JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
SURVEYOR GENERAL'S DEPARTMENT (SGD)

THE STUDY ON DIGITAL MAPPING PROJECT
FOR
THE SMOOTH IMPLEMENTATION
OF THE DEVELOPMENT PLAN
IN SWAZILAND

FINAL REPORT
(SUMMARY)

JULY 2001

KOKUSAI KOGYO CO., LTD.

EXCHANGE RATE

1USD = 7.97MZM = 125.13JPY

July, 2001

PREFACE

In response to the request from the Government of Swaziland, the Government of Japan decided to conduct the study on digital mapping project for the smooth implementation of the development plan in Swaziland and entrusted the study to Japan International Cooperation Agency (JICA).

JICA dispatched a study team headed by Mr. Furukata of Kokusai Kogyo Co., Ltd. to Swaziland, three times between July 1999 and July 2001.

The team held discussions with the officials concerned of the Government of Swaziland and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Swaziland for their close cooperation extended to the team.

July 2001

Kunihiko Saito
President
Japan International Cooperation Agency

Mr. Kunihiko SAITO
President
Japan International Cooperation Agency
Tokyo, Japan

July 2001

Letter of Transmittal

Dear Mr. SAITO

It is a great honor to submit herewith the Final Report following the completion of the **Study on Digital Mapping Project for the Smooth Implementation of the Development Plan in Swaziland**.

The study team, led by myself, implemented the study betweem June 1999 and July 2001, in accordance with the agreement made between the Japan International Cooperation Agency (JICA) and Kokusai Kogyo Co., Ltd.

The study team carried out discussions with the concerned officials of the Government of Swaziland and field surveys, e.g. aerial photography, photo control survey, conversion of the cadastral data into a database and technology transfer. In Japan, digital orthophoto maps were created using the most advanced technologies of digital plotting and a GIS database including cadastral data was created in order to produce digital data of orthophoto maps at the scale of 1:10,000 covering the whole country in the forms of CD-ROMs as well as printed maps.

This Report describes how these results were obtained and gives a proposal on how to deal with future issues.

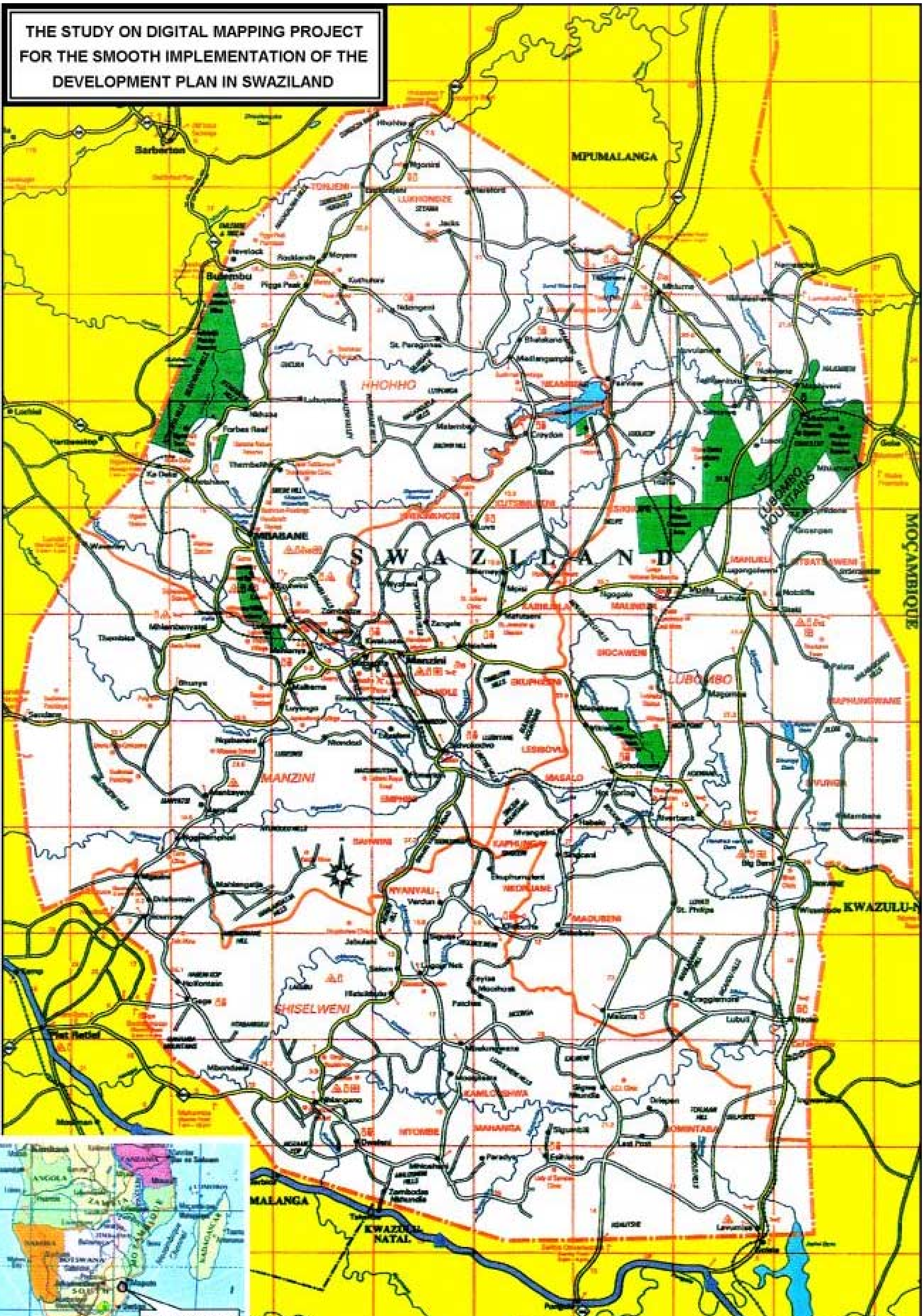
On behalf of the team, I wish to express my heartfelt appreciation to the concerned officials of the Government of Swaziland and the concerned agencies for the warm friendship and cooperation they have extended to us during our stay in Swaziland.

I also wish to express my sincere gratitude to JICA, the Ministry of Foreign Affairs, the Ministry of Construction, the Embassy of Japan and JICA office in South Africa, and all other related organizations for their valuable advice and assistance given to the study team.

Yours Sincerely,

Kazuo Furukata
Study Team Leader
The Study on Digital Mapping Project for the Smooth Implementation of the Development Plan in Swaziland

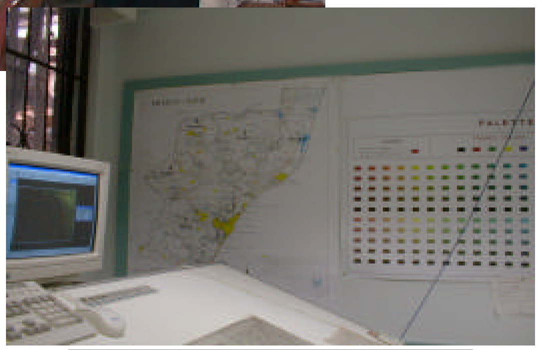
THE STUDY ON DIGITAL MAPPING PROJECT FOR THE SMOOTH IMPLEMENTATION OF THE DEVELOPMENT PLAN IN SWAZILAND



Agreement on the Inception Report M/M

(SGD executives, JICA Study Team, technical advisor)

Signing of M/M for Inception Report



Peripherals for digital compilation (MicroStation)

SGD storage room for aerial photos

Photogrammetry section at SGD

SGD storage room for printed maps

SGD storage room for completed topographic maps

GPS observations at a photo control point

Measurement of elements of eccentricity at a triangulation

GPS observations at a triangulation point

Isolated tree for pricking

Measurement of elements of eccentricity using a TotalStation

Pricking at a benchmark

Pricking at a benchmark

Agreement on the Progress Report M/M

(SGD executives, JICA Study Team, technical advisor)

Explanation on the Progress Report
Discussions on technical matters

Equipment procured at the beginning of the study work in the second year and intermediate results

GPS for high-precision surveying

Negatives of aerial photos and software

Computer for digital orthophotos and GIS database

Discussions on specifications for annotation/administrative boundary data

Creation of annotation data using study equipment and related on-the-job training

Data editing at SGD office

Field completion for points plotted improperly and ambiguous points of photo interpretation

TABLE OF CONTENTS

CHAPTER 1 OUTLINE OF THE STUDY

1-1 STUDY AREA

Basic policies in three fields (operational and technical policies, and others related to technology transfer) were decided and we were able to respect these policies during the implementation of the Study with the cooperation of the Swazi side.

1-1-1 Basic Operational Policies

① Establishment of the most appropriate implementation system

② Careful preparations

③ Strict safety measures

④ Close contact with concerned organizations

1-1-2 Basic Technical Policies

① Appropriate technical specifications

② Quality control and work process control

1-1-3 Basic Policies on Technology Transfer

① Appropriate on-the-job training

② Lectures

③ Preparation of Manuals

1-2 CONTENTS OF THE STUDY

The work items, outline and volume for each study year are shown in the following table.

Table 1-1 Work Volume

Items	Outline of the Work	Work Volume
Aerial photography	1:30,000-scale B&W aerial photography	Approx. 17,363 km2
System design (1)	GIS user survey, hard/soft selection	
Conversion, inspection, revision of cadastral data	Guidance for conversion of topology data and revision of errors	Whole territory
Photo control point survey and pricking	Implemented in the form of OJT with SGD, using GPS	Triangulation points 33 Photo control points 45 Bench marks 57 GPS vertical points 20
Acquisition of administrative boundaries and geographical names	Collection of existing data on administrative boundaries and geographical names	Whole territory
Planning, preparation and system design	Planning of accuracy and schedule, programming for automatic processing	
Film scanning	Scanning of roll negative films in the course of the study	1,593 negas
Automatic aerial triangulation	Division in 3 blocks, computation of elements for plotting	1,526 models
Generation of DTMs, orthos, mosaic, contours	Acquisition of all data for the creation of orthos by automatic processing	Approx. 17,363 km2
Digital plotting (roads, rivers, lakes, contours of wooded areas)	Plotting of roads, rivers, lakes and contours of wooded areas	Approx. 17,363 km2
Input of administrative boundaries and geographical names	Digitising by digitiser or keyboard input	Whole territory
Map output for field survey	Output map for survey of ambiguous points, confirmation of administrative boundaries and geographical names	411 sheets
Inspection of cadastral data	Reverification of SGD revision results and obtainment of the files	Whole territory
System design (2)	Guidance on operation of the selected hard/soft	
Field identification of administrative boundaries and geographical names	Confirmation of correctness of names and positions	Whole territory
Field survey	Confirmation/revision in the field of ambiguous points appearing during the plotting	17,363 km2
Compilation of data on administrative boundaries and geographical names	Revision and addition/deletion on the survey map	Changed/added parts
Input of cadastral database	Linkage to orthos as cadastral data file	Whole territory
Digital compilation, structuring	Compilation of features and contours for orthomap/GIS	17,363 km2
Production of printed maps	Conversion into a format for printing, and production of printed maps/films	411 sheets * 100 copies
Production of CD-ROMs	Recording of multi-layers by size	Approx. 240 CDs
Technology transfer seminar	Operation, maintenance and management of orthophotos, use of GIS	
Formulation of the Final Report (F/R) and preparation of the final products	Completion of the Final Report taking into account the comments from the Swazi side, in English (main report, summary)	30 copies

