(3) Tie point observations

This work was carried out automatically mainly at night using a digital plotter. Tie points are identical points in adjacent photos. The values of the picture co-ordinates of the tie points were computed and recorded using all the photos for which inner orientation had been completed and the initial data obtained by analysing GPS data.

Because of the disparities in halation and the time and day of shooting, differences in contrast and brightness which affect the images were causes for errors in some cases, but these errors were fixed in the subsequent adjustment computations. Automatic processing for tie points located in plains and hills, that comprise most of the Study area, was completed with especially high accuracy. Between several tens and 100 points were acquired per model, depending on the digital plotter used.

Concerning models located in the western mountains with steep topographic features, the applicable area was fixed and manual observations were carried out using the conventional method. Automatic processing of inner orientation and tie point observations were carried out in about 8 hours for each work block (approx. 150 models).

(4) Observations of photo control points

As the points pricked on the photos could not be computed automatically, they were computed by an operator by stereoscopy on the digital plotter.

The results of the pricked points were good but several points were difficult to identify on the digital plotter. This was due to the difference in information content between the photos used for pricking in the field and the digital images, especially for roads with a lack of texture.

(5) Adjustment computations

The accurate slant and position of the perspective centre for each photo and the ground co-ordinates of each tie point were computed by the aerial triangulation program PATB-GPS using the bundle adjustment method, based on the co-ordinates of the photo control points, the photo co-ordinates of the tie points and photo control points obtained with the digital plotter. Aerial triangulation computation results could be used as outer orientation elements in the digital plotter, to allow the creation of stereo models.

During this work, special attention was paid on how to fix the weight of each input value. Especially, the following were taken into consideration: ① As the area was divided into 3 blocks, the photo control point density was not homogenous between each block, and ② when automatic and manual observations for tie points were mixed, it was considered that tie points acquired by automatic observations were less accurate than those acquired manually.

Based on the above considerations, appropriate weight was assigned to each input value after careful evaluation, allowing for satisfying adjustment computation results.

As a result, the maximum control point residuals were under 0.04% of the flight altitude (1.836m) and the standard deviation was under 0.02% (0.918m). The maximum bundle intersection residuals of photo coordinates were under 30 µm, and the standard deviation was under 15 µm. The residuals of common points between adjacent blocks were approximately of the same level as the control point residuals.

During this work, the coordinates of two photo control points listed in the control point description sheets were found inconsistent, but these were obviously errors and did not cause much impediment in the progress of the work.

3-1-8 Generation of DTMs, Orthos, Mosaic and Contours

Fig. 3-11 Digital Stereo Plotting Machine

The work content was as follows:

(1) Automatic DTM generation

This work was conducted automatically using the digital plotter. Automatic DTM generation entails searching and fixing the corresponding points of stereo pairs. It was carried out in accordance with the following steps:

① Generation of epipolar images and epipolar hierarchical images

In order to reduce the volume of computations when searching for corresponding points, the generation of epipolar images and epipolar hierarchical images from the scanned images was conducted by automatic processing. As these images were used for computations only, they were destroyed after the completion of DTM generation. The data size of the images was approximately 1.5 times that of the scanned data.

② Optimisation of automatic DTM generation parameters

As part of the automatic DTM generation process, DTM output is controlled by many parameter settings. In particular, the "window size" of the search range is the most important parameter. Representative topographic features, such as grasslands, forests and urban areas, were grouped and extracted. Automatic DTM generation was attempted in these areas, and the "window size" parameter setting was optimised. Among other parameters, Terrain type (Flat/Undulating/Mountainous) and Smoothing degree

(Low/Medium/High) were carefully adjusted, as they greatly influence the elimination of DTM noise caused by small features such as isolated trees.

③ Image correlation (stereo-matching)

Correspondence points were searched by automatic processing for each stereomodel using epipolar hierarchical images, and random correspondence points were acquired. This operation was carried out at night.

④ DTM output

Following image correlation, 40m DTMs were output by automatic processing. The grid points with a 40m interval were determined by interpolation using the random correspondence points obtained above, and the DTMs were converted and output in text format by automatic processing to facilitate subsequent work. The time required for night processing of automatic DTM generation (including generation of epipolar images and epipolar hierarchical images) was approximately one hour per model.

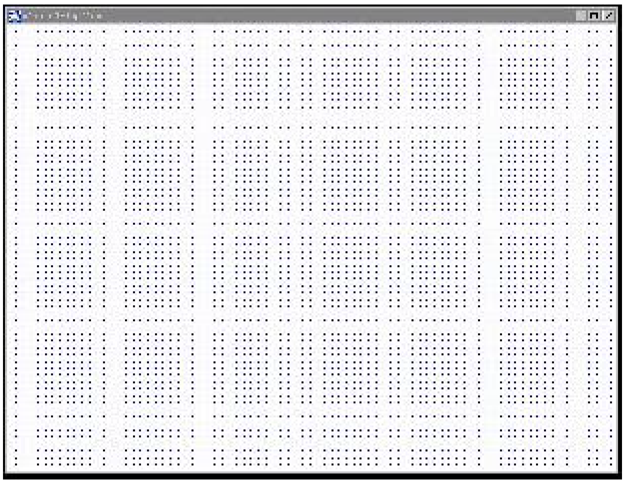


Fig. 3-12 Grid Points with 40m Interval

⑤ Manual additions/revisions of DTMs, re-calculation

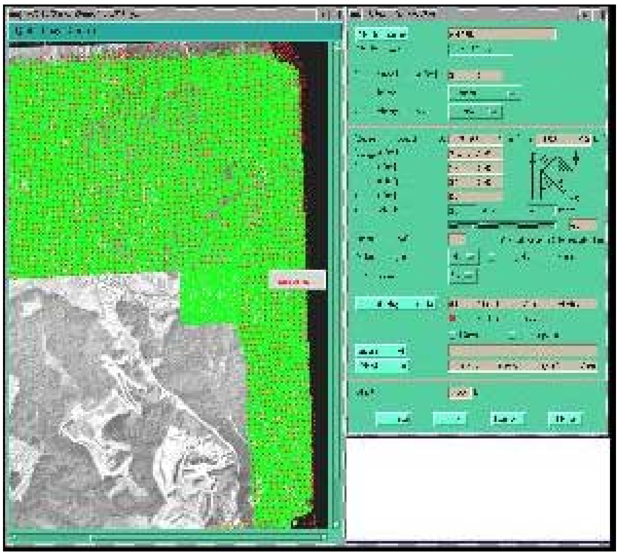


Fig. 3-13 Stereo Matching

The DTMs were checked by stereoscopy for each stereo pair, and the grid points containing gross errors were revised or the plane areas around the faulty points were re-calculated.

Concerning these re-calculations, revision of each DTM point or revision of surfaces were conducted by re-interpolation after plotting break lines and re-generating TINs. For the revision of surfaces, items of digital plotting such as roads and rivers were used effectively shown as break lines.

Revisions of DTM elevations were also carried out for the overlapping parts of adjacent stereomodels. When discrepancies were extremely small (under 1m), a dividing line was drawn between two adjacent stereomodels, and the overlapping parts of the DTM were deleted. When discrepancies were small (under 2m), simple averages were adopted in the overlapping parts of the DTM. When the discrepancies were above 2m, the adjoining portions of the DTM were revised manually by adopting the stereomodel side with the best image correlation conditions.

After the overlapping parts were processed, the DTM data was archived as temporary files for each stereomodel, to be used for other tasks of orthophoto generation and contour generation. Also accuracy control of automatic DTM generation was conducted by checking it against DTM generation using delineation of contour lines.

(2) Automatic Generation of Orthophotos

Fig. 3-14 Orthophoto

This work was conducted at night by automatic processing using the digital plotter. Orthophotos were generated by computation using the photos subjected to inner orientation and the DTMs. At this point, the approximate adjoining lines were fixed manually.

As a rule, the centre areas of the photos were used in order to minimize distortion. Also the ground resolution for output was set to 42.3333 cm. Accuracy control was carried out for each photo on basic items such as resolution.

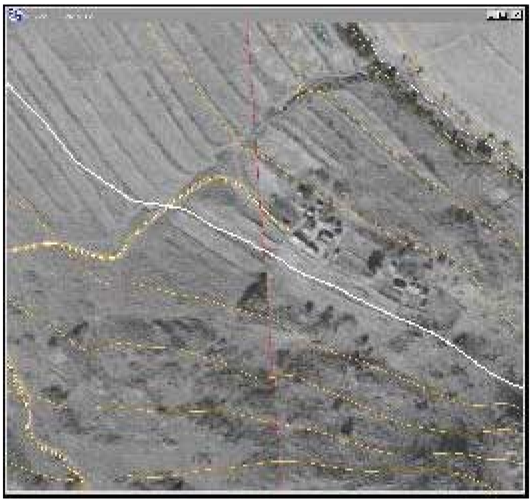
(3) Mosaicing

Fig. 3-15 Before Mosaicing

Each orthophoto generated for each model overlapped the adjacent models, and the adjoining lines within these overlapping parts were fixed manually in areas with the least distortion. Afterwards the orthophotos were divided by neat lines (411 sheets of 80 cm in width and 60 cm in height) using automatic processing. As a rule, the use of neat lines as adjoining lines at this stage was the most effective method in view of the final divisions of the orthophoto maps.

The images output by neat line units were in TIFF format (uncompressed), the output resolution was 600 dpi with a ground resolution of 42.3333 cm. The data size was approximately 260 MB, for a total of approximately 100 GB.

As a rule, the orthophoto data, as the topographic data, covered as far as 300m beyond the frontier. When data covered beyond this 300m fictitious line, these extra areas were not erased but included in the data processing tasks. Areas beyond the frontier for which there were no images were left blank on the sheets.



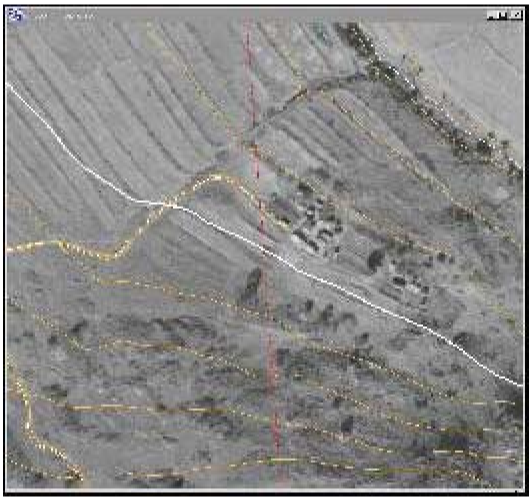


Fig. 3-15 After Mosaicing (without Fethering) After Mosaicing (with Fethering)

(4) Generation of Contour Data

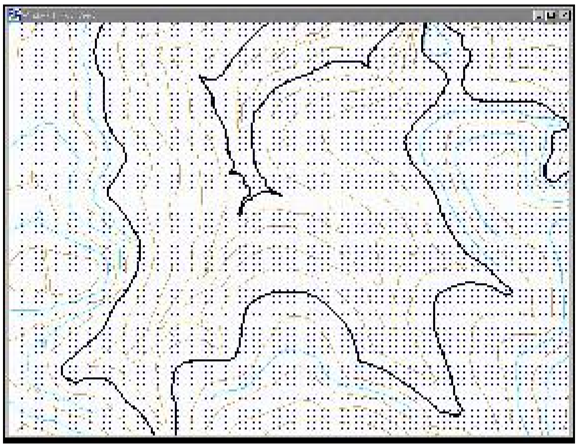


Fig. 3-16 Contour Lines from 40m Grid

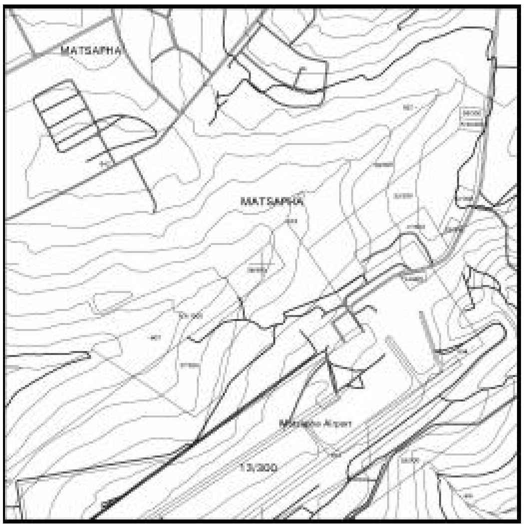
TIN models were prepared from the DTMs, and the contour lines were generated by automatic processing. In order to lighten the processing work for the adjoining of contour lines, it is advisable to process large areas at the same time. Consequently, DTMs corresponding to several stereomodels (approx. 9 models) each were edited into one file from which a TIN model was prepared and then used for contour data generation. At this point, the contour lines were generated with a 5m interval and thinned out in areas, such as mountains, where they became too dense in consideration of the overall balance. Intermediate contours (5m) were omitted in parts where the interval between normal contours (10m) was less than 3~5 cm on the map, in accordance with the map symbol standards.

The contour data was saved as temporary work files until they could be checked against areas with contours which were delineated manually.

3-1-9 Digital Plotting (Roads, Rivers, Lakes, Contours of Wooded Areas)

The work content was as follows. Plotting was implemented in accordance with the map symbols (draft) and the acquisition standards (draft).

(1) Plotting of Feature Data



Features such as roads, rivers and lakes were drawn by an operator on the digital plotter using stereoscopy. The acquired items were river centrelines, river banks, lakeshores, road centrelines, road sides, railroad centrelines, rail/road bridge centrelines, and rail/road tunnel centrelines, in accordance with the map symbols. These features are considered as a basis for the future development of GIS. As these acquired items do not appear on printed maps, they were assigned the non-display attribute.

Fig. 3-17 Contours, topographic data, cadastral data

(2) Plotting of Contours

Contours for wooded areas, where there is a high possibility of errors of over 2.5m in contour lines acquired from DTMs, were plotted by an operator on the digital plotter using stereoscopy. This is because, as forests cover 36% of the national territory of Swaziland, it was faster and more accurate to generate contour data through direct plotting rather than by processing the errors resulting from the use of DTMs. In the end, about one fourth of all contour lines were traced by stereoscopy.

The contour data was stored as temporary files per stereomodel in view of other tasks of orthophoto generation and DTM data generation.

(3) Creation of Final DTMs and Contour Data

TIN models were generated from the contour data acquired by direct plotting, such as for wooded areas. 40m DTMs was generated for these areas based on these TIN models and combined with the DTMs to complete the 40m DTMs for the whole area.

Fig. 3-18 Contours, Topographic Features, Orthophoto

Contour data for the whole area were completed by combining the contours acquired by direct plotting and those automatically processed from DTMs. They were divided into index, normal, and intermediate contours for regular features, for depressions, and DTM points. Then they were archived as 3-dimensional data.

To facilitate the processing of DTM data and its future use in other operations, the areas beyond the frontier lines were given the elevation value of 0m in the DTM data in order to fill the areas within the neat lines and complete the data.

Accuracy control was carried out for each stereomodel and feature codes were inspected for errors or omissions. Additional work and digital compilation were used for the corrections.

3-1-10 Input of Administrative Boundaries and Geographical Names

Administrative boundaries and geographical names acquired during Phase 1 in Swaziland were input and printed out. Ambiguous items were clearly marked on the printouts, which were used later for field identification of administrative boundaries and geographical names.

Administrative boundary data was extracted from the cadastral data provided by the SGD. After changing the display and layer attributes in accordance with the map symbols (draft), the data was divided by neat line units and saved as cadastral data files, based on the file configuration (draft).

Annotation data such as geographical names was also provided by the SGD and divided by neat line units.

This data was integrated into the topographic data files (roads, contours, etc.) after changing their attributes in order to form layers, in accordance with the map symbols (draft).

3-1-11 Map Output for Field Survey

The maps to be used for field identification of annotation data during Phase 2 in Swaziland, were printed out. The appearance of the printed sheets were close to that of the final printed maps. However, the sheet names and marginal information also had to be checked during the field survey.

Marginal information files were created for each sheet, in accordance with the map symbols (draft) and file configuration (draft).

The specifications of the sheets printed out were as follows:

- Orthophoto data
- Cadastral data
- Contours, elevation points and control points among the topographic data

Fig. 3-19 Plotter

- Geographical name data and administrative boundary data provided by the SGD
- Marginal information data

The sheets were printed on an inkjet printer using glossy paper, for a good image rendition. Accuracy control was conducted to check for any output omissions, using the accuracy control form.

3-1-12 Supplementary Digital Compilation

All the data files were edited in accordance with the feature codes, map symbols, acquisition standards and data file configuration discussed and decided with the SGD during Phase 2 in Swaziland.

The map symbols (draft) were created tentatively based on the geographical name data provided by the SGD. However, many inaccuracies were found in this data during Phase 1 in Japan. These problems were corrected before the beginning of Phase 2 in Swaziland.

The main items changed in the map symbols (draft) were as follows:

- Change of cadastral number display: The map symbols (draft) considered 2 layers for cadastral areas, “50ha or above” and “under 50ha”. In addition, the non-display attribute was allocated to cadastral areas covering “1.5ha or under”.
- Integration of annotation layers: Several other layers were added to the proposed 32 annotation layers. To facilitate data file manipulations and their uses in GIS, a total of 38 types of annotation data was divided into 7 categories. The 38 types of annotations were each allocated a unique attribute and can be divided further in the future.
- Deletion of frontier line layers: Layers called Regional Boundary and Game Reserve Boundary were deleted, and the following 2 types were kept: International Boundary and Urban Boundary.
- Slight change in marginal information: The letter sizes and positions in the marginal information proposal were slightly modified.

3-1-13 Compilation of Administrative Boundaries and Geographical Names

The administrative boundaries and geographical names corrected and input during Phase 2 in Swaziland were overlaid on the orthophotos, together with cadastral and topographic data as the final output.

As a rule, the revisions done by the SGD were respected, but obvious errors such as layer input errors and data overlap were revised for convenience.

3-1-14 Input of Cadastral Database

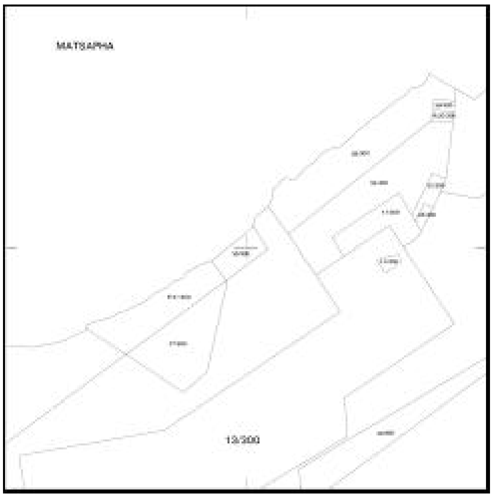


Fig. 3-20 Cadastral data

Many cadastral numbers had to be revised in the cadastral data files, which were already divided into neat line units. As a result, the original data for printing from the cadastral database had to be reprocessed.

First, the revised original data for printing was divided by neat line units and the cadastral numbers that fell on neat lines were edited. Then, in parallel with the compilation of other data, such as topographic, administrative boundary and geographical name data, the final distribution of cadastral numbers was compiled.

3-1-15 Digital Compilation, Structuring

Compilation and structuring of topographic data was conducted using the cadastral data, data of administrative boundaries and geographical names, and digital plotting data compiled above, in accordance with the map symbol specifications.

(1) Work Content

Fig. 3-21 Finished Orthophoto Images

① Planning/preparation

An implementation plan and the work schedule were formulated. The results of the cadastral data, data of administrative boundaries and geographical names, and digital plotting data were prepared.

② Digital compilation

The combined compilation of the cadastral data, data of administrative boundaries and geographical names, and digital plotting data, was conducted using a compilation device. Additions, deletions and revisions were done when necessary.

③ Adjoining adjustments

This was conducted in adjoining areas in order to prevent any inconsistencies.

④ Output of compiled data

When the digital compilation was completed, all data was output at the plotting scale.

⑤ Verification of compiled data

Compilation errors or omissions in the compilation data output were checked.

⑥ Structuring/compilation

This entailed structuring roads, rivers, lakes and administrative boundaries into polygons and maintaining the continuity. Contour lines were structured, maintaining the three dimensions. After the compilation, the structured data was checked and then archived on a recording medium.

⑦ Compilation of marginal information data

Marginal information data was compiled in accordance with the map symbol specifications.

⑧ Organisation of results

The compiled and structured data was organised.

⑨ Archiving of compiled/structured data

A backup of the compiled and structured data was made, and the data was stored in sheet units.

⑩ Preparation of DTM neat line files

The overlapping portions of the DTMs were adjusted, and the DTMs were sectioned by neat lines.

⑪ Archiving of DTM neat line files

A backup of the DTM neat line files was made and the data was stored in sheet units.

(2) Flaws and Revisions of Digital Compilation

Although no problems were found during the accuracy control of the acquired items and layer configuration at the time of plotting, a number of flaws were found in digital compilation.. However, due to the great number of neat lines (411), the main problems had to do with overall consistency, as follows:

- Elevation points: A number of neat lines were found to have too much data compared with the acquisition standards.
- 5m intermediate contours: A number of neat lines were found to have too much data compared with the acquisition standards.
- Roads: Lack of consistency in the adoption/rejection of short dead-end roads.
- Rivers: As there was no clear standard dictating how far upstream the river data should be kept, too much data was often acquired.

After considering the data as a whole, the concerned points were dealt with by deletion or addition.

The errors and omissions of marginal information and annotations, such as cadastral numbers and geographical names, were examined and revised at the compilation stage using the accuracy control forms.

3-1-16 Production of Printed Maps

(1) Conversion into Print Data (Postscript Files)

In order to be able to print the orthophotos, contour lines and other features as overlapping vector data, they had to be converted into a DTP (desktop publishing) software format. For that purpose, the topographic data was converted into Postscript files for printing, and the font consistency and appearance of the characters was adjusted.

A temporary output of the print data was made using an inkjet printer for proofreading. After the proofreading and revision were done, the data was output in the form of positive films using an Image Setter, and in the form of negative films to print the orthophoto maps.

The output conditions were fine tuned so that the scale, line weights and fonts were converted into Postscript files from the compilation system, in accordance with the map symbols.

All the compiled data files, such as cadastral data, topographic data, administrative boundaries and marginal information, were overlaid, and Postscript files were created for each neat line based on the output condition settings. A proof print of each neat line was made using the Postscript print files and the orthophoto files.

(2) Inspection and Revisions

The line weights of selected topographic data were first verified. Four line weights were used but due to the conversion of the line width unit from points to millimetres, as required for topographic maps, line weight errors of about 0.01 mm were found (the line weights are adjusted by 0.024mm increments in the compilation device). The 0.1 mm lines used to show the main contours appeared too thin on the outputs, and were therefore changed to 0.36 pt.

Line weights: 4 types	0.36 pt (0.1mm which became 0.127mm)
	0.60 pt (0.2mm which became 0.212mm)
	0.84 pt (0.3mm which became 0.296mm)
	1.68 pt (0.6mm which became 0.593mm)

The difference of density between image data and the printouts was compared, and the overall density of the data was slightly raised.

3-1-17 Production of CD-ROMs

Ortho image data, cadastral data and graphic data for all the map sheets were compressed and saved onto CD-ROMs. The following standards were adopted for the recording formats:

Each data file was saved in the form of metadata based on ISO/TC211 metadata compatibility level 1.

① Ortho image data format: JPEG or GIF (irreversible compression; compression rate fixed at approx. 10%)

② Cadastral data format: MicroStation dgn format

③ Topographic data format: MicroStation dgn format

④ Other main files: Map symbol specifications (MS Excel 2000), MicroStation Cell Library, font files (ms-ttf), Postscript output setting files (text files)

⑤ Archiving format: CD-ROM (CD-R)

3-2 PRODUCTION OF THE CADASTRAL DATABASE (WITH SGD TECHNICAL COOPERATION)

3-2-1 Production of the Cadastral Database for Orthophotos

(1) Conversion, Inspection and Revision of Graphic Data

The cadastral data (CAD data, topology data) created in the past by the SGD using UNIGIS, an older software, was converted into a format accepted by the latest GIS software that JICA has granted as part of the procured equipment, to enable ① the representation of cadastral data on printed orthophotos, and ② the reconstruction of the database for future GIS use.

This conversion work was conducted jointly by the Study Team and the SGD. All errors found by logical check (such as line and polygon errors) were revised and rechecked back and forth a number of times until the most appropriate database was achieved.

As this represented a huge amount of work, it was divided as follows: cadastral database for printed maps during the first year, and cadastral database for GIS during the second year of the Study.

The workflow for the production of the cadastral database is shown in Figure 3-11.

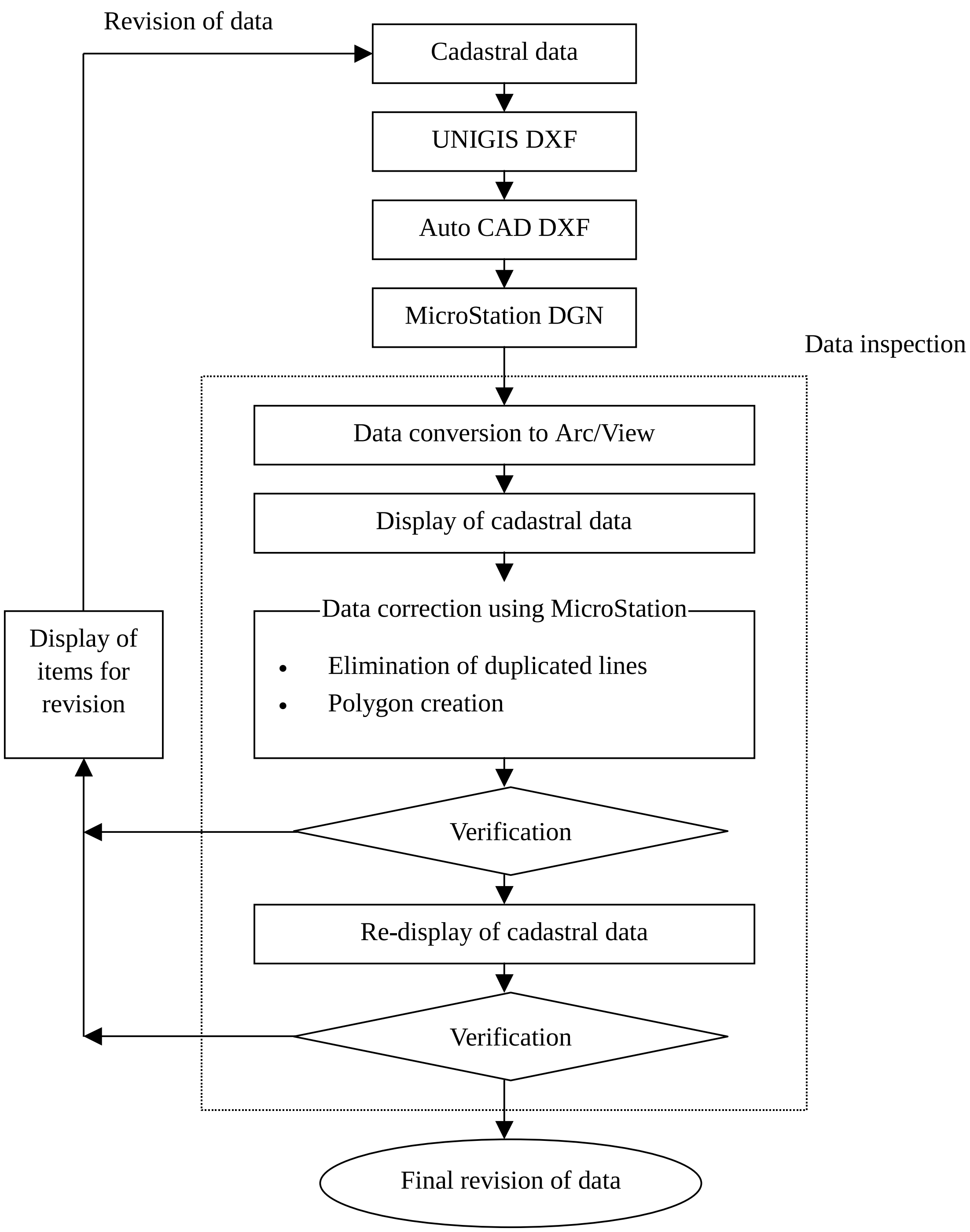


Fig. 3-22 Flowchart of Cadastral Data Conversion

(2) SGD Cadastral Data

① Layer configuration

The original data prepared by the SGD was created using an old software called UNIGIS, and consist of layers ranging from LEVEL 1 to LEVEL 100. The SGD offers these cadastral data to relevant institutions and to the general public in AutoCAD DXF or MicroStation DGN format. The following table shows the content of the cadastral data by level.

