follows:

Item	Type
Image processing software	ESRI Arc/Info; ERDAS ERDAS IMAGINE; LEICA SOCET SET, etc.
Computer	Sun Microsystems ULTRA3, etc.
Image setter	Purup Esdofot MAGNAUM CASSIC IMAGEMAKER

3-10-3 Image processing

(1) Ortho images

In ortho image processing, two methods are available: map-based ortho in which ortho images are produced in the unit of map sheet as topographic mapping, and scene-based ortho in which ortho images are produced in the unit of SPOT image scene. In this study, the map-based ortho image processing was adopted because it is the most suitable for comparison with the existing topographic maps, extraction of secular changes and updating.

(2) Ortho image production

The SPOT images used for ortho image production are as follows:
(See Fig. 3-10-1.)

KJ Address	Date of Acquisition	KJ Address	Date of Acquisition
0416104-2	Dec. 18, 1944	0416104-3	Dec. 18, 1994
0422640-2	Feb. 05, 1995	0422640-3	Feb. 05, 1995
0422640-4	Feb. 05, 1995	055340	Jan. 05, 1994
056338	April 21, 1998	056339	Dec. 28, 1997
0415207-1	Dec. 09, 1994	0415207-2	Dec. 09, 1994
0415207-3	Dec. 09, 1994		

1) Orientation

10 or more points that could be clearly measured in the SPOT satellite image 1A and that have no secular change were selected per scene as the unit acquired from the satellite, and the coordinates of the selected points were read out on the existing topographic map using a digitizer. The orientation element data per scene was created and image orientation based on the data was performed.

2) Creation of digital height model

In this study, the interim data from the Arc/Info software provided by SDG was structuralized to make topographic maps in the unit of meter. The contour line data in the unit of meter was converted from the contour line and water system data in the existing topographic maps made in the unit of foot. Using the contour line data converted into that in the metric unit, the digital topographic model (hereinafter "DTM") was created per scene block of the SPOT image.

3) Ortho image production

An oriented SPOT image was overlaid on the DTM to produce the image that has position displacements due to height shapes. All the scenes were subjected to orthographic projection to produce the scene-based ortho images that reflected the geographic positions correctly.

4) Mosaic processing

Each scene-based ortho image is mosaicked and edited in the 30' x 30' grids as the map sheet units of topographic map. Thus, the map-based ortho images were produced.

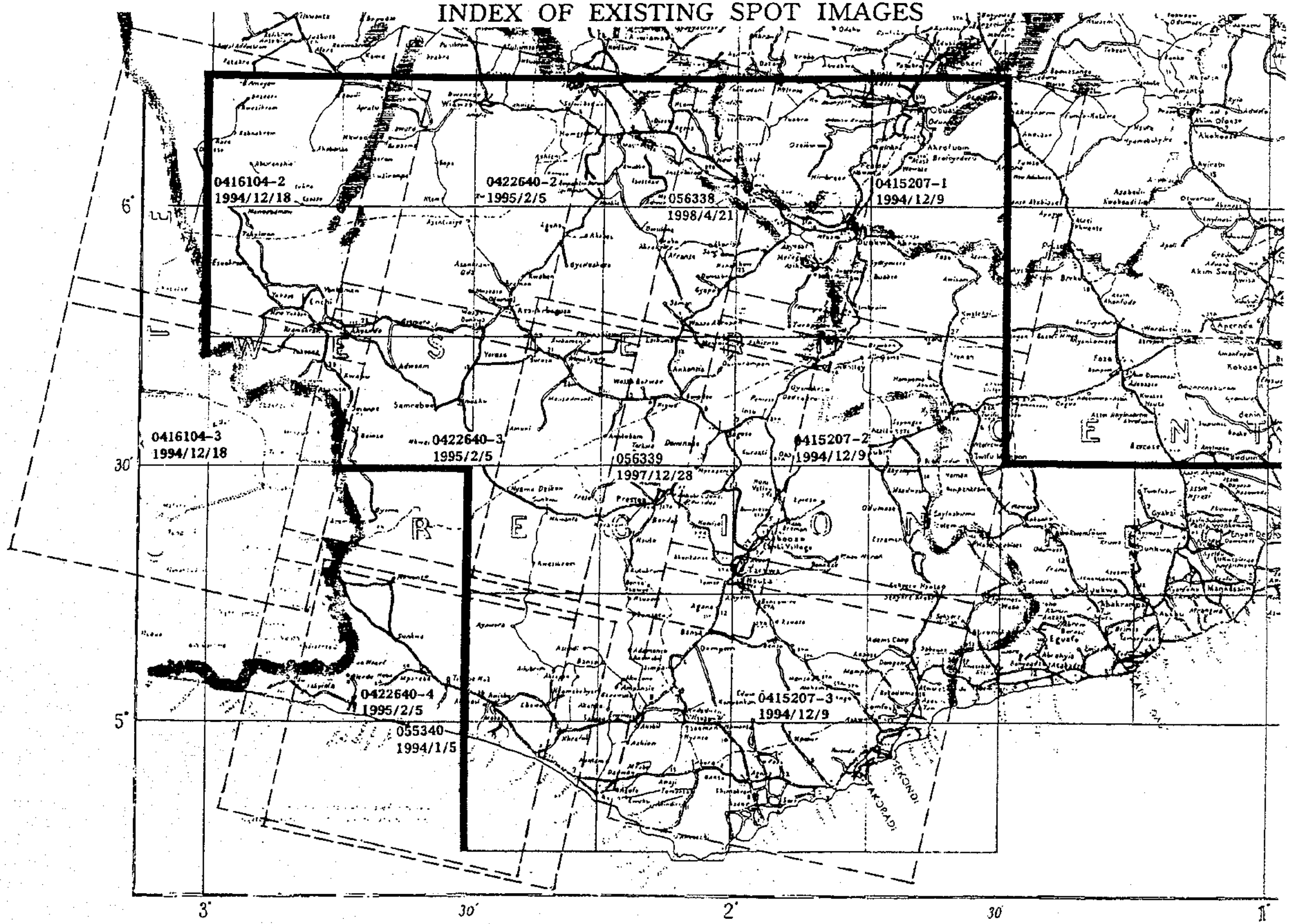
5) In-company Inspection

The map-based ortho images were overlaid on the topographic maps to inspect whether there were image deviations or distortions.

(2) Image outputs

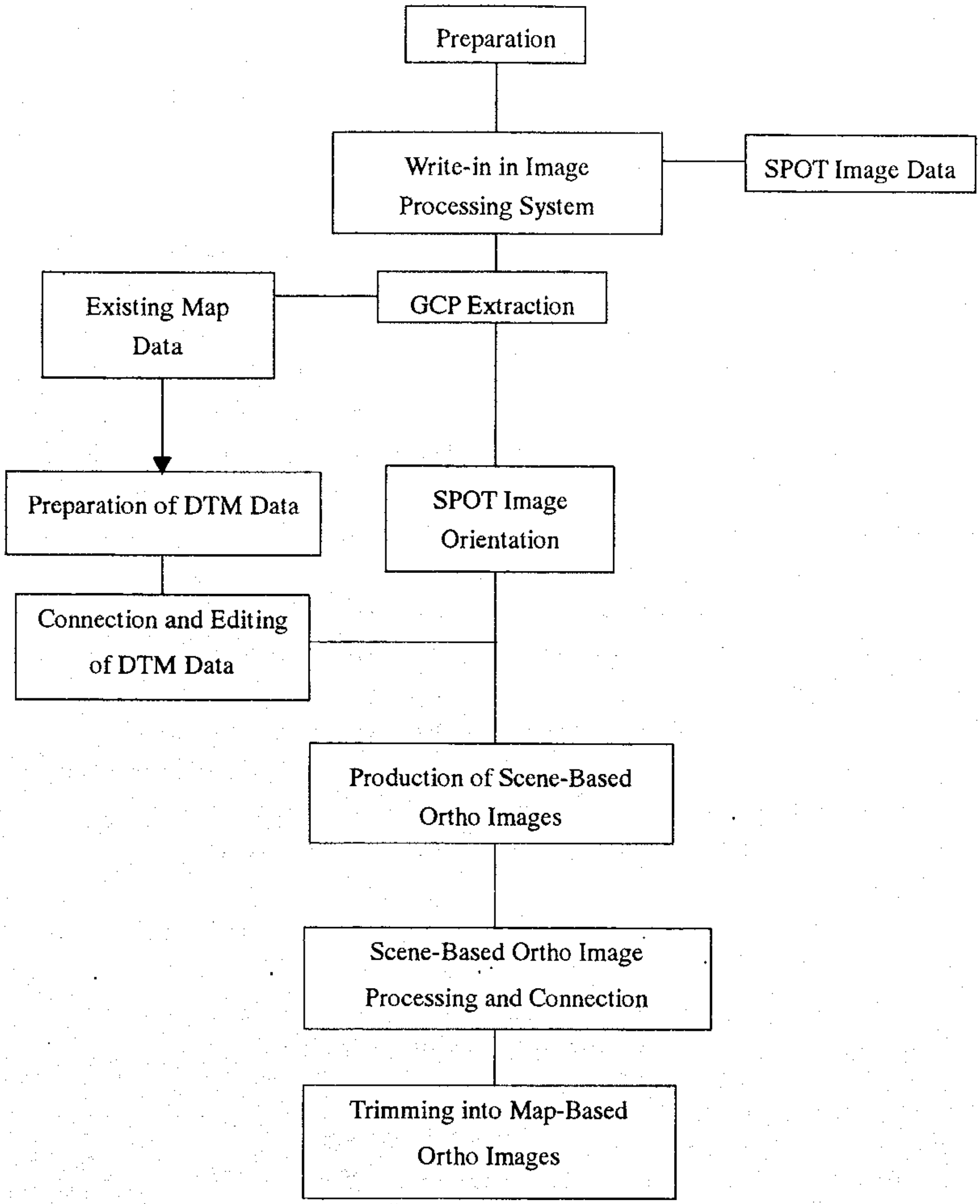
The image outputs were processed in brilliance, gradations and highlighting so that the planimetric features and vegetation can be interpreted easily. The image data necessary for all the map sheets was outputted by the image setter.