Fig. 1-1 Conceptual Diagram of the Study Work

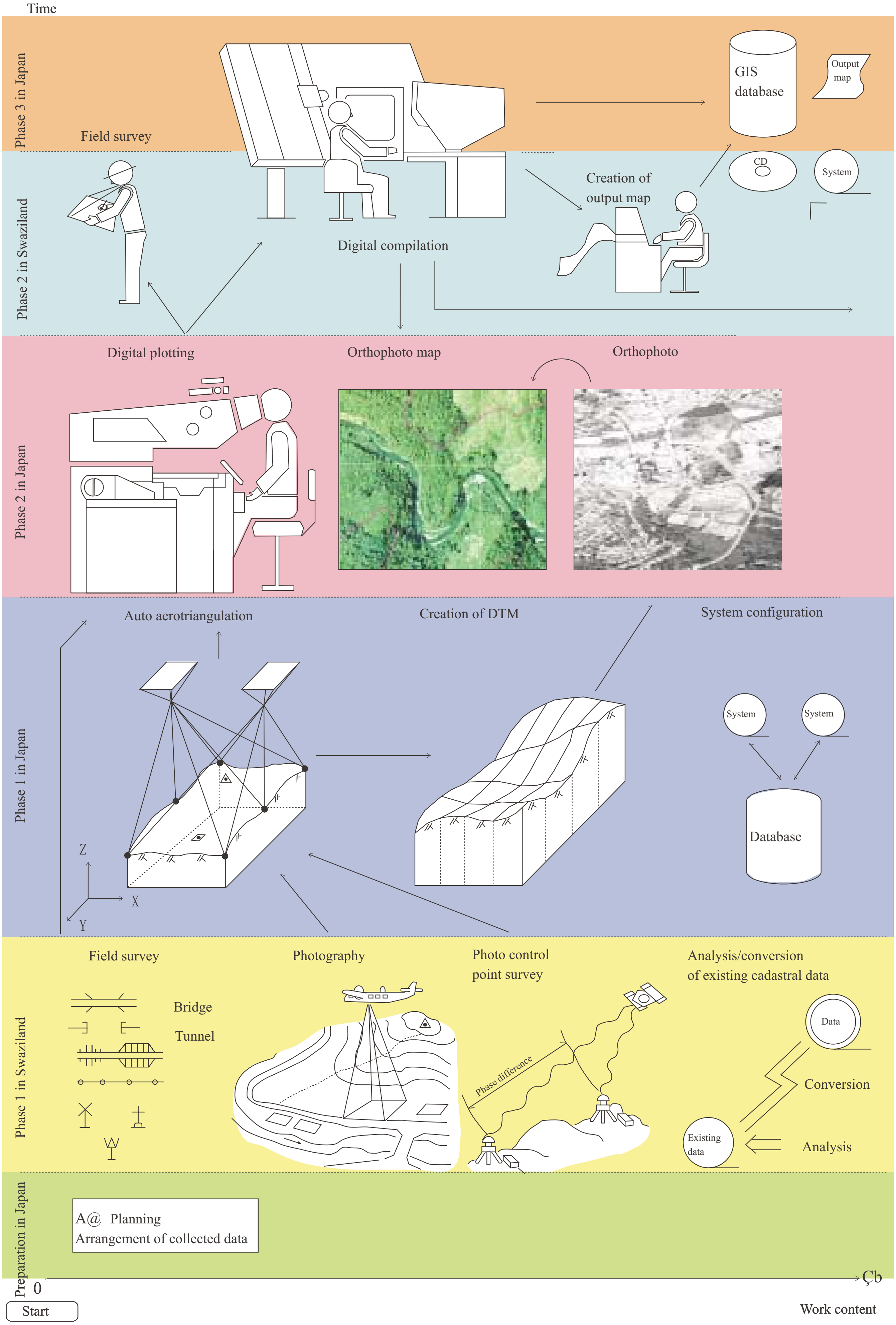


Fig. 1-2 Flowchart

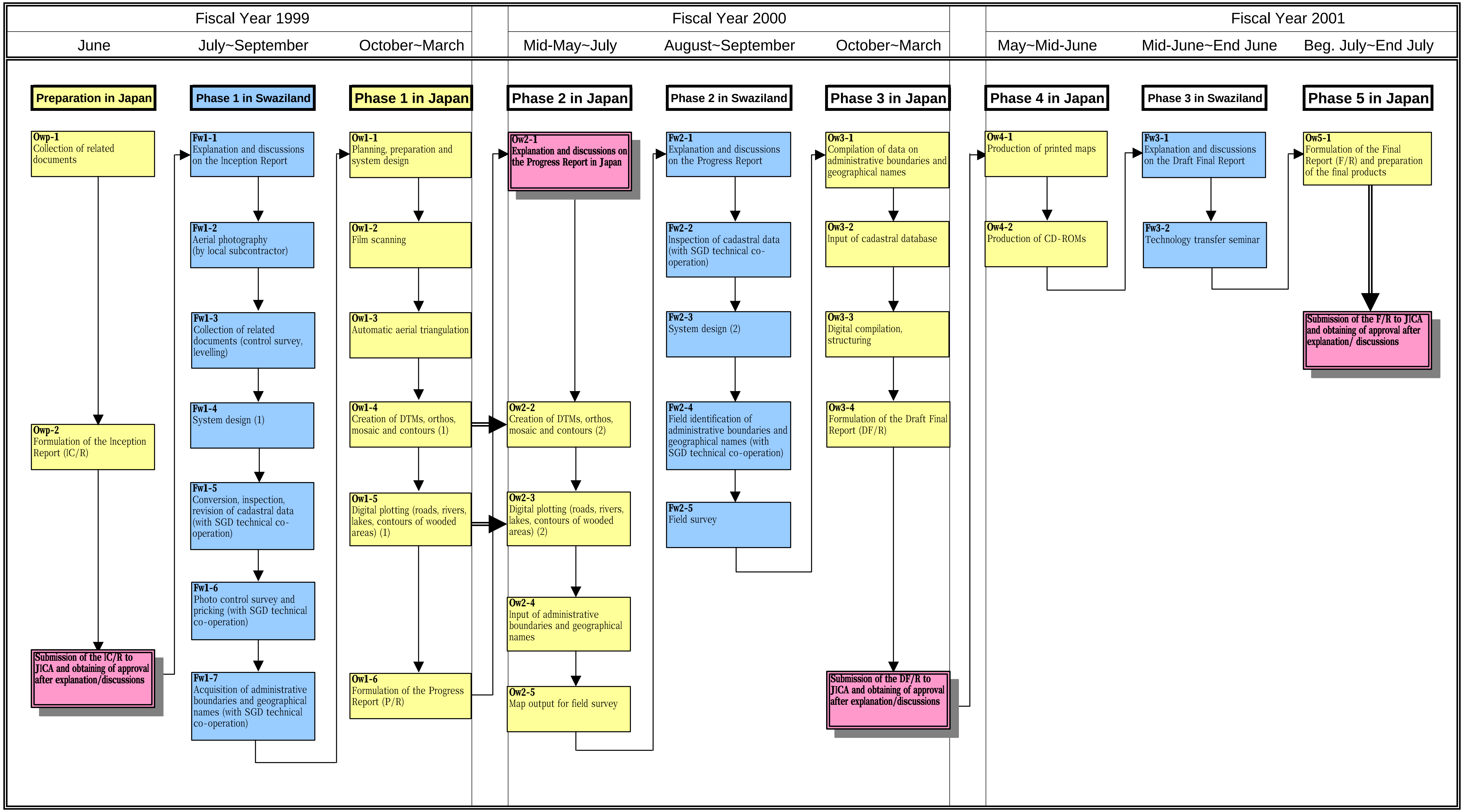
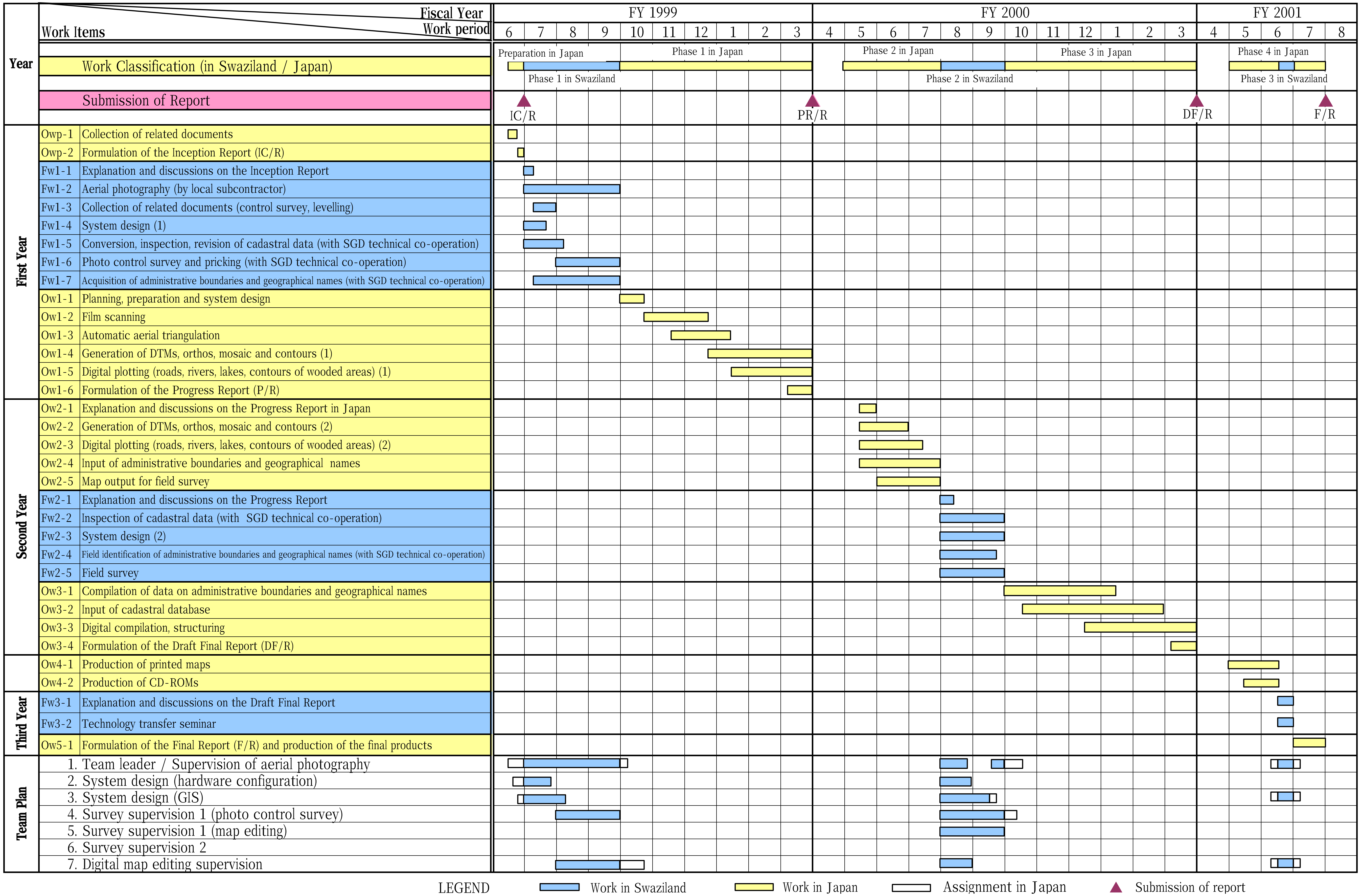


Fig. 1-3 Work Schedule



CHAPTER 2 BACKGROUND AND OBJECTIVES OF THE STUDY

2-1 BACKGROUND OF THE STUDY

2-1-1 Brief Description of Swaziland (Study Area)

Swaziland is a continental country bordered by the Republic of South Africa in the North, West and South, and the Republic of Mozambique in the East, covering 17,363 km^2, with a population of 910,000 (1995). It has a short history of 33 years since it became independent from the United Kingdom, and because of its geographic location, it is strongly influenced by the socio-economic conditions in South Africa. Given these conditions, the Government of Swaziland aims to become socio-economically independent by joining the SADC (Southern African Development Community), and strives to attract foreign capital and diversify the industrial structure.

(1) Topography

Also called the Switzerland of Africa for its scenic beauty, Swaziland has four main types of topography as follows from west to east:

④ Highveld: The Highveld consists of grassy mountains at an average elevation of 1,300m.

⑤ Middleveld: It consists of grasslands at an average elevation of 700m.

⑥ Lowveld: This area of bush and savannah has an average elevation of 250m.

⑦ Lubombo: This area forms a ridge at an average elevation of 600m between the Lowveld in the west and Mozambique in the east.