Table 3-2 Content of the Cadastral Data

Level	Entity	Feature
1	Boundary	International
2	Boundary	Urban area
3	Cadastral	Registered farm / lot
4	Cadastral	Unregistered farm / lot
5	Cadastral	Registered lease
6	Cadastral	Unregistered lease
7	Boundary	District
12	Text	Urban area
13	Text	Registered farm / lot
14	Text	Unregistered farm / lot
15	Text	Registered lease
16	Text	Unregistered lease
17	Text	District
21	River / boundary	International
22	River / boundary	Urban area
23	River / boundary	Registered farm / lot
24	River / boundary	Unregistered farm / lot
25	Cadastral	Registered curvilinear
26	Cadastral	Unregistered curvilinear
50	Line / boundary	1:50,000 map sheet
51	Line / boundary	1:10,000 map sheet
52	Line / boundary	1:5,000 map sheet
53	Line / boundary	1:2,500 map sheet
54	Line / boundary	1:1,000 map sheet
55	Text	1:50,000 map no.
56	Text	1:10,000 map no.
57	Text	1:5,000 map no.
58	Text	1:2,500 map no.
59	Text	1:1,000 map no.
0	Line	Island polygon line

As indicated in the above table, Levels 1 to 7 are boundaries, such as frontiers and cadastral lots, Levels 12 to 17 are text layers corresponding to cadastral numbers, Levels 21 to 26 are rivers which are used as boundaries, and Levels 50 to 59 correspond to map indexes.

② Data coverage

The SGD cadastral data divide the whole territory of Swaziland into 4 REGION data, which contain a number of URBAN AREA data. There are 10 “urban areas” in the whole country. The following table shows which urban areas correspond to which regions.

Table 3-3 Data Coverage

Region	Coverage Name	Urban Area	Coverage Name
Hhohho region	HHOHHO	Mbabane Ezulwini Piggs Peak	MBABANE EZULWINI PEAK
Manzini region	MANZINI	Manzini city Matsapha Mankayane	MANZINI MATSAPHA MANK
Shiselweni region	SHISELO	Hlathikulu Nhlangano Lavumisa	HLATSI NHLANG LAVUMISA
Lubombo region	LUBOMBO	Siteki	SITEKI

(3) Data Conversion to Create Cadastral Data for GIS Use

① Detection of errors

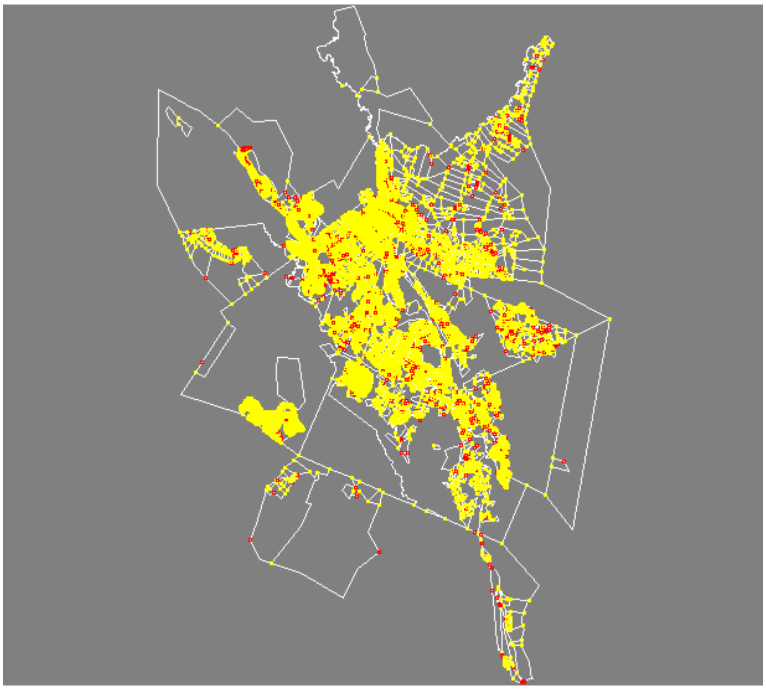


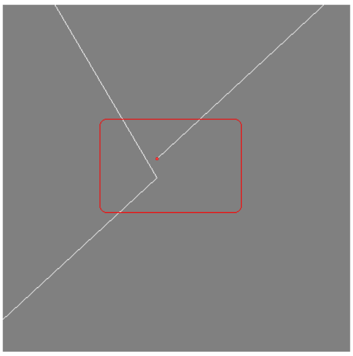
Fig. 3-23 Display of Errors

The converted data were displayed as the figure on the left using a GIS software, and the errors were highlighted in red.

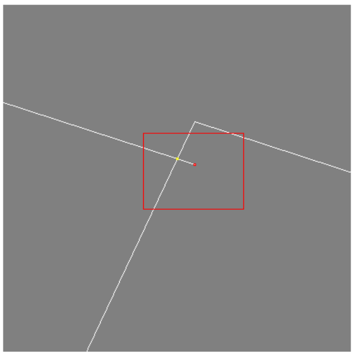
The errors found in the cadastral data were mainly due to the fact that polygons were not formed properly. There were three main types of errors, as shown below.

** Red = Polygons containing errors*

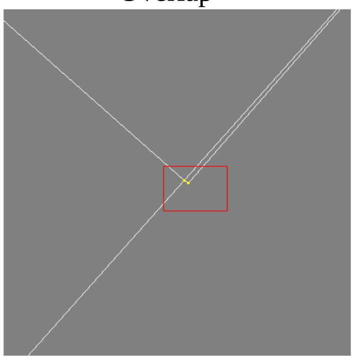
Undershoot



Overshoot



Overlap



② Correction of errors

The Study Team, using the automatic processing functions of their own GIS software (Arc/View, Arc/Info, TNT/mips), proceeded to error correction, after reaching an agreement with the SGD on the conditions. Polygon data was restored and the database for map printing was created.

For errors exceeding the defined conditions, the data was returned to the SGD team, who manually corrected the errors using CAD software (MicroStation).

③ Defining cadastral line data

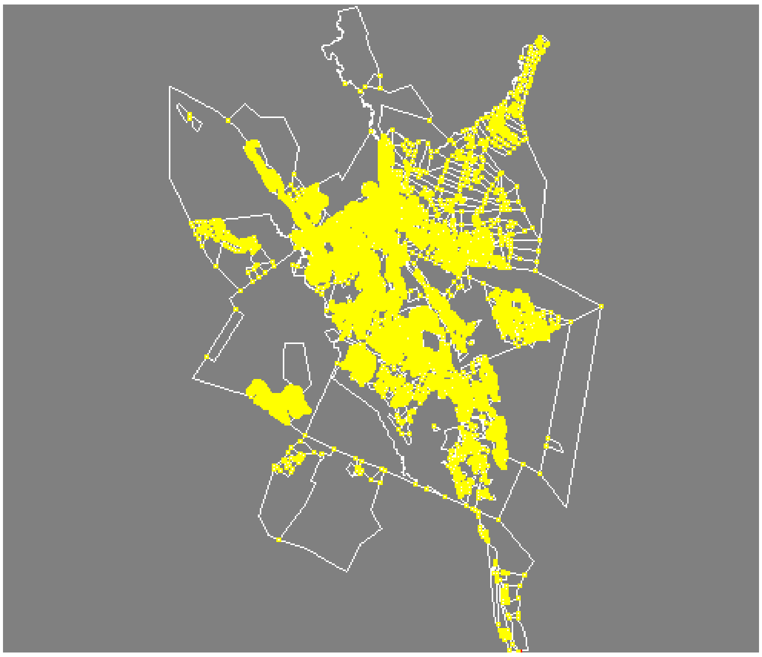


Fig. 3-24 Corrected Data

As a result of the above corrections, all the errors were corrected, and normal polygons covering the whole area were formed. (Compared with the previous figure, all the red has disappeared.)

3-2-2 Production of Cadastral Number Data

The text data for cadastral numbers in the original data was created in various font sizes. When preparing the new orthophoto printed maps, the Study Team discussed with the SGD regarding how to unify the display of cadastral numbers according to cadastral land area.

(1) Classification of Cadastral Number Data

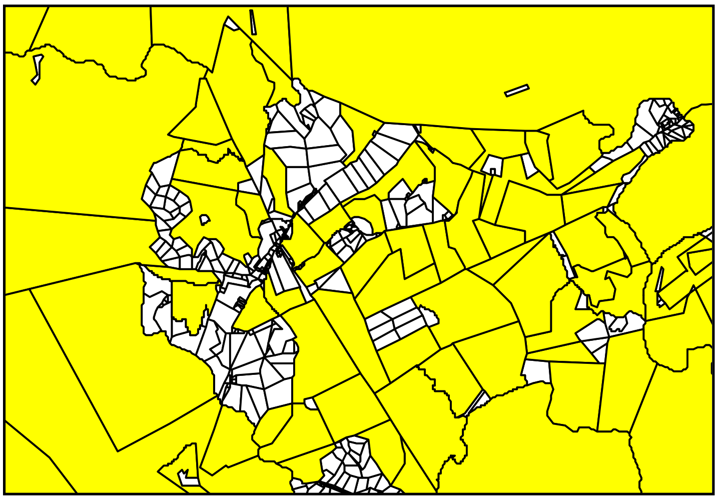


Fig. 3-25 Classification by Area

Figure 3-14 shows divisions into polygons under 50 ha (in white), and polygons 50 ha or more (in yellow), using GIS software (Arc/View).

** White areas: less than 50 ha, yellow areas: 50 ha or more*

(2) Defining Cadastral Number Data

The above data classified using the GIS software owned by the Study Team was returned to the CAD software belonging to the SGD. Based on the original cadastral number data, it was decided to use font sizes 30 and 15 for cadastral numbers (PID) of parcels equal to or above 50ha and under 50ha respectively. However, this would mean that very small parcels would be completely hidden by 15pt PIDs on orthophotos. Consequently, upon further discussions with the SGD, it was decided that the PIDs of parcels equal or under 1.5 ha would not be displayed.

Figure 3-15 shows the display of text over all parcels, and Figure 3-16 shows the result when the PIDs of parcels equal or under 1.5 ha are not displayed.

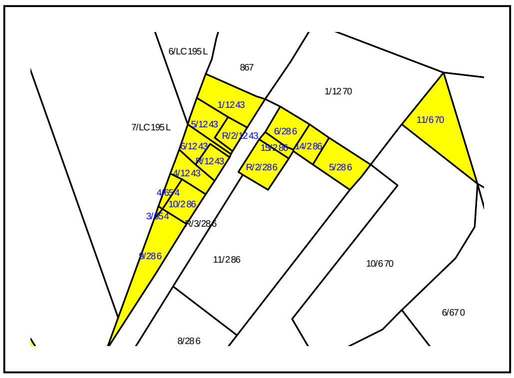


Fig. 3-26

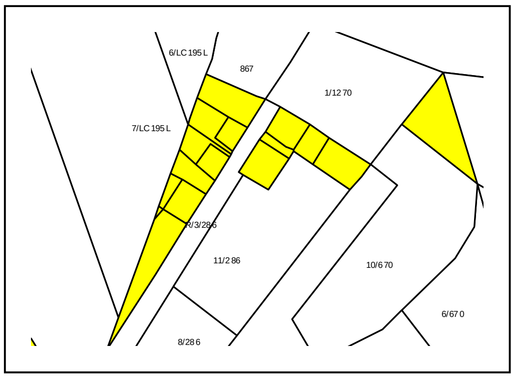


Fig. 3-27

3-2-3 Deletion of River Centreline Data and Conversion of Coordinates

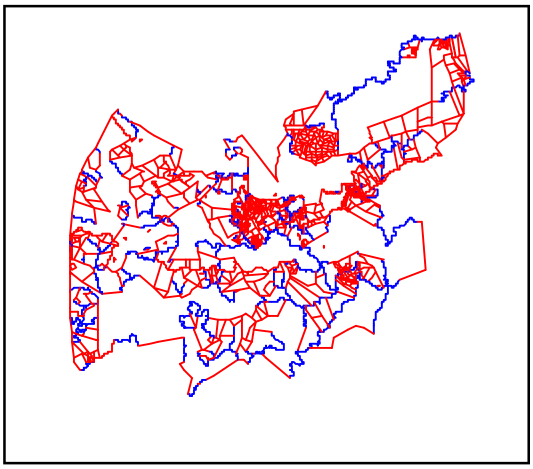


Fig. 3-28 River Centreline Data

Usually, river centrelines are not represented on SGD cadastral maps.

This river data was created a long time ago and have not been surveyed since.

Fig. 3-29 Deletion of River Centreline Data

In other words, there is a high possibility that river shapes have changed in the mean time, due to floods or other natural occurrences.

Consequently, after discussing the issue with the SGD team, river centreline data displayed in blue on Figure 3-17 was deleted.

Fig. 3-30 Results of Coordinate Conversion

As the original cadastral data used an original coordinate system for GIS/CAD, it had to be unified according to the new orthophoto maps created based on the national coordinate system. This conversion entailed shifting the X,Y coordinates and rotating the north-south direction.

3-2-4 Database Integration (Adjoining Regional Data)

Up to this stage, the manipulations of the cadastral database, such as revision of errors, were done region by region. Finally, the four regional databases had to be integrated in order to represent the data on the orthophoto. At this stage, places where boundary lines did not coincide were discovered. Figure 3-20 shows an area between the Hhohho Region and the Lubombo Region where the boundary lines do not coincide. These non-matching items were re-inspected and revised by the SGD team.

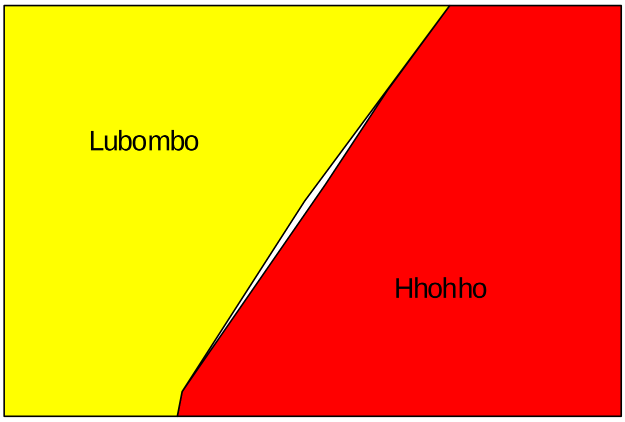


Fig. 3-31 Error Found When Adjoining 2 Regions

3-2-5 Production of the Final Result Data for Display on Orthophotos

After the above errors were eliminated, the cadastral database for display on the orthophotos was finalized. Figure 3-21 shows the result data for the whole territory of Swaziland. The blue cadastral boundary lines correspond to river centrelines, but these will not be displayed on the final results.

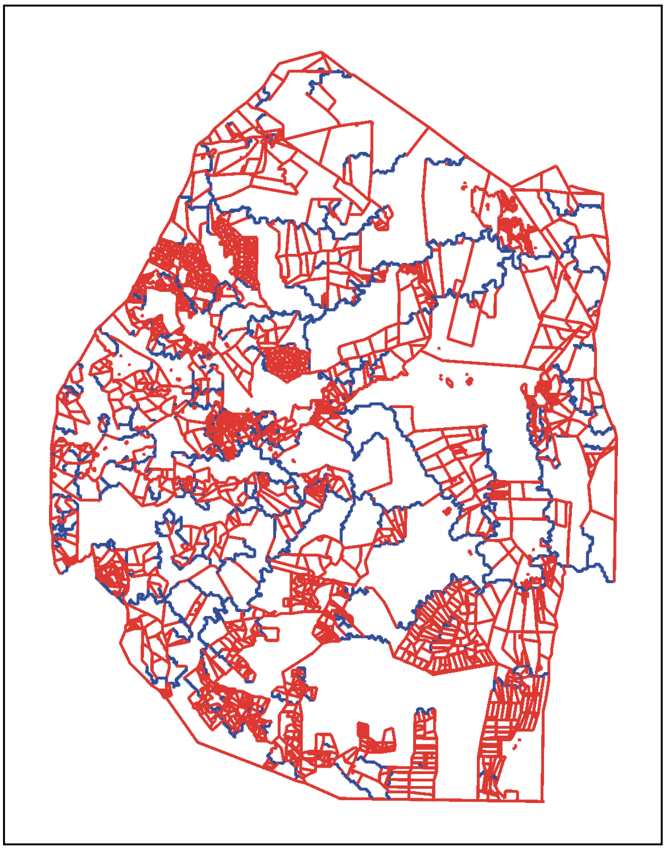


Fig. 3-32 Cadastral Data for the Whole Territory of Swaziland

3-2-6 Production of the Cadastral Database for GIS

The existing cadastral data was transferred into a GIS system so that the cadastral data of the 4 regions and 10 urban areas can be handled using GIS. In the past, cadastral data run by the SGD consisted only of boundary lines, PIDs (cadastral numbers) and attributes related to the PIDs, which could not be introduced into Arc/View GIS for this project and could not be managed using GIS. All the cadastral data was converted into Arc/View so that GIS could be used for data management. The work flow is illustrated by Figure 3-22.

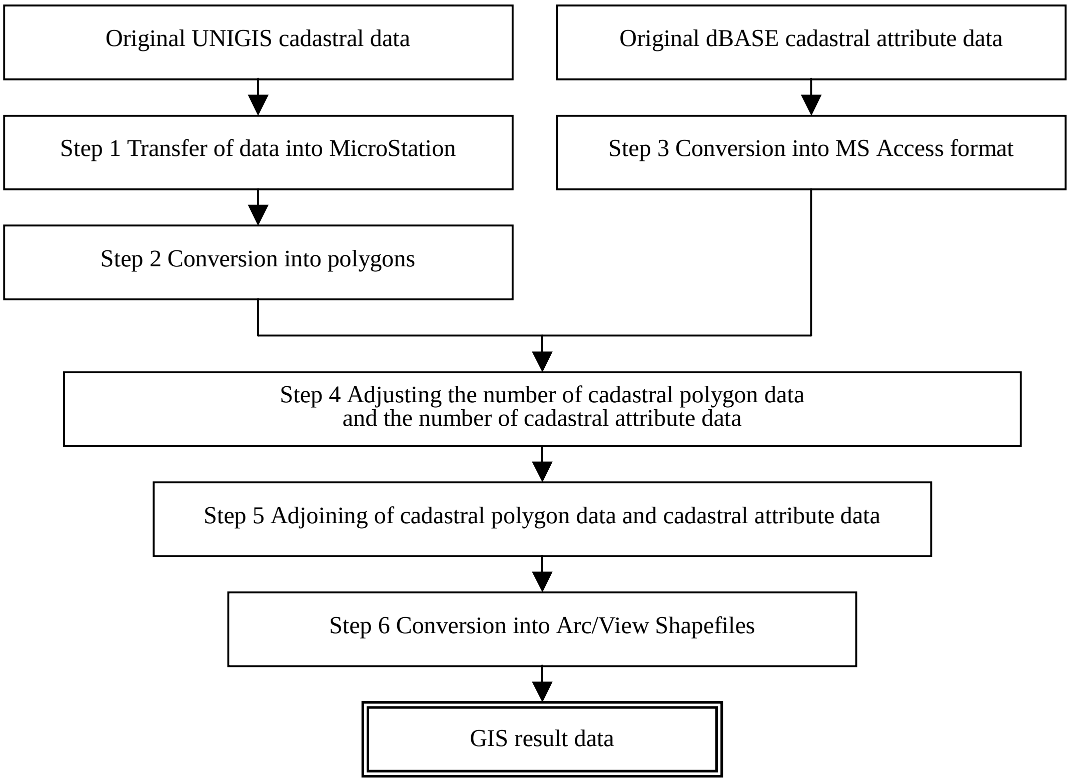


Fig. 3-33 Flowchart for the Creation of Cadastral Data for GIS

(1) Transfer of Data Into MicroStation

Currently, the SGD primarily uses the software MicroStation to manage cadastral data. However, the original cadastral data was managed by an older GIS software called UNIGIS. As this software handles boundaries of cadastral data (line data) and their related attributes, it cannot create polygon data which is necessary for efficient GIS operations. MicroStation can transform this cadastral line data into polygon data, and MicroStation data can be easily imported into Arc/View. Consequently, to construct a GIS cadastral data for this project, the first step was to transfer UNIGIS data into MicroStation.

(2) Conversion into Polygons

Using the polygon creation function of MicroStation, cadastral data transferred into MicroStation from UNIGIS was changed into polygons by the SGD team. Figure 3-23 shows UNIGIS line data. Figure 3-24 shows the cadastral data after it was transformed into polygons by MicroStation (M/S). The yellow code is used to represent polygons.

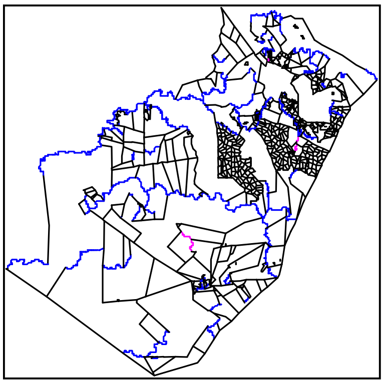


Fig. 3-34 Cadastral Line Data (UNIGIS)

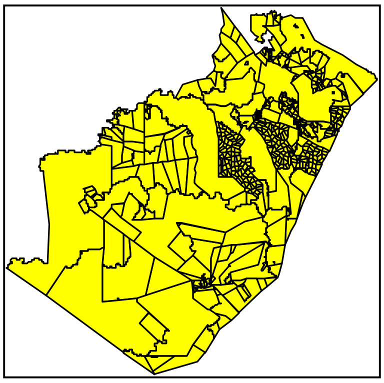


Fig. 3-35 Cadastral Polygon Data (M/S)

(3) Conversion of Cadastral Attribute Data

In general, GIS can manage graphic data as well as attribute data linked to these graphics. Graphic data in UNIGIS was cadastral boundary line data, which was transferred into MicroStation for conversion into polygons. MicroStation can export cadastral attribute data in MS Access format using ODBC (Open Database Connectivity), an application programming interface (API) developed by Microsoft. In addition, as Arc/View also supports ODBC, Microsoft Access (MS Access) data can be easily imported into Arc/View using its SQL connection function.

Given the above situation, as cadastral data will ultimately be managed by Arc/View, all the cadastral attribute data created in UNIGIS was converted into MS Access format with the cooperation of the SGD team.

(4) Adjustment of the Number of Cadastral Polygon Data and Attribute Data

At this point, the number of cadastral polygon data transferred into MicroStation did not coincide with the number of cadastral attribute data in MS Access format. The reason was that the cadastral attribute data transferred from UNIGIS contained old records, whereas the cadastral polygon data converted into MicroStation was updated to the latest information. In other words, this error results from the fact that graphic data and attribute data had not been properly updated at the same time. To fix this error, the SGD team checked the number of cadastral polygon data and the number of cadastral attribute data and produced consistent data.

Table 3-3 shows the data before consistency was achieved and the data after correction.

Table 3-3 Cadastral Data Before and After Correction

Area name	No. of cadastral polygons (DGN file) before correction	No. of cadastral attributes (Access file) before correction	No. of cadastral polygons and attributes after correction
Region			
Hhohho	820	833	820
Lubombo	1,306	1,295	1,306
Manzini	1,166	1,153	1,166
Shiselweni	774	759	774
Urban District			
Ezulwini	423	464	423
Mbabane	6,782	6,683	6,782
Piggs Peak	948	1,275	948
Siteki	1,170	1,168	1,170
Manzini city	4,545	4,613	4,545
Matsapha	691	613	691
Mankayane	324	319	324
Hlathikulu	390	402	390
Nhlangano	1,600	1,604	1,600
Lavumisa	475	473	475

(5) Combining Cadastral Polygon Data and Cadastral Attribute Data in Arc/View

Up to now, MicroStation cadastral polygon data and MS Access cadastral attribute data have been constructed. However, at this point cadastral polygon data and cadastral attribute data have not been combined yet. This was done using the SQL connection function in Arc/View. As previously mentioned, both MicroStation and Arc/View run on Windows and support ODBC. Consequently, attribute fields consisting of common ms-links were defined for cadastral polygon data created in MicroStation and cadastral attribute data in MS Access format.

Cadastral polygons and cadastral attributes were combined using these ms-links as key fields in Arc/View. Table 3-4 is a sample attribute table of cadastral polygons created in MicroStation, Table 3-5 is a sample table for cadastral attributes created in MS Access, and Table 3-6 shows a sample of the combined table.

By combining these attributes, it is possible to assign PIDs and other cadastral attribute data to all cadastral polygon data.

Table 3-4 Attribute Table for Cadastral Polygon Data Created in MicroStation (Sample)

Entity	Layer	Level	Elevation	Color	MSLINK
Shape	50	50	0.00000	9	1
Shape	50	50	0.00000	9	2
Shape	REG TEXT	13	0.00000	4	3
Shape	REG TEXT	13	0.00000	4	4
Shape	REG TEXT	13	0.00000	4	5
Shape	REG TEXT	13	0.00000	4	6
Shape	REG TEXT	13	0.00000	4	7
Shape	REG TEXT	13	0.00000	4	8
Shape	REG TEXT	13	0.00000	4	9
Shape	REG TEXT	13	0.00000	4	10

Table 3-5 Cadastral Attribute Table Created in MS Access (Sample)

MSLINK	PID	SG_NO	AREA	Name	Parent PID	Farmtown
1	7/73	S31/50	8.204100		1/73	73
2	35/73	S77/88	1.842100		8/73	73
3	40/73	S334/91	0.399900		8/73	73
4	41/73	S335/91	0.400000		8/73	73
5	42/73	S336/91	0.400000		8/73	73
6	44/73	S101/94	1.000000		9/73	73
7	45/73	S102/94	1.000000		9/73	73
8	46/73	S103/94	1.000000		9/73	73
9	53/73	S52/96	1.000000		36/73	73
10	52/73	S51/96	1.000000		36/73	73

Table 3-6 Combined Table of Cadastral Polygon and Attribute Data (Sample)

Entity	Layer	MSLINK	PID	SG_NO	Area	PARENT_ PID
Shape	50	1	7/73	S31/50	8.204100	1/73
Shape	50	2	35/73	S77/88	1.842100	8/73
Shape	REG TEXT	3	40/73	S334/91	0.399900	8/73
Shape	REG TEXT	4	41/73	S335/91	0.400000	8/73
Shape	REG TEXT	5	42/73	S336/91	0.400000	8/73
Shape	REG TEXT	6	44/73	S101/94	1.000000	9/73
Shape	REG TEXT	7	45/73	S102/94	1.000000	9/73
Shape	REG TEXT	8	46/73	S103/94	1.000000	9/73
Shape	REG TEXT	9	53/73	S52/96	1.000000	36/73
Shape	REG TEXT	10	52/73	S51/96	1.000000	36/73
Shape	REG TEXT	11	13/73	S154/52	1.157700	1/73

(6) Conversion into Arc/View Shapefiles

In step 5 above, graphic data of the DGN files created in MicroStation and attribute data of the cadastral attribute data created in MS Access were combined in Arc/View. At that point, they were not converted into Arc/View Shapefiles yet.

In this step, in order to be able to handle the final cadastral database for GIS in Arc/View, the combined graphic and attribute data were converted into Shapefiles using the data conversion tool in Arc/View. This means that after this conversion, all the UNIGIS cadastral data and cadastral attribute data constructed by the SGD were converted into a data file format usable in Arc/View. As a result, as each cadastral polygon was associated with cadastral attribute data, it was possible to display into each polygon its PID and SG_NO, as well as other information such as the survey date of the parcel.

Figure 3-25 and Figure 3-26 show examples of cadastral polygon data display.