INDEX OF EXISTING SPOT IMAGES



3-10-4 Flowchart of satellite image processing

The flowchart of satellite image processing is as shown below.



3-11 Field Verification of Satellite Images

3-11-1 Outline

For the area of about 14,400 km^2 (20 map sheets) where aerial photography was not completed, the field verification using the SPOT satellite images was conducted by 4 groups of members. For the districts for which the aerial photos were partially available, the aerial photos were also used as reference materials.

3-11-2 Field verification of satellite images

In the field verification using the satellite images, the aerial photos were partially used as reference materials, but the satellite images with the resolution of 10 m contained many unclear and uninterpretable objects compared with the aerial photos of 1/60,000 scale. There were also many secular changes. Therefore, the field verification including the updating of secular changes was conducted by GPS camera shooting from a light plane in flight, topographic observation from the total station on the land, and by the use of a DGPS (differential GPS) mounted on a car. The survey was made on the following items using the map-based ortho images produced from the SPOT satellite images:

- Field check of the results of reconnaissance
- Check of unclear or small objects on satellite images and data acquisition
- Check of new roads or the like that are not presented in satellite images and data acquisition
- Check of road and railway sections, and related structures, and data acquisition
- Check of other linear objects and data acquisition (such as power transmission lines)
- Check of public buildings such as schools and churches, and data acquisition
- Check of geographic names and administrative names and collection of the related materials
- Check of other matters to be represented on topographic maps, and data acquisition

3-11-3 Major equipment used

The major equipment used for field verification of satellite images is as follows:

Item	Type
DGPS receiver (mobile station)	TRIMBLE GEOEXPLORER II
GPS receiver (fixed station)	TRIMBLE 4000SSE
GPS camera	Konica GPS camera
Total station	Topcon GTS
Software	TRIMBLE PATHFINDER OFFICE, etc.
Computer	TOSHIBA DYNABOOK

3-11-4 Arrangement of field verification results

The data observed by the total station and the data obtained by the DGPS observation were analyzed to create the update data to revise the existing topographic maps.

The results of field verification were arranged on the map-based ortho images in color classification by item in accordance with such standard that the operators in charge of updating the existing topographic maps could make right judgment. Then, the connections between the adjacent scenes of all the SPOT satellite images were also adjusted not to cause any discrepancy. These results were inspected by the chief engineer in Ghana.

3-11-5 OJT in Ghana for map compilation

In this study, it was originally planned to use the analog method for topographic mapping, but the plan was changed to update the secular changes in SDG's existing digital topographic maps for the districts where aerial photography was not completed due to bad weathers. For the districts where new aerial photos could be obtained, it was also planned to produce digital topographic map data. At the same time, SDG represented their keen request that they would have opportunity for more perfect transfer of technology in digital mapping data compilation. JICA accepted their request and provided the OJT in Ghana for the "digital topographic mapping data processing technology" mainly intended for production of digital topographic map data for printing.

1) Major equipment used

The major equipment used for the OJT in Ghana is as follows:

Item	Type
Software	ESRI Arc View; ADOBE Illustrator
Computer	TOSHIBA DYNABOOK
Printer	Canon BJC-800

3-12 Updating of Existing Topographic Map Data

3-12-1 Outline

Over the area of approx. 14,400 km^2 where aerial photography was unfinished of the entire study area, the contour lines data was produced in the metric unit based on the digital data of existing topographic maps and the water system data that were represented in the foot unit. Then, the secular changes in the existing topographic maps were updated based on the results of the field verification using satellite images.

3-12-2 Major equipment used

The major equipment used for updating of the existing topographic map data is as follows.

Item	Type
Software	ESRI Arc/Info; AUTODESK AutoCAD, etc.
Computer	Sun Microsystems ULTRA, etc. DELL Dimension XPS, etc.

3-12-3 Updating of existing topographic map data

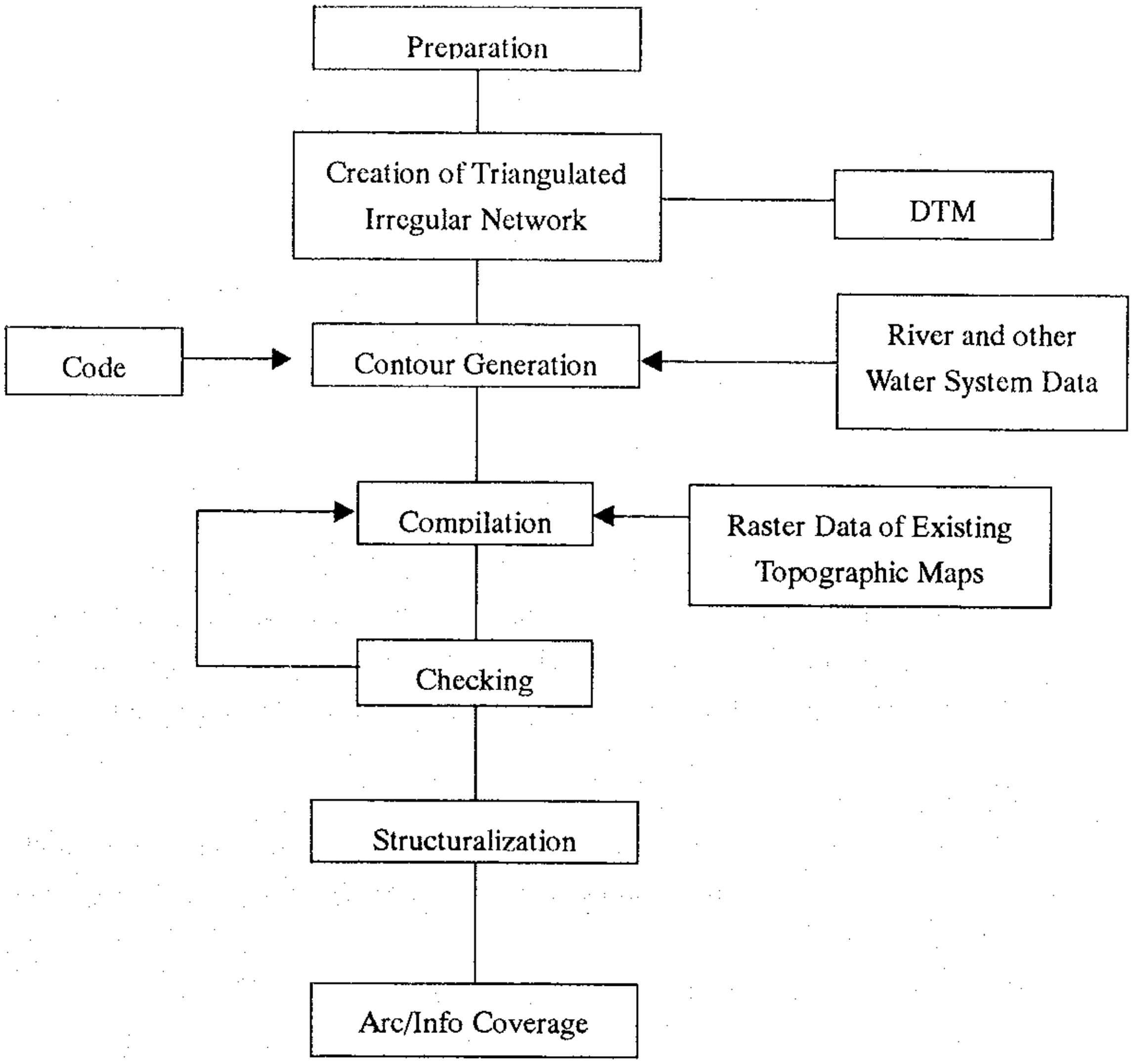
By using the DTM that was the interim product in the ortho image production process, the triangulated irregular network (hereinafter "TIN") was formed. Based on the TIN, the contour lines in the metric unit were automatically created, and compiled by the vector compilation tool referring to the topography on the background of the raster images of the existing topographic maps.

The existing topographic map data was compiled and structuralized based on the data obtained for updating of the secular changes in the field verification of the satellite images and the image materials for the field verification. The structuralized files were converted into the format of the digital mapping compilation files (hereinafter called "existing DM data").

After updating the data, the connections between adjacent maps, the discrepancies between the spot heights and the contour were checked.