(2) Climate

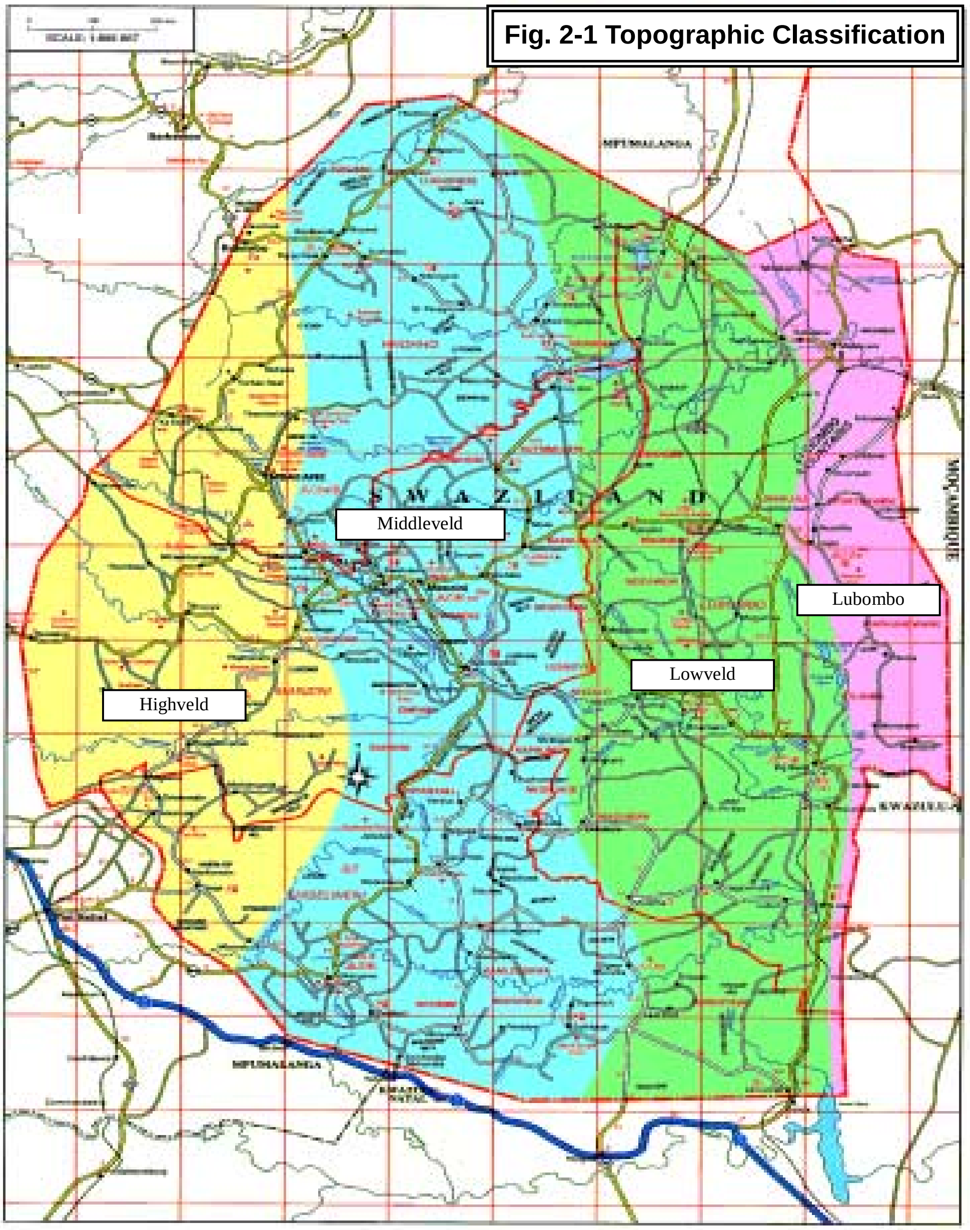
The climate can be roughly divided into three categories corresponding to topographic characteristics as defined above:

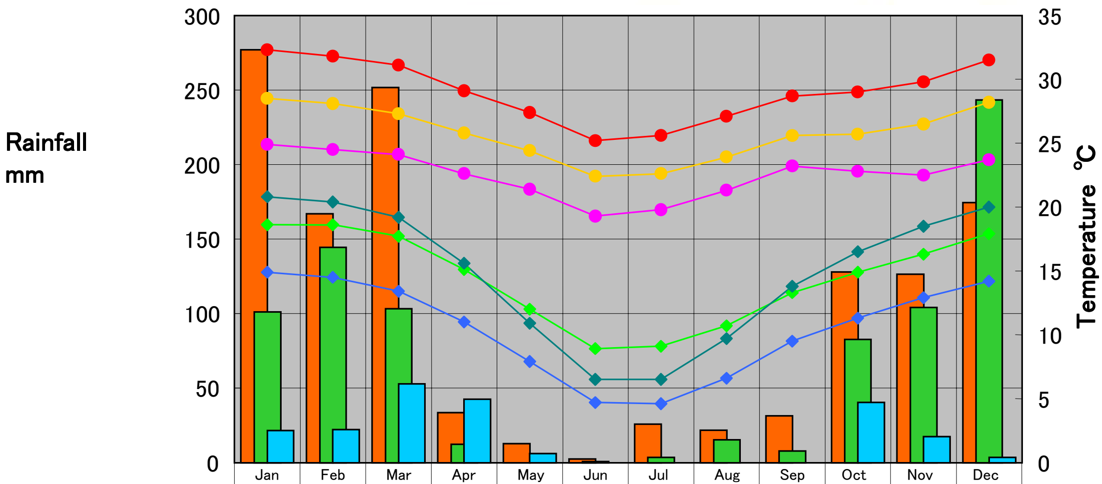
① Highveld: Humid temperate climate with high precipitations (1,000~2,500 mm/year).

② Middleveld and Lubombo: Subtropical climate, with annual precipitations ranging from 750 to 1,150 mm.

③ Lowveld: Tropical climate with the lowest precipitations (500~900mm).

Fig. 2-1 Topographic Classification





	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rain Highveld (Mbabane)	276.9	166.9	251.7	33.4	12.7	2.5	25.8	21.7	31.2	127.8	126.3	174.3
Rain Middleveld (Matsapha)	100.9	144.3	103	12.3	0	0.5	3.5	15.3	7.8	82.6	104.1	243.3
Rain Lowveld (Big Bend)	21.5	22	52.8	42.6	6	0	0	0	0	40.4	17.3	3.5
Max. Temp. Highveld	24.9	24.5	24.1	22.6	21.4	19.3	19.8	21.3	23.2	22.8	22.5	23.7
Min. Temp. Highveld	14.9	14.5	13.4	11	7.9	4.7	4.6	6.6	9.5	11.3	12.9	14.2
Max. Temp. Middleveld	28.5	28.1	27.3	25.8	24.4	22.4	22.6	23.9	25.6	25.7	26.5	28.2
Min. Temp. Middleveld	18.6	18.6	17.7	15.1	12	8.9	9.1	10.7	13.3	14.9	16.3	17.9
Max. Temp. Lowveld	32.3	31.8	31.1	29.1	27.4	25.2	25.6	27.1	28.7	29	29.8	31.5
Min. Temp. Lowveld	20.8	20.4	19.2	15.6	10.9	6.5	6.5	9.7	13.8	16.5	18.5	20

2-1-2 Dispatch of the Study Team

In the past, orthophoto maps were widely used instead of “line maps” (topographic maps) in Swaziland. However, the orthophotos in the possession of the Surveyor General’s Department (herein after referred to as the “SGD”) date from the 1970’s and are too old, therefore, to be put into good use for the implementation of the above mentioned plans and programs.

Also, a number of government institutions have introduced the Geographic Information System (GIS) as a new land management tool. The data in their possession, however, are existing 1:50,000 and 1:250,000 line maps which have been digitised. Consequently, the introduction and operation of GIS based on digital orthophoto maps are strongly called for.

Given the above conditions, in June 1997, the Government of Swaziland requested technical assistance from the Government of Japan to produce digital orthophoto maps at a scale of 1:10,000, which will be used as the national base map.

In response to this request, the Government of Japan dispatched a Preparatory Study Team from 10 to 29 January 1999, and the Scope of Work (S/W) was concluded on 27 January.

2-1-3 Counterpart Agency

The counterpart agency for this study is the Surveyor General’s Department (SGD) under the Ministry of Natural Resources and Energy. The SGD’s main line of activities are surveying the national territory and producing topographic maps that are indispensable for the development of the country.

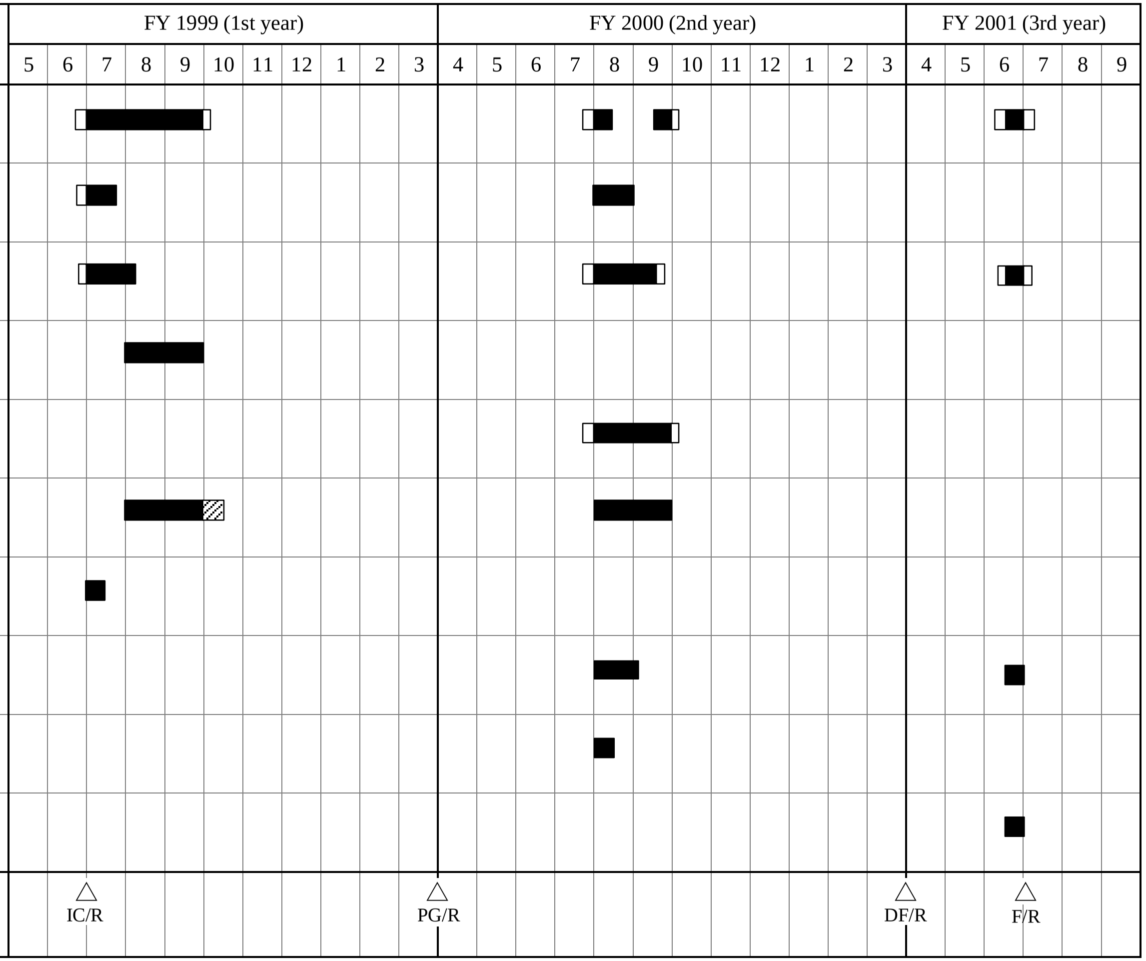
The business plan of the SGD includes the following concrete actions:

- Advising other government agencies and private organizations on surveying and mapping activities;
- Offering survey services and high quality topographic maps for national development and territorial management;
- Offering survey supervision and legal services for land registration;
- Training technicians in order to offer high quality products and services.

As the SGD is suffering budget restrictions, 75% of its budget must be allocated to personnel expenses. Even though the scope of independent survey activities is extremely narrow, the SGD is pursuing its efforts in cadastral survey, re-measurement of triangulation points and digital mapping of urban areas.