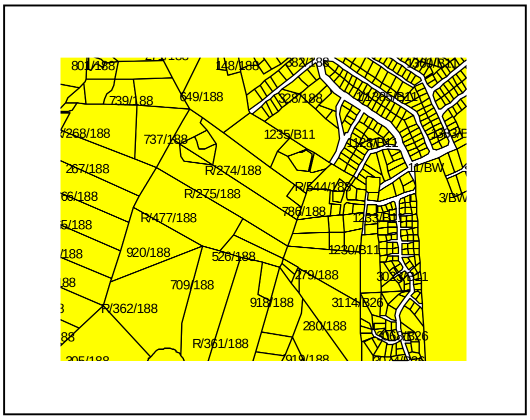


Fig. 3-36 Example of PID Display

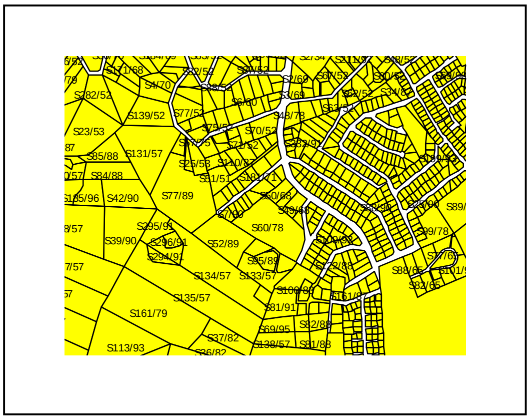


Fig. 3-37 Example of SG_NO Display

It is now possible to use the cadastral data of 4 regions and 10 urban areas owned by the SGD into Arc/View.

CHAPTER 4

THE RECOMMENDED OPERATION/MANAGEMENT AND APPLICATIONS OF THE DATABASE

CHAPTER 4 THE RECOMMENDED OPERATION/MANAGEMENT AND APPLICATIONS OF THE DATABASE

4-1 OPERATION/MANAGEMENT OF THE CADASTRAL DATABASE

4-1-1 Cadastral Data Errors

The cadastral database run by the SGD consists of 4 regions and 10 urban areas. This cadastral database used to be managed by the SGD using the software UNIGIS (attribute information of cadastral data were created in dBASE). The cadastral database is currently managed using MicroStation Geographics, and attribute information of cadastral data has been transferred from dBASE to Microsoft Access (MS Access). As a number of errors were generated when transferring this cadastral database, errors were also created when transferring the data into Arc/View.

The causes of these errors were as follows:

- As the cadastral data created with UNIGIS is line data (not polygons), there were undershoots, overshoots and duplicated lines on the cadastral boundary lines.
- Because of these, errors occurred when forming polygons from cadastral data in MicroStation Geographics, such as several cadastral numbers (PID) for one polygon, or inversely no PID.
- Also, when transferring cadastral information from dBASE to MS Access, the types of errors were data conversion errors or old data mixed with new data (updated).

Table 4-1 shows a comparison between the number of cadastral polygons and the number of cadastral data items.

Table 4-1 Comparison Between the Number of Cadastral Polygons and the Number of Cadastral Data, and Ratio of Error

Name	Total Number of Polygons	Total Number of PIDs	Ratio of error (%)
Regions			
Hhohho	820	833	1.6
Manzini	1166	1153	1.1
Shiselweni	774	759	1.9
Lubombo	1306	1295	0.8
Urban Areas			
Mbabane (Hhohho)	6782	6683	1.5
Ezulwini (Hhohho)	423	464	9.7
Piggs Peak (Hhohho)	948	1275	34.5
Manzini (Manzini)	4545	4613	1.5
Matsapha (Manzini)	691	613	11.3
Mankayane (Manzini)	324	319	1.5
Hlathikulu (Shiselwini)	390	402	3.1
Nhlangano (Shiselwini)	1600	1604	0.3
Lavumisa (Shiselwini)	475	473	0.4
Siteki (Lubombo)	1170	1168	0.2

In the course of this study, cadastral data that was managed using UNIGIS was transferred into Arc/View via MicroStation Geographics. The above errors were corrected with the cooperation of the SGD. In the future, when creating cadastral data or revising the data, it will be necessary to consider the reasons of these errors.

4-1-2 Creation and Revision of the Cadastral Data in the Future

As mentioned above, many errors were generated when transferring the cadastral data managed using UNIGIS into Arc/View. We suggest that the following points are taken into consideration in the future, when the SGD will create new cadastral data or revise the existing data:

- Cadastral boundary data should be created and revised using MicroStation Geographics.
- When creating cadastral boundary data, overshoots, undershoots and duplicated lines should be eliminated.
- Cadastral attribute data should be created and managed using MS Access.

(1) Creation of Cadastral Boundary Data

Currently, the software used at the SGD for the management of cadastral boundary data is mainly MicroStation Geographics. It is advisable to use MicroStation Geographics to input all the cadastral boundaries surveyed in the field in order to construct cadastral boundary data. As the data created using MicroStation Geographics is compatible with Arc/View, it is possible to transfer all the MicroStation Geographics data into Arc/View for analysis. Consequently, we suggest that MicroStation Geographics is used in the future for the creation and revision of cadastral boundary data.

(2) Operation/Management of Cadastral Attribute Data

In the past, the SGD used dBASE for the management of cadastral attribute data, but currently, this task is performed using MS Access. Table 4-2 shows the cadastral information that is currently handled.

Table 4-2 Cadastral Attribute Data Managed at the SGD

Field name	Field description	Field type
PID	Parcel identification code	Character
SG_NO	Surveyor Generals reference no.	Character
AREA	Diagram (legal) area (hectares)	Numeric
NAME	Farm name or township name	Character
PARENT_PID	Parent parcel	Character
FARMTOWN	Farm number or township code	Character
SURV_TYPE	Survey type code	Numeric
TYPE_NAME	Survey type name	Character
SURV_DATE	Survey date	Date
SYSTEM	Coordinate system code	Numeric
SYSTEM_NAM	Coordinate system name	Character
REGISTERD	Registered in the Deeds Office	Logical
OWNER	Registered owner	Character
TENURE	Type of land tenure	Character
IS_URBAN	Is the parcel in an urban area	Logical
URBAN_ID	Urban area id code	Character
U_NAME	Urban area name	Character
TOWN_ID	Township id code	Character
TOWNAME	Township name	Character
DIST_ID	District id code	Character
D_NAME	District name	Character
PIN	Parcel identification number	Character

This shows that the SGD currently uses 22 items of cadastral information for each cadastral boundary data (polygon data).

In recent years, among other projects of international organizations that use Arc/View, MS Access has been adopted in many cases for the construction of attribute databases. This is because MS Access is currently the most powerful Windows-based database construction and management software (many functions, high data compatibility, etc.). Moreover, as MS Access supports ODBC (Open Database Connectivity), databases constructed in MS Access can be easily introduced into Arc/View using its SQL Connection. ODBC is an open interface developed by Microsoft to access data in relational or non-relational database management systems in various configurations.

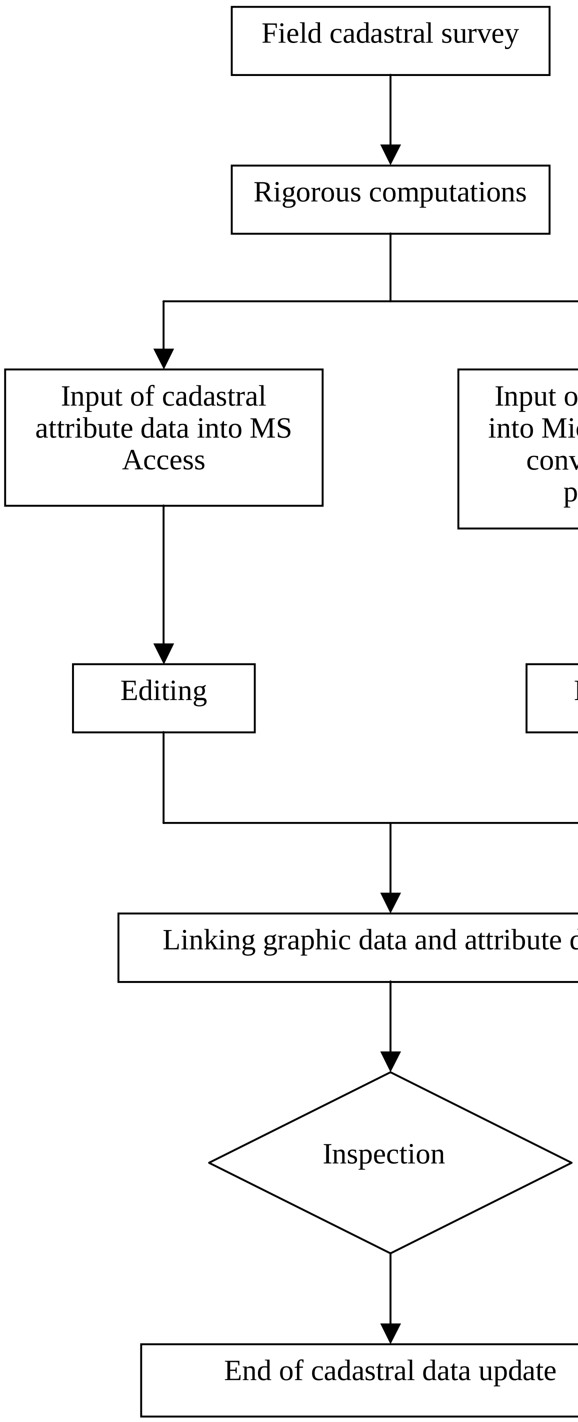


Fig. 4-1 Flowchart of Update of New Cadastral Data

The above table shows that future operation/management of the cadastral attribute information should be carried out by the SGD using MS Access.

The following describes database management using MS Access (new data, addition, revision, deletion, import of outside data, export as outside data). It is imperative for the construction of a cadastral database that the attribute table of cadastral spatial data (polygon data) contains the same ID numbers as the cadastral attribute database (created in MS Access). In this case, we recommend that a common field called Item contains the PIDs (cadastral numbers).

① Creation of new data

In Swaziland, the current cadastral data cover 4 regions and 10 urban areas. In the future, new urban areas will be designated and it will be necessary to create new data in order to construct the corresponding cadastral attribute information.

As shown in Table 4-2, when creating cadastral attribute information, the PID is input as the first item (Field), and the other necessary cadastral information is input starting from the second item.

② Addition, revision (update) and deletion of data

Unlike topographic, geological or soil data, cadastral data has a relatively short change cycle. This is why updating cadastral boundaries and revising cadastral attribute are extremely important tasks, so that the database always contains the latest information. This can be done using the graphic editor functions in Arc/View, and the database editor functions.

To use the graphic data editor functions, existing data is displayed in Arc/View and the shapes can be easily modified on screen. Moreover, it is possible to change cadastral boundaries using the digitiser supported by Arc/View.

Also, attribute data in the cadastral attribute database can be easily deleted, added and revised using the attribute table edit function in Arc/View.

Consequently, by using Arc/View, the SGD can now update, add and delete cadastral data much faster and efficiently than with other software.

There are 2 types of tasks for adding data into an existing database. One consists in adding new cadastral boundary data, and the other one in adding new attribute information linked to existing cadastral boundary data. In the former, a newly created PID is added into an existing database, and its corresponding cadastral attribute information is input. In the latter, information is input into a blank space in an existing database.

Data revisions consist of replacing old information by new one in the database to reflect changes. If the history of previous information must be kept, just create a new Item where the new information is input.

There are 2 types of data deletion tasks. One consists in deleting cadastral attribute information to reflect the disappearance of cadastral boundary data, and the other one in deleting unnecessary items and information in an existing database.

These tasks are done by simple keyboard strokes in MS Access. However, before inputting data, the type of data in each Item must be decided in advance. For example, cadastral numbers are entered as text, and areas as numeric values.

③ Import from an external database/export towards an external database

As part of managing a database, in addition to data editing, it is necessary to know how to import data from an external database, or inversely export data towards an external database. This could happen when using the database of another agency or providing a database to an outside organization. MS Access supports many data formats for importing/exporting databases, as shown in Table 4-3.

Table 4-3 Data Formats Supported by MS Access

Data Input Format	Data Output Format
・ Access ・ Excel ・ Exchange ・ Outlook ・ Lotus ・ Paradox ・ Text ・ HTML document ・ dBASE ・ ODBC databases	・ Access ・ Excel ・ Lotus ・ Paradox ・ Text ・ HTML ・ dBASE ・ MS Word Merge ・ MS Active Server Pages ・ MS ⅡS1-2 ・ RTF ・ ODBC databases

4-2 Applications of Orthophoto Maps and the Cadastral Database

4-2-1 GIS Situation in Swaziland

Before considering the future use of orthophoto images and the cadastral database, let’s examine the current situation of GIS use in Swaziland. This study of the GIS situation covered the counterpart SGD, the Ministry of Agriculture, the Ministry of Health and Social Welfare, the Ministry of Natural Resources and Energy, Swaziland Electricity Board, Swaziland Water Services Corporation and Swaziland Komati project Enterprise Ltd.

As shown in Table 4-4, apart from the plotter, the hardware currently used at the SGD is quite obsolete, and it is considered very difficult for them to run GIS on a background of orthophoto maps, which are extremely large files.

Table 4-4 Surveyor General's Department Computer Hardware Inventory

Maker	Model	Date of supply	Monitor	Processor type	Hard disk space	Memory
Acer	AcerMate 425s (920)	5/4/94 (12/2/97)	AcerView76I	486sx25 (Pentium100MHz)	6Gb	4Mb (16Mb)
Acer	AcerPower 466de	18/1/95	AcerView76I	486dx66	340Mb	16Mb
Acer	Acer Altos 700/e		AcerView76I	Pentium 90MHz	640Mb (1.1Gb+3 Gb)	40Mb
Acer	AcerMate 425s (920)	5/4/94 (14/3/97)	14"vga	486sx25	250Mb (640Mb)	4Mb+4Mb (16Mb)
Acer	AcerMate 386 (920)		Philips 17"	386SX20 (Pentium 100MHz)	120Mb (640Mb)	1Mb (16Mb)
Acer	AcerEntra	7/97	AcerView 76c	Pentium MMX 266MHZ	2.37Mb	32Mb
Acer	AcerMate 3000	7/97	AcerView 76c	Pentium MMX 266MHZ	2.37Mb	32Mb
Acer	AcerPower 6000		Wen	Pentium II 266MHZ	8.4Gb	32Mb
Acer	AcerPower 6100	1/1999	Wen	Pentium 333MHz Celeron	6Gb	32Mb
Acer	AcerPower 6100	8/1999	AcerView77c	Pentium 333MHz Celeron	3Gb	32Mb
Olystar	Olystar PentiumII		Wen	Pentium 200MHz	2Gb	32Mb
Olystar	Olystar Pentium		LITEON 17"	Pentium 200MHz	2Gb	32Mb
Olystar	Olystar Pentium		AcerView 76i	Pentium 200MHz	4.1Gb	32Mb
HP	Laserjet III	17/2/92	N/A	N/A	N/A	1Mb
HP	Laserjet 6P	1/99	"	"	"	4Mb
HP	DesignJet 750 Plus					11Mb
HP	DraftMaster Sx Plus	17/2/92	"	"	"	1Mb
GTCO	Super LII		"	"	"	
SMC	Elite 3812TD	7/4/94	N/A	N/A	N/A	N/A
HP	SureStore CD-Writer plus	6/98	"	"	"	"

The network at the Surveyor General's Department is supported by Novell NetWare Version 4.11 and Version 5 running on two servers.

(1) GIS Environment at the SGD

① Currently, GIS is used mainly for the construction, management and operation of the digital cadastral database (DCDB), but also for digital mapping and digitising maps of urban areas.

② The DCDB was constructed based on the results of cadastral surveys conducted by the Field Survey Section, and digitising by the Computer Office.

③ Currently, existing orthophoto maps at the SGD are in analogue form, and there is no digital data covering the national territory that can be used as background data for GIS.

④ The Mapping Section, which consists of the Computer Office, the Drawing Office and the Photogrammetry Office, is linked by a network, and they plan to put all the data in common. The Mapping Section is in charge of GIS, and is equipped mainly with the equipment listed in Table 4-4. The main softwares used are MicroStation 95, MicroStation Geographics and dBASE IV.

(2) Ministry of Agriculture

At the Ministry of Agriculture, GIS is used in the Land Use Planning Section. They run the GIS data listed in Table 4-5.

Table 4-5 GIS Databases at the Ministry of Agriculture

Theme	Coverage	Scale of input data	Data formats	Reference system
Agro-ecological unit	Swaziland	1:250,000	Idrisi vector & raster	SA survey grid 31
Physiography	Swaziland	1:250,000	Idrisi vector & raster	SA survey grid 31
Present land use	Swaziland	1:250,000	Idrisi vector & raster	SA survey grid 31
Land tenure	Swaziland	1:250,000	Idrisi vector & raster	SA survey grid 31
Hydro-geology	Swaziland	1:250,000	Idrisi vector & raster	SA survey grid 31
Rainfall zones	Swaziland	1:250,000	Idrisi vector & raster	SA survey grid 31
Temperature zones	Swaziland	1:250,000	Idrisi vector & raster	SA survey grid 31

The above databases have been created using the GIS software IDRISI. As the Ministry also uses Arc/View and Arc/Info, their data can also be distributed in Arc/View and Arc/Info formats. The Present land use data has been created using satellite data.

The Ministry of Agriculture is interested in the orthophoto maps and cadastral database created in this study, which would be useful in various fields, such as agricultural development.

(3) Ministry of Health and Social Welfare

A distribution map of medical facilities at the scale of 1:50,000 has been created at the Ministry of Health and Social Welfare using GPS and Arc/View. However, although this map is used in GIS, it only shows the distribution of medical facilities. It does not provide any other information, such as attribute data on each medical facility (name of the facility, address, telephone number, number of doctors/beds, specialties, etc.). Moreover, this distribution map does not use any background and just shows points on a white map. The ministry officials expect to introduce orthophoto images produced as part of this study and use them in GIS as background maps for their distribution map.

The Ministry of Health and Social Welfare wants to put GIS into good use by also compiling social information (population, distribution of population by gender and age) and creating simulations for the spread of malaria. Also, as the Ministry consists of 3 sections (Finance, Planning, Manpower management), they wish to put all common information to all sections into a database which would be accessed via a network.

(4) Ministry of Natural Resources and Energy

① Rural Water Supply Branch

This section manages the pipe network map using MicroStation. As this pipe map is superimposed on old orthophoto images, the managers of this section hope to introduce the latest orthophoto images as soon as possible. When the pipe network is represented on orthophoto maps, it will be easier to explain the situation to the residents when laying new pipes for example.

Also, as they use MicroStation, only water supply pipe network data appear in this database, without any pipe attributes. By introducing GIS, they wish to add various information, such as tank position, size, pipe material, size, well water quality and pipe layout, but also information that will be useful for the operation/management of water supply facilities, such as public buildings, schools, medical facilities, other buildings and topography (elevation, slope).

② Energy Section

The Energy Section mainly uses 1:50,000-scale topographic maps. However as there are many secular changes, they must survey the current conditions in the field each time they formulate a plan. 70% of Swazi inhabitants live in the regions, among which only about 5% have electricity. Currently, 3 out of 5 members of staff conduct surveys and revise map sheets in order to establish plans using MicroStation. However, if they could use orthophoto maps, it is thought that 2 among the above 3 members of staff would work using primarily GIS. They wish to apply GIS to create models for solar energy and small-scale hydroelectric power generation.

(5) Swaziland Water Services Corporation

Like in (3) above, this organization uses old orthophoto maps superimposed with the water pipe network to create map sheets. They do not use GIS yet but use MicroStation for CAD applications. They are considering introducing GIS for the management of water fee, fee collection, pipe network, material, size, attributes, etc. They also wish to make the most of the new orthophoto maps as soon as they are available.

(6) Swaziland Electricity Board (S.E.B)

They currently use 1:250,000 and 1:50,000 maps and conduct ground surveys. However, as they do not have any map with the latest information, operation/management of existing power lines and planning of new lines is difficult.

They use MicroStation for CAD applications, but will decide whether or not to introduce GIS after discussions with the SGD.

(7) Swaziland Komati Project Enterprise Ltd.

This organization has been established with joint capitals from the governments of Swaziland and South Africa for the development of the Komati river watershed, which flows in both countries.

They already use simple orthophoto images created by converting aerial photos made as part of this study. However, they are eagerly waiting for the finished results of this study because these images do not have elevation data.

The Swaziland Komati Project Enterprise has introduced the latest version of Arc/Info for the efficient formulation of plans, and there is no doubt that they will make the most of the digital orthophoto maps of this study.

Based on the above results of the study on the current GIS situation, all the organizations surveyed are interested in using the latest orthophoto images and cadastral GIS database and introducing GIS. We are therefore confident that the orthophoto images of the whole territory of Swaziland and the cadastral database prepared as part of this study will be put into good use.

4-2-2 Design of the GIS System to Introduce at the SGD

(1) Usefulness of the Database

Based on the results of the study on the current situation and future plans at other relevant public organizations, it is clear that the digital orthophoto maps covering the national territory, created in the course of this Study, will be an invaluable GIS database in the future.

(2) Dissemination of GIS

In view of the fact that GIS use should increase rapidly, even at public organizations which are not currently equipped, future GIS software at the SGD should meet the following requirements:

a. Many functions, high reliability
b. Low-cost main software
c. Easy upgrades when necessary, and many optional software
d. User-friendly
e. High compatibility

The hardware was chosen based on the following requirements: a fast processor with the capacity to smoothly process huge volumes of orthophoto data, and easy maintenance.

(3) Selected equipment

- Software
  Main software: ESRI Arc/View 3.2
  Options: Network Analyst, Spatial Analyst, 3D Analyst

- Hardware
  Computer: DELL Precision Workstation 610MT
  Plotter: HP Design Jet 2500

4-2-3 Making the Most of Orthophoto Images and the Cadastral Database

During this study, orthophoto maps covering the whole territory of Swaziland and a cadastral database (4 regions, 10 urban areas) were prepared. These represent a huge amount of information, and we would like to propose ways of making the most of these products so that they are used efficiently for the formulation of development plans (agricultural development, forestry development, urban planning, environmental planning, etc.).

Based on the results of the study on current GIS use in Swaziland, as mentioned above, here are some proposals of future applications of the newly created orthophoto images and cadastral database in various fields.

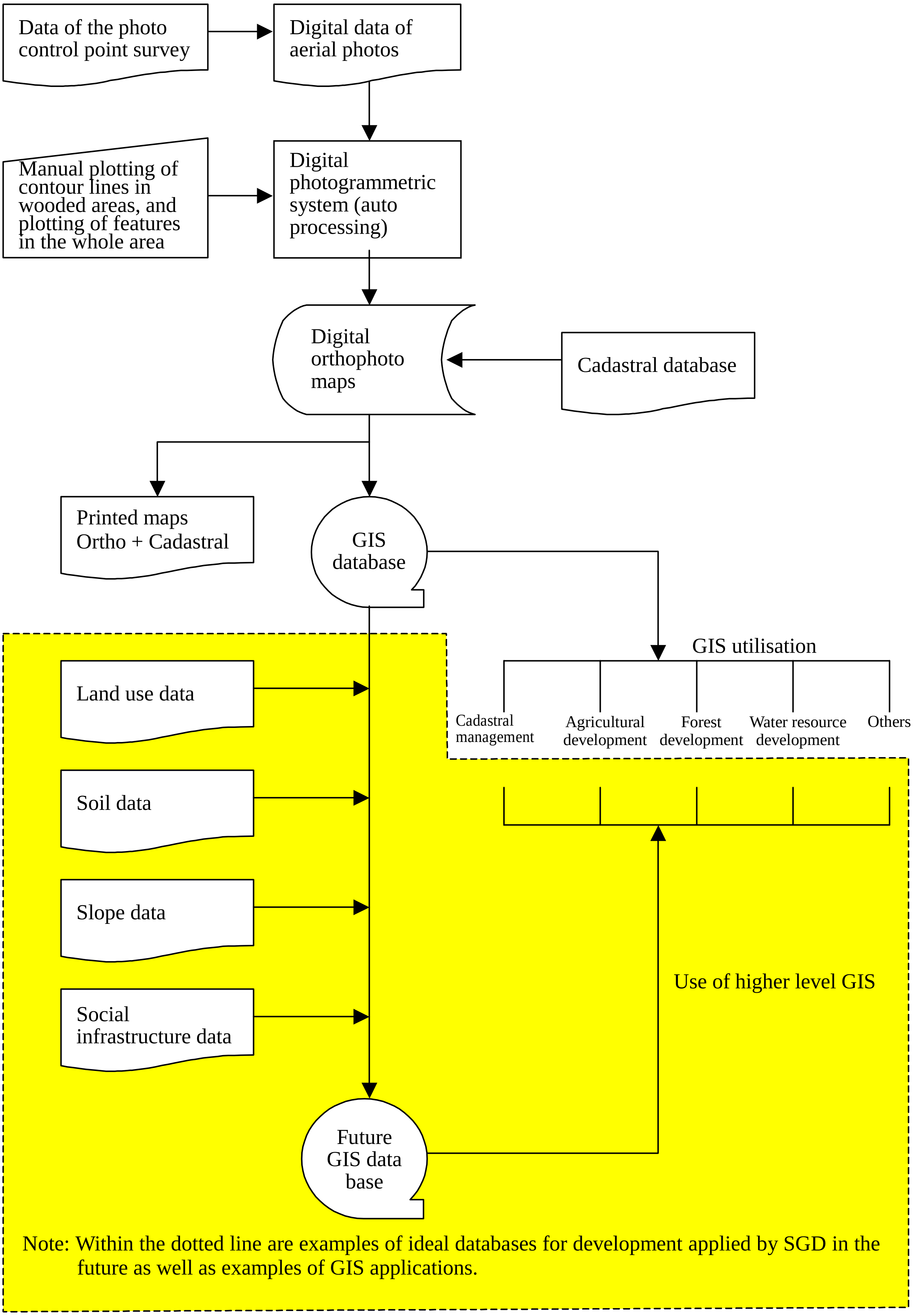


Fig. 4-2 Data Flow in this Study and Examples of Future Applications

(1) Urban Planning

Information needed for urban planning cover a wide range of fields, such as base map, legal matters, urban facilities, buildings, population, land use, cadastral data, current roads and planned roads. Especially, in order to produce planning maps for land use development, land use and cadastral information are vital, which means that the data must be up-to-date. Also, when explaining proposed planning maps to concerned organizations or the public, the contents of these planning maps must be clear and easy to understand.

Using orthophoto images and cadastral boundary data as background maps, various information such as land use and land owners (public, private) can be obtained instantly. And when adding topographic data, especially elevation data (DTM), it is possible to show orthophotos and cadastral data in 3 dimensions and display a proposal with more visual impact.

This shows that many effective applications of the data created during this study can be utilized in the field of urban planning.

(2) Agricultural Development (Selection of Appropriate Land)

Factors such as topography (elevations, slope angles, slope directions), soil, current land use, weather, water resources (dams, reservoirs, rivers, lakes, wells) and population must be known for agricultural development. In general, in order to select agricultural land, topographic data and soil are first analysed to evaluate whether a given land is appropriate for agriculture or not. Then, using land use data to understand current land use conditions, the area selected based on topographic and soil data is assessed taking into account current land use and cadastral data in order to determine the possibility of actually turning this area into agricultural land.

This shows that the latest orthophoto and cadastral data are also extremely valuable information in the field of agricultural development.

(3) Forestry Development (Protection, Reforestation)

Orthophoto data and cadastral data can also be put into good use in the field of forestry development, especially forest protection and reforestation plans. The current forest distribution situation can be easily understood using orthophoto data. By adding slope angle/direction data, soil data and cadastral data to forest distribution data, it is possible to define areas which must be protected or reforested.

Using cadastral data superimposed on orthophoto images as a background map, it is possible to create orthophoto images showing protected and reforested areas, which become invaluable tools as basic data for forestry development and planning.

(4) Watershed Management (Dam Construction)

Currently in Swaziland, the international Komati River watershed is being developed (for dam construction, irrigation). Orthophoto data, which show elevation, is an extremely valuable information for dam construction. For example, using elevation data, it is possible to determine the area that must be flooded for the construction of the dam. Also, by representing the area to be flooded on orthophoto images, it is possible to understand what kind of land use will be lost. In addition, by superimposing cadastral data, the types of land to be lost and their owners can be identified on the spot.