3-12-4 Flowchart of updating of existing topographic mapping data

The flowchart of updating of existing topographic mapping data is as shown below.



3-13 Map Compilation

3-13-1 Outline

Map compilation was performed using the new structuralized DM data, the existing DM data with updated secular changes, the results of field verification and the collected materials. This process was conducted using a computer and in accordance with map symbols and application rules.

3-13-2 Map compilation

In the map compilation, the digital compilation work instruction manual and sample data were prepared in order that members of each group can perform the work in the uniform map symbol representation system. The work was performed with consistence among the group members.

(1) Data

The interchange files (interim files in Arc/Info) provided by SDG and classified by code were structuralized to create the coverage. All the map sheets in the coverage were converted by code into the format of the Illustrator used in the mapping compilation. All these data files were composed into each map sheet unit using the Illustrator.

(2) Compilation method

The map symbols and application rules were applied to the method of compilation, in which the objects (graphics) divided in layers by map sheet were compiled in the following order:

- Ground control points and independent spot heights
- Roads and railways
- Rivers and water system
- Contour lines
- Buildings and marks for point indication
- Vegetation
- Annotations and contour indication
- Displacement
- Connection

Major equipment used

The major equipment used for map compilation is as follows:

Item	Type
Software	ADOBE Illustrator
Computer	Macintosh Power Mac, G3, etc.
Plotter	HEWLETT PACKARD, Hp 2500C, etc.

3-14 Field Completion

3-14-1 Outline

Field completion was performed mainly to re-check the aerial photos used for field verification and digital plotting, the field verifications and survey in the urban districts where secular changes were remarkable in the satellite images, and the unclear matters pointed out in the work processes of digital plotting and compilation.

3-14-2 Field completion

Field completion was conducted on the items described below using the output maps after digital compilation. Each field group includes one counterpart, taking into account of the better communications with the local inhabitants in hearing and his more experience in grasping the points in the study.

- Questions pointed out in each work process in digital plotting, secular change updating and digital mapping compilation
- Study of locations where the field verification was unconfirmed or insufficient, and data acquisition
- Study of secular change after the field verification, and data acquisition
- Reconfirmation of roads, especially roads marked with two lines, and data acquisition from newly constructed roads
- Study of unconnected points of linear objects pointed out in digital plotting, and data acquisition
- Other matters required in the field completion work and discussions with SDG

3-14-3 Major equipment used

The major equipment used for the field completion is as follows:

Item	Type
DGPS receiver (mobile station)	TRIMBLE GEOEXPLORER II
GPS receiver (fixed station)	TRIMBLE 4000SSE
Total station	Topcon GTS310
Software	TRIMBLE PATHFINDER OFFICE, etc.
Computer	TOSHIBA DYNABOOK

3-14-4 Arrangement of the results of field completion

The operators in charge of data compilation arranged the results of field completion on the digital compilation maps in the standard made for easy judgement. They adjusted the connections between adjacent map sheets. The data observed by the use of the DGPS and other equipment was also analyzed and the Arc/Info coverage was produced for digital compilation.

3-15 Data Revising

3-15-1 Outline

The data revising was performed in accordance with the map symbols and application rules, and the digital topographic mapping data (Arc/Info coverage) and the map compilation data (Illustrator) were updated based on the data and materials obtained field completion, using a computer.

3-15-2 Data Revising

(1) Digital mapping topographic data (Arc/Info coverage)

In revising the digital topographic mapping data, the data of the coverage produced by structuralizing the Arc/Info interim files was updated based on the data acquired in the field completion, various map materials newly obtained, rechecked and restudied. The updated data was converted into the Illustrator's format used in the digital mapping compilation. The points, arcs and polygons classified by code for each map sheet were compiled in the following order:

- Ground control points and spot heights
- Roads and railways
- Rivers and water system
- Contour lines
- Buildings and marks for point indication
- Vegetation
- Annotations and contour indication
- Displacement
- Connection

(2) Mapping data (Illustrator data)

The results of revising the mapping data were updated in the map symbols and application rules and referring to the arranged drawings of various diagram materials that were rechecked, restudied and newly obtained.

The objects classified by code for each map sheet were updated in the following order:

- Ground control points and spot heights
- Roads and railways
- Rivers and water system
- Contour lines
- Buildings and marks for point indication
- Vegetation
- Annotations and contour indication
- Displacement
- Connection

3-15-3 Major equipment used

The major equipment used for the data revising process is shown below.

Item	Type
Software	ESRI Arc/Info, Arc/View; AUTODESK AutoCAD; ADOBE Illustrator, etc.
Computer	Sun Microsystems ULTRA; DELL Dimension XPS Macintosh Power Mac, etc.
Plotter	Hewlett Packard HP750 and 2500C, etc.

3-15-4 Arrangement

The connections between adjacent map sheets, annotations and the matters related to the representation system for topographic maps were subjected to inspection. The output maps, the materials of field completion and the annotation diagram materials were arranged for each map sheet.

3-16 Preparation of Plate-making Film

3-16-1 Outline

The mapping data updated in the data revising process, then subjected to the in-company inspection was converted into EPS films, from which the plate-making films were produced in color separations (5 colors) for each map sheet using an image setter.

3-16-2 Major equipment used

The major equipment used for production of plate-making films is shown below.

Item	Type
Image setter	PURUP ESKOFOT MAGNUM CASSIC IMAGEMAKER

(3) Quality control

In quality control, all the map sheets outputted per color separation by the image setter were checked on the color tone and distortion in gradations.

3-17 Printing

3-17-1 Outline

The maps were printed in 5 colors by the offset machine based on the color tone and marginal data specifications as agreed upon by the study team and SDG.

3-17-2 Plate-making

Using the color separation plate-making film outputted from the image-setter, PS aluminum printing plates were made one for each color.

3-17-3 Proof maps

The proof maps were produced from the PS films by the offset printing machine. The produced proof maps were carefully inspected on the color tones, register marks, print map dimensions and lines. As the result of inspection, the inadequate maps were reproduced and subjected to inspection.

3-17-4 Paper

The paper used for printing was of B1 size (weight 90g/m^2). The paper has the features of fold-resistance and high strength against tension, break and tears. The quality paper type of small expansion and contradiction which is thought most suited for topographic maps was selected.

3-17-5 Printing

Each map sheet was printed in 1,002 copies by the offset printing machine. After printing, all the copies were inspected carefully.

3-17-6 Major equipment used

The major equipment used for printing is shown below.

Item	Type
PS processor	Fuji Film PS Processor
Vacuum framing machine	Ueno Vacuum framing machine
Offset printing machine	Akiyama Printing BESTECH40

3-18 Preparation of Digital Data File

3-18-1 Outline

Two types of final products, namely the Arc/Info coverage updated from the existing digital topographic maps and the mapping data outputs from the Illustrator were stored in the CD-ROMs that are the most suitable media for saving the digital data files produced in this study and reproducing the copies.

3-18-2 Preparation of digital data file

Two types of digital data files were produced: the Arc/Info coverage and the Illustrator data. The data files were reproduced in the CD-ROMs that were provided with label coating indicating the study name and the date of production because the CD-ROMs were most suitable for producing a number of copies at low cost at SDG later on. Then, it was checked whether the digital data files were rightly written in the CD-ROMs.

3-18-3 Major equipment used

The major equipment used for production of digital data files is shown below.

Item	Type
CD writer	Logitec LCW-748
Computer	DELL Dimension XPS T450

3-19 Final Products and Materials

The final products and materials obtained in each process in this study are listed below.

(1) Plan of Operation (P/O) English 30 copies per fiscal year

(2) Aerial photography

- Film negatives: 1 set
- Film positives (for common use with aerial triangulation): 1 set
- Contact prints: 1 set
- Double-enlarged photos: 1 set

- Index maps: 1 set
- Photography records: 1 set
- Accuracy control table: 1 set

(3) Ground control point survey

- Final results: 1 set
- Observation records: 1 set
- Meteorological observation records: 1 set
- Field computation notes: 1 set
- Computation notes: 1 set
- Descriptions of points: 1 set
- GPS observation network diagrams: 1 set
- Accuracy control table: 1 set

(4) Leveling

- Final results: 1 set
- Observation notes: 1 set
- Computation notes: 1 set
- Aerial photos with position indications: 1 set
- Descriptions of points: 1 set
- Leveling route map: 1 set
- Accuracy control table: 1 set

(5) Pricking

- Records of pricked points: 1 set
- Eccentric element measurement records and eccentric computation notes: 1 set
- Aerial photos with pricked point indications: 1 set
- Pricked point map: 1 set
- Accuracy control table: 1 set

(6) Aerial triangulation

- Results of aerial triangulation and Implementation table: 1 set
- Film positives for aerial triangulation: 1 set
- Contact prints for aerial triangulation: 1 set
- Table of control point residuals and table of discrepancy of pass points and tie points: 1 set
- Accuracy control table: 1 set

(7) Field verification (Aerial photos)

- Double-enlarged photos with arranged verification results: 1 set
- Overlay of the above aerial photos: 1 set
- Satellite images arranged with verification results: 1 set
- Other related materials: 1 set
- Accuracy control table: 1 set

(8) Digital plotting

- Digital plotting data: 1 set
- Control point map materials: 1 set
- Orientation records: 1 set
- Other reference materials: 1 set
- Accuracy control table: 1 set