Table 2-1 Man/Month Work Schedule

RESPONSIBILITY	NAME	COMPANY	Rank
Team leader/aerial photography supervision	Kazuo FURUKATA	Kokusai Kogyo Co., Ltd.	2
System design (hardware configuration)	Masami SUGITA	Kokusai Kogyo Co., Ltd.	3
System design (GIS)	Kazutoshi MASUDA	Kokusai Kogyo Co., Ltd.	4
Survey supervision 1 (photo control point survey)	David J.M. BIGGERT	Swazi Surveys	3
Survey supervision 1 (map editing)	Satoru NISHIO	Kokusai Kogyo Co., Ltd.	3
Survey supervision 2	Morten STRAND	Fjellanger Widerøe AS	4
Coordinator	Odile GAYON	Kokusai Kogyo Co., Ltd.	5
Digital map data editing supervision	Daisaku KIYOTA	Kokusai Kogyo Co., Ltd.	4
Coordinator	Masahiko TAKAHASHI	Kokusai Kogyo Co., Ltd.	4
Coordinator	Chiyo KIGASAWA	Kokusai Kogyo Co., Ltd.	5
REPORTS			



LEGEND:
- Work in Swaziland
- Work in Japan
- Work in Japan by a foreign national

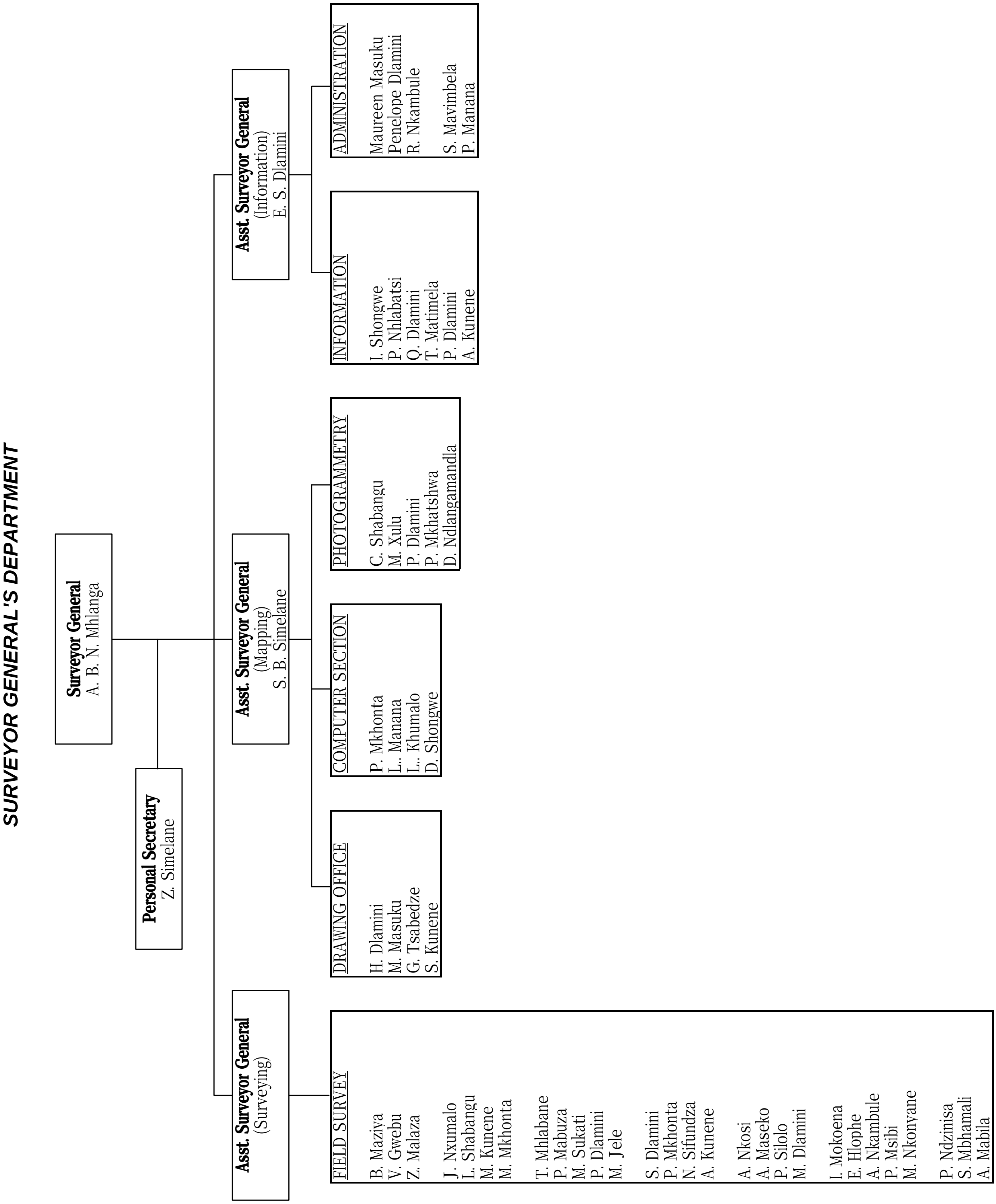


Fig. 2-2 Composition of the Counterpart Team

2-2 OBJECTIVES OF THE STUDY

2-2-1 Preparation of Digital Orthophoto Maps

The main objective of this study was to produce digital orthophoto maps covering the whole country at a scale of 1:10,000, for the smooth implementation of the Development Plan.

Another objective was to revise and update the cadastral survey results produced until then by the SGD, and to rebuild a GIS database using the digital orthophoto maps as a base.

2-2-2 Technology Transfer

Throughout the implementation of this Study, technology was transferred to the staff of the SGD, which acted as the counterpart, in the fields of digital orthophoto map operation and maintenance methods, effective methods of using these maps in GIS, and other related techniques.

Technology transfer related to orthophoto maps was conducted in the form of on-the-job training, as the photo control survey necessary for plotting, and the survey on annotations, administrative boundaries, geographical names and other information which must be shown on the maps, were jointly carried out with the SGD, making effective use of the latter’s assistance.

Technology transfer on GIS was conducted in the form of a technology transfer seminar also addressed to related government agencies, NGOs and other organizations. This seminar highlighted the usefulness of GIS and presented various possible applications.

Orthophoto created from a photo taken in 1988 (scale 1:7,500)
Centre of Mbabane

Extract of 1:50,000-scale topographic map (MBABANE, 1991)
Actual size, Mbabane

Photo:	Central projection
Orthophoto:	Orthographic projection
Line map (topographic map):	Orthographic projection

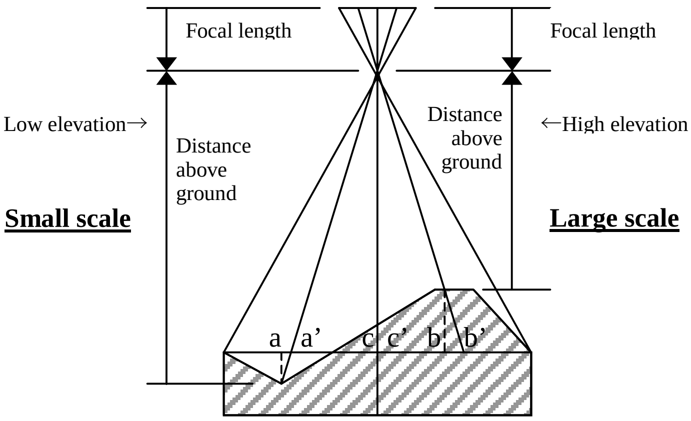
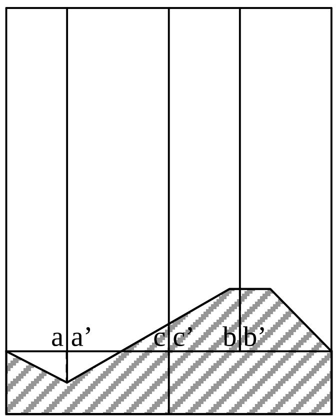


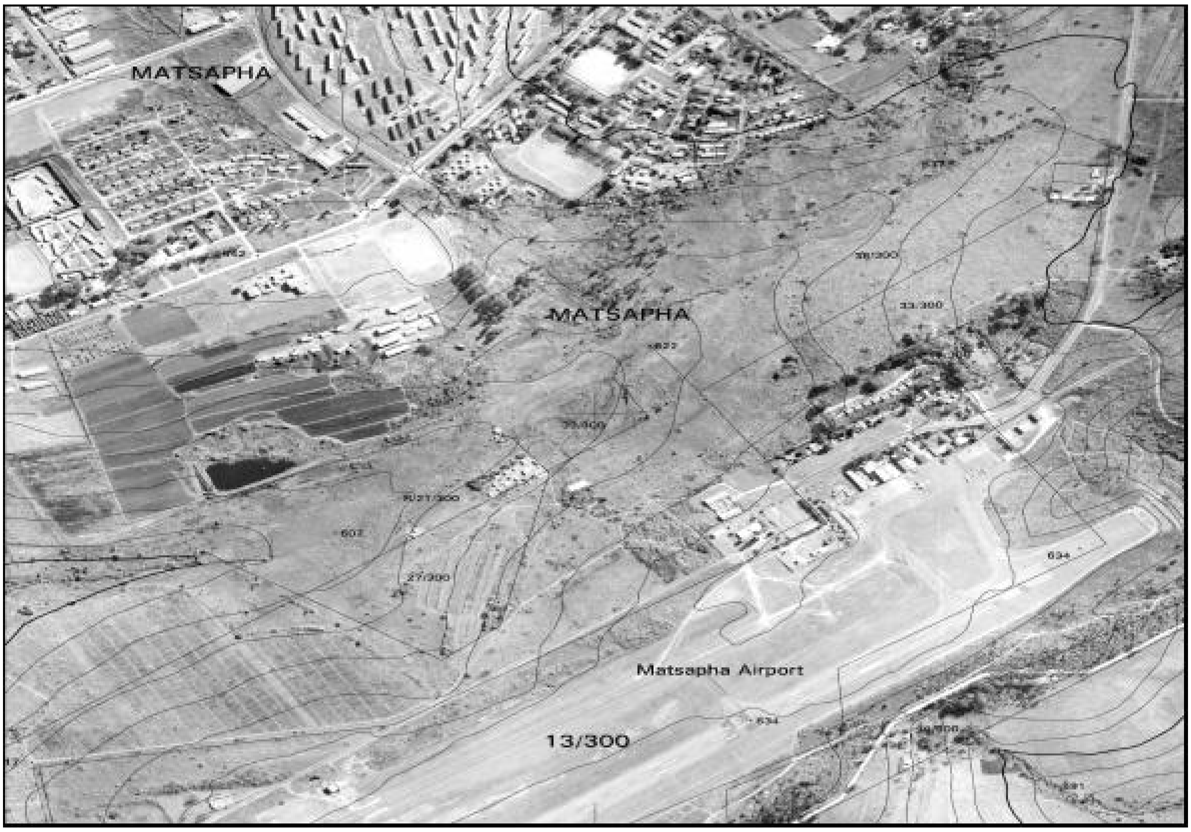
Photo image (central projection)



Orthophoto and topographic map image (orthographic projection)