As shown above, orthophoto and cadastral data can be applied effectively to watershed management, especially dam construction projects.

(5) Health Care, Education

The Ministry of Health and Social Welfare has a distribution map of medical facilities, but it is just a few dots on a blank map. Medical facilities could be represented on orthophoto data. By superimposing administrative boundary data and population data on these orthophoto images, and comparing these data files with the current situation of medical facility distribution, it would be possible to determine the areas where facilities are insufficient. Moreover, as orthophoto data would serve as the background map, it would be possible to grasp the current land use situation when planning new facilities and to determine whether construction is possible or not.

The current data only show the current distribution of medical facilities, but using GIS would enable attribute information (address, telephone number, specialties, number of doctors/beds, etc.) to be added to these distribution data (spatial data). The same could also be done for educational facilities.

The above shows that orthophoto and cadastral data can also be used effectively in the medical and educational fields, especially if GIS is applied.

(6) Disaster Management

Disasters such as forest fires, floods and landslides can occur in Swaziland. Last year (2000), Mbabane was flooded due to the effects of torrential rains in Mozambique. Orthophoto data/maps, which are 3-dimensional, are extremely useful information for flood preparation. They allow simulations of flood areas by making the most of elevation data (DTM). Also, using administrative boundary and population data, evacuation routes and areas can be easily worked out. Moreover, medical facilities mentioned in (5) above could also be added to determine which hospital eventual disaster victims should be transported to.

Slash and burn is a widespread custom in Swaziland, and is often the cause of forest fires. Just as for floods, all sorts of information such as evacuation routes, evacuation areas and medical facilities can be superimposed on orthophotos, making them extremely useful tools.

This shows that orthophoto data is an extremely efficient information in relation to disasters. Disaster maps could be created and distributed to the residents of areas where damages are forecast.

The efficient uses of orthophoto and cadastral data have been examined in the fields described in the above sections (1) to (6). We are convinced that the orthophoto data (including 3-dimensional data) and cadastral data produced as part of this study will prove to be very useful for the implementation of the development plan in Swaziland.

4-2-4 Making the Landuse Maps by the Use of the Orthophoto Images

As described above, it is apparent that the combination of this study's final outputs, orthophoto images and cadastral database, is sufficient to meet the needs of the real world. However, by providing the latest large-scale landuse maps, the variety and the advantages of using this study's outputs can be further strengthened.

In general, when initiating a new plan, the first priority is to know the current land use conditions. And the second is to study the conditions of soil, geology, water resource, and slope gradients etc. The third is to design a new landuse plan. And finally, a new development plan is flamed based on the new landuse plan.

Currently, Swaziland maintains the landuse maps produced by FAO in 1995. Since they are in such small scale as 1/250,000, it is useful for designing a macro plan for the entire country. However, it is not large enough to obtain local information at micro level. As you can see from this instance, when creating landuse maps, it is very important to clarify the purposes of their uses. Otherwise, it is difficult to make full use of the landuse maps. In view of the fact that the precise landuse maps are the most important data for national land development, it is vital to focus on the areas with many on-going developments and implement the development plans according to the priority level.

After the completion of this project, it is desirable for the national land development that SGD starts the production of the latest large-scale landuse maps by the use of orthophoto images.

Aerial photos sum up to 1,600 photos when they cover the whole country. On the other hand, orthophoto maps cover the country with only 411 images. Hence, obviously the task of photo interpretation and also field surveys can be greatly reduced by the use of orthophoto maps.

First of all, landuse classifications are displayed on the printed orthophoto images and verified by the field surveys. The second is to digitise the boundaries of the landuse classes and create polygons and attributes. As a result, this database will be highly applicable for GIS and the national land development.

Our strong wish is that SGD will implement those applied uses of this study's final products and greatly benefit from them for the country's sustainable development.

CHAPTER 5

THE RECOMMENDED SGD REORGANIZATION PLAN

CHAPTER 5 THE RECOMMENDED SGD REORGANIZATION PLAN

5-1 THE CURRENT PURPOSE AND MISSION, SITUATION AND PROBLEMS OF THE SGD

5-1-1 Purpose and Mission

The Surveyor General's Department (SGD) is part of the Ministry of Natural resources and Energy, and its main purpose is providing an information service related to survey and mapping to other government departments, the private sector and the general public. The information on survey and mapping is essential for the sustainable economic development of Swaziland. The SGD's Mission is "To provide a centre of excellence in surveying and mapping to meet the needs of Swaziland". The main strategic aims in the SGD business plan are:

① To provide high standards of advice to government departments and others on all survey and mapping matters.

② To fulfil efficiently all statutory requirements to supervise and control surveys of land for registration purposes.

③ To provide surveying services to the Swazi Government to support effectively the development and management of its land.

④ To maintain and make available accurate and up-to-date mapping, to meet the needs of the nation.

⑤ To maintain control of Swaziland's survey framework, which underpins the development of the nation.

The SGD currently provides various survey services and maps to a large number of government departments, (free of charge), and to private firms and individuals. Approximately 45% of maps are currently supplied free of charge to government and community customers, whilst 55% of maps are sold through the information office, which brought an annual income of about E 100,000 in recent years and only equals 5% of the total annual budget of the SGD.

5-1-2 The Current Environment of the SGD

The current environment of the SGD is not so favourable due to the following business and economic conditions and trends:

(i) The central Ministry within the Swazi government is continuing with the Public Sector Management Program (PSMP), seeking to introduce changes in working practices, such as pay-by-achievement. The PSMP will likely affect the SGD in the form of further pressure for budget and staff cuts.

(ii) Swaziland's economy has been stagnant in recent years, the economic growth having declined to a 3% annual growth in recent years (1995-1999). This has reduced the demand for survey and maps, especially by foreigners (comprising 30-40% of the reduction in demand).

(iii) Technical co-operation with the SGD has been declining in recent years, limiting opportunities for training and new products.

(iv) There are four licensed private land surveyors in Swaziland, and many in neighbouring South Africa, and competition for survey work may increase in the future.

(v) The surveying profession has a low status profile amongst the population, leading to recruitment and training difficulties.

New technologies in the survey and mapping fields are progressing rapidly, with the introduction of digital mapping and GIS systems. For example, the SGD must train existing staff in new technologies and purchase new equipment in order to keep up with the competition of other surveyors and map producers in the future. However, this is difficult for the SGD due to budget limitations.

5-1-3 Major Problems Faced by the SGD

The business and economic environment is creating several particular problems for the SGD that impede the given Mission and further progress of the Survey and Mapping industry in Swaziland.

(i) The revenues and budget allocation for the SGD will be limited by the limited demand for survey and maps, caused by predicted low economic growth of only 3%.

(ii) There will be further restrictions for SGD budget and staff, due to continued reductions of costs and structural reforms by the PSMP.

(iii) The SGD will have continuing difficulties in attracting highly qualified staff, due to the low profile of the profession and limited training and promotion opportunities. At present, the promotion system is strictly based on the education level, rather than performance and efforts. More flexible promotion and increased training are needed to attract more staff and motivate them to work harder.

(iv) Investment in new equipment and technology is limited, due to limited funds and reduced technical assistance available to the SGD. In the recent budget allocation (1998/99) of E3.4 Million, 80% (E2.5 million) was wages and only about 1.5% (E0.045 Million) was allocated for durable material and equipment.

Under these conditions, the SGD may find itself in a ‘Vicious Cycle’ whereby budget and staff restrictions bring about lower service quality, leading to further budget and staff cuts and worsening service delivery system. Therefore, the SGD should consider some options available for improving the current difficult environment, to turn the ‘Vicious Cycle’ into a ‘Virtuous Cycle’.

5-2 FUTURE PROSPECTS OF SGD: FROM VICIOUS CYCLE TO VIRTUOUS CYCLE

5-2-1 Survey and Mapping: Essential Services for Sustainable Economic Development

The SGD has been facing an unfavourable environment in recent years. However, it has an important mandate and mission for the sustainable economic growth of the nation. In any development program, survey and mapping are essential services and products. Swaziland is still underdeveloped and survey and mapping works will be essential in the future.

5-2-2 Shift Toward Independence

Worldwide experience has shown that survey and mapping services can be improved significantly via restructuring a government agency into a more flexible and business-like organization, such as an independent agency or even an independent public corporation. Survey and mapping services are more likely to evolve when they are run by a more business-like independent agency or public corporation than by a regular government service, as worldwide experiences have shown.

5-2-3 New Technology and Products: Possible New Income Sources for the SGD

Fortunately, the SGD is currently improving its mapping programs, thanks to technical assistance, by creating 1:10,000 digital maps using new computer technology, which will significantly improve product quality and productivity. If the new digital maps are used to create new products in various forms combined with other information, such as physical, social and economic data, in cooperation with other ministries in the future, high value-added products can be created and offered not only to government agencies but also to the private sector, just as is now happening in many other countries.

Utilizing all of the above positive factors, the SGD may be able to turn the danger of a ‘Vicious Cycle’ into the promise of a ‘Virtuous Cycle’ by restructuring into an independent agency.

5-2-4 Possible Future Scenarios for SGD

(1) Current Trend Scenario: 'Vicious Cycle'"

In the current trend, the SGD has become stuck in a vicious cycle and the future is not promising. There may be continued limited demand for surveys and mapping; limited budget; difficulties in recruitment of qualified staff, poor motivation of existing staff; poor services, and limited development of new products and services.

(2) Desired Scenario: 'Virtuous Cycle'

Major changes in the structure of the SGD would enable the situation to be turned around to 'Virtuous Cycle' from the current 'Vicious Cycle': If new structure is adopted immediately; improvement in work and management will take place; new and innovative products will be introduced; the financial situation will improve; more qualified people will be attracted; further progress for SGD will take place.

Under the desired scenario, the SGD will be given independent agency status. Many similar departments elsewhere in the world have received such a status, and have been successfully transformed into an efficient and more business-oriented agency. The shift to a more independent agency is consistent with the current government PSMP policy of reducing dependency on the government budget. The SGD is likely to receive support for such restructuring because such a shift is likely to reduce required government support and at the same time improve the services and products, as shown by the experiences of other countries.

5-3 THE WORLD SURVEY AND MAPPING INDUSTRY

5-3-1 Government Organization

For many years, the survey and mapping services in nearly every country were provided by government organizations. Since surveys and mapping are important, even essential forms of information, many countries, particularly developing countries still maintain this government control. However, since the 1980's, many countries have been experimenting in transforming such government organization into more independent and flexible organizations, such as independent agencies or public corporations

5-3-2 Independent Agencies

European countries were the first to shift survey and mapping operations to a system of independent agencies, which allowed for more flexibility and freedom in management and operations, so that efficiency could be improved, keeping up with the rapidly changing survey and mapping technology. As a result of this shift, most European survey and mapping organizations have been successfully transformed..

5-3-3 Public Corporations

Now many countries have moved to a public corporation system, with more flexibility and freedom to act in the fast-changing globalisation of technology. In order to compete with other service providers in the global market, fast decisions and actions are needed and it is always necessary to adopt new technology. The corporation system allows such fast decisions. Many survey and mapping organizations, especially international operations, are now organized wholly or partially as either private or public corporations. Survey and mapping services are considered a business in the international market place.

5-3-4 World Trend: From Independent Agencies to Public Corporations

Experience indicates that the world trend is to first shift to an independent agency system, and then, after several years of more business-oriented operation, to shift further to a more flexible public corporation. This world trend is likely to continue, not only in the industrialized countries, but also in the developing countries, such as Vietnam.

The main difference between independent agencies and public corporations is that the latter are based on given capital (investment), rather than an annual budget system, and have flexibility similar to private corporations.

5-3-5 An Example of a Public Corporation: The British Model (Ordnance Survey)

(i) Public Sector Trading Fund: Capital is publicly funded. Return to capital is expected to be 9%, and any return above 9% can be used for other purposes.

(ii) GD has full responsibility for operation, investment, borrowing and staffing (just as any private company) in the given mandate areas of survey, mapping and related services.

(iii) Capital Structure Fund is the excess of assets over liabilities, after evaluating all equipment, buildings, maps and property rights. The excess is treated as public capital of the Fund.

(iv) Borrowing: There is a set maximum borrowing allowance (the External Financing Limit). Also, each year, a targeted return on the public capital is set as a goal (1999 was 9% for the National Interest Mapping Service Agreement).

(v) Income and Expenditure: Income is earned from payments made by customers (including a government department as surrogate customer) for its products and services.

(vi) Operation in a business-oriented environment: if the revenue exceeds expenditure, the surplus can be retained and can be invested in an interest-bearing account approved by the treasury.

5-3-6 Actual Global Experience.

(1) Finland

A public Corporation (Finnmap) is responsible for the domestic survey and mapping operations, international operations are conducted by a government company (FM-International), operating as a corporation in competition with other international survey and mapping companies.

(2) France

The parent agency in France is the French National Mapping Agency, and the International commercial corporation (IGN France International), conducts business in essentially the same way as the FM-International above.

(3) England

Ordnance Survey became an independent agency in 1990, and in 1999, it became a public corporation, operating a ‘Fund’ , which is equivalent to the capital of a stock company. Ordnance Survey is required to pay 9% dividends, and surplus revenue can be retained for investment and other purposes. Ordnance Survey has an international division which operates as an independent business.

(4) Sweden

National Land Survey of Sweden is an independent agency, and the international public corporation, Swedesurvey, operates in exactly the same way as a state-owned company. It conducts international operations just as other similar European organizations.

(5) Vietnam

A developing country, Vietnam transformed their survey and mapping agency into an independent public corporation, operating not only in the survey and mapping business, but also in other related business.

5-4 FUTURE OPTIONS FOR THE SGD

The SGD has three options, as shown below:

(1) Option 1: Remain as a Government Department

The SGD can remain as a government department of the Ministry of Natural Resource and Energy. However, under this option, the SGD will face many problems and may not be able to escape the 'Vicious Cycle'.

(2) Option 2: An Independent Agency

The SGD could be given independent agency status, as is the case in many countries who have successfully reformed in the past two decades. Under this option, the SGD may be able to transform the current difficult situation into a 'Virtuous Cycle', by improving efficiency and the introduction of innovative new products.

(3) Option 3: A Public Corporation

The SGD could even be given an independent public corporation status immediately, as in some industrialized countries. However, this would mean a very drastic change.

5-5 RECOMMENDED OPTION FOR THE SGD: INDEPENDENT AGENCY STATUS

(1) The best choice for the SGD would be to adopt option 2, and after some years of successful experience of this, to move to Option 3 in the future.

In the current situation, the SGD should be given independent agency status for the time being, and in the future be allowed to become a public corporation, which would have even greater flexibility, but more responsibility.

(2) Organizational Framework as an Independent Agency

As an independent agency, the SGD will have more flexibility in decisions concerning employment, wage structure, contracts for survey and mapping, financing and investment. In order to allow the independent agency system to work, overall budget allocations must be changed significantly, so as to provide other ministries with budgets for survey and mapping services. Thus, the SGD will be able to receive revenue from those ministries, based on the services and products provided to them. The SGD management will fully utilize the new flexibility in such a way as to improve efficiency productivity, and in particular produce innovative products and services by adopting new technology and utilizing new sources of accumulated information. Staff training should be provided in order that the staff can keep pace with new technology.

The SGD will be run by a Management Board, and operated by an executive officer (the Surveyor General). The SGD should be able to operate more freely than now, adjusting its provision of survey and mapping services to meet the needs of both government and private customers, while at the same time being responsive to new technologies.

Under the independent agency status, a special target for revenue should be set based on the business plan for every year. If surplus revenue is obtained, this can be shared between the Treasury and the Agency, based on the original agreed percentage (Perhaps 30% for the Treasury and 70% for the Agency). The surplus revenue could be used for various purposes such as capital investment, increased wages or staff training. If the revenue is below the target, the agency would be asked to reduce the cost and increase productivity to meet the target in the following years. Under these arrangements, the management and staff should be motivated and willing to work harder and to adjust to the rapidly changing business environment.

(3) The New Mandate and The Mission of The SGD

The SGD will have the same duties and objectives as before, but new mandates and objectives might be added, as shown below (based on those of other existing independent agencies):

① To maintain the National Topographic Database (NTD) at a sufficiently up-to-date level, and of sufficient quality of information and graphic presentation so as to meet the current and future data needs of a wide range of clients.

② To play a leading role in the development of land and property, ensuring that the NTD is included in any new proposals.

③ To make available a range of products and services from the NTD to meet present costumer needs.

④ To Anticipate and meet the future needs of customers through innovative new products, partnerships and services, and adherence to ‘Service First’ principles.

⑤ To develop existing markets and enter new markets with increased efficiency and productivity.

⑥ To develop the competence of staff in a way which provides the SGD with the necessary skills, and prepares employees to meet the ever-changing needs of the business environment.

⑦ To implement a business strategy that makes necessary investment a priority, delivers financial targets set by the government and providing the best value-for-money for customers.

⑧ To facilitate the operations of government through collaboration with other private and government organizations and users.

⑨ To play a leading role in the development of a National Geospatial Data Framework, by linking the National Topographic Database to other special data, such as those held by other government agencies, thus facilitating the provision of a 'One stop shop' for customers for all geospatial data.

⑩ To safeguard the historical and public records of the Swazi landscape provided by the SGD maps and data.

⑪ To provide advice to the Swaziland Government on all matters related to survey, mapping and geographical information.

The above are possible new mandates and objectives for the SGD under the independent agency status, which allows a wider mandate and also more new business opportunities. The key point under the independent agency system is that the newly obtained freedom and flexibility will allow the SGD to be more innovative and efficient, and to take initiatives in all aspects of management and daily operations. Thus, this change in status will benefit not only the SGD, but also the Government and all its clients.

(4) Budget and Financial Arrangements

The Government should allocate the SGD a new budget based on the survey services to be provided by the SGD, in particular benchmark maintenance and boundary survey. Other survey projects and mapping products should be marketed just as in a private business, and the SGD will make contracts with clients both in government and private sectors.

Currently the SGD is only receiving about E 100,000 revenue from sales of maps and other services. This is only about 5% of the budget of the SGD. There seem to be two main reasons for this limited revenue. One reason is that the pricing of SGD products and services may be too low compared with the market value or the cost incurred. A large portion of services and products are also provided free of charge to other Ministries. These products are then valued less than the real market value and are therefore likely to be wasted. They may also be sold on to private users, as is the experience in other countries. The second reason is that under the current arrangement that there is no incentive to produce new value-added products, such as new maps and digital information .

In order to improve the situation, the SGD must increase revenues by aggressive marketing, producing innovative new products and cutting costs. To do this, they must be given freedom to manage themselves and operate more freely.

Under independent agency status, the SGD will be allowed to borrow funds for both long term capital investment and short term operation costs, within a given limit set by the governing board and guaranteed by the treasury. Utilizing this new freedom to borrow, the SGD will be able to invest in new equipment and products, which will have a favourable return in the near future.

(5) Employment, Wages and Training

If the SGD obtains agency status, the wages, promotion and training systems must be restructured. The structure should recognize individual capabilities and performance, in order to provide more incentive and motivation. Under this private business-oriented organization, the SGD should improve productivity and efficiency by eliminating unnecessary positions and establishing more flexible job assignments and a bonus system based on performance, as in any private business. The training of staff should also become an important objective. It may become necessary to recruit new qualified staff as revenue starts to increase.

(6) New Products, Pricing and Property Rights

The SGD must seriously consider adding new products to the existing line of products and services. In particular, the recently completed 1:10,000-scale digital orthophoto maps should be used to produce new maps and computer information products, by adding more information to the base. Also, the price of these products should be increased to a level based on the market value in other countries, to reflect the costs of production and property rights. If there is no property right law applicable to these products, a new law should be passed to protect them.

The pricing of these products is normally assessed by a government body from time to time. If Swaziland doesn’t have such a regulatory body, such a body should be established.

5-6 CONCLUSION

In the current surrounding environment of the SGD, and considering unfavourable trends we recommend restructuring the SGD, from being one of the Departments of the Ministry of Natural Resources and Energy to becoming an independent agency. Based on the experiences of many similar survey and mapping organizations in the world, the SGD should be given a chance to prove that it is able to transform the current ‘Vicious Cycle’ conditions to those of a more ‘Virtuous Cycle’.

Of course, such a transformation will not materialize automatically. It will require a lot of effort by the SGD management and all the staff towards improving efficiency and productivity, as well as introducing innovative new products and services which maximise the use of the information and data accumulated by the SGD in the past. The freedom and flexibility which comes with the independent status should make such a transformation possible, as it has in many other places in the world. Since Swaziland is still under developed, there is a pressing need for survey and mapping services, and much improvement is needed, and we believe this is the best change for SGD to become an independent agency. The SGD should be able to improve revenue sources significantly, particularly by fully utilizing the recently completed 1:10.000-scale digital orthophoto maps. While continuing to play a leading role in providing survey and mapping services, they should also be able to shift to the more modern business of Geospatial information and data, by further investing in new technology and staff training

If this suggested re-organization into an independent agency is carried out and the SGD is successfully transformed to a more profitable and progressive agency, we consider that everyone, including the SGD, the Swazi Government, and all users will benefit. We are hoping that our preliminary suggestion for re-organizing the SGD will be examined further and a decision can be made soon.

APPENDIX

1. SPECIFICATIONS OF THE ORTHOPHOTO MAPPING
2. GUIDELINE FOR STATIC GPS SURVEYING AND PHOTO CONTROL INSTALLATION
3. GUIDELINE FOR PREPARATION AND MAINTENANCE OF ORTHOPHOTO DATA
4. GUIDELINE FOR GIS OPERATION
5. SCOPE OF WORK
6. MINUTES OF MEETING ON THE SCOPE OF WORK
7. MINUTES OF MEETING ON THE INCEPTION REPORT
8. MODIFICATION REQUEST
9. TENTATIVE SPECIFICATIONS OF THE ORTHOPHOTO MAPPING
10. AGREEMENT ON THE UTILIZATION OF THE GPS EQUIPMENT AND THE AERIAL PHOTOGRAPHY
11. MINUTES OF MEETING ON THE PROGRESS REPORT
12. MODIFICATION REQUEST OF THE FINAL PRODUCTS
13. ACKNOWLEDGEMENT RECEIPT OF THE NEGATIVE FILMS, THE COMPUTER, AND THE GIS SOFTWARE
14. AGREEMENT FOR THE SPECIFICATIONS OF THE ORTHOPHOTO MAPPING
15. MINUTES OF MEETING FOR THE DRAFT FINAL REPORT

APPENDIX 1

SPECIFICATIONS OF THE ORTHOPHOTO MAPPING

SEPTEMBAR 2000

SWAZILAND 1:10,000 ORTHOPHOTO MAPS

Specification

Rev.2

September 2000

S G D
J I C A

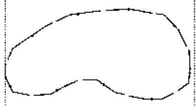
SEQ. No	Feature Class	Feature Code	Description	Figure	Microstation Attribute Lv	Co	S	W	Cl	Type	Font	Height(m)	Remarks
0001	Cadastral	**1101**	Farm Number (>=50ha)	R/C/233	1	0	0	0	P	text	Universe U/C	30	·The upper side of the map has to face north. ·Put the standard position of the letters on the center of the feature. ·As a rule, put the letters on about the gravity center of the feature horizontally. In case the feature is very thin and long, put the letters obliquely. ·Make sure, that if the feature sit on/over the frame, put the letters on each sheet. ·As a rule, do not overlay with other features (include other level's features). ·Universal Capital Letters (U/C) ·Z (height) value is 0m.
0002		**1102**	Farm Number (<50ha) / Farm Number (=<1.5ha)	12/233	2	1	0	0	P (C)	text	Universe U/C	15	·Same as the remark of 1101. ·In case tiny features are congregated, put each one of the letters outside the feature horizontally using FC (feature code) 1104. ·In case tiny features are scattered, put each one of the lines (letters) on about the gravity center of the feature horizontally without using FC (feature code) 1104. (It can be stuck out of the shape of the cadastral) ·For the feature (=<1.5ha), the name of the feature should be construction(invisible) attribute.
0003		**1103**	Cadastral Line		3	2	0	0	P (C)	line			·As a rule, no editing is needed. ·For the paper map, cadastral data has to be cut by frame unit. ·Z (height) value is 0m. ·The line overlapped with the International boundary should not be expressed on paper map and should be construction attribute.
0004		**1104**	Indicate Line (For Farm Number)		4	3	0	0	P	line			·The line data has certain direction; the center of the target area should always sit on the right side of the line. ·The line should be one "line" data (do not use multiple lines to build this line.). ·The start and end point of the line have to sit on middle part of each side of the annotation data. ·Z (height) value is 0m.

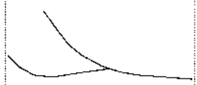
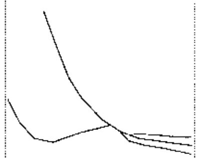
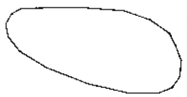
SEQ. No	Feature Class	Feature Code	Description	Figure	Microstation Attribute								Remarks
					Lv	Co	S	W	Cl	Type	Font	Height (m)	
0005	Boundary	**2101**	Town Name	TOWN NAME	5	0	0	0	P	Text	Universe U/C	50	・Upper side of the map always faces north. ・The features cut by a frame should be delivered to each section adjacent to the frame. ・As a rule, put the line horizontally. ・As a rule, do not overlay with other features (include features in other levels.). ・(U/C---Capital letters for each letter.) ・Z (height) value is 0m.
0006		**2102**	Township Name	TOWNSHIP NAME	5	1	0	0	P	Text	Universe U/C	30	・Same as the remark of 2101.
0007		**2103**	Game Reserve Name	GAME RESERVE NAME	5	2	0	0	P	Text	Universe U/C	30	・Same as the remark of 2101
0008		**2104**	Country Name	COUNTRY NAME	5	3	0	0	P	Text	Universe U/C	50	・Same as the remark of 2101
0009	Communication	**2201**	Railway Station	Railway Station	6	0	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101. ・Put the line obliquely along the shape of the feature (without bending the line itself). ・(U/L/C---Capital letter for the very fist letter and lower case letters for the rest.)
0010		**2202**	Airport	Airport	6	1	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0011		**2203**	Airstrip	Airstrip	6	2	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0012	Water Feature	**2301**	River Name	*River Name*	7	0	0	0	P	Text	Universe.I U/L/C	25	・Same as remark of 2101 ・Put the line obliquely along the shape of the feature (without bending the line itself).
0013		**2302**	Canal	*Canal*	7	1	0	0	P	Text	Universe.I U/L/C	25	・Same as the remark of 2101.
0014	Facility	**2401**	Dipping Tank Name	Dipping Tank Name	8	0	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0015		**2402**	Dam Name	Dam Name	8	1	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0016		**2403**	Power Station	Power Station	8	2	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0017		**2404**	Fire Lookout Post	Fire Lookout Post	8	3	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0018		**2405**	Transmission Station	Transmission Station	8	4	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.

SEQ. No	Feature Class	Feature Code	Description	Figure	Microstation Attribute								Remarks
					Lv	Co	S	W	Cl	Type	Font	Height (m)	
0019		**2406**	Border Post	Border Post	8	5	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0020		**2407**	Fire Station	Fire Station	8	6	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0021		**2408**	Sewerage Works	Sewerage Works	8	7	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0022	Building	**2501**	School Name	School Name	9	0	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0023		**2502**	Hospital	Hospital	9	1	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0024		**2503**	Health Centre	Health Centre	9	2	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0025		**2504**	Clinics	Clinics	9	3	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0026		**2505**	Church	Church	9	4	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0027		**2506**	Post Office	Post Office	9	5	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0028		**2507**	Police Station	Police Station	9	6	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0029		**2508**	Store	Store	9	7	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0030		**2509**	Hotel	Hotel	9	8	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0031		**2510**	R.D.A.	R.D.A	9	9	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0032		**2511**	Inkhundla	Inkhundla	9	10	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0033		**2512**	Institution	Institution	9	11	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0034	Topographic Feature	**2601**	Forest Name	FOREST NAME	10	0	0	0	P	Text	Universe U/C	30	・Same as the remark of 2101.
0035		**2602**	Place Name	PLACE NAME	10	1	0	0	P	Text	Universe U/C	30	・Same as the remark of 2101.
0036		**2603**	Area Name	AREA NAME	10	2	0	0	P	Text	Universe U/C	30	・Same as the remark of 2101.
0037		**2604**	Hill Name	HILL NAME	10	3	0	0	P	Text	Universe U/C	30	・Same as the remark of 2101.
0038		**2605**	Mountain/Range Name	MOUNTAIN/ RANGE NAME	10	4	0	0	P	Text	Universe U/C	30	・Same as the remark of 2101. ・Put the line obliquely along the shape of the feature (without bending the line itself).