(9) Satellite image processing

- SPOT satellite image data (1A): 1 set
- SPOT satellite image data (Ortho images): 1 set
- Accuracy control table: 1 set

(10) Existing topographic mapping data revising

- Existing topographic mapping data: 1 set
- Accuracy control table: 1 set

(11) Digital topographic map compilation

- Digital topographic map compilation data: 1 set
- Accuracy control table: 1 set

(12) Field completion

- Map materials for administrative and geographic names: 1 set
- Control point map materials (updated by field completion): 1 set
- Road map materials (updated by field completion): 1 set
- Water system map materials (updated by field completion): 1 set
- Marginal information data map materials (updated by field completion): 1 set
- Other related map materials: 1 set
- Accuracy control table:: 1 set

(13) Data revising

- Data for data revising: 1 set
- Accuracy control table: 1 set

(14) Plate-making film production

- Plate-making films: 1 set
- Accuracy control table: 1 set

(15) Printing

- Printed maps: 1 set
- Accuracy control table: 1 set

(16) Reports

- Work Implementation (Completion) Report: 3 copies
- Study Work Reports (English I, II, III, IV): 35 copies each (20 copies to Ghana)
- Final report (English): 50 copies (20 copies to Ghana)
- Package of technical materials: 40 copies

4. Considerations

The study of 1/50,000-scale topographic mapping was implemented for the area of approximately 25,500 km^2 in the Southern Part of the Republic of Ghana. For the area of approximately 11,1000 km^2 where aerial photography was completed of the entire study area, new digital topographic maps were created. For the area of approximately 14,400 km^2 where aerial photography was unfinished, topographic maps and digital mapping data were produced by updating the secular changes on the existing topographic maps with SPOT satellite images. As this study was completed, the results of consideration on each process of it will be described below.

4-1 Signalization for Aerial Photography

It was originally planned to use 4 existing control points, but as the result of reexamination of the observation network, it was re-planned to add another existing control point CG112. As there were no eccentric points such as planimetric features around it that could be observed clearly on aerial photos, however, aerial photo signals were installed. The SDG counterparts, who had had no opportunity of participating in the survey for topographic mapping, endeavored to master the technology through the field work in this study.

The SDG engineers installed the aerial photo signals under the consultation of the study team. Through this work, the SDG engineers endeavored to master the method of installing the aerial photo signals judging the field conditions.

In the work of aerial photo signalization, higher efficiency was not expected than in the method of conducting the ground control point survey and pricking after aerial photography. In considering the insufficient experience of the SDG engineers in photographic survey, however, it was deemed that training would be necessary for comparison of the terrain scale on the aerial photos with the actual scale in the field. Therefore, it is desirable to adopt the method of installing aerial photo signals in aerial photography for the photographic survey that SDG will conduct in the future.

4-2 Aerial Photography

It is likely to think that there would be a little trouble in aerial photography due to bad weathers in dry seasons. However, cloudy and rainy weathers continued and visibility was very low despite the dry season in the area where aerial photography was conducted. The photographic work was continued in 4 fiscal years, but the weather was bad for any period of photography. Thus, aerial photography was finished only in about 44% of the study area, but it was unfinished in the entire study area.

From this experience in aerial photography, it was considered that aerial photography should be challenged for a sufficient period without losing a good opportunity, and that preparation of a high performance camera is the requisite for successful aerial photography. It is also necessary to judge a change of plan depending upon the conditions.

The use of SPOT satellite images with 10m resolutions as decided in this survey provided far less information on the terrain than the use of 1/60,000-scale aerial photos in the original plan of this study. If satellite images with higher resolutions is available at stable low costs, they will have wider applications for the future topographic mapping work.

4-3 Ground Control Point Survey

Since only 5 existing control points were used as given points in the study area, the existing control point network could not be provided sufficiently. In this study, therefore, 39 ground control points (XYZ) and 34 points (Z) were added by GPS survey in the districts where the existing control points are insufficient.

The SDG engineers knew this new technology as information, but they saw the GPS receivers actually and observed with those for the first time. Therefore, the study team explained them about the principle and method of GPS survey and conducted transfer of the technology, in which many SDG engineers could participate to try to master the most advanced technology.

In Ghana where the national control point network has not been provided, it is necessary to provide more control points that are usable as existing control points in the survey to be conducted for city and rural development plans. It is desirable that GPS survey will be more used for installing highly accurate control points efficiently.

4-4 Leveling

In Ghana, a considerable number of leveling routes had been provided, but there are some limited areas in which bench marks are insufficient to produce topographic maps for those areas. In those areas, it is necessary to provide more bench marks for conducting surveys for topographic mapping and local development, though it will be in the future development plan. It is desirable to add bench marks as needed in the future.

The leveling in this study was performed to install the ground control points at the heights necessary for aerial triangulation and digital plotting in those areas. The measured heights were recorded at index points in the aerial photos and the fixed points were installed in about 4km intervals using the existing structures.

In the study, a digital level and a barcode staff were installed for observation at each existing point as a rule. At the existing bench marks at which it was difficult to install the instruments, closure or two-way observation was conducted to maintain the accuracy. The accuracy at each point was within the limit value of $\pm 50\text{mm}\sqrt{S}$ (S=km), so that the results of observation at the fixed points can also be used in the survey for any other purpose. Similarly to the GPS survey, the principle and method of leveling were explained to many SDG engineers and transfer of the technology was executed in the field work, in which they participated to try to master the most advanced technology.

4-5 Pricking of Ground Control Points

In making the photographic survey, it is a very efficient method to make aerial photography without installing aerial photo signals, select distinct points on the aerial photos and install ground control points necessary for aerial triangulation and digital plotting. In this survey, some clear planimetric features and existing structures were selected as eccentric points for eccentric observation, because it was often difficult to preserve buried stones at ground control points.

In considering that the SDG engineers had insufficient experience in photographic observation, it is recommendable at present to conduct the ground control point survey by installing aerial photo signals. However, it is desirable that they will have more experience in this method and master the technology because it is a very effective method in conducting the photographic survey in city areas in the future.

4-6 Pricking of Bench Marks

The existing bench marks distributed in the study area and the fixed points installed by leveling were pricked to maintain the height accuracy for aerial triangulation and digital plotting. It is required to make the existing bench marks eccentric relative to the intersection points, branch points and curves of distinct roads and fit the fixed points directly with heights on aerial photos as indexes.

Pricking of bench marks with little differences of height has no problem. However, at the bench marks with large differences of height, it is necessary to take full care of conformity between the pricked points in the field and those on the aerial photos and prevent the deterioration in the height accuracy due to inconformity.

4-7 Field Verification

Field verification was made in accordance with the 1/50,000-scale topographic map symbols and application rules agreed between SDG and the study team. With the definition of each symbol and its application standard, the map symbol suited for the land of Ghana could be represented. The smooth progress of the discussions on these matters was greatly owed to the enthusiastic cooperation of the SDG counterparts.

For the annotations such as geographic names, the SDG counterparts surveyed those in their shared assignments to prepare the annotation map materials. This field verification was divided into the short-time works in two years due to the progress of aerial photography and made favorably to obtain the necessary results.

It was with the enthusiastic cooperation of SDG counterparts that the field verification works were conducted efficiently in the study area where the climate, natural features and customs were different and varied to the Japanese engineers.

4-8 Aerial Triangulation

In aerial triangulation, 18 courses and 323 models of 1/60,000 for which aerial photography was newly conducted were divided into three blocks and adjustment computation of these blocks was made using the independent model method. The program used in the block adjustment computation was PAT-M that had been widely used in many countries.

In the adjustment computation, the differences of pass points and tie points and the control point residuals were the favorable results that were much lower than the limit values specified in the JICA Overseas Survey Work Rules. In the background of these good results were the conditions that aerial photos conformed to the necessary requirements for the survey, that the existing control points, the ground control points, the existing bench marks and the fixed points had sufficient accuracy, and that the indoor work was executed properly.

Aerial triangulation is a technology that requires high mathematical knowledge and wealthy experience. However, there is no engineer having much experience in aerial triangulation within SDG at present. If surveys are made for various future development programs and land information development, there may be cases of creating aerial photos to enable collection and analysis of a wide range of land information with a given accuracy on a more real-time base or the ortho images using satellite images. Therefore, it is necessary to make the opportunity for the SDG engineers to master the technology of aerial triangulation that is the base of survey.

4-9 Digital Plotting

Digital plotting was conducted in accordance with the S/W that provides the basic specifications for the planned topographic mapping and the JICA Overseas Survey (for Topographic Mapping) Work Rules that specify the details of topographic mapping. The digital plotting work was carried out for the area of 11,100 km^2 (20 sheets) of the entire study area based on the aerial triangulation and the final verification works in the first and second year. The operators in charge of plotting were engaged in this process after the work specifications in regard to the map symbols and application rules and the concrete method of measurement were explained them with the instruction manuals to standardize the plotting specifications. As the plotting work was changed into the digital system, the digital plotting work was performed with classification codes in accordance with the GIS specifications using an analytic plotter.

In the measurement of planimetric features, roads, rivers, railways and other linear objects ware measured, and then buildings, small objects and vegetation were measured in this order.