Fig. 1-3 Orthophoto Map and Line Map (Topographic Map) Comparison

ORTHOPHOTO MAP IMAGE



LINE MAP WHICH CAN BE EASILY OPERATED IN GIS

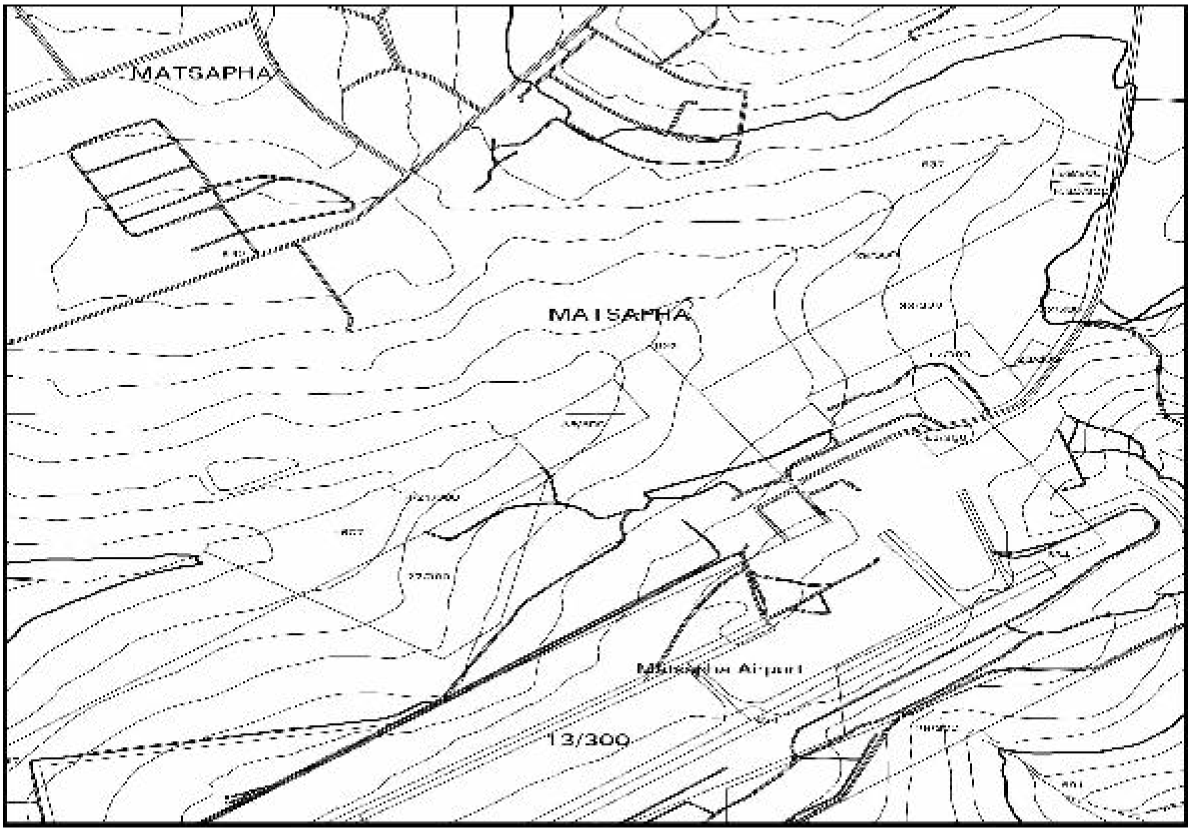


Fig. 1-4 Finished Images

CHAPTER 3 DETAILS AND RESULTS OF THE STUDY

3-1 PRODUCTION OF ORTHOPHOTO MAPS

3-1-1 Specifications

(1) Survey Standards and Work Specifications

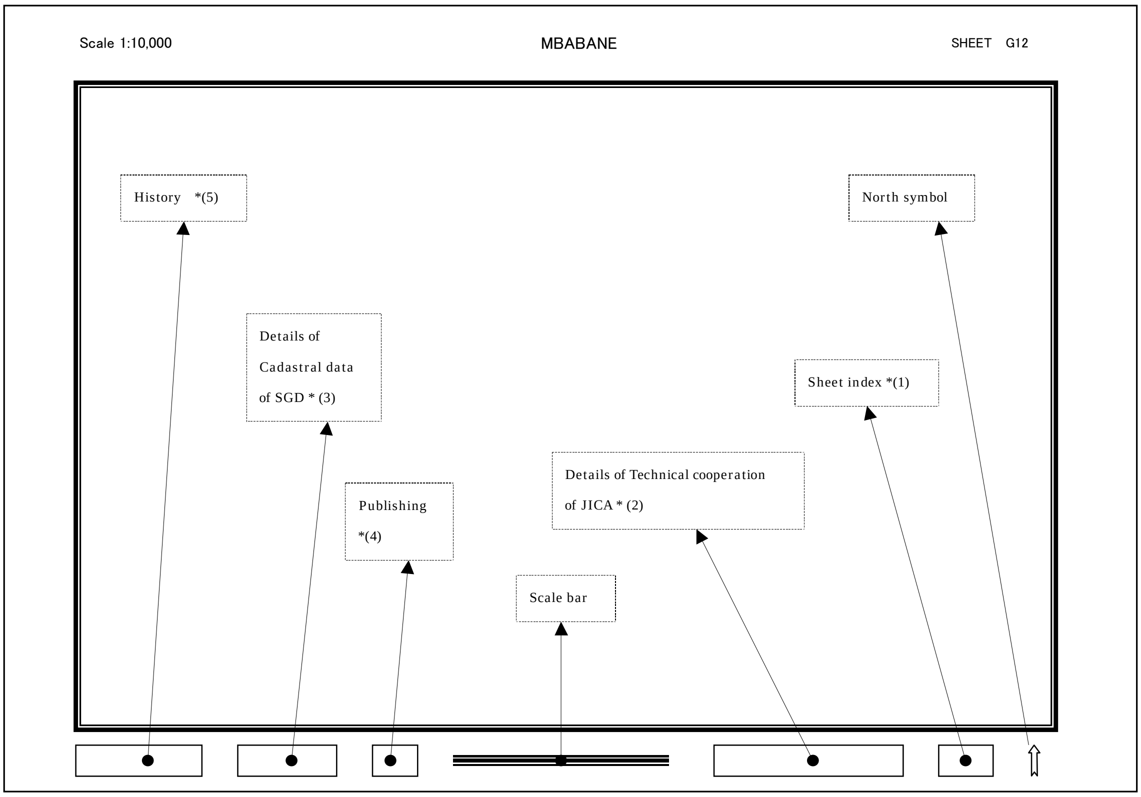
a) Reference ellipsoid: Clarke 1880 (a=6,378,249.145, f=1/293.466307656)
b) Projection method for topographic mapping: UTM projection method
c) Position of datum station: Meridian direction = E. Long. 31°, Lat. = Equator
d) System of coordinates: South African survey coordinate system Lo. 31
e) Datum of elevation: B.M. (National Elevation System = Mean Sea Level)

(2) Discussions on and Selection of Map Symbols

① The map symbols to be used on the orthophoto maps, marginal information and the sheet index were discussed and confirmed based on existing maps of Swaziland.

② Other marginal information (history, details of cadastral data, copyright, scale bar, index to adjoining sheets, sheet names and numbers, etc.) were discussed, and agreed as indicated in Figure 3-1.

③ The sheet index was prepared after confirming the frontiers delineating the territory of Swaziland, and is shown in Figure 3-2.



* (1) Sheet Index

F 11	G 11	H 11
F 12	***G 12***	H 12
F 13	G 13	H 13

* (2) Details of Technical Cooperation of JICA

These data were prepared jointly by the Japan International Cooperation Agency (JICA) under the Japanese Government Technical Cooperation Program, and the Government of Swaziland.

* (3) Details of Cadastral data

・*Regional Coverage : All cadastral details are depicted above except rivers.*
・*Urban Coverage : Only urban boundaries are depicted above.*
・*Final Cadastral update : March 1999*

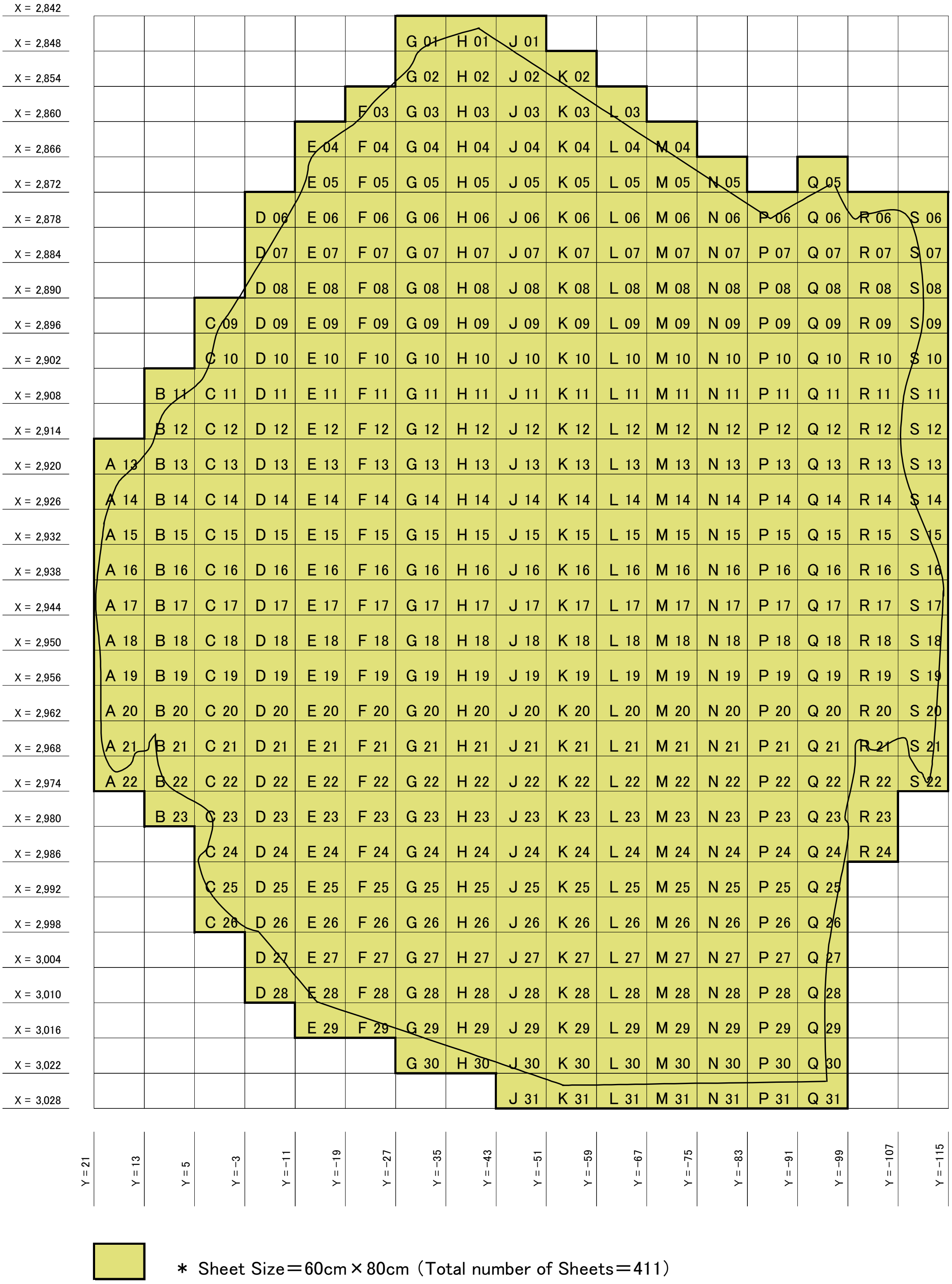
* (4) Publishing

Published by the : Surveyor General's Department
Ministry of Natural Resources & Energy
P.O. Box 4700
Mbabane, Swaziland

* (5) History

・*Aerial Photography : July & August 1999*
・*Photo Control Survey : September 1999*
・*Orthophoto Mapping : October 1999 – March 2001*
・*Coordinate System : Lo 31*
・*Datum Height : Mean Sea Level*
・*Contour Interval : 5 & 10m*

Fig. 3-1 Marginal Information



＊ Sheet Size＝60cm × 80cm（Total number of Sheets＝411）

＊ X・Y values besed on National Coordinate System Lo=31 (km)

Fig. 3-2　Sheet Index for Orthophotos

3-1-2 Aerial Photography (by Local Subcontractor)

(1) Selection of the Local Subcontractor

① Three South African companies were pre-selected as sub-contractors.

② The flight map, flight plan (coordinates of the photography beginning and ending points, flight length and altitude) and aerial photography specifications were sent to these three companies, and they were requested to submit a proposal and an estimate.

(2) Acquisition of Proposals and Estimates, Technical Evaluation and Signing of the Contract

① The three companies submitted their proposals and estimates prior to the team's entry into Swaziland.

② The tenders were evaluated based on proposal contents, tendered amounts, equipment, technical skills and experience, and one company was selected.

(3) Sequence of Evaluation and Selection

① A comparative investigation on the three companies was conducted on the basis of experience, equipment, contract amount, etc.

② DTM company was selected based on the facts that it owned the latest camera equipment and GPS navigation system, it already had a permit to fly over Swaziland, and it proposed the lowest estimate amount. The photography work started as soon as the selection was approved by JICA.

(4) Specifications of Aerial Photography

① Aerial camera equipment
Leica RC30 camera
Leica PAV30 Gyromount
GPS (for photo coordinates measurement and navigation)
FMC (forward motion compensation)

② Aerial photos
Focal length: f = 15 cm
Picture size: 23 x 23 cm
Photographic scale: 1:30,000
Mean overlap: Approx. 60%
Mean sidelap: Approx. 40%

(5) Results of Photography

Figure 3-3 shows the flight index and Table 3-1 shows the accuracy control table.

(6) Film Annotations

As instructed by the Study Team, film annotations were input in the camera at the time of photography, so that the following indications appears on each contact print:

SWAZILAND	**C09**	**23/07/99**	**1:30,000**	**JICA-SGD**

Concerning the photo numbers, as shown in Table 3-1, three photos have the same number, presumably due to a camera operation error during the photography work.

To avoid any error in subsequent work, new numbers were assigned to all the photos, in order from north to south for the north-south flight lines, and from west to east for the east-west flight lines, starting from 1 at each line.