SEQ. No	Feature Class	Feature Code	Description	Figure	Microstation Attribute								Remarks
					Lv	Co	S	W	Cl	Type	Font	Height (m)	
0039		**2606**	Golf Course	Golf Course	10	5	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0040		**2607**	Sports Fields	Sports Fields	10	6	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.
0041		**2608**	Mineral Works	Mineral Works	10	7	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101
0042		**2609**	Plantation	Plantation	10	8	0	0	P	Text	Universe U/L/C	25	・Same as the remark of 2101.

SEQ. No	Feature Class	Feature Code	Description	Figure	Microstation Attribute Lv	Co	S	W	Cl	Type	Font	Height (m)	Remarks
0043	Boundary	**3101**	International Boundary		11	0	boundary_ international	3	P	Line			・As a rule, no editing or modification is needed. ・Should not be ceased by the feature sitting on other levels. ・Cut by frame unit. ・Z (height) value is 0m.
0044		**3102**	Urban Boundary		12	1	boundary_ urban	0	P	Line			・Same as the remark of 3101. ・The line data has certain direction; the center of the target area should always sit on the right side of the line.
0045	Topographic Feature	**3201**	Index Contour Line		13	0	0	2	P	Line			・50m index contour. ・Either stereophotogrammetry plotting or automated plotting by interpolation with DEM data are acceptable. ・The interval of the each points of the line should be the distance in which the shape of the line looks smooth on 1:10,000 scale (about 1～5mm at the bending part of the line). ・Height errors more than 2.5m (by trees, building and etc.) should be modified manually. ・Especially the tiny depression (less than about 5mm on paper map) by tree or house should be deleted. ・As a rule, the lines should not be ceased, except for the space for the height values. ・Z (height) value is represent actual height.
0046		**3202**	Intermediate Contour Line		14	1	0	0	P	Line			・10m intermediate contour line. ・Same as the remark of 3201
0047		**3203**	Supplementary Contour Line		15	2	contour_ 5m	0	P	Line			・5m supplementary contour. ・Same as the remark of 3201. ・In the plane area, contour should be inserted. ・Contour should not be inserted as the distance between the intermediate lines is less than 3cm～5cm in the mountain area.
0048		**3204**	Index Contour Line (Depression)		16	0	contour_ dep50m	2	P	Line			・50m index contour. ・Same as the remark of 3201. ・The tiny depression (less than about 5mm on paper map) by tree or house should be deleted. ・The line data has certain direction; the center of the target area should always sit on the right side of the line.

SEQ. No	Feature Class	Feature Code	Description	Figure	Microstation Attribute Lv	Co	S	W	Cl	Type	Font	Height (m)	Remarks
0049		**3205**	Intermediate Contour Line (Depression)		17	1	contour_ dep10m	0	P	Line			・10m intermediate contour for depression. ・Same as the remark of 3202. ・The line data has certain direction; the center of the target area should always sit on the right side of the line.
0050		**3206**	Supplementary Contour Line (Depression)		18	2	contour_ dep5m	0	P	Line			・5m supplementary contour for depression. ・Same as the remark of 3203. ・The line data has certain direction; the center of the target area should always sit on the right side of the line.
0051		**3207**	Index Contour Value		19	0	0	0	P	Text	Universe U/C	15	・About 4 of them are needed per sheet. ・Put the value by insert a space into the contour line as small as possible. ・Z (height) value represent the actual height.
0052		**3208**	Trig Point (Symbol)	△	20	1	0	0	P	Cell TRIG			・In case the point sit on the frame, it can be stuck out of the frame. ・Z (height) value represent the actual height.
0053		**3209**	Trig point (Name)	Scaba △	21	1	0	0	P	Text	Universe U/C	15	・Put the name upper side of the 3208 feature. ・The standard point has to sit on the gravity center of the line. ・Put the value under the feature 3208 in one place of decimal number. ・Z (height) value represent the actual height. ・Upper side of the symbol faces North.
0054		**3210**	Spot Height (Symbol)	·	22	2	0	0	P	Cell SPOT			・The density of the points has to be one in 10c㎡. ・As a rule, put the height on the mountain top, ridge, convex slope or depression or etc., even in using the stereophotogrammetric plotting. ・Z (height) value represent the actual height.
0055		**3211**	Spot Height (Value)		23	2	0	0	P	Text	Universe U/C	15	・Put the value right side of the feature 3210 primarily, or left side in a integral number. ・Z (height) value represent actual height. ・The Upper side of the symbol faces north.
0056		**3212**	Boundary Pillar (Symbol)	▲	24	1	0	0	P	Cell BOPI			・Put it on the boundary. ・Z (height) value is 0m.
0057		**3213**	Boundary Pillar (Name)	▲BP	25	1	0	0	P	Text	Universe U/L/C	15	・Put the name aside the pillar. ・Primarily put it right side of the pillar, if not possible, put left side, if not, then upper side, then lower side. ・Z (height) value is 0m. ・Upper side of the symbol faces North.

SEQ. No	Feature Class	Feature Code	Description	Figure	Microstation Attribute								Remarks
					Lv	Co	S	W	Cl	Type	Font	Height (m)	
0058		**3214**	DEM Points		26	3	0	0	C	Line			•Acquire 40m DEM as point data. •The points on the frame should be expressed. (It can be overlapped on the adjacent frame.) •As a rule, the height value of each point has to be consistent with the height value of the contour lines. •Should not be expressed on the paper map. •This shape is a line without length. •Z (height) value represent the actual height (m).
0059	Water Feature	**3301**	River Centre Line		27	0	0	0	C	Line			•Acquire the center line of the river without ceasing the line. •Should not expressed on the paper map. •Z (height) value is 0m.
0060		**3302**	River Edge Line		28	1	0	0	C	Line			•If the width of the river on the map is more than 1cm, acquire the outline (of the water part) of the river. •The terminal point of the line has to connect to the line acquired as 3301 or the frame. •Bank inside the river should be omitted. •Should not be expressed on the paper map. •Z (height) value is 0m.
0061		**3303**	Lake Border Line (Marsh Border Line)		29	2	0	0	C	Line			•Acquire the shore line of lakes, ponds and etc. •The lines should be closed (same as depression). •Should not be expressed on the paper map. •Z (height) value is 0m.
0062	Communication	**3401**	Road Centre Line		30	0	0	0	C	Line			•Acquire the center of the road in which cars can run. (The line does not have to be always accurate.) •Even at cross section, the line should no be ceased. •Acquire the rough shape of the line to express the tunnel and the line should not be ceased. •Should not be expressed on the paper map. •Z (height) value is 0m.

SEQ. No	Feature Class	Feature Code	Description	Figure	Microstation Attribute Lv	Co	S	W	Cl	Type	Font	Height (m)	Remarks
0063		**3402**	Road Edge Line		31	1	0	0	C	Line			・For the road acquired as 3401, acquire the edge of the road either stereophotogrammetry plotting or automated plotting by using the center line (in case using the center line, the edge should fit the road on the photo.). ・At cross section, the line should no be ceased. ・Acquire the rough shape of the line to express the tunnel and the line should not be ceased. ・Should not be expressed on the paper map. ・Z (height) value is 0m.
0064		**3403**	Railway Centre line		32	2	railway	0	C	Line			・Acquire the center of the rails. ・At cross section, the line should no be ceased. ・Acquire the rough shape of the line to express the tunnel and the line should not be ceased. ・Should not be expressed on the paper map. ・Z (height) value is 0m.
0065		**3404**	Bridge Centre Line (Road)		33	3	road_ bridge	2	C	Line			・Acquire the center line of the bridge independently. (The line should overlap with the road center line acquired as 3401). ・Should not be expressed on the paper map. ・Z (height) value is 0m.
0066		**3405**	Bridge Centre Line (Railway)		34	4	railway_ bridge	2	C	Line			・Acquire the center line of the bridge independently. (The line should overlap with the railway center line acquired as 3403) ・Should not be expressed on the paper map. ・Z (height) value is 0m.
0067		**3406**	Tunnel Centre Line (Road)		35	5	road_ tunnel	2	C	Line			・Acquire the center line of the tunnel independently. (The line should overlap with the railway center line acquired as 3401). ・Should not be expressed on the paper map. ・Z (height) value is 0m.
0068		**3407**	Tunnel Centre Line (Railway)		36	6	railway_ tunnel	2	C	Line			・Acquire the center line of the tunnel independently. (The line should overlap with the railway center line acquired as 3403). ・Should not be expressed on the paper map. ・Z (height) value is 0m.

SEQ. No	Feature Class	Feature Code	Description	Figure	Microstation Attribute Lv	Co	S	W	Cl	Type	Font	Height (m)	Remarks
0069	Marginal Information	**4101**	Destination	Mbabane	62	0	0	0	P	Text	Universe (U/L/C)	25	•Put the destination of major road and rails outside the inner frame (close to it). •The angle of the destination should be same angle as the road or rails. •Z (height) value is 0m.
0070		**4102**	Grid (Coordinate Value)	-50000K	62	1	0	0	P	Text	Universe (U/C)	25	•Put the coordinates of each 4 corner of inner frame on out side (and close to) of each corner. •Integral number on "Km" unit. •Z (height) value is 0m.
0071		**4103**	Sheet Name	LUVE	62	2	0	0	P	Text	Universe (U/C)	100	•Put on the upper side and center of the map. •Z (height) value is 0m.
0072		**4104**	Map Scale	Scale 1:10,000	62	3	0	0	P	Text	Universe (U/L/C)	50	•Put the line on the lower left side of the marginal section. •Z (height) value is 0m.
0073		**4105**	Sheet Number	K12	62	4	0	0	P	Text	Universe (U/C)	50	•Put the line on the lower right side of the marginal section. •Z (height) value is 0m.
0074		**4106**	Sheet Index	G12	62	5	0	0 6	P	Text	Universe (U/C)/ Universe.I (U/C)	25	•Put the line on lower right side of the marginal section. •Z (height) value is 0m. • * (include shapes)
0075		**4107**	JICA Note	Detailed of	62	6	0	0	P	Text	Universe.I (U/L/C)	25	•Z (height) value is 0m.
0076		**4108**	SGD Note	Detailed of	62	7	0	0	P	Text	Universe.I (U/L/C)	25	•Z (height) value is 0m.
0077		**4109**	History	History	62	8	0	0	P	Text	Universe.I (U/L/C)	25	•Z (height) value is 0m.
0078		**4110**	Publishing	Publishing	62	9	0	0	P	Text	Universe.I (U/L/C)	25	•Z(height) value is 0m.
0079		**4111**	Scale Bar		62	10	0	0 6	P	Text	Universe (U/L/C)	25	•Put the line on about the center of the marginal section. •Z(height) value is 0m. • * (include shapes)
0080		**4112**	North Symbol		62	11	0	0	P				•Put the line on the lower right side of the marginal section. •Z (height) value is 0m. • * (include shapes)
0081		**4113**	Map Frame / Grid Ticks		62	12	0	3 0	P				•Outer frame (lineal frame of sheet line), Inner frame (sheet line), Grid ticks. •Z (height) value is 0m.
0082		**4114**	Map Inner Frame		63	0	0	0	C				•For work only. •Should not be displayed on paper map. •Z (height) value is 0m.

APPENDIX 2

GUIDELINE FOR STATIC GPS SURVEYING AND PHOTO CONTROL INSTALLATION

JUNE 2001

Guidelines for Static GPS Surveying and Photo-control Installation

SGD
JICA

June 2001

INDEX

Introduction

This guide outlines how to carry out Static and Rapid Static GPS surveys and Photo-control installation. It emphasises those points to particular care has to be paid. Provided that certain basic rules are followed GPS surveying is relatively straightforward and will produce good results. From a practical point of view it is more important to understand the basic rules for planning, observing and computing GPS surveys rather then detailed theoretical knowledge of the Global Positioning System. This manual has basically been compiled from information provided by Leica Geosystems Ltd. and the practical experience of the author in GPS surveying and photo-control installation.

1. Overall planning for a GPS survey

1.1 Baseline length

A GPS receiver measures the incoming phase of the satellite signals to millimetre precision. However, as the satellite signals propagate through space to earth they pass through and are affected by the atmosphere. The atmosphere consists of the ionosphere and the troposphere. Disturbances in the atmosphere cause degradation in the accuracy of observations.

GPS surveying is a differential method. A baseline is observed and computed between two receivers. When the two receivers observe the same set of satellites simultaneously, most of the atmospheric effects cancel out. The shorter the baseline the truer this will be, as the more likely it is that the atmosphere through which the signals pass to the two receivers will be identical.

Rapid Static surveys feature short observation times. It is particularly important for Rapid Static that ionospheric disturbances are more or less identical for both sites.

Thus, for all GPS surveying, and for Rapid Static in particular, it is sound practice to minimise baseline lengths.

1.2. Temporary reference stations for Rapid Static surveys

As observation time and accuracy are mainly a function of baseline length, it is highly recommended that baseline lengths should be kept to a minimum.

Depending on the area and number of points to be surveyed by GPS, you should consider establishing one or more temporary reference stations.

Baselines radiating from a temporary reference station can be several kilometres in length. Remember, however, that it is advantageous to minimise baseline lengths. The table in section 4 provides a guide to baseline lengths and observation times.

In terms of productivity and accuracy, it is much more advantageous to measure short baselines (e.g. 5 km) from several temporary reference stations rather than trying to measure long baselines (e.g. 15 km) from one central point.

1.3. Check the newly surveyed points

In all types of survey work it is sound practice to cross check using independent measurements. In classical survey you check for inaccurate or wrong control points, wrong instrument orientation, incorrect instrument and target heights, etc. You close traverses and level loops, you fix points twice, you measure check distances! Depending on the job and accuracy needed it is well worthwhile applying the same principles to GPS surveying.

One should be particularly careful with Rapid Static with short observation times. If the observation time is too short, or the satellite geometry (GDOP) is poor, or the ionospheric disturbances are very severe, it can happen that the post-processing software will resolve ambiguities but the results may exceed the quoted specifications.

Depending on the accuracy needed, the user should be prepared to check newly surveyed points. This is particularly important if observation times have been cut to a minimum and recommendations regarding GDOP ignored.

For a complete independent check:

Occupy a point a second time in a different window. This ensures that the set-up, the satellite constellation, and the atmospheric conditions are different.

Close a traverse loop with a baseline from the last point to the starting point.

Measure independent baselines between points in networks.

A partial check can be obtained by using two reference stations instead of one. You will then have two fixes for each point but each will be based on the same roving-receiver observations and set up.

1.4. Night versus day observations. Measuring long lines

Generally speaking, the longer the baseline the longer one has to observe.

The ionosphere is activated by solar radiation. Thus ionospheric disturbance is much more severe by day than by night. As a result, the baseline range for night observations with Rapid Static can be roughly double that of day observations. Or, put another way, observation times for a baseline can often be halved at night

At the present time ionospheric activity is at peak, high levels in an 11 -year cycle.

The table in section 3 provides a guide to baseline lengths and observation times under the current very unfavourable ionospheric conditions.

For baselines up to about 20 km, one will usually attempt to resolve the ambiguities using the Rapid Static algorithm in SKI post-processing software.

For baselines over 20 km, it is usually not advisable to resolve ambiguities. In this case a different post-processing algorithm is used in SKI. This algorithm eliminates ionospheric influences to a large degree but destroys the integer nature of the ambiguities.

1.5. Observation schedule - best times to observe

When you inspect the satellite summary and GDOP plots, you will usually see several good windows distributed through a 24-hour period. As you can only work with Rapid Static during good windows, you should plan your schedule carefully.

It is impossible to plan GPS observations to the minute. Rather than trying to squeeze the maximum number of points into a window by cutting observation times to the bare minimum, it is usually better to measure one point less and to observe for a few minutes longer. Particularly for high-accuracy work, it pays to be conservative and not to risk poor results.

1.6. Consider the transformation to local co-ordinates

System 500 provides accurate relative positions of points that are observed in a GPS network and linked in postprocessing. The co-ordinates are based on the WGS 84 datum.

For most projects it will be necessary to transform the WGS 84 co-ordinates obtained from GPS survey into local grid co-ordinates, i.e. into Lo31 on the local projection based on the local ellipsoid.

In order to be able to compute this transformation, known points with local co-ordinates have to be included in the GPS network. These common points, with WGS 84 and local co-ordinates, are used to determine the transformation parameters and to check the consistency of the local system.

The common points should be spread evenly around (and even throughout) the project area. For a correct computation of all transformation parameters (shifts, rotations, scale), at least three - but preferably four or more - points have to be used.

Read the SKI software manual for details on transformation using Datum and Map.

1.7. Network design

GPS surveys performed by static methods where accuracy is a primary consideration require that observations be performed in systematic manner and that closed geometric figures be formed to provide loops.
In terms of productivity and accuracy, it is usually preferable to measure short baselines from several temporary reference stations rather than trying to measure long baselines from just one central point.
In summary, the following are the major points of network design:

- **The network should consist of closed loops or other geometric figures.**
- **Ties should be made to at least three horizontal control points which should also be directly occupied.**
- **Ties should be made to at least four vertical control points by most direct means.**

Check network of temporary reference stations using double fixes or independent baselines.
Fix new points from temporary reference stations using Rapid-Static radial baselines.
Consider the need to check critical points.

1.8 Overall Planning

✔ **Plan the campaign carefully**

✔ **Consider the job, number of points, accuracy needed**

✔ **Consider connection to existing control**

✔ **Consider the transformation to local co-ordinates**

✔ **Consider the best ways to observe and compute**

✔ **For high accuracy, keep baselines as short as possible**

✔ **Use temporary reference stations**

✔ **Consider the need for independent checks:**
- **Occupying points twice in different windows**
- **Closing traverse loops**
- **Measuring independent baselines between points**

✔ **Consider using two reference stations**

✔ **Use good windows**

✔ **Consider observing long lines at night.**

✔ **For high-accuracy work, try not to squeeze the maximum number of points into a window**

2. Mission planning

2.1. GDOP - Geometric Dilution of Precision

The GDOP value helps you to judge the geometry of the satellite constellation. A low GDOP indicates good geometry. A high GDOP tells you that the satellite constellation is poor. The better the GDOP the more likely it is that you will achieve good results.

Poor satellite geometry can he compared with the "danger circle" in a classical resection. If the geometry is poor, the solution in post-processing will be weak.

For Rapid Static you should observe when the GDOP is less than or equal to 8. A GDOP of 5 or lower is ideal.

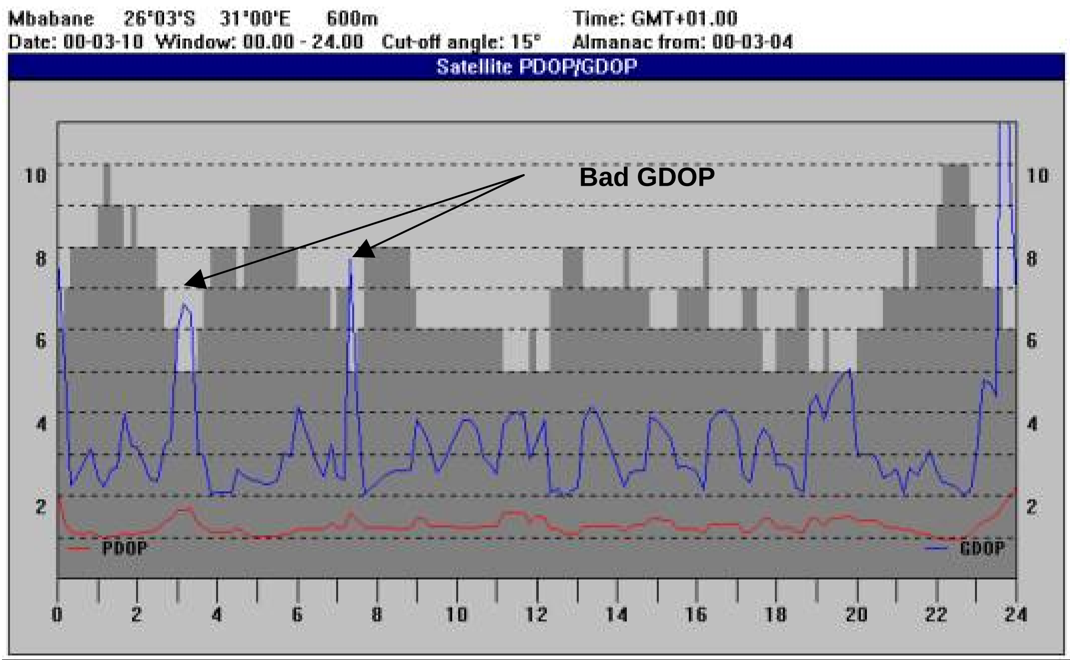


Figure 2.1. GDOP plot.

2.2. Selecting good windows for successful GPS surveying

For successful, high-accuracy GPS surveying it is essential that the observations are taken in good windows. Provided that you know the latitude and longitude to about 1°, the satellite summary, GDOP, elevation, and sky-plot panels in the Survey Design component of SKI will help you to select good windows in which to observe.

You should take particular care when selecting windows for Rapid Static observations.

A suitable observation window for Rapid Static must have four or more satellites, with GDOP < or = 8, above a cut-off angle of 15 at both the reference and roving receiver.

GDOP plots often show steep flanks at each side of a good window. These flanks of rapidly changing GDOP are usually due to rising or setting satellites. Avoid these flanks. Avoid taking Rapid Static observations when the GDOP is changing quickly.

Poor windows should only he used to bridge between two or more good windows when observing for long periods of time, e.g. at reference stations and for long lines.

If there are obstructions near a point, use the sky plot to find out if the signals from a satellite could be blocked. This could cause the GDOP to deteriorate. Check the GDOP by clicking the satellite "off' in the Survey Design component. A careful reconnaissance of such sites is well worthwhile.

Selecting Good Windows

Window for Rapid Static:
✔ **4 or more satellites above 15° cut-off angle**
✔ **GDOP < or =8**

Whenever possible:
✔ **5 or more satellites**
✔ **GDOP < or =5**
✔ **Satellites above 20°**

✔ **Avoid flanks of rapidly changing GDOP at side of good windows**

✔ **Use sky plot to check for obstructions. Recompute GDOP if a satellite is obstructed**
✔ **Be wary if 2 out of 4 or 5 satellites are low (<20°)**

3. Observation times and baseline lengths

The observation time required for an accurate result in post-processing depends on several factors: baseline length, number of satellites, satellite geometry (GDOP), ionosphere.

As you will only take Rapid Static observations when there are four or more satellites with GDOP < or = 8, the required observation time is mainly a function of the baseline length and ionospheric disturbance.

Ionospheric disturbance varies with time and position on the earth's surface. As ionospheric disturbance is much less at night, night-observation times for Rapid Static can often be halved, or the baseline range doubled. Thus it can be advantageous to measure baselines from about 10 km to 20 km at night.

Ionospheric activity is currently at a peak, high levels in an 11-year cycle. As the activity decreases it can be expected that observation times can be reduced or baseline lengths increased.

Ionospheric activity is also a function of position on the earth's surface. The influence is usually less in mid latitudes than in polar and equatorial regions.

Lines above about 15 km (day) or 20 km (night) should be observed for at least 1 hour with a good satellite coverage. For lines of about 30km and over, one should observe for at least two hours in order to reach the 5mm + 1 ppm specification (1 part per million).

Note that signals from low-elevation satellites are more affected by atmospheric disturbance than those from high satellites. For Rapid Static observations, it can be worth increasing the observation times if two out of four or five satellites are low (say <20°).

Times and Baseline Lengths

Observation time depends upon:

- **Baseline length**
- **Number of satellites**
- **Satellite geometry (GDOP)**
- **Ionosphere**

Ionospheric disturbance varies with time, day/night, month, year, position on earth's surface

Unless one is extremely restrictive, it is impossible to quote observation times that can be fully guaranteed. The following table provides a guide. It is based on tests in mid-latitudes under the current high levels of ionospheric disturbance.

No. of sats **GDOP** <=8	Approximate **baseline lenght**	Approximate observation time **by day**	Approximate observation time **by night**
Rapid Static			
4 or	5 Up to 5 km	10 to 15 mins	10 mins
4 or 5	5 to 10 km	20 to 25 mins	15 to 20 mins
4 or 5	10 to 15 km	Over 30 mins	25 to 35 mins
Static			
4 or 5	5 to 30km	1 to 2 hours	1 hour
4 or 5	Over 30 km	2 to 3 hours	2 hours

Table 3. Observation time and baseline length

The table provides an approximate guide to baseline lengths and observation times for mid latitudes under the current very high levels of ionospheric activity.

4. Field observations

4.1. Reference site

GPS surveying is a differential technique with baselines being "observed" and computed from the reference to the rover. As many baselines will often be measured from the same reference station, the choice and reliability of reference stations are of particular importance.

To avoid multipath or imaging effects, it is recommended that any vehicle be parked as far away as possible from the antenna. Parking the vehicle at least 15 m away from the antenna is adequate.
A rather minor problem using GPS should not be overlooked: the calibration of tribrachs. ***A survey will only be as accurate as the surveyor's ability to centre the antenna over the survey point.***
Sites for reference stations should be chosen for their suitability for GPS observations. A good site should have the following characteristics:

- **No obstructions above the 15° cut-off angle**

- **No reflecting surfaces that could cause multipath**
- **Safe, away from traffic and passers-by. Possible to leave the receiver unattended**
- **No powerful transmitters, (radios, TV antennas, etc.) in the vicinity**

The results for all roving points will depend on the performance of the reference receiver! Thus the reference receiver must operate reliably:

- **Power supply must be ensured. Use a fully-charged battery. Consider connecting two batteries. Consider a car battery**
- **Double-check the antenna height and offset**
- **Make sure that the mission parameters (observation type, recording rate etc) are correctly set and match those of the roving receiver**

Note that the reference receiver does not have to be set up on a known point. It is far better to establish temporary reference stations at sites that fulfil the requirements listed above than to set up the reference receiver on known points that are not suitable for GPS observations.

For computing the transformation from WGS 84 to the local system, known points with local co-ordinates have to be included in the UPS network. These points do not have to be used as reference stations. They can be measured with the roving receiver.

4.1.1. Need for one known point in WGS 84

The computation of a baseline in data processing requires that the co-ordinates of one point (reference) are held fixed. The co-ordinates of the other point (rover) are computed relative to the "fixed" point.

In order to avoid that the results are influenced by systematic errors, the co-ordinates for the "fixed" point have to be known to within about 20 meters in the WGS 84 coordinate system. Whenever possible, the WGS 84 co-ordinates for the "fixed" point should be known to within about 10 meters otherwise scale errors of about 1 to 2 ppm will be introduced.

This means that for any precise UPS survey the absolute co-ordinates of one site in the network have to be known in WGS 84 to about 10 meters. WGS 84 co-ordinates for one site will often be available or can be easily derived as explained in section 6.

If WGS 84 co-ordinates for one site are not known or cannot be derived, the Single Point Position computation in SKI can be used. Remember, however, that *Selective Availability* (SA) is usually switched on. The only way to overcome SA is to observe for sufficient time for the effects of SA to be averaged out in the Single Point Position computation.

The reference receiver will usually observe for several hours as the rover moves from point to point. In such a case, the Single Point Position for the reference receiver computed in SKI should be relatively free from the effects of SA.

If a Single Point Position is computed from only a few minutes of observations, the effects of Selective Availability will not be averaged out. The result could be wrong by 100 m or more due to SA.

When computing the Single Point Position for the starting point of a network, always compute for a site for which you have several hours of observations. The resulting WGS 84 co-ordinates should then be correct to within about 10 meters.