The measurement of contour lines was made deliberately because the intervals of main curves were determined to be 10 m. In the absolute orientation, the existing bench marks and the fixed points distributed in each model were used to enhance the height accuracy. After completion of the measurement, the results were verified with the collected photo materials in the field verification and checked the conformity with the map symbols so as to prevent any omission of measurement.

4-10 Satellite Image Processing

For the districts of 14,400 km^2 (20 sheets in the unit of map sheet) where aerial photography was not available, the existing SPOT satellite images covering the study area were purchased to process the images necessary for updating the secular changes in the existing 1/50,000-scale topographic maps. By the satellite image processing, 4 sets of image per map sheet were created for field verification. For the image processing, the digital height data that SDG produced based on the existing 1/50,000-scale topographic maps was used to correct the image distortions due to the heights in the satellite images and produce the orthographic images.

All the SDG counterparts had no or little experience in aerial photography and satellite image processing. The facilities for image processing were also not provided. The more use of satellite images is an important factor not only in topographic mapping but also in development of land information for land utilization and analysis. Therefore, it is necessary to offer more extensive technical cooperation in this field to Ghana in the future.

4-11 Field Verification of Satellite Images

Field verification with satellite images was conducted for the districts of 14,400 km^2 (20 sheets in the unit of map sheet) where aerial photography was not completed. The terrain information in the satellite images with the resolution of 10m was very inferior to that in the 1/60,000-scale aerial photos, but the effectiveness of the images was fully confirmed. The lacking information was filled up by photos of secular changes and other necessary information with a GPS camera on a light airplane and the secular changes measured by the land mobile DGPS receivers.

If satellite images are available at stable, low costs in future, information acquisition can be selected from a wider range of means and various matters that the SDG counterparts experienced in satellite image processing in this study will be demonstrated effectively.

4-12 Data Compilation from Existing Topographic Maps

In data compilation from the existing topographic maps, the existing topographic mapping data with the contour lines represented in the foot unit was converted into the metric unit. The converted data was updated with the arranged matters such as the secular changes obtained in the field verification with satellite images.

In producing topographic maps with a computer, a number of effective interim products are generated. The contour lines in the metric unit were produced by an automatic contour generation tool utilizing the DTM produced in creating the ortho images. The data converted into the metric unit was overlaid on the existing topographic mapping data to compile the topographic representations.

Thus, a number of interim products with high accuracy can be produced by changing the analog topographic mapping into the digital system. The digital system requires a longer work period than the analog system in the initial development stage, but a wide range of information can also be provided by regular data updating and data compilation for each purpose of use.

In this study, SDG made a keen request for more detailed training mainly for data compilation for digital topographic maps. JICA accepted the request and dispatched the expert engineers to SDG to provide the OJT in Ghana. SDG engineers are willing to receive the technical training for this process. If further training is requested in future, it is necessary to provide more detailed OJT for each work process.

4-13 Digital Compilation

Digital compilation was conducted for topographic map display based on the digital data of a total of 40 sheets covering the area of about 11,100 km^2 (20 sheets) where aerial photography was newly performed and the area of about 14,400 km^2 (20 sheets) for which the secular changes were updated with the satellite images.

In the OJT that SDG requested for, the lecture on the compilation of the digital topographic data and data management was held through actual work though it was for a short period. A number of SDG engineers participated in this lecture to study the technologies enthusiastically. It is also necessary to successively make such an opportunity in future.

4-14 Field completion

Field completion was conducted to recheck the unclear matters pointed out in the work process such as field verification, digital plotting and digital compilation mainly in the urban districts having remarkable secular changes in the aerial photos and satellite images that were used in field verification and digital plotting. The operators of data compilation arranged the clear points on the digital compilation maps in accordance with the standard established to enable easy judgment. In the field, the Japanese engineers instructed the operators the necessary details of the survey as well as the map symbols and application rules based on the written results of survey. The methods of observation, analysis and arrangement by the use of DGPS receiver were also instructed. Thus, it is necessary to make such an opportunity for the SDG operators to have more work experience in all aspects of topographic mapping.

4-15 Data Revising

Based on the results of field completion survey, the digital topographic mapping data was updated. The updated data was also converted into the format for digital compilation, and rechecked and reexamined in the field completion survey based on the map symbols and application rules. The data per map sheet was also updated in reference with the arranged maps such as various map materials newly obtained.

The topographic maps and digital mapping data are normally completed as final products in a certain period after aerial photos and satellite images are acquired. During the period, the social infrastructure is likely expanded and strengthened from time to time mainly in the urban district where the population is concentrated. Therefore, it is indispensable to recheck and update the problems in each work process and some secular changes before completion of the final products.

4-16 Data Output

As the result of producing and processing the objects of the topographic maps as digital data by layer, it is possible to classify the layers by color separation for printing and to directly output quality film positives by using an image setter. These films can be used for reproduction of the topographic maps for a long time if they are maintained properly.

4-17 Printing

From the original films outputted per color separation by the image setter, one aluminum PS form per color was produced by a vacuum framing machine and a PS processor and the proof maps were produced by an offset printing machine. The proof maps were used to inspect the color tones, register marks, the dimensions of printed maps and drawn lines carefully. The quality print paper of B1 size (weight of $90g/m^2$) that has the proper strength in fold resistance, tension, break, and tear as well as little expansion and contradiction was adopted as the most suitable for topographic maps.

The most up-to-date computer-controlled offset printing machine was also used to printing the topographic maps. The ink concentration and paper slip were controlled by the computer and printing was performed under the proper quality control.

4-18 Preparation of CD-ROMs

The completed digital topographic map data and the mapping data were stored in CD-ROMs that were suitable for data conservation, use and reproduction.

5. Maintenance and Updating of Digital Topographic Mapping Data

5-1 Introduction

The maps of the largest scale that can cover the entire land of the Republic of Ghana (hereinafter called "Ghana") are the 1/50,000 topographic maps. These topographic maps were produced by the suzerain England and Canada 25 years or more ago, but the heights and contour lines were indicated in the foot unit and no update was made after production. Thus, these maps were very different from the actual conditions of the land. Especially, the most basic and important map information including expansion of city and rural areas, the road net connecting these areas, the improved roads within the city areas and increase of buildings is lacking. Therefore, these maps could not be used as the basic materials for planning various policies and programs such as regional development in city and rural areas, environmental conservation and industrial development.

Under these circumstances, the Ghana Survey Department (hereinafter "SDG") implemented the "Ghana Environmental Resources Management Project (GERMP)" under the finance of the World Bank to digitize 364 sheets of the old 1/50,000-scale topographic maps for the entire country for developing the GIS basic data of about 1/250,000 scale. In this study, 40 sheets of digital topographic mapping data for the southern part of Ghana were produced, of which 20 sheets were based on aerial photos newly taken. The remaining 20 sheets were produced by using the digital mapping data digitized in the GERMP because aerial photography was not performed.

Therefore, the 1/50,000-scale digital map data that SDG possesses at present is classified into the following three types:

1) Digital map data digitized in the GERMP (324 sheets).
2) The map sheets (20 sheets) updated in this study using the map data in the GERMP.
3) The map sheets (20 sheets) newly created in this study.

5-2 General Rules for Maintenance and Updating

In general, city areas have little change because they are densely populated and have no spaces to be changed, but the environs of the city areas are drastically changing. On the other hand, the change in the rural and mountainous areas is less than the environs of the city areas.

In Japan, the maintenance and updating of maps (map data) is systematically performed depending upon the changes in the city and rural areas by setting the following updating periods:

1) Areas with drastic changes (in periods of 3 to 5 years; the environs of a large city)
2) Areas with not so large changes, mainly in plain areas (in periods of 5 to 8 years; the rural areas in plains)
3) Mountainous areas (in periods of 10 years or more)

The maps are updated in the above periods entirely (entire updating), but if the important map elements in a map sheet such as the express highways and main highways inaugurated and the railways newly constructed and rehabilitated are updated and changed, the maps are partially updated (partial updating).

In entire updating, aerial photography was conducted for the area to be updated and all the changed districts are plotted. In partial updating of large changes, only newly constructed or rehabilitated roads or newly developed housing areas are partially photographed. In the case of not so large changes, the maps are updated based on the materials such as plan diagrams, or the data acquired at the sites using the ground surveying instruments.

In addition, if the maps are updated for 30% or more of changes, it is deemed to be more effective in Japan to create the new maps from the point of view of cost effectiveness.

In Ghana, for the other districts than the updated districts in the topographic maps in this study, more than 25 years had passed since the creation of the maps. Therefore, the changes in those districts are deemed to be large. If SDG plans to update the topographic maps, it is necessary to determine the updating method from new map creation, entire updating or partial updating by surveying the conditions of changes and studying the cost effectiveness.

5-3 Basic Guidelines for SDG's Map Maintenance and Updating

The 1/50,000-scale digital topographic map data possessed by SDG can be classified into 3 types as described above. Each type of data will be discussed below.

(1) Digital map data digitized in the GERMP (324 sheets)

The data of 324 sheets that was created more than 25 years ago with the contour lines and heights represented in the foot unit was digitized as it was. However, it is presumed that the secular changes for more than 25 years were not updated and the contours had largely changed due to the topographic changes in open pit mine districts.