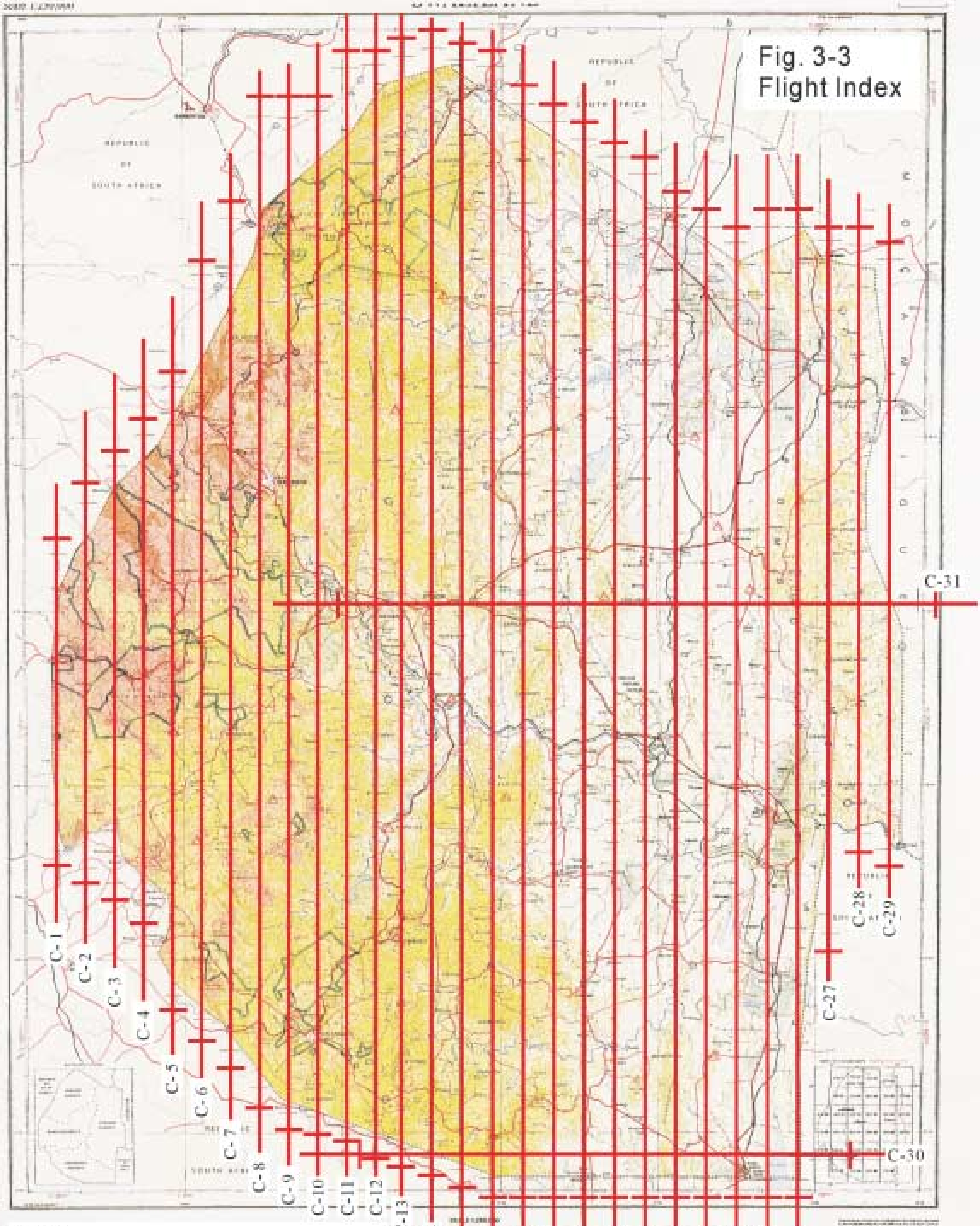


Fig. 3-3 Flight Index

LEGEND

		Number of Courses	Number of Photos
	Flight Course N-S	29	1,533
	Flight Course W-E	2	60
	Total	31	1,593