The minimum observation for the computation of a reliable Single Point Position is probably about 2 to 3 hours with four or more satellites and good GDOP. The longer the observation time, the better the Single Point Position will be.

4.2. Observing new points with the roving receiver

The operator of the roving receiver should also pay attention to certain points. This is particularly important for Rapid Static surveys with short measuring times.

Make sure that the mission parameters (observation type, recording rate etc) are correctly set and match those of the reference receiver.

Check the antenna height and offset.

Watch the GDOP when observing for only a short time at a point.

For 5 to 10mm + 1 ppm accuracy with Rapid Static, only take measurements with GDOP <or = 8.

GDOP plots often show steep flanks with rapidly changing GDOP. Avoid these flanks in Rapid Static observations. It is better to stop logging data than to observe when the GDOP is changing quickly. In such circumstances wait for a reasonable GDOP and then measure again.

4.2.1. Use the Stop and Go Indicator as a guide

The Stop and Go Indicator in the Controller provides the roving-receiver operator with an approximate guide to measuring times for Rapid Static observations with four or more satellites and GDOP less than or equal to 8. It estimates when sufficient observations should have been taken for successful post-processing (ambiguity resolution) to be possible.

At the present time estimates are calculated for two baseline ranges, 0 to 5 km and 5 to 10 km. The estimates are based approximately on the current situation for GPS observations in mid latitudes and assume that the reference and roving receiver are tracking the same satellites.

As the Stop and Go Indicator can only monitor the roving receiver it can only provide an estimate for the required measuring time. It should be used only as a guide.

4.3. Fill out a field sheet

As with all survey work, it is well worthwhile filling out a field sheet for each site when taking GPS observations. Field sheets facilitate checking and editing at the data-processing stage.
Each set-up should be logged on GPS observation sheets, defining the following information:

- **Point identifier**
- **Antenna type**
- **Antenna height**
- **Antenna offset**
- **Point sketch**
- **Start and end of observation interval**

Please refer to GPS booking sheet for details.

Reference Stations

- ✔ **No obstructions above 15° cut-off angle**
- ✔ **No reflecting surfaces (multipath)**
- ✔ **Safe, can leave equipment unattended**
- ✔ **No transmitters in vicinity**
- ✔ **Reliable power supply**
- ✔ **Ample memory capacity**
- ✔ **Correct mission parameters (observation type, recording rate)**
- ✔ **Check antenna height and offset**
- ✔ **Does not have to be a known point**
- ✔ **It is better to establish temporary reference stations at good sites rather than at unsuitable known points**
- ✔ **For precise GPS surveying, WGS 84 co-ordinates for one point have to be known to about 10 meters**

Roving Receiver

- ✔ **15° cut-off angle**
- ✔ **Obstructions should not block signals**
- ✔ **No reflecting surfaces (multipath)**
- ✔ **No transmitters in vicinity**
- ✔ **Fully-charged battery**
- ✔ **Sufficient memory capacity**
- ✔ **Correct mission parameters (observation type, data-recording rate)**
- ✔ **Check antenna height and offset**
- ✔ **Observe in good windows**
- ✔ **Watch the GDOP <or =8**
- ✔ **Use Stop and Go Indicator as a guide**
- ✔ **Fill out a field sheet**

Practical Hints

- ✔ **Tribrachs: check the bubble and optical plummet**
- ✔ **Level and centre correctly**

- **Check the height reading and antenna offset.**
  An error in height affects the entire solution!

- **Use a radio to maintain contact between reference and rover**

- **Consider orienting the antenna sensors for the most precise work**

GPS BOOKING SHEET SGD

Station and Project Information

Station Name	Date(YY-MM-DD)

Receiver Type/ Serial Number	Session

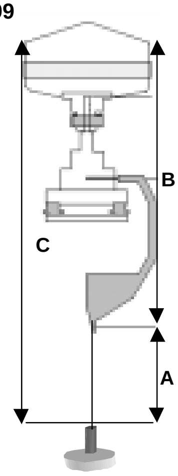
GMT/UTC start	GMT/UTC stop

Antenna Height Vertical Meas. SR299/SR399

Before Meas.	After Meas.
A=	A=
B=0.441	B=0.441
C=	C=

Antenna Eccentrisity:
SR299 B=0.441

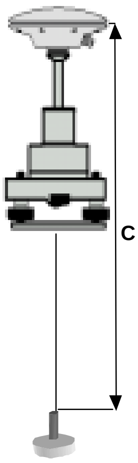
Distance to ARP:
AT302 =0.091



A=Vertical Reading
B=Vertical Offset
C=Pillar setup/ Direct vertical reading

Antenna Height Slope Meas. AT502

Before Meas.	After Meas.
C=	C=



C=Pillar setup/ Direct vertical reading

Station Setup/Station Diagram	**Description/Comment**

Operator	**Control of Tripod**

5. Data transfer and backup of projects

5.1. Checking and editing during data transfer

Data can be transferred to SKI the from the PCMCIA card, from the Controller, or from a disk with backed-up raw data. During data transfer, the operator has the opportunity to check and edit certain data. It is particularly advisable to check the following:

Point identification: Check spelling, upper and lower case letters, spaces etc.

Make sure that points that have been observed twice have the
same point identification. Make sure that different points in the same project have different point identifications.

Height reading and antenna offset: Compare with field sheets

Initial co-ordinates: As explained in 4.1.1, for precise survey the co-ordinates of one site in a network should be known in WGS 84 to about 10 meters. It is preferable to input these values during Import rather than after computation using the View and Edit.

Note that some of the above site-related parameters can be changed in View and Edit. However, the affected baselines have then to be recomputed.

5.2. Backing up raw data and projects

After reading in a data set always make a back-up on a floppy disk or on the hard disk. You can then erase and reuse the memory card but you still have the raw data. When backing up data from several memory cards, it is advisable to create a directory for each card.

After importing all the data related to the project it is often worthwhile making a backup of the whole project directory before starting to process the data. If for some strange reason the project data base should become corrupted you have now only to delete all files in the original directory and restore the backup files This is quicker than importing all the raw data again

6. Deriving initial WGS 84 co-ordinates for one point

As explained in 5.1.1, the computation of a baseline requires that the co-ordinates of one point are held fixed. The co-ordinates of the other point are computed relative to the "fixed' point.

For any precise GPS survey the absolute co-ordinates of ONE site in the network have to be known in WGS 84 to about 10 meters. WGS 84 co-ordinates for one site will often be available or can be easily derived.

Using the Datum and Map component of SKI it is easy to transform the grid co-ordinates of a known point to geodetic or cartesian co-ordinates on the local ellipsoid. If the approximate shifts between the local datum and WGS 84 are known, WGS 84 co-ordinates to well within the required accuracy can be obtained.

As explained in 5.1, the reference receiver does not have to be on a known point. If the reference receiver was on a new (unknown) point and a known point was observed with the roving receiver, simply compute the first baseline from the known point (rover) to the unknown point (reference) in order to obtain and store the required initial WGS 84 co-ordinates for the reference receiver.

If good initial WGS 84 co-ordinates for the reference site are not known or cannot be derived as explained in the last two paragraphs, the Single Point Position computation in SKI can be used. When using the Single Point Position computation always compute for a site for which there are several hours of observations. The effects of Selective Availability should then average out and the resulting WGS 84 co-ordinates should be correct to within the required 10 meters. See section 6 for further details.

Always keep in mind that poor initial co-ordinates for the reference receiver will affect the baseline computation and can lead to results outside the quoted specifications.

7. Data-processing parameters

7.1. Cut-off angle

It is common practice in GPS surveying to set a 15° cut-off angle in the receiver. 15° is also the system default value in data processing. Avoid cut-off angles less than 15° if precise results are to be obtained.

Although you can increase the cut-off angle you should be cautious when doing so. If the cut-off angle for data processing is set higher than in the receiver some observations will not be used for the baseline computation and you may 'lose" a satellite. It could happen that only three satellites would be used in the computation instead of four. You cannot expect a reliable answer with only three satellites.

It can sometimes be advantageous, however, to increase the cut-off angle to about 20° in case of a disturbed ionosphere and provided that sufficient satellites above 20° with good GDOP have been observed (use the Survey Design component in SKI to check the GDOP).

You may sometimes find that a baseline result is outside specifications even though five satellites have been observed. If one of the satellites never rises above about 20' the observations to this satellite may be badly affected by the ionosphere. Raising the cut-off angle and computing with only four high-elevation satellites can sometimes produce a better result.

7.2. Tropospheric model

It does not make much difference whether you select Hopfield or Saastamoinen, but you should never work with "no troposphere". You cannot expect to achieve good results if no tropospheric model is used.

7.3. Ionospheric model

This parameter is only used for baselines up to the limitation value (see 7.7.), that is for baselines for which SKI will try to resolve ambiguities.

The Standard model is based on an emperical ionospheric behaviour and is a function of the hour angle of the sun. When the Standard model is chosen corrections is applied to all phase observations. The corrections depend on the hour angle of the sun at the time of measurement and the elevation of the satellites.

An incorrect ionospheric model or no model will introduce a scale factor in the computed baselines. The computed baselines will usually be too short if "no model" is applied.

If the option "no model" is used no corrections are applied. Results of baselines observed during day can then be too short by up to 4 to 5 ppm.

For long lines above the limitation value (see 7.7), the ionospheric effects are eliminated by evaluating a linear combination of L1 and L2 measurements, the so-called L3 observable. Ambiguity resolution is not attempted.

7.4. Ephemeris

SKI uses the broadcast ephemeris recorded in the receiver. This is standard practice throughout the world for all routine GPS surveying. For standard GPS survey work there is little to be gained by using a precise ephemeris.

7.5. Data used for processing

For precise GPS surveying, one will normally accept the system default setting of "code and phase".

"Code only" can be used for the rapid calculation of baselines when high accuracy is not required, for instance in exploration or offshore work. If only code observations are evaluated the accuracy cannot be better than about a meter.

For the precise measurement of baselines it should make little difference whether one processes "code and phase" measurements together or "phase only". The results should be more or less identical.

For long lines above about 100 km, code observations can assist a high accuracy solution provided that the ephemerides are sufficiently good.

If code measurements are corrupted for some reason, one can process baselines using "phase only".

For processing kinematic data, "code and phase" have to be used for precise results. Code only can be used if high accuracy is not required.

7.6. Frequency

The SR299 and SR 530 are dual-frequency receivers. Short observation times with Rapid Static are only possible with dual-frequency observations. Long lines can only be processed successfully using L1 and L2 data.

Thus there is little point in processing with anything but L1 and L2. Take full advantage of the System 200 and 530 dual-frequency hardware and software. Always use "L1 and L2".

7.7. Limitation

With this parameter you can determine how SKI should compute baselines. The system default value is 20 km.

For baselines up to the limitation value, L1 and L2 measurements are introduced as individual observations into the least-squares adjustment.
Resolution of the L1 and L2 integer ambiguities using *the Fast Ambiguity Resolution Approach* (FARA) is always attempted.

For baselines above the limitation value, a so-called L3 solution is performed. The L3 observable is a linear combination of the L1 and L2 measurements. The advantage of the L3 solution is that it eliminates the influence of the ionosphere. However, it also destroys the integer nature of the ambiguities, therefore no ambiguity resolution can be carried out. This is not important, however, as successful ambiguity resolution over long distances is in any case hardly feasible.

7.8. Solution update

Solution update only applies to kinematic data. It allows you to define the interval (epoch) at which a kinematic solution is required.

7.9. À priori rms

The à priori rms (root mean squares) is used to minimize the possibility of unreliable baseline results.

During the computation of a baseline, the least-squares adjustment computes the root mean square (rms) of a single-difference phase observation (i.e. the rms of unit weight). This value is compared with the à priori rms.

The rms of a single-difference phase observation is largely dependent on the baseline length, observation time, and ionospheric disturbance. Ionospheric disturbance is less at night.

The following table provides a very approximate guide to the rms of a single difference that a user could expect:

Distance	Day		Night	
	Observation time		Observation time	
	≤10 min	>10 min	≤10 min	>10 min
	rms	rms	rms	rms
Up to 5km	<10mm	<10mm	<10mm	<10mm
5 to10km	<15mm	<25mm	<10mm	<15mm
10 to 20km	<15mm	<40mm	<10mm	<15mm

Table 7.9. Rms values and observation times

If the rms of a single-difference observation exceeds the à priori rms, the baseline solution with fixed ambiguities will be rejected and only the float solution will be presented (ambiguities not resolved).

The system default value for à priori rms is 10 mm.

For Rapid Static observations with up to 10 minutes of measurement time, one should be cautious about increasing the à priori rms because an unreasonably high rms value could lead to a weak solution being accepted.

For longer observation times - let us say about 30 minutes or more - the à priori rms can be set higher without undue risk.

Note that the à priori rms applies only to base lines up to the limitation value (see 7.7). For base lines over the limitation value ambiguity resolution is not attempted.

7.10 Receiver clock offset

Always leave at the 5 microsecond default value when processing data from WILD SR299. Increasing the clock-offset value may be necessary when processing data from non-WILD receivers.

8. Baseline selection and strategy for computation.

Before starting data processing one should consider carefully how best to compute the network. Points to be considered include:

- **Obtaining good initial WGS 84 co-ordinates for one point**
- **Connections to existing control**
- **Computing the co-ordinates of temporary reference stations**
- **Rapid static measurements from temporary reference stations**
- **Long lines**
- **Short lines**

If more than one temporary-reference station has been used, this "network" of temporary-reference stations should he computed first. This may also involve the connection to existing control points. Select and compute line by line, inspect the results, and store the co-ordinates of temporary reference stations if the baseline computations are in order.

It is highly advisable to check the co-ordinates for each temporary-reference station using double fixes or other means, as all radial roving points depend on temporary-reference stations.

Once the "network" of temporary-reference stations has been computed, all remaining baselines - i.e. the radial baselines from the temporary-reference stations to roving receiver points - can be computed.

If baselines of greatly differing lengths have to be computed, it can be worthwhile making two or more baseline selections and computation runs. In this way you can select and compute batches of baselines which fall into the same category of expected à priori rms (see 7.9).

Try to avoid mixing baselines of totally different lengths in the same computation run. And avoid mixing short-observation Rapid-Static baselines with long-observation Static baselines.

Before starting the computation, consider if it would be advantageous to change the à priori rms from the 10mm default value.

Data Import and Computation

Check and edit during data transfer:

- **Point identification**
- **Height reading and antenna offset**
- **WGS 84 co-ordinates of initial point**

Back up raw data and project

Consider the following carefully:

- **How best to compute the network**
- **The need for good WGS 84 co-ordinates for one point**
- **Connection to existing control**
- **The need to transform to local co-ordinates**
- **Computation of network of temporary reference stations**
- **Computation of new points from temporary reference stations**
- **Long lines**

- **Short lines**
- **Data-processing parameters**

9. Interpreting the baseline results

When interpreting the results, one has to distinguish between baselines up to the limitation value and baselines above this value (see 7.7).

For baselines up to the limitation value, ambiguity resolution using the *Fast Ambiguity Resolution Approach* (FARA) is always attempted.

For baselines above the limitation value, a so-called L3 solution (linear combination of L1 and L2 measurements) is performed. This eliminates the ionospheric effects but destroys the integer nature of the ambiguities. Thus ambiguity resolution is not carried out.

9.1. Baselines up to the limitation value

9.1.1. Ambiguities resolved (A=Y)

For baselines up to 20 km (system default for limitation), ambiguity resolution should always be successful if good results are to be achieved.

For baselines up to the limitation value, FARA searches for all possible combinations of ambiguities and evaluates the rms of a single-difference observation for each set of ambiguites. It then compares the two solutions with the lowest rms values. If there is a significant difference between the two rms values, the ambiguity set yielding the lowest rms value is considered as the correct one. This decision is based on statistical methods.

The least-squares adjustment can only provide the "most probable" values. These will usually be the "true values".

However, one should also be aware that very severe ionospheric disturbances can cause systematic biases in the phase observations. In this case, although the results of the least-squares adjustment will be statistically correct, they could be biased away from the true values.

The statistical methods implemented in FARA are based on very restrictive criteria in order to try to ensure the highest probability of a reliable result.

When the ambiguities are resolved, you know that the FARA algorithm has found a "most probable" solution with an rms value that is significantly lower than for any other possible ambiguity set.

If the guidelines for baseline lengths, observation windows, number of satellites, GDOP, and observation times are followed (combined perhaps with your own experience), the results of baselines for which the ambiguities are resolved should be within the system specifications.

Nevertheless, as explained above, it is simply impossible to eliminate completely the possibility of the occasional biased result.

9.1.2. Ambiguities not resolved (A=N)

As already explained, ambiguity resolution should always be successful for baselines up to 20 km if good results are to be obtained.

If insufficient observations were taken or the satellite constellation was poor, the FARA algorithm will not be able to resolve the ambiguities. If the ambiguities are not resolved it is most unlikely that the system specifications will be achieved.

If the ambiguities are not resolved in Rapid Static (short observation times) it is difficult to give an indication of accuracy. However, as a rough guide, one could multiply the sigma values for each estimated co-ordinate by 10 in order to obtain an approximate estimate of the accuracy of the baseline computation.

Note that for baselines up to 20 km, it should normally be possible to resolve the ambiguities provided that sufficient observations have been taken (see section 3 for a guide to baseline lengths and observation times). If the ambiguities are not resolved check the rms values in the logfile (see section 10).

9.2. Baselines above the limitation value

For baselines above the limitation value (system default = 20 km), SKI eliminates the ionospheric effects but does not attempt to resolve ambiguities.

Thus the result will always show "ambiguities not resolved" (A=N).

Note that there is usually no benefit in trying to resolve ambiguities for lines over 20km.

10. Inspecting the logfile and comparing results

10.1. Baselines up to the limitation value

For baselines up to the limitation value, ambiguity resolution using the *Fast Ambiguity Resolution Approach* (FARA) is always attempted.

When you look at the logfile, you will find a summary of FARA at the end of each baseline output. You should check the following:

- Number of satellites: there should always be at least four.
- The rms float: this is the rms value before fixing ambiguities.
- The rms fix: this is the rms value after fixing ambiguities. The rms fix will usually be slightly higher than the rms float.

The à priori rms: this is the value set in the data-processing parameter table.

As explained in 7.9, if the rms float exceeds the à priori rms, the baseline solution with fixed ambiguities will be rejected and only the float solution will be presented (ambiguities not resolved). Thus if ambiguities are resolved the rms float and rms fix have to be lower than the a' priori rms.

The table in 7.9 provides an approximate guide to the rms values (float and fix) that can be expected.

If the a priori rms is lower than the rms float or rms fix one can consider increasing the a priori rms value. However, as explained in 7.9, one should exercise a certain amount of caution when doing this for Rapid Static observations with up to 10 minutes of measurement time. The reason is that this could allow unreasonably high rms float and fix values and could lead therefore to a weak solution being accepted.

For longer observation times - let us say about 30 minutes or more - the à priori rms can usually be set higher without undue risk.

Widening the à priori rms value for successful baseline computation requires a certain amount of experience and judgement.

If baselines of greatly differing lengths have to be computed, it is advisable to make two or more computation runs. In this way you can select and compute batches of baselines which fall into the same category of expected à priori rms (see 7.9).

Note that the logfile does not contain information about satellite windows, GDOP etc. When planning the survey and measuring in the field, the user should ensure that observations are taken in good windows to sufficient satellites with good GDOP and that the observation times are sufficient for the baseline lengths and time of day.

10.2. Baselines above the limitation value

For baselines above the limitation value (system default = 20 km), SKI eliminates the ionospheric effects but does not attempt to resolve ambiguities.

When inspecting the logfile check the following:

The number of satellites observed. The rms of unit weight.

The rms of unit weight should be less than about 20 mm for lines of about 20 km to 50 km. For lines over 50 km the rms of unit weight will usually be higher due to the minor inaccuracies in the broadcast ephemeris.

10.3. Compare the logfile against the field sheets

If the results are not as good as you would expect, it can be well worthwhile comparing the information in the logfile with that in the field sheets. Check if the number of satellites used in the baseline computation is the same as that noted in the field sheets. Remember to check the reference Station as well as the rover. If the number of the satellites is not the same, the GDOP values could be higher than you expected. Check the actual GDOP for the satellites used in the computation using the Survey Design Component of SKI.

10.4. Compare the results for double fixes

If a point was observed twice in different windows or two reference receivers were operating simultaneously, you should compare the resulting co-ordinates.

11. Storing the results

After inspecting the summary of results and the logfile, store the results that meet your accuracy requirements.

The co-ordinates are averaged (weighted mean) if more than one solution for a point is stored. For instance if you store the co-ordinates for point A from one baseline solution and then you compute and store the co-ordinates for point A again from another baseline solution, the stored co-ordinates will be updated to the weighted mean values from the two solutions. The weighted mean is taken provided the co-ordinates agree to within the averaging limit set in the "project" component of SKI (default = 0.075m).

It follows that you should exercise a certain amount of care when storing points that have been fixed in more than one baseline computation. Compare the results before storing.

Interpreting and storing the results

For lines up to 20 km, ambiguity resolution should be successful if high-accuracy results are to be obtained

For long lines over 20 km, the L3 solution without ambiguity resolution will normally be used

Baselines up to the limitation value (default = 20 km):
Ambiguities resolved (A=Y):
- **FARA has found most probable solution**
- **Results should normally meet specifications**
  Ambiguities not resolved (A=N):
- **Float solution presented**
- **Result outside specifications, inspect logfile**
- **Consider increasing à priori rms and recomputing**

Baselines above the limitation value (default = 20 km):
- **Static, FARA not used**
- **L3 solution, ambiguity resolution not attempted**
- **Results should meet specifications provided**
- **sufficient observations taken**
- **Long lines need long observation times**

Inspect double fixes, independent baselines etc

Store results that meet accuracy requirements Co-ordinates are avveraged if more than one result stored

12. Transformations and output of results

The results of the baseline computations are co-ordinates in the WGS 84 system. Using the Datum and Map component of SKI, these co-ordinates can be transformed into co-ordinates in the Lo31 grid system using the seven parameter transformation solution. Please refer to the help files of the SKI program for details.

13. Guidelines to establishment of photo-control points

13.1. Setting and installation of photo-control points

Selection of good sites for installation of photo-control is essential for a successful completion of the aerial triangulation process. Extra care should be taken when selecting the environment of the site. The following points should be considered:

- **Photo-control points should be installed in open area free of obstacles**
- **Select signal background which is dark and gives good contrast**

- **The ground should be as flat as possible**
- **Do not install signal in environment where it can be confused with other objects**
- **Select signal material that is off-white**
- **Fill in the photo-control sheet**
- **Make a detailed sketch of the photo-control point and the surroundings**
- **Ensure correct signal size**

13.2. Signal material

Signal colour should be off-white. Material like white limestone or light grey paint can be used for this purpose. The off-white colour prevents overexposure of the signals in the aerial photos.

Photo 13.2. Installation of signal using slaked lime

When installing a signal made of slaked lime consider the following:

- **Remove the topsoil using a shovel or spade**
- **Fill the excavation with a thin layer of lime**
- **Add water to the lime**
- **Let the mixture of lime and water dry**

13.3. Background colour

Install the signal on a non-reflecting surface. When possible select sites with dark surface. Avoid surfaces that are coloured white, light grey or red (example red soil). Surface with the same grey scale as the material of signal, makes it difficult to identify the photo-control in the aerial photos. It’s a good idea to burn down the grass and small vegetation around the signal.
Add small piles of rocks around the outline of the signal to increase the contrast.

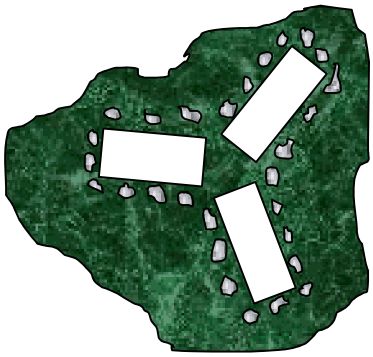
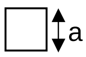
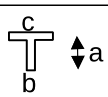
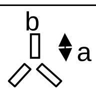
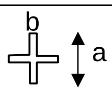


Figure 13.2 Contrast of signal

13.4. Signal shape and size

Always keep in mind that **it is better to make the signal too big than too small.**
The minimum size of floating mark of an analytic plotter is approximate 40 mμ. The projection of the signal in the aerial photo should not be smaller than the minimum size of the floating mark.
The signal is often slightly overexposed in the aerial photo, sometimes as much as 30%.

The following table provides recommendatory size of photo-control signals compared to the scale of the aerial photo and flight altitude (wide-angle lens, focal length 153mm).

Shape	**Dimensions of photo-control signals**			
	Photo scale 1:5000	**Photo scale 1:8000**	**Photo scale 1:10000**	**Photo scale 1:20000**
	Flight altitude 800m	**Flight altitude 1200m**	**Flight altitude 1500m**	**Flight altitude 3000m**
	a=0.4 m	a=0.5 m	a=0.6 m	a=1.2 m
	a=0.6 m b=0.2 m c=0.6 m	a=0.8 m b=0.3 m c=0.8 m	a=1.1 m b=0.4 m c=1.1 m	a=2 m b=0.6m c=2 m
	a=0.4 m b=0.2 m	a=0.6 m b=0.3 m	a=0.8 m b=0.4 m	a=1.2 b=0.55
	a=0.6 m b=0.2 m	a=0.8 m b=0.3 m	a=1.1 m b=0.4 m	a=2 m b=0.6 m

13.5. Free line of sight to the horizon

It is important that there are no major obstructions that can destroy the free line of sight from the photo-control to the aircraft operating the camera.
Free line of sight is defined by a pyramid with top angle 90°.

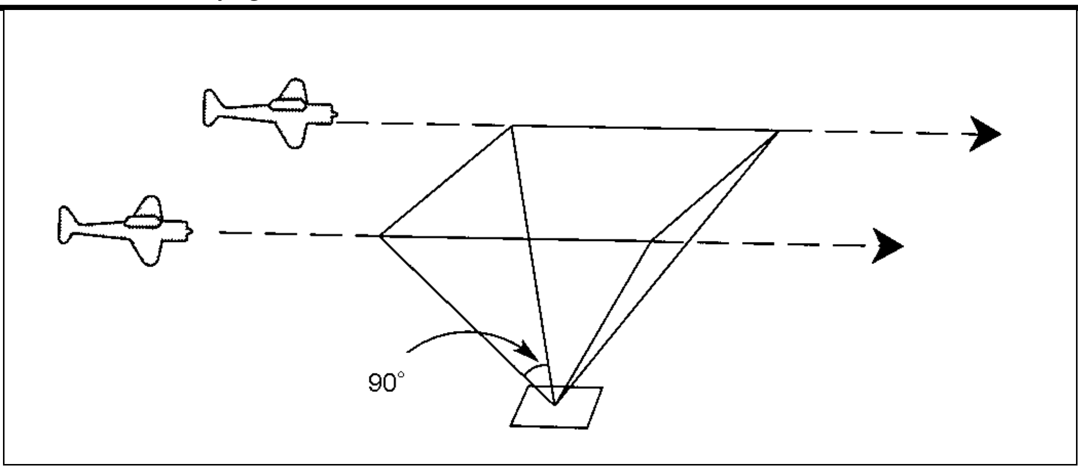


Figure 13.5.1. Line of free sight

As a rule no obstacles should exceed 45°. Ideal conditions for a GPS survey is no obstructions above 15° degrees cut-off angle.