Therefore, it is desirable to newly create the maps for these districts by conducting aerial photography and digital plotting in the metric unit, and to create new map data including the secular changes of the terrain, roads, houses and other objects.

(2) The map sheets (20 sheets) updated in this study using the map data in the GERMP.
These 20 sheets of maps were newly created using the map data produced in the GERMP because aerial photos were not available.

The contour data was converted from the foot unit into the metric unit, but the conversion method was not established technically. In particular, the accuracy of the contours at the mountain top districts and mild slope districts was low. Therefore, it is desirable to conduct aerial photography and digital plotting newly in the future.

The secular changes in these districts were updated by using satellite image data. This data was 2 to 3 years old, so that some secular changes during the period until the time of the study. The newly constructed roads were converted into images using the linear data acquired by travelling on the roads with a mobile GPS receiver and the results of the GPS survey were entered into the map data. For other objects, the change data was acquired with the ground survey equipment such as the total station to update the map data.

In any case, no aerial photos were available for these districts, so that the maps were created as the temporary measure. Therefore, it is desirable to newly create the maps for these districts.

(3) The map sheets (20 sheets) newly created in this study
These maps were newly created by newly conducting aerial photography and digital plotting, and they include the latest topographic information. These maps can be used for various purposes for the time being. However, these districts are located in the coastal area including the capital of Accra with many changes. After a certain period has passed, therefore, it is necessary to update the secular changes caused after the creation of the maps and make proper maintenance. If such proper maintenance is not made, the necessity of newly creating these maps may be caused and it would be not advisable in the cost effectiveness.

5-4 SDG's Maintenance and Updating Methods

(1) For the changes of the important map elements such as roads, rivers and buildings, it is desirable that the changed districts should be photographed (partial photography) to plot and update the changed objects in the maps.

However, if the changes are small and partial updating is possible, the changed data should be acquired in the method as described below. The acquired changes should be updated in the map data using the hardware and software such as the ground survey instruments used in the transfer of technology for digital topographic mapping data and assigned to SDG after this study.

1) Data acquisition from the newly constructed or rehabilitated roads

   It is necessary to travel by a vehicle loaded with a mobile GPS receiver on the roads, convert the acquired digital data into graphic linear figures and to set the graphic figures into the digital map data after verification with the old maps.

2) Planar and local changes such as collective housing complex

   Planar or local survey should be made from the total station based on the control points such as triangulation points or some distinct points on the maps and the results of survey should be set in the maps. If there is no control or distinct point around the district, it is necessary to fix the position coordinates of the reference points using GPS for conducting the successive work.

3) Digital compilation of digital map data

   To output the updated digital map data in the form of maps, it is necessary to symbolize the data. In this process, digital compilation should also be made using the computer and mapping software as assigned to SDG in this study. The transfer of technology in digital compilation was conducted in the fifth year in this study, but it was not satisfactory because so many as 20 officials participated in the training and the period of training was limited. Therefore, it is desirable that SDG should make own efforts to make its officials to master the technology.

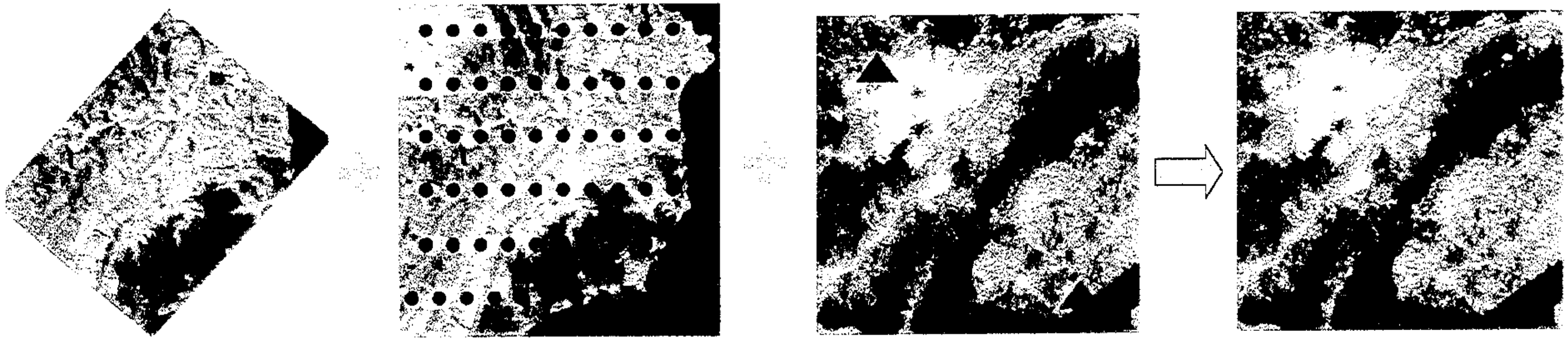
Appendix 1

- List of Abbreviations
- Ortho-rectified Spot image
- Updating by Arc/Info
- Digital Compilation
- Digital Data Structure and Codes
  Southern Ghana Topographic Mapping Project

List of Abbreviations

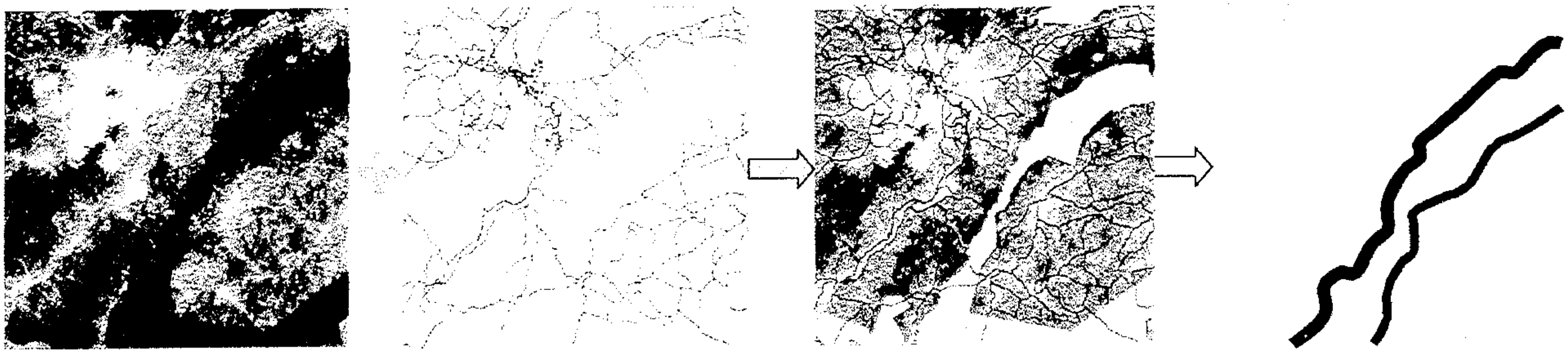
AOC	Aircraft operating Company
BMs	Bench Marks
CTK	CTK Network Aviation Ltd
DM	Digital Mapping
GCP	Ground Control Points
GERMP	Ghana Environmental Resources Management Project
DGPS	Differential Global Positioning System
GIS	Geographic Information System
GPS	Global Positioning System
JICA	Japan International Cooperation Agency
OJT	On the Job Training
P/O	Plan of Operation
S/W	Scope of Work
SDG	Survey Department of Ghana
M.S.L	Main Sea Level