C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	C-11	C-12	C-13	C-14	C-15	C-16	C-17	C-18	C-19	C-20	C-21N	C-21S	C-22	C-23	C-24	C-25N	C-25S	C-26	C-27	C-28	C-29	C-30	C-31
21	23	26	32	39	46	52	60	61	62	65	65	62	65	64	67	66	64	63	62	41	27	58	57	54	18	43	58	41	35	36	25	35
1. 3585	1. 3542	1. 4000	1. 4057	1. 3457	1. 3541	1. 3444	1. 3333	1. 3332	1. 3210	1. 3209	1. 3081	1. 4058	1. 4184	1. 4185	1. 2253	1. 2254	1. 2383	1. 2384	1. 2508	1. 2509		1. 4250	1. 4340	1. 4450	1. 4451		1. 2556	1. 4559	1. 4488	1. 4558	1. 0282	1. 0001
2. 3584	2. 3543	2. 4001	2. 4056	2. 3458	2. 3540	2. 3443	2. 3334	2. 3331	2. 3211	2. 3208	2. 3082	2. 4059	2. 4183	2. 4186	2. 2252	2. 2255	2. 2382	2. 2385	2. 2507	2. 2510		2. 4251	2. 4341	2. 4449	2. 4452		2. 2557	2. 4560	2. 4489	2. 4557	2. 0281	2. 0002
3. 3583	3. 3544	3. 4002	3. 4055	3. 3459	3. 3539	3. 3442	3. 3335	3. 3330	3. 3212	3. 3207	3. 3083	3. 4060	3. 4182	3. 4187	3. 2251	3. 2256	3. 2381	3. 2386	3. 2506	3. 2511		3. 4252	3. 4342	3. 4448	3. 4453		3. 2558	3. 4561	3. 4490	3. 4556	3. 0280	3. 0003
4. 3582	4. 3545	4. 4003	4. 4054	4. 3460	4. 3538	4. 3441	4. 3336	4. 3329	4. 3213	4. 3206	4. 3084	4. 4061	4. 4181	4. 4188	4. 2250	4. 2257	4. 2380	4. 2387	4. 2505	4. 2512		4. 4253	4. 4343	4. 4447	4. 4454		4. 2559	4. 4562	4. 4491	4. 4555	4. 0279	4. 0004
5. 3581	5. 3546	5. 4004	5. 4053	5. 3461	5. 3537	5. 3440	5. 3337	5. 3328	5. 3214	5. 3205	5. 3085	5. 4062	5. 4180	5. 4189	5. 2249	5. 2258	5. 2379	5. 2388	5. 2504	5. 2513		5. 4254	5. 4344	5. 4446	5. 4455		5. 2560	5. 4563	5. 4492	5. 4554	5. 0278	5. 0005
6. 3580	6. 3547	6. 4005	6. 4052	6. 3462	6. 3536	6. 3439	6. 3338	6. 3327	6. 3215	6. 3204	6. 3086	6. 4063	6. 4179	6. 4190	6. 2248	6. 2259	6. 2378	6. 2389	6. 2503	6. 2514		6. 4255	6. 4345	6. 4445	6. 4456		6. 2561	6. 4564	6. 4493	6. 4553	6. 0277	6. 0006
7. 3579	7. 3548	7. 4006	7. 4051	7. 3463	7. 3535	7. 3438	7. 3339	7. 3326	7. 3216	7. 3203	7. 3087	7. 4064	7. 4178	7. 4191	7. 2247	7. 2260	7. 2377	7. 2390	7. 2502	7. 2515		7. 4256	7. 4346	7. 4444	7. 4457		7. 2562	7. 4565	7. 4494	7. 4552	7. 0276	7. 0007
8. 3578	8. 3549	8. 4007	8. 4050	8. 3464	8. 3534	8. 3437	8. 3340	8. 3325	8. 3217	8. 3202	8. 3088	8. 4065	8. 4177	8. 4192	8. 2246	8. 2261	8. 2376	8. 2391	8. 2501	8. 2516		8. 4257	8. 4347	8. 4443	8. 4458		8. 2563	8. 4566	8. 4495	8. 4551	8. 0275	8. 0008
9. 3577	9. 3550	9. 4008	9. 4049	9. 3465	9. 3533	9. 3436	9. 3341	9. 3324	9. 3218	9. 3201	9. 3089	9. 4066	9. 4176	9. 4193	9. 2245	9. 2262	9. 2375	9. 2392	9. 2500	9. 2517		9. 4258	9. 4348	9. 4442	9. 4459		9. 2564	9. 4567	9. 4496	9. 4550	9. 0274	9. 0009
10. 3576	10. 3551	10. 4009	10. 4048	10. 3466	10. 3532	10. 3435	10. 3342	10. 3323	10. 3219	10. 3200	10. 3090	10. 4067	10. 4175	10. 4194	10. 2244	10. 2263	10. 2374	10. 2393	10. 2499	10. 2518		10. 4259	10. 4349	10. 4441	10. 4460		10. 2565	10. 4568	10. 4497	10. 4549	10. 0273	10. 0010
11. 3575	11. 3552	11. 4010	11. 4047	11. 3467	11. 3531	11. 3434	11. 3343	11. 3322	11. 3220	11. 3199	11. 3091	11. 4068	11. 4174	11. 4195	11. 2244	11. 2264	11. 2373	11. 2394	11. 2498	11. 2519		11. 4260	11. 4350	11. 4440	11. 4461		11. 2566	11. 4569	11. 4498	11. 4548	11. 0272	11. 0011
12. 3574	12. 3553	12. 4011	12. 4046	12. 3468	12. 3530	12. 3433	12. 3344	12. 3321	12. 3221	12. 3198	12. 3092	12. 4069	12. 4173	12. 4196	12. 2243	12. 2265	12. 2372	12. 2395	12. 2497	12. 2520		12. 4261	12. 4351	12. 4439	12. 4462		12. 2567	12. 4570	12. 4499	12. 4547	12. 0271	12. 0012
13. 3573	13. 3554	13. 4012	13. 4045	13. 3469	13. 3529	13. 3432	13. 3345	13. 3320	13. 3222	13. 3197	13. 3093	13. 4070	13. 4172	13. 4197	13. 2242	13. 2266	13. 2371	13. 2396	13. 2496	13. 2521		13. 4262	13. 4352	13. 4438	13. 4463		13. 2568	13. 4571	13. 4500	13. 4546	13. 0270	13. 0013
14. 3572	14. 3555	14. 4013	14. 4044	14. 3470	14. 3528	14. 3431	14. 3346	14. 3319	14. 3223	14. 3196	14. 3094	14. 4071	14. 4171	14. 4198	14. 2241	14. 2267	14. 2370	14. 2397	14. 2495	14. 2522		14. 4263	14. 4353	14. 4437	14. 4464		14. 2569	14. 4572	14. 4501	14. 4545	14. 0269	14. 0014
15. 3571	15. 3556	15. 4014	15. 4043	15. 3471	15. 3527	15. 3430	15. 3347	15. 3318	15. 3224	15. 3195	15. 3095	15. 4072	15. 4170	15. 4199	15. 2240	15. 2268	15. 2369	15. 2398	15. 2494	15. 2523		15. 4264	15. 4354	15. 4436	15. 4465	1. 2660	15. 2570	15. 4573	15. 4502	15. 4544	15. 0268	15. 0015
16. 3570	16. 3557	16. 4015	16. 4042	16. 3472	16. 3526	16. 3429	16. 3348	16. 3317	16. 3225	16. 3194	16. 3096	16. 4073	16. 4169	16. 4200	16. 2239	16. 2269	16. 2368	16. 2399	16. 2493	16. 2524		16. 4265	16. 4355	16. 4435	16. 4466	2. 2659	16. 2571	16. 4574	16. 4503	16. 4543	16. 0267	16. 0016
17. 3569	17. 3558	17. 4016	17. 4041	17. 3473	17. 3525	17. 3428	17. 3349	17. 3316	17. 3226	17. 3193	17. 3097	17. 4074	17. 4168	17. 4201	17. 2238	17. 2270	17. 2367	17. 2400	17. 2492	17. 2525		17. 4266	17. 4356	17. 4434	17. 4467	3. 2658	17. 2572	17. 4575	17. 4504	17. 4542	17. 0266	17. 0017
18. 3568	18. 3559	18. 4017	18. 4040	18. 3474	18. 3524	18. 3427	18. 3350	18. 3315	18. 3227	18. 3192	18. 3098	18. 4075	18. 4167	18. 4202	18. 2237	18. 2271	18. 2366	18. 2401	18. 2491	18. 2526		18. 4267	18. 4357	18. 4433	18. 4468	4. 2657	18. 2573	18. 4576	18. 4505	18. 4541	18. 0265	18. 0018
19. 3567	19. 3560	19. 4018	19. 4039	19. 3475	19. 3523	19. 3426	19. 3351	19. 3314	19. 3228	19. 3191	19. 3099	19. 4076	19. 4166	19. 4203	19. 2236	19. 2272	19. 2365	19. 2402	19. 2490	19. 2527		19. 4268	19. 4358	19. 4432		5. 2656	19. 2574	19. 4577	19. 4506	19. 4540	19. 0264	19. 0019
20. 3566	20. 3561	20. 4019	20. 4038	20. 3476	20. 3522	20. 3425	20. 3352	20. 3313	20. 3229	20. 3190	20. 3100	20. 4077	20. 4165	20. 4204	20. 2235	20. 2273	20. 2364	20. 2403	20. 2489	20. 2528		20. 4269	20. 4359	20. 4431		6. 2655	20. 2575	20. 4578	20. 4507	20. 4539	20. 0263	20. 0020
21. 3565	21. 3562	21. 4020	21. 4037	21. 3477	21. 3521	21. 3424	21. 3353	21. 3312	21. 3230	21. 3189	21. 3101	21. 4078	21. 4164	21. 4205	21. 2234	21. 2274	21. 2363	21. 2404	21. 2488	21. 2529		21. 4270	21. 4360	21. 4430		7. 2654	21. 2576	21. 4579	21. 4508	21. 4538	21. 0262	21. 0021
	22. 3563	22. 4021	22. 4036	22. 3478	22. 3520	22. 3423	22. 3354	22. 3311	22. 3231	22. 3188	22. 3102	22. 4079	22. 4163	22. 4206	22. 2233	22. 2275	22. 2362	22. 2405	22. 2487	22. 2530		22. 4271	22. 4361	22. 4429		8. 2653	22. 2577	22. 4580	22. 4509	22. 4537	22. 0261	22. 0022
	23. 3564	23. 4022	23. 4035	23. 3479	23. 3519	23. 3422	23. 3355	23. 3310	23. 3232	23. 3187	23. 3103	23. 4080	23. 4162	23. 4207	23. 2232	23. 2276	23. 2361	23. 2406	23. 2486	23. 2531		23. 4272	23. 4362	23. 4428		9. 2652	23. 2578	23. 4581	23. 4510	23. 4536	23. 0260	23. 0023
		24. 4023	24. 4034	24. 3480	24. 3518	24. 3421	24. 3356	24. 3309	24. 3233	24. 3186	24. 3104	24. 4081	24. 4161	24. 4208	24. 2231	24. 2277	24. 2360	24. 2407	24. 2485	24. 2532		24. 4273	24. 4363	24. 4427		10. 2651	24. 2579	24. 4582	24. 4511	24. 4535	24. 0259	24. 0024
		25. 4024	25. 4033	25. 3481	25. 3517	25. 3420	25. 3357	25. 3308	25. 3234	25. 3185	25. 3105	25. 4082	25. 4160	25. 4209	25. 2230	25. 2278	25. 2359	25. 2408	25. 2484	25. 2533		25. 4274	25. 4364	25. 4426		11. 2650	25. 2580	25. 4583	25. 4512	25. 4534	25. 0258	25. 0025
		26. 4025	26. 4032	26. 3482	26. 3516	26. 3419	26. 3358	26. 3307	26. 3235	26. 3184	26. 3106	26. 4083	26. 4159	26. 4210	26. 2229	26. 2279	26. 2358	26. 2409	26. 2483	26. 2534		26. 4275	26. 4365	26. 4425		12. 2649	26. 2581	26. 4584	26. 4513	26. 4533		26. 0026
			27. 4031	27. 3483	27. 3515	27. 3418	27. 3359	27. 3306	27. 3236	27. 3183	27. 3107	27. 4084	27. 4158	27. 4211	27. 2228	27. 2280	27. 2357	27. 2410	27. 2482	27. 2535		27. 4276	27. 4366	27. 4424		13. 2648	27. 2582	27. 4585	27. 4514	27. 4532		27. 0027
			28. 4030	28. 3484	28. 3514	28. 3417	28. 3360	28. 3305	28. 3237	28. 3182	28. 3108	28. 4085	28. 4157	28. 4212	28. 2227	28. 2281	28. 2356	28. 2411	28. 2481	28. 2536		28. 4277	28. 4367	28. 4423		14. 2647	28. 2583	28. 4586	28. 4515	28. 4531		28. 0028
			29. 4029	29. 3485	29. 3513	29. 3416	29. 3361	29. 3304	29. 3238	29. 3181	29. 3108	29. 4086	29. 4156	29. 4213	29. 2226	29. 2282	29. 2355	29. 2412	29. 2480	29. 2537		29. 4278	29. 4368	29. 4422		15. 2646	29. 2584	29. 4587	29. 4516	29. 4530		29. 0029
			30. 4028	30. 3486	30. 3512	30. 3415	30. 3362	30. 3303	30. 3239	30. 3180	30. 3109	30. 4087	30. 4155	30. 4214	30. 2225	30. 2283	30. 2354	30. 2413	30. 2479	30. 2538		30. 4279	30. 4369	30. 4421		16. 2645	30. 2585	30. 4588	30. 4517	30. 4529		30. 0030
			31. 4027	31. 3487	31. 3511	31. 3414	31. 3363	31. 3302	31. 3240	31. 3179	31. 3110	31. 4088	31. 4154	31. 4215	31. 2224	31. 2284	31. 2353	31. 2414	31. 2478	31. 2539		31. 4280	31. 4370	31. 4420		17. 2644	31. 2586	31. 4589	31. 4518	31. 4528		31. 0031
			32. 4026	32. 3488	32. 3510	32. 3413	32. 3364	32. 3301	32. 3241	32. 3178	32. 3111	32. 4089	32. 4153	32. 4216	32. 2223	32. 2285	32. 2352	32. 2415	32. 2477	32. 2540	1. 4334	32. 4281	32. 4371	32. 4419		18. 2643	32. 2587	32. 4590	32. 4519	32. 4527		32. 0032
				33. 3489	33. 3509	33. 3412	33. 3365	33. 3300	33. 3242	33. 3177	33. 3112	33. 4090	33. 4152	33. 4217	33. 2222	33. 2286	33. 2351	33. 2416	33. 2476	33. 2541	2. 4333	33. 4282	33. 4372	33. 4418		19. 2642	33. 2588	33. 4591	33. 4520	33. 4526		33. 0033
				34. 3490	34. 3508	34. 3411	34. 3366	34. 3299	34. 3243	34. 3176	34. 3113	34. 4091	34. 4151	34. 4218	34. 2221	34. 2287	34. 2350	34. 2417	34. 2475	34. 2542	3. 4332	34. 4283	34. 4373	34. 4417		20. 2641	34. 2589	34. 4592	34. 4521	34. 4525		34. 0034
				35. 3491	35. 3507	35. 3410	35. 3367	35. 3298	35. 3244	35. 3175	35. 3114	35. 4092	35. 4150	35. 4219	35. 2220	35. 2288	35. 2349	35. 2418	35. 2474	35. 2543	4. 4331	35. 4284	35. 4374	35. 4416		21. 2640	35. 2590	35. 4593	35. 4522	35. 4524		35. 0035
				36. 3492	36. 3506	36. 3409	36. 3368	36. 3297	36. 3245	36. 3174	36. 3115	36. 4093	36. 4149	36. 4220	36. 2219	36. 2289	36. 2348	36. 2419	36. 2473	36. 2544	5. 4330	36. 4285	36. 4375	36. 4415		22. 2639	36. 2591	36. 4594		36. 4523		
				37. 3493	37. 3505	37. 3408	37. 3369	37. 3296	37. 3246	37. 3173	37. 3116	37. 4094	37. 4148	37. 4221	37. 2218	37. 2290	37. 2347	37. 2420	37. 2472	37. 2545	6. 4329	37. 4286	37. 4376	37. 4414		23. 2638	37. 2592	37. 4595				
				38. 3494	38. 3504	38. 3407	38. 3370	38. 3295	38. 3247	38. 3172	38. 3117	38. 4095	38. 4147	38. 4222	38. 2217	38. 2291	38. 2346	38. 2421	38. 2471	38. 2546	7. 4328	38. 4287	38. 4377	38. 4413		24. 2637	38. 2593	38. 4596				
				39. 3495	39. 3503	39. 3406	39. 3371	39. 3294	39. 3248	39. 3171	39. 3118	39. 4096	39. 4146	39. 4223	39. 2216	39. 2292	39. 2345	39. 2422	39. 2470	39. 2547	8. 4327	39. 4288	39. 4378	39. 4412		25. 2636	39. 2594	39. 4597				
					40. 3502	40. 3405	40. 3372	40. 3293	40. 3249	40. 3170	40. 3119	40. 4097	40. 4145	40. 4224	40. 2215	40. 2293	40. 2344	40. 2423	40. 2469	40. 2548	9. 4326	40. 4289	40. 4379	40. 4411		26. 2635	40. 2595	40. 4598				
					41. 3501	41. 3404	41. 3373	41. 3292	41. 3250	41. 3169	41. 3120	41. 4098	41. 4144	41. 4225	41. 2214	41. 2294	41. 2343	41. 2424	41. 2468	41. 2549	10. 4325	41. 4290	41. 4380	41. 4410		27. 2634	41. 2596	41. 4599				
					42. 3500	42. 3403	42. 3374	42. 3291	42. 3251	42. 3168	42. 3121	42. 4099	42. 4143	42. 4226	42. 2213	42. 2295	42. 2342	42. 2425	42. 2467		11. 4324	42. 4291	42. 4381	42. 4409		28. 2633	42. 2597					
					43. 3499	43. 3402	43. 3375	43. 3290	43. 3252	43. 3167	43. 3122	43. 4100	43. 4142	43. 4227	43. 2212	43. 2296	43. 2341	43. 2426	43. 2466		12. 4323	43. 4292	43. 4382	43. 4408		29. 2632	43. 2598					
					44. 3498	44. 3401	44. 3376	44. 3289	44. 3253	44. 3166	44. 3123	44. 4101	44. 4141	44. 4228	44. 2211	44. 2297	44. 2340	44. 2427	44. 2465		13. 4322	44. 4293	44. 4383	44. 4407		30. 2631	44. 2599					
					45. 3497	45. 3400	45. 3377	45. 3288	45. 3254	45. 3165	45. 3124	45. 4102	45. 4140	45. 4229	45. 2210	45. 2298	45. 2339	45. 2428	45. 2464		14. 4321	45. 4294	45. 4384	45. 4406		31. 2630	45. 2600					
					46. 3496	46. 3399	46. 3378	46. 3287	46. 3255	46. 3164	46. 3125	46. 4103	46. 4139	46. 4230	46. 2209	46. 2299	46. 2338	46. 2429	46. 2463		15. 4320	46. 4295	46. 4385	46. 4405		32. 2629	46. 2601					
						47. 3398	47. 3379	47. 3286	47. 3256	47. 3163	47. 3126	47. 4104	47. 4138	47. 4231	47. 2208	47. 2300	47. 2337	47. 2430	47. 2462		16. 4319	47. 4296	47. 4386	47. 4404		33. 2628	47. 2602					
						48. 3397	48. 3380	48. 3285	48. 3257	48. 3162	48. 3127	48. 4105	48. 4137	48. 4232	48. 2207	48. 2301	48. 2336	48. 2431	48. 2461		17. 4318	48. 4297	48. 4387	48. 4403		34. 2627	48. 2603					
						49. 3396	49. 3381	49. 3284	49. 3258	49. 3161	49. 3128	49. 4106	49. 4136	49. 4233	49. 2206	49. 2302	49. 2335	49. 2432	49. 2460		18. 4317	49. 4298	49. 4388	49. 4402		35. 2626	49. 2604					
						50. 3395	50. 3382	50. 3283	50. 3259	50. 3160	50. 3129	50. 4107	50. 4135	50. 4234	50. 2205	50. 2303	50. 2334	50. 2433	50. 2459		19. 4316	50. 4299	50. 4389	50. 4401		36. 2625	50. 2605					
						51. 3394	51. 3383	51. 3282	51. 3260	51. 3159	51. 3130	51. 4108	51. 4134	51. 4235	51. 2204	51. 2304	51. 2333	51. 2434	51. 2458		20. 4315	51. 4300	51. 4390	51. 4400		37. 2624	51. 2606					
						52. 3393	52. 3384	52. 3281	52. 3261	52. 3158	52. 3131	52. 4109	52. 4133	52. 4236	52. 2203	52. 2305	52. 2332	52. 2435	52. 2457		21. 4314	52. 4301	52. 4391	52. 4399		38. 2623	52. 2606					
							53. 3385	53. 3280	53. 3262	53. 3157	53. 3132	53. 4110	53. 4132	53. 4237	53. 2202	53. 2306	53. 2331	53. 2436	53. 2456		22. 4313	53. 4302	53. 4392	53. 4398		39. 2622	53. 2607					
							54. 3386	54. 3279	54. 3263	54. 3156	54. 3133	54. 4111	54. 4131	54. 4238	54. 2201	54. 2307	54. 2330	54. 2437	54. 2455		23. 4312	54. 4303	54. 4393	54. 4397		40. 2621	54. 2608					
							55. 3387	55. 3278	55. 3264	55. 3155	55. 3134	55. 4112	55. 4130	55. 4239	55. 2200	55. 2308	55. 2329	55. 2438	55. 2454		24. 4311	55. 4304	55. 4394			41. 2620	55. 2609					
							56. 3388	56. 3277	56. 3265	56. 3154	56. 3135	56. 4113	56. 4129	56. 4240	56. 2199	56. 2309	56. 2328	56. 2439	56. 2453		25. 4310	56. 4305	56. 4395			42. 2619	56. 2610					
							57. 3389	57. 3276	57. 3266	57. 3153	57. 3136	57. 4114	57. 4128	57. 4241	57. 2198	57. 2310	57. 2327	57. 2440	57. 2452		26. 4309	57. 4306	57. 4396			43. 2618	57. 2611					
							58. 3390	58. 3275	58. 3267	58. 3152	58. 3137	58. 4115	58. 4127	58. 4242	58. 2197	58. 2311	58. 2326	58. 2441	58. 2451		27. 4308	58. 4307					58. 2612					
							59. 3391	59. 3274	59. 3268	59. 3151	59. 3138	59. 4116	59. 4126	59. 4243	59. 2196	59. 2312	59. 2325	59. 2442	59. 2450													
							60. 3392	60. 3273	60. 3269	60. 3150	60. 3139	60. 4117	60. 4125	60. 4244	60. 2195	60. 2313	60. 2324	60. 2443	60. 2449													
								61. 3272	61. 3270	61. 3149	61. 3140	61. 4118	61. 4124	61. 4245	61. 2194	61. 2314	61. 2323	61. 2444	61. 2448													
									62. 3271	62. 3148	62. 3141	62. 4119	62. 4123	62. 4246	62. 2193	62. 2315	62. 2322	62. 2445	62. 2447													
										63. 3147	63. 3142		63. 4122	63. 4247	63. 2192	63. 2316	63. 2321	63. 2446														
										64. 3146	64. 3143		64. 4121	64. 4248	64. 2191	64. 2317	64. 2320															
										65. 3145	65. 3144		65. 4120		65. 2190	65. 2318																
															66. 2189	66. 2319																
															67. 2188																	
21	23	26	32	39	46	52	60	61	62	65	65	62	65	64	67	66	64	63	62	41	27	58	57	54	18	43	58	41	35	36	25	35