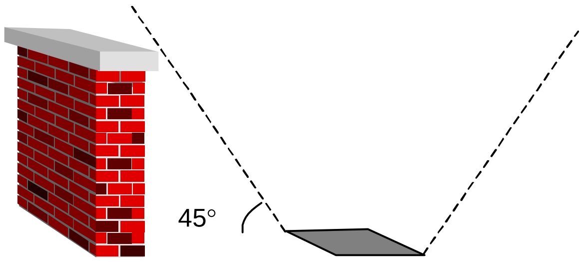


Figure 13.5.2. Obstructions should not exceed 45°

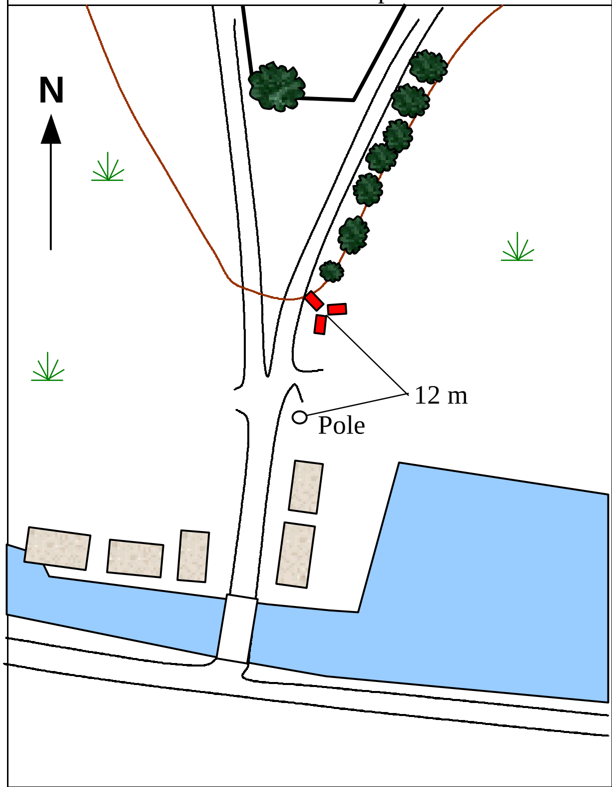
13.6. Fill in a fieldsheet

AIR PHOTO SIGNAL DESCRIPTION SGD/JICA

Point name	**CP8**		Operator	John Surveyor		
Signal shape	Y-SHAPE	Signal distance	From benchmark	0 m	Inspector	Mr B.I.G. Boss
			Above benchmark	0 m		
Color	WHITE		Above ground	0 m	Date of installation	02.01.00

Coordinat	Lo31	X	Y	H
Point coordinates	Main point	233045.663	23002.4	1553.214
	Eccentric point			
	Alternative point			

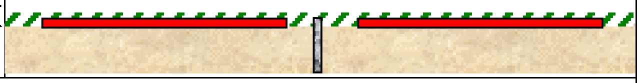
Schematic map



Ground photography

Profile:

Signal 0.05 below top of bencmark



Adjacent aerial photographs for stereo rendition

Flight strip No.: C4 Photo No.: 8

NORTH

Flight strip No.: C4 Photo No.: 9

13.7. Flight plan

Establishment of a good flight plan for aerial photography is not easy and straightforward work. It takes years of experience to master this field. The cost of aerial photography is high. It is therefor important to minimise the cost of aerial photography by making a good flight plan. The following points should be considered:

- **Accuracy of plotted map**
- **Coverage of aerial photos**
- **Distribution of ground control points, new and existing**
- **Topography**
- **Economy**

The table below shows the size and scale of a aerial photo taken with *wide angle camera* at different flight altitudes.

Flight Altitude	Negative Image Scale	Size of photo in terrain (m)	Base length Overlap (60%)	Minimum size of a quadratic signal (m)	Base length Sidelap (30%) (m)
400	2600	600	240	0.3	420
450	2900	680	270	0.3	470
500	3300	750	300	0.3	530
600	3900	900	360	0.3	630
650	4200	980	390	0.3	680
700	4600	1050	420	0.4	740
800	5200	1200	480	0.4	840
900	5900	1350	540	0.4	950
1000	6500	1500	600	0.4	1050
1100	7200	1650	660	0.5	1160
1200	7800	1800	720	0.5	1260
1300	8500	1950	780	0.5	1370
1400	9200	2100	840	0.5	1470
1500	9800	2250	900	0.6	1580
1600	10500	2410	960	0.6	1680
1700	11100	2560	1020	0.6	1790
1800	11800	2710	1080	0.7	1890
1900	12400	2860	1140	0.7	2000
2000	13100	3010	1200	0.8	The
2300	15000	3460	1380	0.9	2420
2600	17000	3910	1560	1.1	2740
3000	19600	4510	1800	1.2	3160
3400	22200	5110	2040	1.4	3580
3800	24800	5710	2280	1.6	4000
4200	27500	6310	2530	1.8	4420
4600	30100	6920	2770	1.9	4840

Table 13.7. Photo scale determined by flight altitude for a wide-angle camera.

13.8. Selection of correct photo scale

Accuracy of the plotted map is primary determined by the flight altitude of the aircraft taking the aerial photos and the distribution of ground control points. The flight altitude and the focal length of the camera determine the photo scale. The relationship is shown below.

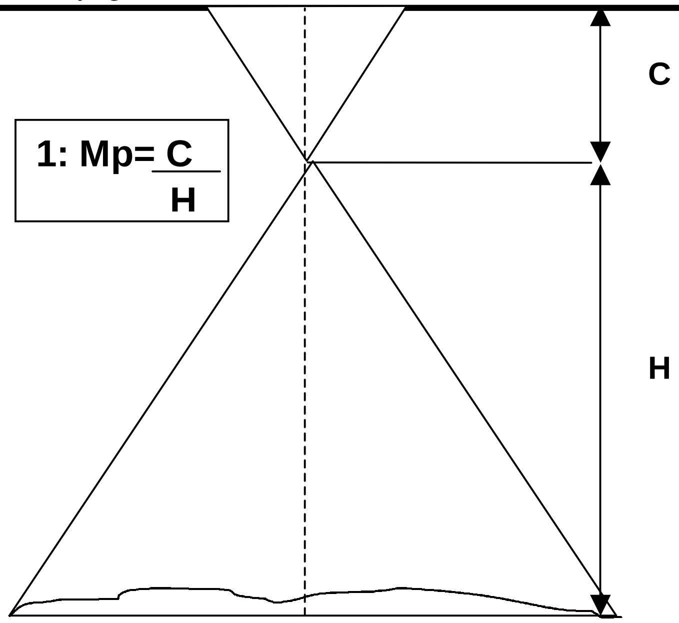


Figure 13.8.
The focal length (C) and the average flight altitude (H) above the ground determine the photo scale (1:Mp).

Relationship between photo scale and mapping scale is given in the table below. The table is only intended as a guide.

Photo scale	Mapping scale
1: 3500	1:500
1: 6000	1:1000
1:12000	1:2000
1:15000	1:5000
	1:10000
1:30000	1:20000

Table 13.8. Corresponding photo and mapping scale

13.9. Camera

The camera used for aerial photography should have built-in motion compensation and gyro stabilisation. Normally is a wide-angle lens with focal length 153 mm used in combination with panchromatic film for aerial photography. In open landscape with few obstructions and trees it can be advisable to use a super wide-angle camera. The major advantage about super wide-angle cameras is the reduction of flight altitude, which means better photogrammetric accuracy. The disadvantage about the super wide-angle camera compared to the wide-angle camera is danger of losing stereo coverage due to obstructions and undulating terrain. The table below shows different types of cameras used for aerial photography.

Lens	Focal length (cm)	Base of photo (cm)
Normal lens	21	8
Wide-angle lens	15	23
Super wide-angle lens	9	23

Table 13.9. Camera characteristics

13.10. Film

The size of a standard aerial photo is **23x23cm**. The longitudinal overlap between photos in a strip should not be less than 60%.

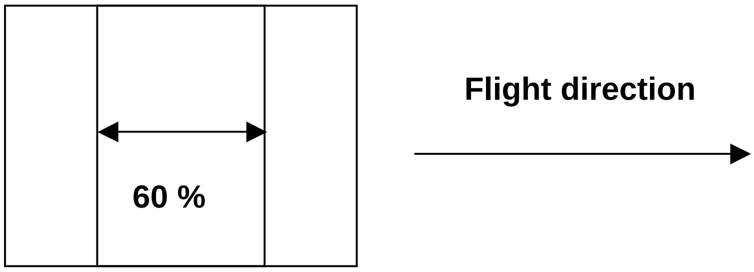


Figure 13.10.1. Longitudinal overlap

The sidelap between parallel strips is normally 25-30%.

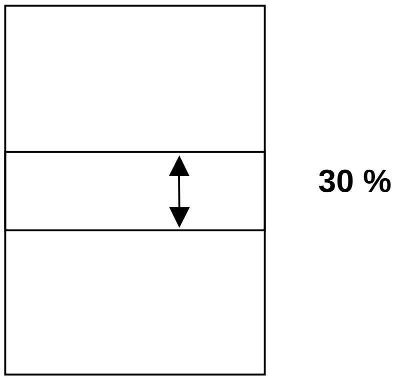


Figure 13.10.2. Sidelap between parallell strips

13.11. Distribution of ground control points

There is no fixed rule for the total amount of ground control points inside a photogrammetric block. New technology with GPS supported aerial triangulation reduces the need of photo-control points dramatically. As a general rule the photo-control points with fixed X,Y, and Z values should be distributed along the borderline of the mapping area. Points with known height should be established inside the block. The photo-control points inside the block should be spread evenly around. The number of points that has to be established also depends on the available aerial triangulation software. Please get advice from the company responsible for the plotting.

13.12. Post identification of photo-control points

There is always a danger that photo-control points can be destroyed before the aerial photography is carried out. In many cases it will be better to use natural features as photo-control points instead of artificial signals. Natural photo-control points should be should be easy to identify in the aerial photos. *It is essential to select features that can be viewed with stereoscope in both photos in one stereo model.* The shape of the signal should be distinct and not a blur. Examples on natural photo-control points are shown in the diagram below. A natural photo-control doesn't need to have co-ordinates in 3 dimensions. Sometimes the Z-value is most important (known height). This yields for ground control points inside the block.

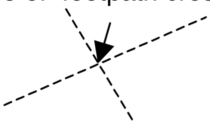
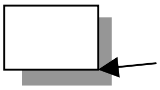
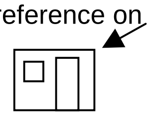
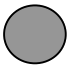
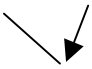
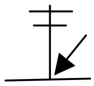
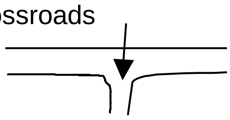
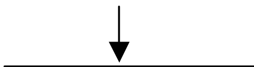
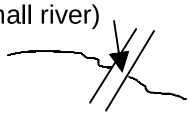
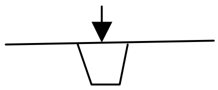
Centre of footpath crossing 	Height reference on ground in centre of footpath
Corner of flat roof 	Select corner where it is shade. Height reference on top of roof 
Centre of small tree or bush 	Select small dense symmetric bushes. Height reference on ground level 
Man-made or natural features. Example: Manhole cover 	Dark or light coloured details that are easy to spot in the photos. Use your imagination!
At the base of a telephone pole 	Z-value only. 
Crossroads 	Z-value only. In the centre of intersection 
Intersection of bridge and brooklet (small river) 	Z-value only 

Figure 13.12. Natural photo-control points

13.13. pricking of photo-control points

Each control point identified must be pricked on one of their stereo photographic pairs, and should be accompanied by an identification sheet listing containing:

- **Control point name**
- **Surveyors name**
- **Date of installation**
- **Schematic identification plan**
- **Two ground photographs, together with their orientations**
- **Ground profile plan**
- **Identification of the stereo pair and strip number**

Please refer to air photo signal description for details.
The photo-control point should be pricked in the centre of the aerial photo

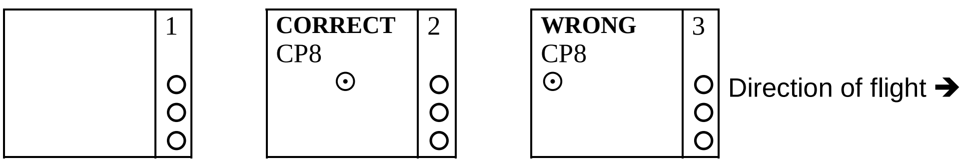


Figure 13.13. Pricking of photo-control points

14. Appendices

GPS Booking Sheet

Air Photo Signal Description

GPS BOOKING SHEET

SGD

Station and Project Information

Station Name	Date(YY-MM-DD)

Receiver Type/ Serial Number	Session

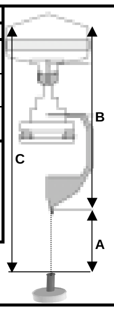
GMT/UTC start	GMT/UTC stop

Antenna Height Vertical Meas. SR299

Before Meas.	After Meas.
A=	A=
B=0.441	B=0.441
C=	C=

Antenna Eccentrisity:
SR299 B=0.441

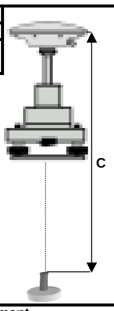
Distance to ARP:
SR399 C=0.091



A=Vertical Reading
B=Vertical Offset
C=Pillar setup/ Direct vertical reading

Antenna Height Slope Meas. AT502

Before Meas.	After Meas.
C=	C=



C=Pillar setup/ Direct vertical reading

Station Setup/Station Diagram	Description/Comment

Operator	Control of Tripod ☐

Station and Project Information

Station Name	Date(YY-MM-DD)

Receiver Type/ Serial Number	Session

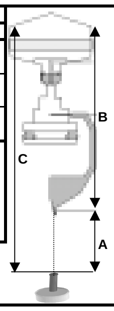
GMT/UTC start	GMT/UTC stop

Antenna Height Vertical Meas. SR299

Before Meas.	After Meas.
A=	A=
B=0.441	B=0.441
C=	C=

Antenna Eccentrisity:
SR299 B=0.441

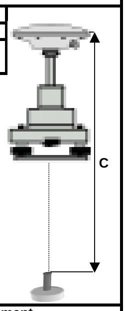
Distance to ARP:
SR399 C=0.091



A=Vertical Reading
B=Vertical Offset
C=Pillar setup/ Direct vertical reading

Antenna Height Slope Meas. AT502

Before Meas.	After Meas.
C=	C=



C=Pillar setup/ Direct vertical reading

Station Setup/Station Diagram	Description/Comment

Operator	Control of Tripod ☐

Station and Project Information

Station Name	Date(YY-MM-DD)

Receiver Type/ Serial Number	Session

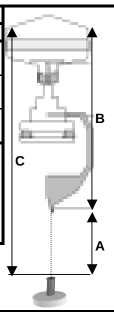
GMT/UTC start	GMT/UTC stop

Antenna Height Vertical Meas. SR299

Before Meas.	After Meas.
A=	A=
B=0.441	B=0.441
C=	C=

Antenna Eccentrisity:
SR299 B=0.441

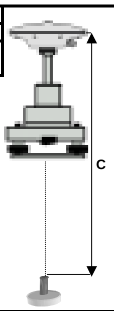
Distance to ARP:
SR399 C=0.091



A=Vertical Reading
B=Vertical Offset
C=Pillar setup/ Direct vertical reading

Antenna Height Slope Meas. AT502

Before Meas.	After Meas.
C=	C=



C=Pillar setup/ Direct vertical reading

Station Setup/Station Diagram	Description/Comment

Operator	Control of Tripod ☐

Station and Project Information

Station Name	Date(YY-MM-DD)

Receiver Type/ Serial Number	Session

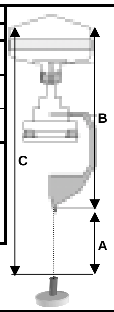
GMT/UTC start	GMT/UTC stop

Antenna Height Vertical Meas. SR299

Before Meas.	After Meas.
A=	A=
B=0.441	B=0.441
C=	C=

Antenna Eccentrisity:
SR299 B=0.441

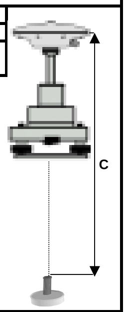
Distance to ARP:
SR399 C=0.091



A=Vertical Reading
B=Vertical Offset
C=Pillar setup/ Direct vertical reading

Antenna Height Slope Meas. AT502

Before Meas.	After Meas.
C=	C=



C=Pillar setup/ Direct vertical reading

Station Setup/Station Diagram	Description/Comment

Operator	Control of Tripod ☐

AIR PHOTO SIGNAL DESCRIPTION **SGD/JICA**

<table>
<tr><td>Point name</td><td colspan="2"></td><td>Operator</td><td colspan="4"></td></tr>
<tr><td rowspan="2">Signal shape</td><td rowspan="2"></td><td rowspan="3">Signal distance</td><td>From benchmark</td><td></td><td rowspan="2">Inspector</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>Above benchmark</td><td></td></tr>
<tr><td>Color</td><td></td><td>Above ground</td><td></td><td>Date of installation</td><td colspan="2"></td></tr>
</table>

<table>
<tr><td>Coordinate zone</td><td>L031</td><td>X</td><td>Y</td><td>H</td></tr>
<tr><td rowspan="3">Point coordinates</td><td>Main point</td><td></td><td></td><td></td></tr>
<tr><td>Eccentric point</td><td></td><td></td><td></td></tr>
<tr><td>Alternative point</td><td></td><td></td><td></td></tr>
</table>

Schematic map	Ground photography
N	
	Profile

Adjacent aerial photographs for stereo rendition

Flight strip No.: Photo No.: NORTH Flight strip No.: Photo No.:

APPENDIX 3

GUIDELINE FOR PREPARATION AND MAINTENANCE OF ORTHOPHOTO DATA

JUNE 2001

Guidelines for Orthophoto Data Management

SGD
JICA

June 2001

Table of Contents

1. Introduction

There has been a growing interest in orthophoto data recently. The digital photogrammetric system makes the creation of orthophoto data easy and inexpensive in comparison with the line map, and because these data are highly informative, they can be used in various ways. In contrast to line maps, however, there are no guidelines and specifications for the use of orthophoto data. Therefore, new guidelines and specifications should be made in order to accurately produce and use orthophoto data. An integration of the various technical information required in the production and management of orthophoto data, as well as containing the work specifications, this guideline (draft) was created for the revision and use of the sets of master data derived from orthophoto data and the attribute mapping data produced during the orthophoto mapping project in Swaziland. This guideline is also made with the hope that it will be helpful in the production of manuals and work specifications. The manuals of the respective software for the use of GIS and digital photogrammetric system will be used as references.

The items covered in this guideline are arranged by category as shown below according to their degree of importance.

Operational preparations： **Items to be observed**
Explanations： **Explanation of the standard of operation**
Technical Information： **Additional information for reference**

Also, explanations will be added with regard to work issues that have to be strictly followed.

2. Digital Aerial Photo Image

2-1.Type

Digital aerial photo image is classified into source image and processing method. Digital aerial photo images can be classified into several types including orthophotos. In this guideline, the names were standardized based on the classification in the table below.

Source Image

Aerial photo	Taken from an aircraft (fixed wing/helicopter) using a camera for measurements. Commonly requires the digitization of negative films.
Satellite photo	Taken by satellite. Commonly provided as digital data.
Others	Tilting aerial photos and synthetic aperture radar (SAR) taken from an aircraft using a camera not for measurement.

Processing Method

Mosaic Image	Use of single photos	Image resulting from adjoining multiple photos developed by normal methods, e.g. affine conversion of single photos using control points in topographic maps. Digitizing of analog mosaics produced using printed version.
Simplified Orthophoto Image	Use of single photos	Image produced by correcting the differential displacement using elevation data of the existing DEM, after the orientation of single photos using the 3D control points in every photo. Adjoining of every multiple sets of photos.
Precision Orthophoto Image	Use of stereo photos	Extraction of detailed DEM from the source image using the digital photogrammetric system, as a basis for the correction of the differential displacement. Joining of each multiple set of photos. This forms the master data.

2-2. Accuracy

The method for the production and accuracy of the digital aerial photo images will be decided based on the accuracy and resolution specified for the products.

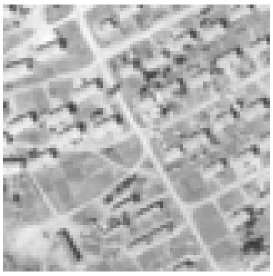
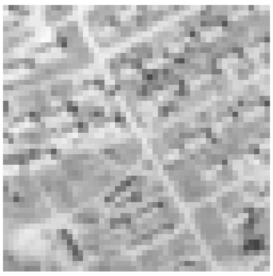
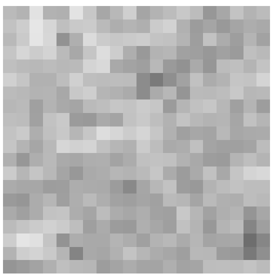
Accuracy of position

Mosaic Image	The distortion caused by the tilting of the camera during the photo session will be corrected. However, the distortion caused by the difference in topographic elevation will not be repaired. Accuracy of the position varies according to the photo scale, but the target accuracy is set at 1/30,000 and a disparity of 400 to 500m is permitted.
Simplified Orthophoto Image	Aside from distortions caused by the tilting of the camera during the photo session, distortions resulting from the difference in the altitude of the area will also be corrected. Although the accuracy for the overall position is standardized, there are also times when the high relative altitude of cliffs and ravines in some areas cannot be corrected. Although this is not actually possible, the positioning accuracy will be fixed within the adopted DEM maximum interval.
Precise Orthophoto Image	Aside from the distortions resulting from the tilting of the camera during the photo session, most of the distortions due to the large disparity in the relative height of some sections of cliffs and ravines can be corrected. Positioning accuracy depends on the interval of the created DEM. Therefore, as the DEM interval is 40m, the maximum positioning accuracy for original orthoimage data will be 40m (although this is not actually possible).

2-3.Resolution & Use

Resolution refers to the actual size of the image on the ground, which is calculated based on the pixel size of these image data. Although the resolution varies widely by color and shape of the image, images with a resolution of 3 to 4 times can be interpreted.

Resolution

Spatial Resolution	Image (200mx200m)	Identifiable objects/structures	Scale of data that can be created
25cm		Small vehicles, illegally dumped waste, detailed condition of the bank protection work	1/2,500
1m		Vehicles, small houses, bank protection 1/10,000	1/10,000
2.5m		General houses, pathways, boundaries for vegetation and cultivated fields	
4m		General houses that are barely decipherable, roadways, desiccated rivers, canals	
10m		Railway Vegetation at the basin level Land use at the basin level	1/50,000～1/100,000

Spatial resolution is an absolute value that refers to the resolution of the actual features and is measured in real-world units (ground units). On the one hand display resolution, which is represented by dpi (dots per inch), refers to the resolution of images measured at an optional scale. It is easier to distinguish one from the other by referring to the former as the absolute degree of sharpness of the image and the latter as the degree of sharpness of the section of the image on display.

The Relationship between Spatial Resolution & Display Resolution

Spatial Resolution (m)	Display Resolution (dpi) 1/10,000	Display Resolution (dpi) 1/25,000	Display Resolution (dpi) 1/50,000	Display Resolution (dpi) 1/250,000	Remarks
0.42333	600	1500	3000	15000	Corresponds to master data
0.5	508	1270	2540	12700	
1.0	254	635	1270	6350	
2.5	101.6	254	508	2540	
4.0	63.5	158.8	317.5	1587.5	
10.0	25.4	63.5	127	635	

2-4. Color Tone & Quality

Color refers to the depth of the color of these data, which is used to determine the data bit or the number of bands to be allocated per pixel. The table below indicates the colors commonly used and their respective characteristics.

Colors

Color tone	Characteristic	Data volume per pixel	Use
2	2 hues per pixel; the image will be represented either in black or white.	1 bit	Digitizing of data of existing map
Grey Scale	256 hues (white to black) per pixel (8 bits) for panchromatic images	1 bit	Panchromatic photo
Index Color	Random division of 256 hues per pixel (8 bits) for the band width of a color that looks natural visually. For reproduction, the information used to divide the hues is required.	1 byte	illustrations computerized display
True Color	16,777,216 colors will be used to represent the 3 bands of RGB which will be divided into 256 hues each per pixel (8 bits)	3 bytes	Color photos
Others	For satellite images, sharper colors will be used. More than 10 bits will be used to represent panchromatic photos and each band of the near infrared RGB will be allocated with more than 8 bits for representation.		Remote sensing

2-5.Compression of Image Data

Image data compression may be reversible or irreversible, and the latter is carried out only to the extent that would ensure that the quality of the image is maintained.

Ideally, to guarantee the quality of the master data for future use, compression should not be carried out, or if it is, the reversible compression method should be adopted. However, the management of the master data is not easy because orthophoto data would total more than 100 gigabytes.

To cope with this, these data are compressed irreversibly using JPEG-JFIF to 1/10 of its original volume in order to prevent any deterioration in quality, which can be confirmed visually, and facilitate the use of these data for the measurement map.

Principal Image Format

Format	Characteristics	Use
TIFF	This format enables the wide application of the image, and allows reversible and irreversible compression.	Printing/computer system
GeoTIFF	This is the expanded format of TIFF, and enables the storage of position information using geographic coordinates.	GIS
JPEG-JFIF	Highly effective for the irreversible compression of data	Used for master data
GIF	High compression rate; only index color	Used for transmitting information to the internet
BMP	Standard format for Windows; allow reversible compression of data	Comparatively easy to understand as the format used to describe the images is standardized.
MrSID	Enables high compression rate. A special software is required for the conversion of the image format.	Uses the MrSID software for image management. Can be used with other software for GIS・Image processing.

３． Data Application & Management

3-1. First Version of Orthophoto Data

These data to be revised shall be in accordance with the master data specification.

The table below explains the data sets in the CD provided.

Group of Data Sets

Data Type	Qty	Remarks
Detailed Orthoimage Data	411	
Reduced Detailed Orthoimage Data	411	Detailed orthoimage data processed in 2-dimensional form
Position Data for Neat Lines	411	
DEM Data	411	
Map Data (Cadastral Information)	411	
Map Data（Annotation）	411	
Map Data (Topographic Information)	411	
Map Data (Neat Line Information)	411	
Meta Data	-	1 pair for each data file

Description of the specification of each data set.

Detailed Orthoimage Data Set

Item	Explanation	Remarks
Data Format	JPEG-JFIF	The standard compression rate is set at 1/10.
Color Tone	Grey Scale	
Spatial Resolution	42.333cm	
Display Resolution	600dpi	1/10,000
Storage Unit	1/10,000 neat line（8000m×6000m）	
Pixel (row×Column)	18898×14173	
Data Volume	Approximately 270MB	When expanded
File Naming Rules	Same with the 1/10,000 neat line name	
Extended File Name	.Jpg	
No. of Files	411	
Location Information	Use the location information parameter file. Tiff-World format shall be adopted.	

Reduced Detail Orthoimage Data Set

Items	Explanation	Remarks
Spatial Resolution	3.387m	
Display Resolution	75dpi	1/10,000
Pixel	2362x1772	
Data Volume	Approximately 4MB	When expanded

*Items identical with the orthophoto data set were omitted.

Position Data of Neat Lines

Items	Explanation	Remarks
Data Format	Tiff –World format	Details of the format are described below
Coordinates	UTM Zone31	
File Naming Rules	Same as the 1/10,000 file name	
No. of Files	411	
Extended File Name	.tfw	

Explanation of the Tiff-World Data Format:

.tfw files are formatted as follows:

Sx cos θ

-Sx sin θ

Sy sin θ

Sx cos θ

C

F

where,

C,F: coordinates of pixels at the upper left of the raster data

Sx: size of 1 pixel on the X axis

Sy: size of 1 pixel on the Y axis

（always a negative value as the Y axis in raster data and on the map is in the opposite direction） θ: rotation angle（with respect to north）

For example a 2359.jpg file with the following format Sx=0.2、Sy=-0.2、θ=-52.63135°, C=-41386.5610、F=21594.2240 will be converted as a 2359.tfw file with the following format:

0.12138 (0.2×cos(-52.63135))
0.79474 (-0.2×sin(-52.63135))
0.15894 (-0.2×sin(-52.63135))
-0.12138 (-0.2×cos(-52.63135))
-41386.5610
21594.2240

DEM Data Set

Items	Explanation	Remarks
DEM Interval	40m	
Data Format	ASCII codified text data I10, 3F15.3 Sequence No, X, Y, Z	
Storage Unit	1/10,000 neat line	Data points for neat lines are included.
No. of Data Points	30351 points	
No. of Files	411	
File Naming Rules	Same as the 1/10,000 neat line name	
Order of Arrangement	Optional	

Meta Data Set

Items	Explanation	Remarks
Standard	Level 1 (in conformity with the ISO/TC211 meta data)	

Map Data Set

This will be in accordance with Specification Rev. 2 (September 2000). The outline (Appended Data) is as shown below.