Ortho-rectified Spot image



Spot image | DTM | GCP (GPS+Existing Map) | Ortho image

Updating by Arc/Info



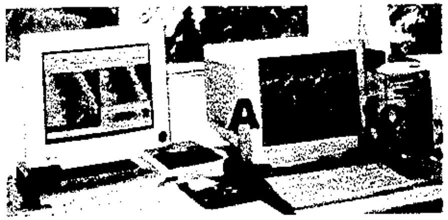
Ortho image

Existing vector data from GSD

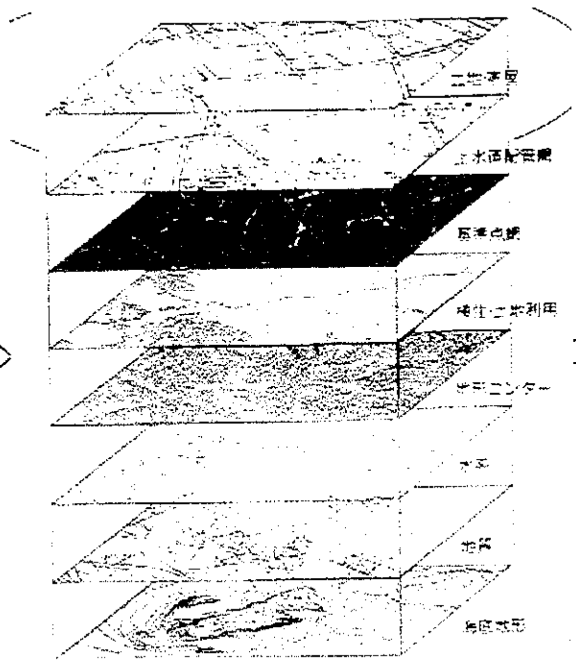
Super imposing method

Updated data

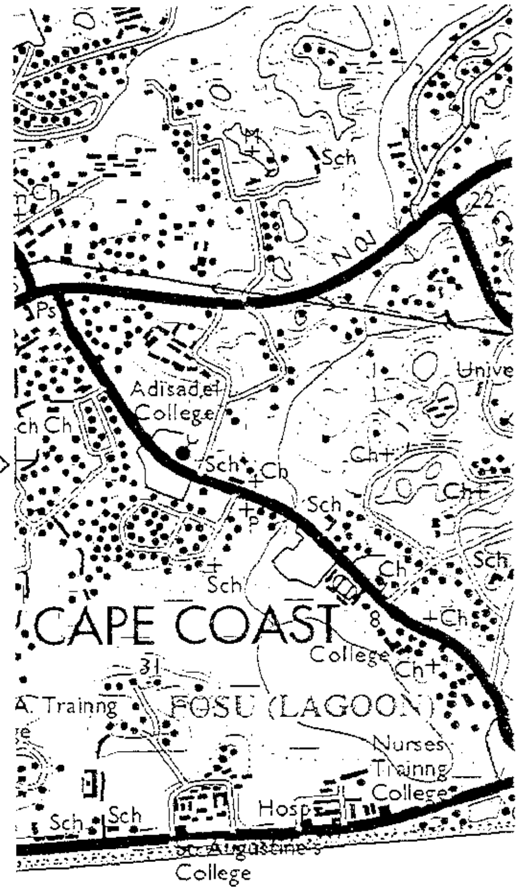
Digital Compilation



DM Data



Coverage creation



Digital Cartography

Digital Data Structure and Codes
Southern Ghana Topographic Mapping Project

Survey Department of Ghana (SDG)
Japan International Cooperation Agency (JICA)
May 8, 2000

Data Documentation

COVERAGE NAME : cult-poly

PRECISION : Double

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : POLYGON

DESCRIPTION : Major buildings, built-up areas, salt ponds, mining areas

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
AREA	8	18	F	5
PERIMETER	8	18	F	5
CULT-POLY#	4	5	B	-
CULT-POLY-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

AREA : Area in Square Meter
PERIMETER : Perimeter in Meter
CULT-POLY# : Internal ID Number
CULT-POLY-ID : User Defined ID Number
CODE : Code Number

CODE DESCRIPTION:

CODE	DESCRIPTION
0	Holes or complex polygons within this data set (not drawn)
2044	salt pond (polygon)
2050	Village (with a high density of structures)
2051	Village (with a medium density of strctures)
2054	Villages
3006	mineral working area (including mine dump)
3015	gravel pit centroid

COVERAGE NAME : cult-poly

PRECISION : DOUBLE

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : LINE

DESCRIPTION : Outlines of cult-poly (polygon) features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
FNODE#	4	5	B	-
TNODE#	4	5	B	-
LPOLY#	4	5	B	-
RPOLY#	4	5	B	-
LENGTH	8	18	F	5
CULT-POLY#	4	5	B	-
CULT-POLY-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

FNODE#	: From Node
TNODE#	: To Node
LPOLY#	: Left Polygon#
RPOLY#	: Right Polygon#
LENGTH	: Lenght of the ARC
CULT-POLY#	: Internal ID Numberl
CULT-POLY-ID	: User defined ID Number
CODE	: Code Number for each features

CODE DESCRIPTION:

CODE	DESCRIPTION
2005	Building to scale
2006	Build up area (village)
2034	Salt pond
3005	Mineral working area (including mine dump)
3016	Gravel pit

COVERAGE NAME : cultural

PRECISION : DOUBLE

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : POINT

DESCRIPTION : Cultural, infrastructure, and related point features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
AREA	8	18	F	5
PERIMETER	8	18	F	5
CULTURAL#	4	5	B	-
CULTURAL-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

AREA : Area in Square Meter
PERIMETER : Perimeter in Meter
RD_PTS# : Internal ID Number
RD_PTS-ID : User Defined ID Number
CODE : Code Number

COVERAGE NAME : cultural

CODE DESCRIPTION

CODE	DESCRIPTION
1001	Borehole/waterhole
1028	Water works
2001	Beacon
2003	Building (round)
2004	Building (square)
2007	Mission
2008	Church
2009	Court house
2010	Dam – single
2012	Hospital
2013	Barrier
2014	Lighthouse
2015	Market
2016	Military barracks
2017	Silo
2018	Electric substation
2019	Mosque
2020	Police station
2021	Post office
2022	Railway station
2023	Sports ground (angle)
2024	Rest house
2025	School
2026	Post and telecommunications
2027	Shed
2028	Fort
2029	Palace
2030	Tower
2033	Radio transmission/wireless station
2035	Ruin
2036	Health post
2037	Clinic
2040	Tank symbol
2043	Cemetry
2053	Ancient site
2063	Telecommunication office
2082	Castle
2091	Temple
3004	Mineral working (including mine)
4002	Boundary pillar
4012	Survey pillar, bench mark
4016	Geodetic point, trig station
7002	Photo center

COVERAGE NAME : cultural

PRECISION : DOUBLE

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : LINE

DESCRIPTION : Cultural, infrastructure and related line features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
FNODE#	4	5	B	-
TNODE#	4	5	B	-
LPOLY#	4	5	B	-
RPOLY#	4	5	B	-
LENGTH	8	18	F	5
CULTURAL#	4	5	B	-
CULTURAL-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

FNODE#	: From Node
TNODE#	: To Node
LPOLY#	: Left Polygon#
RPOLY#	: Right Polygon#
LENGTH	: Lenght of the ARC
CULTURAL#	: Internal ID Numberl
CULTURAL-ID	: User defined ID Number
CODE	: Code Number for each features

CODE DESCRIPTION:

CODE	DESCRIPTION
2041	Dry doc
3002	Cutline
3007	Quarry
3012	Feature outline (misc.)
3013	Embankment
3031	Sports ground (to scale)
3032	Cable ways, conveyor belts
3033	Fence, concrete or block wall
3034	Ancient wall
3035	Jetty
3036	Quay
3037	Wharf
4007	International boundary

COVERAGE NAME : forest

PRECISION : Double

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : POLYGON

DESCRIPTION : Forest reserve areas

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
AREA	8	18	F	5
PERIMETER	8	18	F	5
FOREST#	4	5	B	-
FOREST-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

AREA : Area in Square Meter
PERIMETER : Perimeter in Meter
FOREST# : Internal ID Number
FOREST-ID : User Defined ID Number
CODE : Code Number

CODE DESCRIPTION:

CODE	DESCRIPTION
0	Holes or complex polygons within this data set (not drawn)
4021	Forest reserve area

COVERAGE NAME : forest

PRECISION : DOUBLE

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : LINE

DESCRIPTION : Forest reserve and other boundary line features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
FNODE#	4	5	B	-
TNODE#	4	5	B	-
LPOLY#	4	5	B	-
RPOLY#	4	5	B	-
LENGTH	8	18	F	5
FOREST#	4	5	B	-
FOREST-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

FNODE#	: From Node
TNODE#	: To Node
LPOLY#	: Left Polygon#
RPOLY#	: Right Polygon#
LENGTH	: Lenght of the ARC
FOREST#	: Internal ID Number
FOREST-ID	: User defined ID Number
CODE	: Code Number for each features

CODE DESCRIPTION:

CODE	DESCRIPTION
4006	Forest reserve boundary
9109	Boundary (national park)
9110	Boundary (hunting area)
9111	Boundary (other)

COVERAGE NAME : veg-poly

PRECISION : Double

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : POLYGON

DESCRIPTION : Vegetation types as areas

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
AREA	8	18	F	5
PERIMETER	8	18	F	5
VEG-POLY#	4	5	B	-
VEG-POLY-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

AREA	: Area in Square Meter
PERIMETER	: Perimeter in Meter
VEG-POLY#	: Internal ID Number
VEG-POLY-ID	: User Defined ID Number
CODE	: Code Number

CODE DESCRIPTION:

CODE	DESCRIPTION
0	Holes or complex polygons within this data set (not drawn)
4023	Light forest
4024	Savannah
4030	Plantation
4025	Thick Forest
4031	Cultivation

COVERAGE NAME : hydro

PRECISION : Double

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : POLYGON

DESCRIPTION : Water and water related area features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
AREA	8	18	F	5
PERIMETER	8	18	F	5
HYDRO#	4	5	B	-
HYDRO-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

AREA : Area in Square Meter
PERIMETER : Perimeter in Meter
HYDRO# : Interal ID Number
HYDRO-ID : User Defined ID Number
CODE : Code Number

CODE DESCRIPTION:

CODE	DESCRIPTION
0	Holes or complex polygons within this data set (not drawn)
1007	Flooded land areas
1008	Islands
1009	Lakes and rivers
1011	Marsh area
1015	Sand, mud flats or dunes
1104	Ponds

COVERAGE NAME : hydro

PRECISION : DOUBLE

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : LINE

DESCRIPTION : Water and water related line features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
FNODE#	4	5	B	-
TNODE#	4	5	B	-
LPOLY#	4	5	B	-
RPOLY#	4	5	B	-
LENGTH	8	18	F	5
HYDRO#	4	5	B	-
HYDRO-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

FNODE#	: From Node
TNODE#	: To Node
LPOLY#	: Left Polygon#
RPOLY#	: Right Polygon#
LENGTH	: Lenght of the ARC
HYDRO#	: Internal ID Numberl
HYDRO-ID	: User defined ID Number
CODE	: Code Number for each features

CODE DESCRIPTION:

CODE	DESCRIPTION
1006	Flooded area outlines
1010	Marsh area outlines
1014	Sand, mud flats or dune outlines
1016	Shoreline
1017	Shoreline (virtual segment)
1018	Coastline
1019	Coastline (virtual segment)
1023	Watercourse
1024	Watercourse indefinate
1025	Watercourse virtual segment
1027	Reservoir
1042	Pond outline
1105	Trench, gutter
2011	Dam (to scale)

COVERAGE NAME : hypso

PRECISION : DOUBLE

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : LINE

DESCRIPTION : Hypsographic, and contour related line features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
FNODE#	4	5	B	-
TNODE#	4	5	B	-
LPOLY#	4	5	B	-
RPOLY#	4	5	B	-
LENGTH	8	18	F	5
HYPSO#	4	5	B	-
HYPSO-ID	4	5	B	-
CODE	4	5	B	-
ELEVATION	8	8	F	3

ITEM DEFINITION:

FNODE#	: From Node
TNODE#	: To Node
LPOLY#	: Left Polygon#
RPOLY#	: Right Polygon#
LENGTH	: Lenght of the ARC
HYPSO#	: Internal ID Numberl
HYPSO-ID	: User defined ID Number
CODE	: Code Number for each features
ELEVATION	: Elevation value of the feature

CODE DESCRIPTION:

CODE	DESCRIPTION
8001	Approximate index contour
8002	Approximate intermediate contour
8004	Depression index contour
8005	Depression intermediate contour
8006	Index contour
8007	Intermediate contour
8050	Basin shallow depression

COVERAGE NAME : hypso

PRECISION : DOUBLE

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : POINT

DESCRIPTION : Elevation related point features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
AREA	8	18	F	5
PERIMETER	8	18	F	5
HYPSO#	4	5	B	-
HYPSO-ID	4	5	B	-
CODE	4	5	B	-
ELEVATION	8	8	F	3

ITEM DEFINITION:

AREA	: Area in Square Meter
PERIMETER	: Perimeter in Meter
HYPSO#	: Internal ID Number
HYPSO-ID	: User Defined ID Number
CODE	: Code Number
ELEVATION	: Elevation value of the feature

CODE DESCRIPTION

CODE	DESCRIPTION
8008	Spot elevation height

COVERAGE NAME : landform

PRECISION : DOUBLE

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : POINT

DESCRIPTION : Topographic and related point features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
AREA	8	18	F	5
PERIMETER	8	18	F	5
LANDFORM#	4	5	B	-
LANDFORM-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

AREA : Area in Square Meter
PERIMETER : Perimeter in Meter
LANDFORM# : Internal ID Number
LANDFORM-ID : User Defined ID Number
CODE : Code Number

CODE DESCRIPTION

CODE	DESCRIPTION
1002	Boulder area
1005	Flat rock area
1012	Rapids (single)
1021	Water fall (single)

COVERAGE NAME : landform

PRECISION : DOUBLE

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : LINE

DESCRIPTION : Topographic and related line features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
FNODE#	4	5	B	-
TNODE#	4	5	B	-
LPOLY#	4	5	B	-
RPOLY#	4	5	B	-
LENGTH	8	18	F	5
LANDFORM#	4	5	B	-
LANDFORM-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

FNODE# : From Node
TNODE# : To Node
LPOLY# : Left Polygon#
RPOLY# : Right Polygon#
LENGTH : Lenght of the ARC
LANDFORM# : Internal ID Numberl
LANDFORM-ID : User defined ID Number
CODE : Code Number for each features

CODE DESCRIPTION:

CODE	DESCRIPTION
1003	Boulder or rocky outline
1004	Flat rocky outline
1013	Rapids (to scale)
1022	Waterfall (to scale)
3001	Cliff outline
3008	Rocky outcrop
3109	Steep slope

COVERAGE NAME : landpoly

PRECISION : Double

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : POLYGON

DESCRIPTION : Topographic and related area features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
AREA	8	18	F	5
PERIMETER	8	18	F	5
LANDPOLY#	4	5	B	-
LANDPOLY-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

AREA : Area in Square Meter
PERIMETER : Perimeter in Meter
LANDPOLY# : Interal ID Number
LANDPOLY-ID : User Defined ID Number
CODE : Code Number

CODE DESCRIPTION:

CODE	DESCRIPTION
0	Holes or complex polygons within this data set (not drawn)
3116	Rock Outcrops
3117	Water course rapids (to scale)
3118	Flat rock areas
3119	Boulders and rocks

COVERAGE NAME : neatline

PRECISION : Double

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : POLYGON

DESCRIPTION : Neatline, and international boundary area features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
AREA	8	18	F	5
PERIMETER	8	18	F	5
NEATLINE#	4	5	B	-
NEATLINE-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

AREA : Area in Square Meter
PERIMETER : Perimeter in Meter
NEATLINE# : Interal ID Number
NEATLINE-ID : User Defined ID Number
CODE : Code Number

CODE DESCRIPTION:

CODE	DESCRIPTION
0	Holes or complex polygons within this data set (not drawn)
4022	International boundary area

COVERAGE NAME : neatline

PRECISION : DOUBLE

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : LINE

DESCRIPTION : Neatline and international boundary line features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
FNODE#	4	5	B	-
TNODE#	4	5	B	-
LPOLY#	4	5	B	-
RPOLY#	4	5	B	-
LENGTH	8	18	F	5
NEATLINE#	4	5	B	-
NEATLINE-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

FNODE# : From Node
TNODE# : To Node
LPOLY# : Left Polygon#
RPOLY# : Right Polygon#
LENGTH : Lenght of the ARC
NEATLINE# : Internal ID Numberl
NEATLINE-ID : User defined ID Number
CODE : Code Number for each features

CODE DESCRIPTION:

CODE	DESCRIPTION
4003	Boundary (virtual segment)
7001	Neatline

COVERAGE NAME : transport

PRECISION : DOUBLE

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : POINT

DESCRIPTION : Bridges, airports and related transportation point features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
AREA	8	18	F	5
PERIMETER	8	18	F	5
TRANSPORT#	4	5	B	-
TRANSPORT-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

AREA : Area in Square Meter
PERIMETER : Perimeter in Meter
TRANSPORT# : Internal ID Number
TRANSPORT-ID : User Defined ID Number
CODE : Code Number

CODE DESCRIPTION

CODE	DESCRIPTION
2002	Bridge
2038	Airport, aerodrome
2038	Culvert
4008	Milepost
5003	Level crossing
5016	Airstrip
5102	Footbridges

COVERAGE NAME : transport

PRECISION : DOUBLE

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : LINE

DESCRIPTION : Roads, and related transportation line features

DATABASE SCHEMA DEFINITION:

ITEM NAME	TEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
FNODE#	4	5	B	-
TNODE#	4	5	B	-
LPOLY#	4	5	B	-
RPOLY#	4	5	B	-
LENGTH	8	18	F	5
TRANSPORT#	4	5	B	-
TRANSPORT-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

FNODE# : From Node
TNODE# : To Node
LPOLY# : Left Polygon#
RPOLY# : Right Polygon#
LENGTH : Lenght of the ARC
TRANSPORT# : Internal ID Numberl
TRANSPORT-ID : User defined ID Number
CODE : Code Number for each features

CODE DESCRIPTION:

CODE	DESCRIPTION
5001	Ferry
5002	Ford
5004	Railway (double line)
5005	Railway LG (single line)
5007	Road Type 1
5008	Road Type 2
5009	Road Type 3
5010	Railway siding
5011	Road Under Construction
5012	Track
5013	Trail, or footpaths
5014	Airstrip, runway
5015	Railway (abandoned)
5070	Motorway
5080	Streets and main roads

COVERAGE NAME : utility

PRECISION : DOUBLE

PROJECTION : Transverse; Units: Meters; Sph: Clarke1880; Scale Fac: 0.99975; Long: -1 0 0; Lat: 4 40 0; False Easting (Meters) 300000.0

FEATURE TYPE : LINE

DESCRIPTION : Power, communications and related utility line features

DATABASE SCHEMA DEFINITION:

ITEM NAME	ITEM WIDTH	ITEM OUTPUT WIDTH	ITEM TYPE	ITEM DECIMAL PLACES
FNODE#	4	5	B	-
TNODE#	4	5	B	-
LPOLY#	4	5	B	-
RPOLY#	4	5	B	-
LENGTH	8	18	F	5
UTILITY#	4	5	B	-
UTILITY-ID	4	5	B	-
CODE	4	5	B	-

ITEM DEFINITION:

FNODE#	: From Node
TNODE#	: To Node
LPOLY#	: Left Polygon#
RPOLY#	: Right Polygon#
LENGTH	: Lenght of the ARC
UTILITY#	: Internal ID Numberl
UTILITY-ID	: User defined ID Number
CODE	: Code Number for each features

CODE DESCRIPTION:

CODE	DESCRIPTION
2042	Pipeline
6001	Telegraph or telephone line
6002	Telegraph or telephone line (virtual segment)
6003	Transmission line
6004	Power transmission line
6005	Power transmission line