Items	Explanation	Remarks
Data Format	Microstation DGN format	
Data Structure	4 files for every neat line. C: Cadastral T: Text L: Landform M: Marginal	
Storage Unit	1/10,000 neat lines	
No of Files	411	

3-2.Management of Master Data

3-2-1.Management of Master Data Sets

The master data provided in a CD will require successive revisions. After one revision is completed, the revised data set will be saved separately from the master data in the CD. If possible, multiple copies of these new data will be created and saved on the hard disk so that other users can access the file. A duplicate of the CD will be made after checking for any damage or deterioration in the quality of the media.

As a rule the specifications for the data, e.g. resolution, etc., shall be in accordance with the master data. This rule, however, may not apply depending on the type and condition of the source image for the revision work. In this case, it is important to note this condition in the meta data and historical information.

3-2-2. Access to Data by Other Users

Data access and display may also either be by map sheets or seamless (continuously reading of data beyond the neat lines). In particular, the GIS software that allows the use of survey coordinates and positioning information files is desirable for the latter.

3-2-3. Use of Reduced Images

Reduced orthoimage data are used to efficiently identify the positions and master data files. An index map indicating the reduced data sets and map sheet index will be produced at a scale of 1:250,000.

Although offset printing is desirable, an ink jet plotter will be used to facilitate the printing of multiple copies.

3-2-4. Data Processing

For data processing, particularly for cutting or joining of orthoimage data, the CAD system or GIS software will be used for detailed digital processing. Microstation Descartes is recommended for the CAD system, while ArcInfo is one of those recommended for the GIS software.

In addition, an image processing software is also highly recommended due to its efficiency for simple data processing work, e.g. changing the resolution and/or image format.

3-2-5. Creation of Historical Data

The historical data file of the data set that uses the map as a standard will be updated or created. The historical data file will reflect the meta data and will allow the confirmation of the processingoutline of all data. The data file will be created in CSV format so that it can be displayed for various purposes using a tabular software.

Historical data file contents:

- File name
- Date file was created,
- Name of person who created the file
- Data category

- Reasons for revision/update
- Source of revision/update.

CSV Format

This refers to a text file where each record is separated by a new line, and every field is divided by a comma. This data format can be used in tabular calculations, database, and GIS.

3-2-6. File Naming

File names should not be changed even after revisions, and revisions (e.g. date, area revised) should be specified for data management. With GIS software, the data set is specified by the file name in most cases, and the GIS database is revised by replacing the files with the updated ones.

3-2-7.Backup for Revised Data

The intermediate results during the revision work will be given a different name, and saved separately from the master data to a CD as a backup for the revision work.

3-3.Provision of Data to Other Systems

The user is normally expected to find it difficult to decide suitable data specifications without information about the orthoimages. For data provision, the intended data use and operating software are taken into consideration in to recommend the most suitable data. These data should only be incorporated into the work once its functions are understood.

3-3-1.Changes in the Resolution

The resolution of the orthophotos of the master data is 600dpi at a scale of 1:10,000, and it can be printed using the high quality offset printing method. This resolution, however, is useless if printed using a plotter, which cannot effectively output most of these data. There may be a need to change the resolution using an image processing software.

The table below shows the resolutions commonly set for printing devices to attain outputs of maximum quality. These values should be changed however, depending on the actual device. Further, the use of the computer monitor mostly involves enlargements and/or reductions of the image on display. As a rule, therefore, resolutions are set in consideration of the maximum scale of the intended use of these data.

Optimum Output Resolution

Printing Device	Resolution	Remarks
Offset Printer (black & white)	600dpi	
Offset Printer (color)	300dpi	
Ink Jet Plotter	200～300dpi	Could vary depending on the type of printing device
Computer Monitor	100～150dpi	Could vary depending on the type of printing device

Image resampling is performed through any of the following methods:

- nearest neighbor method
- bilinear method
- bi-cubic method

With the bi-cubic method, information loss is kept to a minimum, and, as a rule, this method will be used for the image reconstruction work.

3-3-2.Change of Image Format

As a rule, the image will be converted into the most suitable format that is compatible with the software in use.

Changes of the image format should not in anyway affect the data resolution and depth. In addition, the change of image formats that contain position data, e.g. GeoTIFF, will be reflected in the position data file.

3-3-3. Change of Neat Lines

For data cutting and joining work, the positions of the data will be controlled digitally in detail. A new position data file will be created when changing the neatlines of a data file, and attached to the orthoimage data.

3-3-4. Saving Data

The reduced image data file and position data file will be created and saved together to CD with the completed image data, in accordance with the specifications for the master data set. If the map data file is to be saved, a table showing the functions of the map data will be included on the CD.

The file explaining the contents of the data files (according to the items shown below) will be saved as a text file.

- List of data files
- Brief explanation for each data file
- Date & time CD was produced
- Person who produced the data file

3-4. Software

A list of software for data accessing and processing is shown below for reference.

Relevant Software

Use	Maker	Name	Category	Remarks
Data access and viewing	ESRI (USA)	Arc-View	GIS	Tfw file can be directly used with this software. The software can also be used with compressed forms, e.g. MrSID.
Data access/processing	Bentley (USA)	MicrostationMicrostation Descartes	GIS CAD Data capture	Can be used to jointly access the map data. Allows the detailed cutting and adjoining of image data.
Data access/processing	LizardTech (USA)	MrSID	Image Processing （compression）	High compression rate Fast display functions
Data access/processing	ERDAS	IMAGINE	GIS（image）	All-purpose use
Data processing	Inpho (Germany)	OrthoVista	Mosaic Color adjustment	A tfw. file can be directly used with this software.
Data processing	Adobe (USA)	Adobe Photoshop	General image processing	For detailed adjustments of printed maps, etc.

4. Maintenance & Revisions

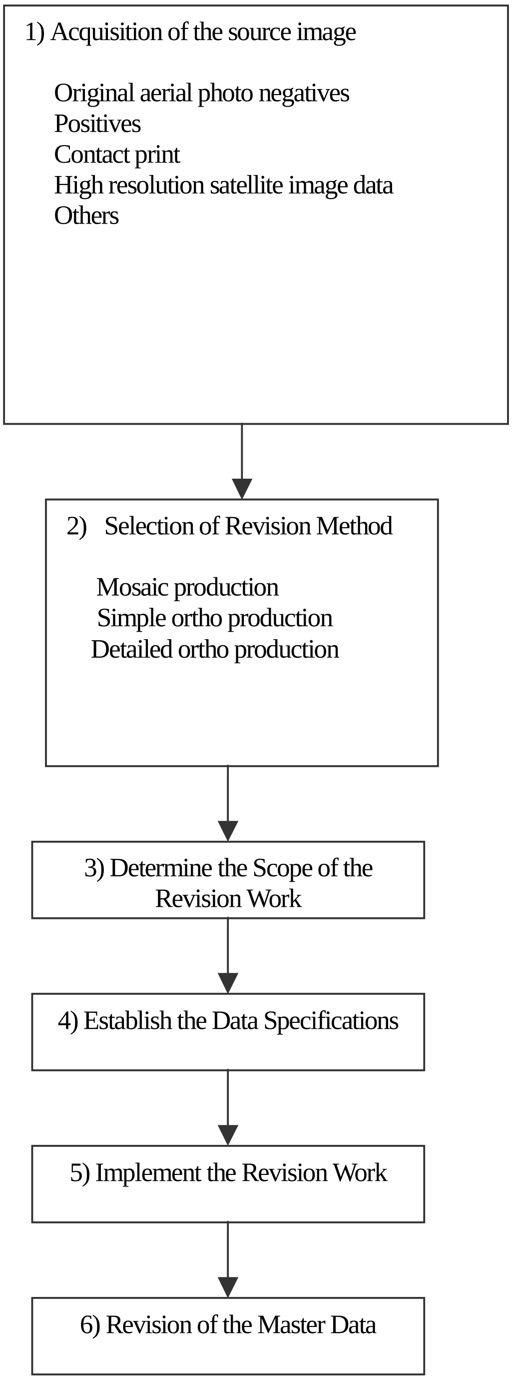
Revisions can be made if a new and revisable source image exists.

4-1.Selection of Revision Method

As a rule, revisions will not affect the accuracy and resolution of the master data regardless of the method used, which will be determined by considering the scale of the source materials, e.g. source image, expenses, device, scope of the revision work.

The equipment necessary for the revision work will vary depending on the method selected. For simple revision methods, an inexpensive all-purpose image processing software (e.g. Adobe Photoshop), instead of a photogrammetric instrument, would be satisfactory.

Revision work flow.



1) Acquisition of Source Image

New aerial photo images will be acquired for the revision of the master data.
Special attention should be given to the choice of source images to ensure highly accurate revisions.

Medium for the source image

Type	Explanation	Remarks
Original aerial photo negatives	This source will give the best results	
Positives	This source will have virtually no impact on data accuracy. Printing resolution may affect image quality.	
Contact print	This source should be handled carefully to ensure data accuracy and image quality.	
High resolution satellite image data	This source should not be used for important areas, e.g. towns, cities, as the spatial resolution is low.	Only data with a spatial resolution of less than 1m can be used.
Others （e.g. oblique photos）	This source should be used in the same manner as aerial photos, however the image scale and camera distortion should be considered.	As a rule, this will not be used as a source.

2) Selection of Revision Method

The revision method will be selected based on the source image and revision scale, as well as expense.

Suitability, Accuracy and Expense of Revision Method Based on Source Image

Source Image	Mosaic Image	Simple Orthoimage	Detailed Orthoimage	Remarks
Original aerial photo negatives	○	○	◎	
Positives （for stereo pair）	○	○	◎	
Positives （for single photos）	○	◎	×	
Contact print （for stereo pair）	○	◎	△	
Contact print （for single photos）	○	◎	×	
High resolution satellite image	◎	×	×	Might change conditions
Oblique photos （for single photos）	△	△	×	
Ortho image	◎	×	×	Image that has already been processed
Accuracy	low←――――――――――――――――→high			
Expenses	cheap←――――――――――――――――→expensive			

Suitability ◎：Recommended ○：Possible △：Possible but involves difficulties ×：Impossible

Efficiency Based on the Revision Method and Scale

	Source Image (1 to 10)	Source Image (11 to 100)	Source Image (More than 100)
Mosaic image	◎	△	×
Simple orthoimage	◎	○	△
Detailed orthoimage	○	◎	△
Detailed orthoimage (implementation of aerial photogrammetry)	△	◎	◎

Efficiency ◎：Extremely efficient ○：Efficient △：Efficient but involves difficulties ×：inefficient

3) Determining the Scope of the Revision Work

Based on the acquired source image, preliminary photo-interpretation will be carried out to determine the scope of the revision work.

The master data and the acquired source image will be compared, and the areas that have changed will be designated on either of the maps of the two compared data, to prepare the preliminary photo-interpretation map. Termination of the work will be considered if the results of the preliminary photo-interpretation indicate only a small number of changes and a low cost-effective ratio.

The smallest rectangular field that encompasses all the areas that have changed will be the scope of the revision work. The rectangular field shall be placed using ground coordinates (Figure 1).

Revision of linear objects, e.g. rivers, railroads, etc., will also be carried out as a series of small rectangular fields (Figure 2).

Sections of rectangular fields that have no source image will be designated as Null data sections, and care will be taken so that these sections do not bear any impact on the master data overlay.

Figure 1. Determining the Scope of the Revision Work

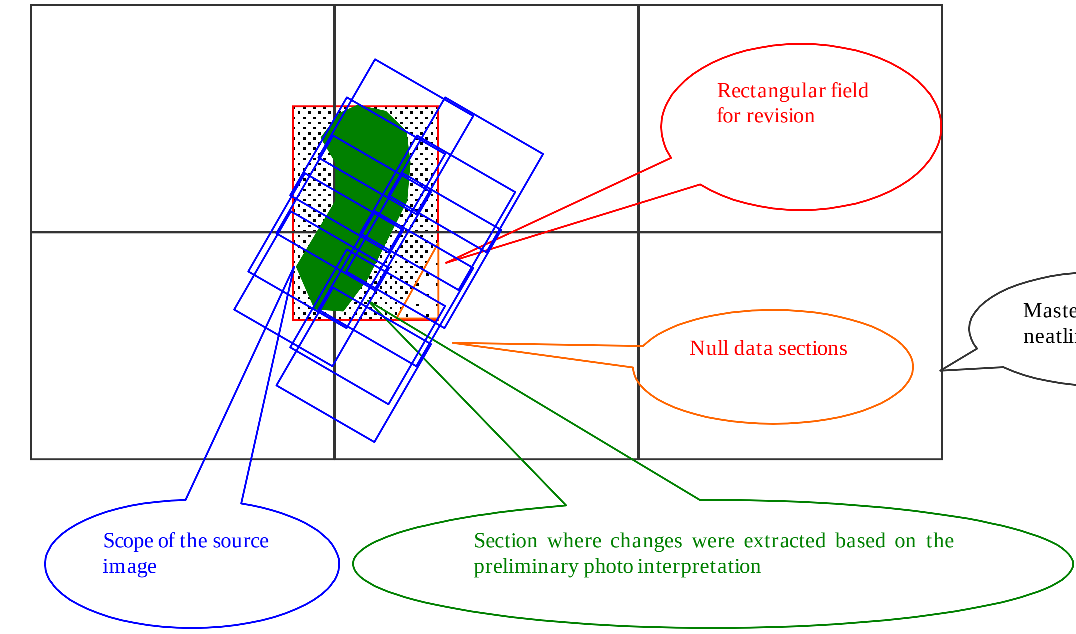
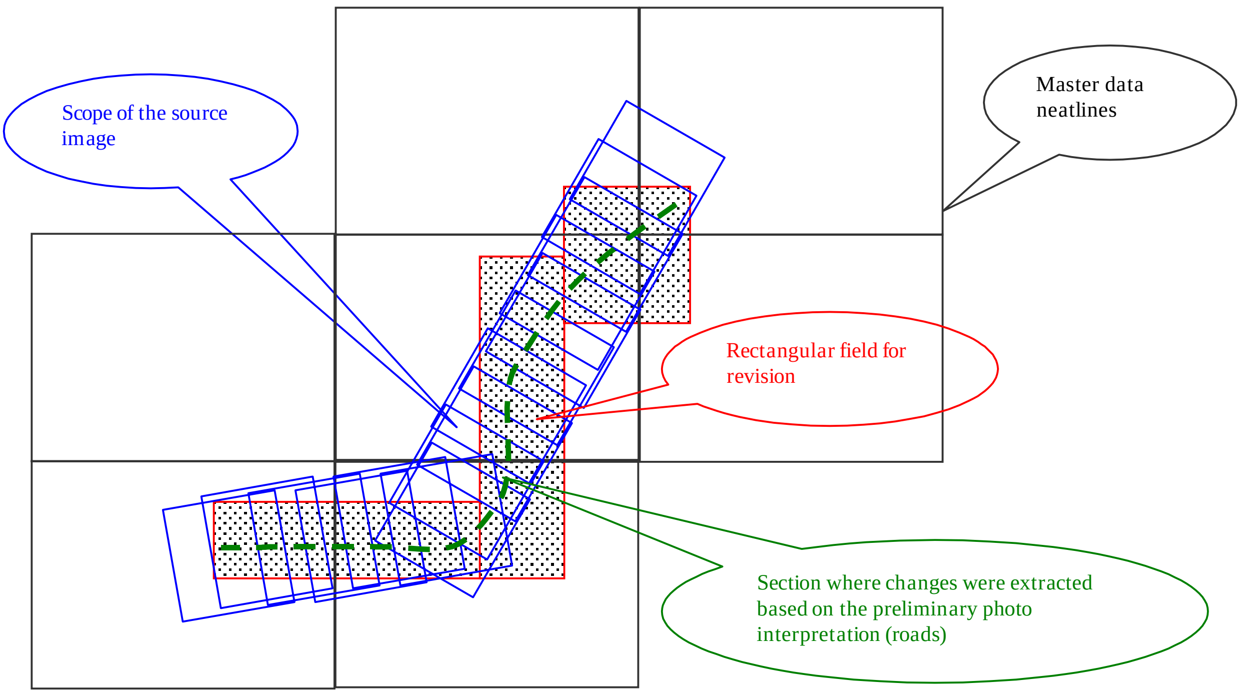


Figure2. Determining the Scope of the Revision Work (linear changes)



*Null data sections not shown in the above diagram.

4-2. Establishing the Data Specifications

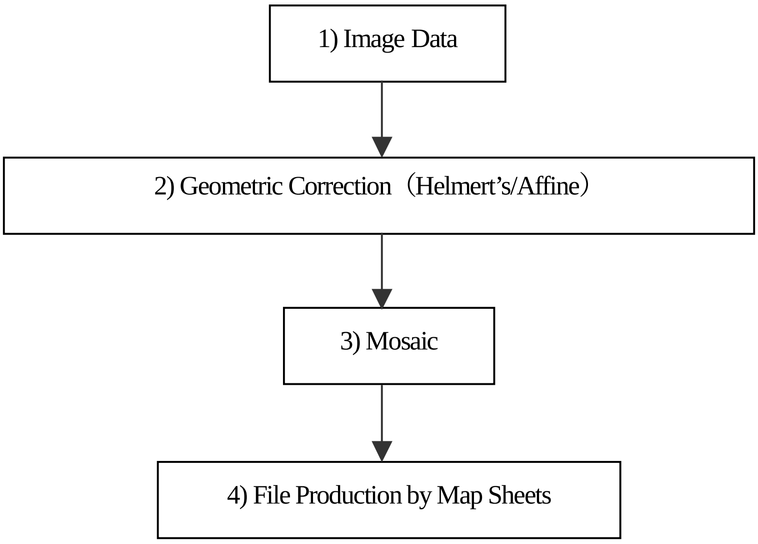
As a rule, the resolution of data for revision shall be in accordance with the master data. Even in specific cases, such as when the source image (high resolution satellite image data) resolution is lower than the master data resolution, the same principle applies. For scanning of the source image, the resolution will be derived from the ratio of the nominal scale of the source image to the scale of the master data (1:10,000), to prevent quality deterioration.

Source Image Scanning Resolution

Source Image Scale	Scanning Resolution dpi（μm）	Remarks
1/10,000	Over 600 (42.3)	
1/20,000	Over 1200 (21.2)	
1/30,000	Over 1800 (14.1)	
1/40,000	Over 2,400 (10.6)	
1/50,000	Over 3000 (8.5)	

4-3. Production of Orthophotos

4-3-1. Mosaic Image Production Process



1) Image Data

Scanning will use the minimum number of photos that encompass the area for revision and will not require a stereo pair. As a rule, a high resolution scanner should be used for high accuracy photogrammetry.

2) Geometric Correction

Geometric correction will be carried out by matching the data with the horizontal control points on an existing map using a two dimensional coordinate conversion formula (Helmert/Affine). The control points required for each photo will be established by the conversion method, and the standard deviation of the control point residual will be minimized through measurements. This work will use either a GIS software or image processing software.

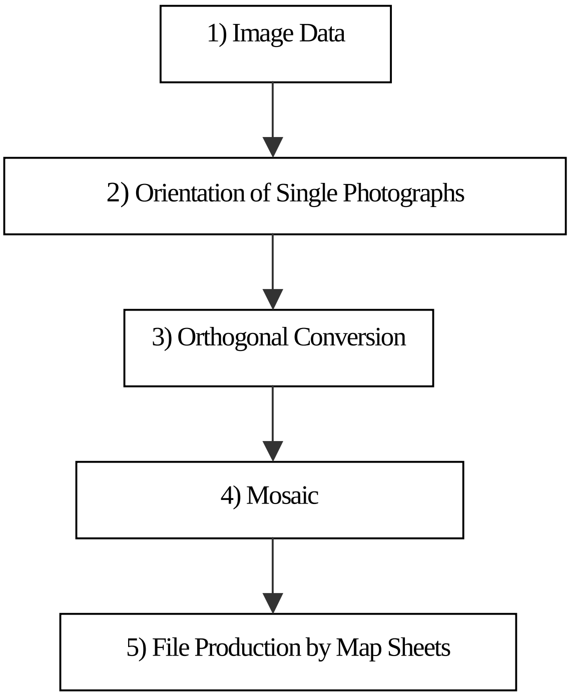
3) Mosaic

A number of geometrically corrected images are joined to produce a seamless mosaic image for the specified scope of the revision work.

4) File Production by Map Sheets

Data will be extracted from the seamless basic orthoimage, and arranged by map sheets at a scale equivalent to the master data (1:10,000) and saved individually.

4-3-2.Production of Basic Orthoimages



1) Image Data

Scanning will use the minimum number of photos that encompass the area for revision and will not require a stereo pair.

2) Orientation of Single Photographs

The fiducial mark of each photo will be determined to complete the interior orientation. This is then matched with the horizontal control points on an existing map to calculate the exterior orientation components by space resectioning. The control points required for each photo will be established and the standard deviation of the control point residual will be kept to a minimum. The photogrammetric system will be indispensable for this work.

3) Orthogonal Conversion

Orthogonal conversion will use the DEM master data and the photographs used for orientation, to produce a basic orthoimage of each photograph. The photogrammetric system will be indispensable for this work.

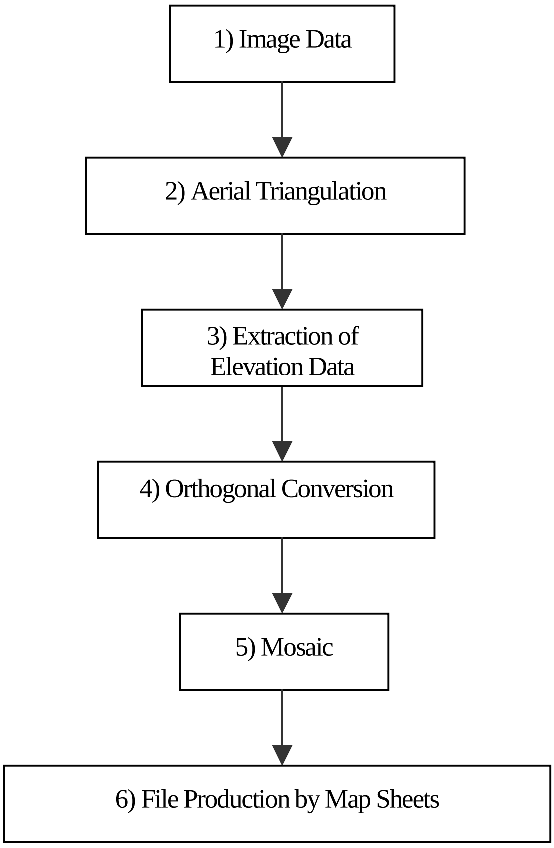
4) Mosaic

Multiple basic orthoimages are joined to produce a seamless orthoimage.

5) File Production by Map Sheets

Data will be extracted from the seamless basic orthoimage, and arranged by map sheets at a scale equivalent to the master data (1:10,000) and saved individually.

4-3-3. Production of Detailed Orthoimage



1) Image Data

Scanning will use the minimum number of photos that encompass the area for revision and will not require a stereo pair.

2) Aerial Triangulation

Aerial triangulation of the image data uses the digital photogrammetric system. The measurement of pass points, tie points, and control points, as well as their adjustment calculation, will be carried out until the measurement error and control point residual are within the specified limit. The results of the adjustment calculation will be shown in each image using the digital photogrammetric system to construct a stereo-model.

3) Extraction of Elevation Data (DEM)

Elevation data will be extracted from the stereo model, either manually by the operator or automatically (stereo matching extraction). If the latter is used, the gross error should be inspected visually and corrected. The elevation data can be represented either as discretized elevation data at fixed intervals, randomly arranged elevation data, or surface data using contours and breaklines for objects.

Standards for the Data Density by DEM Type

Type	Density	Characteristics	Remarks
DiscretizedElevation Data (DEM)	Standard interval of 4mm by product scale: 40m for a product scale of 1:10,000.	Data processing is easy.	Can be handled in almost all digital photogrammetric systems.
Random Elevation Data	The density of the data shall be based on the DEM. For flat topographic sections, the density may be reduced.	Allows the compression of data size and improves topographic reproduction capacity. Data processing is slightly difficult.	Partly dependent on the functions of the software in use.
Breakline	Object data is acquired based the items (e.g. contour intervals, etc.) that are usually plotted according to the product scale: 10m contour, elevation point, road center, and center of the river scale (1:10,000).	Highly capable of large scale reproductions of topographic features. Data processing is difficult.	Partly dependent on the functions of the software in use.

4) Orthogonal Conversion

Orthogonal conversion is used for the newly acquired elevation data and the photographs used for orientation, to produce a detailed orthoimage of each photograph. The photogrammetric system will be indispensable for this work.

5) Mosaic

Multiple basic orthoimages are joined to create a seamless detailed orthoimage covering the specified scope of the revision work.

6) File Production by Map Sheets

Data will be extracted from the seamless basic orthoimage, and arranged by map sheets at a scale equivalent to the master data (1:10,000) and saved individually.

4-4. Revision of Data File

The revised image cut and saved by map sheets will be superimposed on the master data using the data processing software, for composite data processing. As much as possible, composite data processing will be digitally controlled to prevent any changes of the resolution and position data.

4-5. Saving Data

The orthoimages created through the methods aforementioned will be incorporated into the master data and saved.

4-5-1. Historical Data Revision

The revised data will be described in the historical data file (history.csv).

4-5-2. CD Creation

The map sheet data of the revised data will be saved to a CD. The revised data will be stored on two CDs. The revised data will be added to the CD containing the master data file.

4-5-3. Back up File in CD for Revision Work

All data files used in the revision work will be saved as back up files to a CD (or tape back up device).

4-5-4.Revision of Master Data for Data Access

The revised data will be superimposed on the master data copy on the hard disk for data access, to update the data with the latest changes.

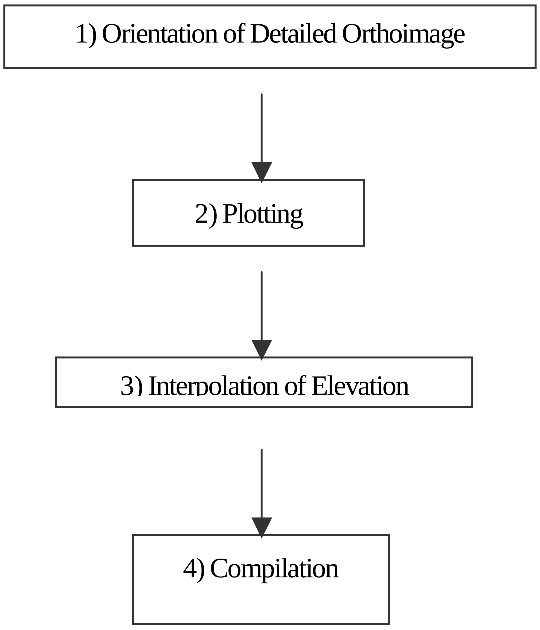
5. Others

5-1. Colorization of Master Data

In the future, the master data will be colorized by map sheets, that is if a colored source image can be acquired. The colors will be partly changed in data files where the color of the detailed orthoimage data and the reduced detailed orthoimage data is converted from gray scale to true color.

5-2. Basic Plotting

The master data set is created with a 40m DEM and an error of less than a few meters. (Although this is not actually possible, it would still be a maximum of 40m.) Consequently, this would allow the creation of a large scale map (over 1:10,000). The work flow chart is shown below.



1) Orientation of Detailed Orthoimage

The detailed orthoimage will be installed for the CAD or GIS software, using the position data file.

2) Plotting

Objects will be delineated for interpretation on the detailed orthoimage, according to the data layers for plotting.

3) Interpolation of Elevation

Based on the DEM data set, 3 dimensional plotted data will be created by interpolating the elevation. The contours will be automatically created during the interpolation. The 3 dimensional plotted data is then checked for errors and correctioned to obtain the desired topographic map scale.

4) Compilation

Compilation will be carried out using a CAD or GIS software to correct the basic symbols for the object data and to establish consistency with the contours. The topographic map is usually completed after the data symbols are compiled and the annotations are created.

5-3. Computer Graphics

The use of the orthophoto data set and a 40m DEM data set allows a 3 dimensional representation of the country.

View of Mbabane City from the south