TOTAL PHOTO NUMBER = 1593

3-1-3 Photo Control Survey and Pricking (With SGD Technical Co-operation)

Existing control points and benchmarks installed in the territory of Swaziland were confirmed based on the photo control survey plan which had been prepared during the Preparation in Japan. After discussions with the SGD, the final photo control survey plan was confirmed.

(1) Outline of the Study Implementation

As a rule, most of the study work in the field was implemented jointly by JICA Study Team and the SGD.

The field survey staff of the SGD used to conduct mainly cadastral surveys of the national territory. They acquired new techniques through the efficient use of the latest GPS equipment and analysis software provided by JICA and concrete implementation techniques and methods.

For two months, in the course of the field survey implementation, technology transfer was conducted in the form of on-the-job training and lectures related to each study step, such as collection of data, planning, surveying, analysis and computations of results.

(2) Study Preparation

① Instrument calibration
② Communication
③ Preparation of aerial photos
④ Preparation of 1:50,000 map sheets
⑤ Benchmark details
⑥ Composition of the teams

a. Survey supervisors (JICA Study Team)	2 persons
b. Survey technicians (SGD)	15 persons in total
Senior surveyors	5 persons
Survey assistants	10 persons

⑦ Survey logistics
The country was split into two sections, north and south, each supervisor being in charge of one sector.

⑧ Control points
The number of control points required to be identified for level and positional control for aerotriangulation totalled as follows:
a. 59 existing benchmarks denoted as “L” (originally 57)
b. 50 photo control points denoted as “CP” (originally 45)
c. 20 GPS-fixed benchmarks denoted as “G”

⑨ d. 34 existing triangulation points denoted as “T” (originally 33)

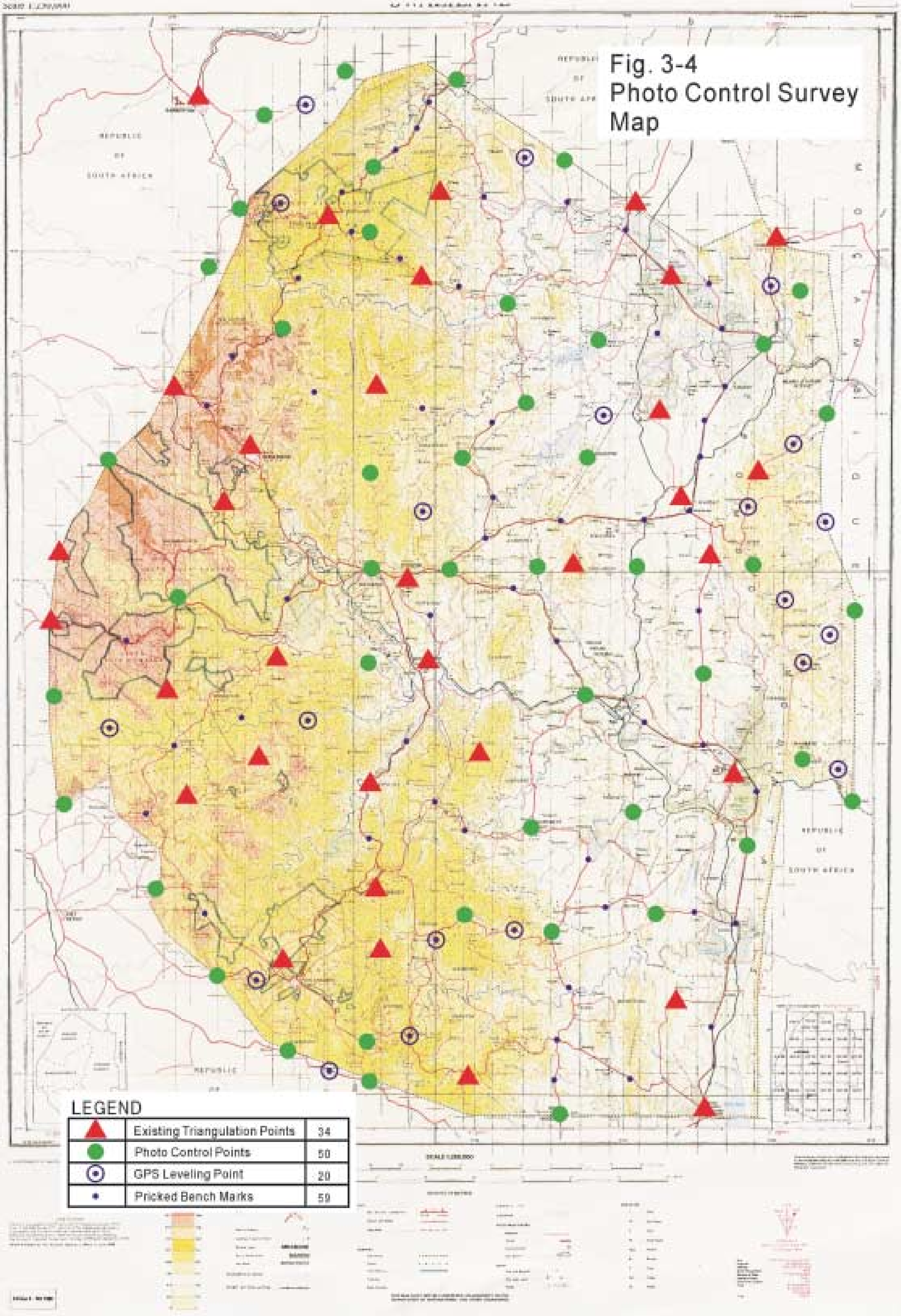


Fig. 3-4 Photo Control Survey Map

(3) Point Identification and Pricking

① Methodology

All points to be identified were inspected/selected by the survey supervisor of each team. It was necessary to make decisions in the field, based on the locality of existing SGD triangulation points and benchmarks, as to the most suitable places for pricking on aerial photos. Each of SGD senior surveyors was required to identify details from the photographs, in conjunction with both survey supervisors. If suitable, the selected points were utilised.
Each photo control point chosen was pricked on its corresponding stereo photographic pair, and control point description sheets were established with the following information for each point:

② Security

It was suggested that it would be necessary to obtain security personnel from the Swaziland Defense Force for possible protection when selecting points in the extreme east of the country near the frontier with Mozambique.

③ Re-flying

As approximately 40% of the Study area had to be re-flown, the points that had already been selected had to be transferred onto the new aerial photos. All points, except one, could be transferred with ease.

④ Training as part of technology transfer

During this phase of the Study, SGD senior surveyors who were involved in the joint work were trained in the selection of suitable photo control points. Acceptable practices in the fields of levelling and point co-ordination were confirmed, and directions given when problems arose. Both survey supervisors are confident that SGD senior surveyors can now select and fix points unsupervised.

(4) GPS Survey

① Methodology

All four survey teams were to work as a single unit, and overlap periods were predetermined for each days’ set of observations.
GPS observation session sheets were issued everyday to each team by the responsible supervisor.

② Daily planning and satellite configuration

The poor availability of satellites was confined to two one-hour periods, one at approximately midday and one in the late afternoon. A decision was made to extend observation sessions to 75 minutes and not to observe during the poor period. This had the consequence that only 3 observation sessions could be achieved per day.

③ Processing of baselines

Processing of GPS baselines was carried out on a daily basis to ensure that baselines could be resolved and loop misclosures were within the allowable limits of accuracy. Baselines that presented problems were re-observed at a later date in the Study.

④ Training as part of technology transfer

All SGD staff members involved in this phase of the Study were trained in the process of GPS observations. Special care was taken to ensure that SGD members were capable of independently setting up new projects.

(5) Adjustment Computations

① Level control

All the levelling work conducted in the course of this Study entailed determining the elevations of eccentric points for photo control points and triangulation points, and covered short routes ranging from a few meters to a few hundred meters.

The whole levelling process was carried out with the co-operation of SGD surveyors. The accuracy for all the level values was within the requirement.

② GPS control

- After the observations and baseline analysis were completed, the whole region was unified into a single network on which adjustment and network analysis were implemented and the horizontal and vertical co-ordinates of each photo control point were determined. The adjustment module of an engineering software called “Ski version 2.3” was used to compute positional information of photo control points.

③ Positional control using a total station

A total of 29 eccentric points, in close proximity to existing triangulation points, had to be installed. Of these, 28 points have been measured by a total station.

④ Training as part of technology transfer

Training of two SGD staff members was undertaken dealing with the downloading, processing and adjustment of the GPS observation results, using the software included with the GPS receivers provided by JICA.

(6) Projection and Datum

Grid	South African Survey Grid Lo. 31°
Projection	Transverse Mercator
Spheroid	Clarke 1880 Modified
Semi-major axis	6378249.145
Inverse flattening	293.466307656
Unit of Measurement	Metre
Meridian of Origin	31° East of Greenwich
Latitude of Origin	Equator
Scale Factor of Origin	Unity
Datum	1935 Arc

3-1-4 Acquisition of Administrative Boundaries and Geographical Names (with SGD Technical Co-operation)

Basically, these data were to be provided by the Swazi side to the Study Team. They were prepared by the Drawing Office within the Mapping Section of the SGD, based mostly on the existing cadastral database, 1:50,000 topographic maps and 1:10,000 orthophoto maps.

(1) Administrative Boundary Data

① Cadastral data were converted, inspected and revised to acquire administrative boundary data.

② Administrative boundary data and geographical name data for printing differ from data for GIS use. The original data were modified, e.g. deletion of river data and use of two font sizes, in order to keep only information that must appear on printed maps.

(2) Sheet Names, Administrative Names, and Geographical Names

Sheet names were decided by the SGD during Phase 1 in Swaziland, based on existing topographic maps (1:50,000, 1:250,000) after confirming the frontier lines on these sheets, and establishing the sheet index for the whole area.

Data of administrative names and geographical names were also created by the SGD based on existing topographic maps, and submitted to the Study Team.

3-1-5 Planning, Preparation and System Design for Orthophoto Plotting

The system was designed considering planning and preparation (i.e., use of automatic processing functions for digital photogrammetry) to ensure efficiency in the execution of the work.

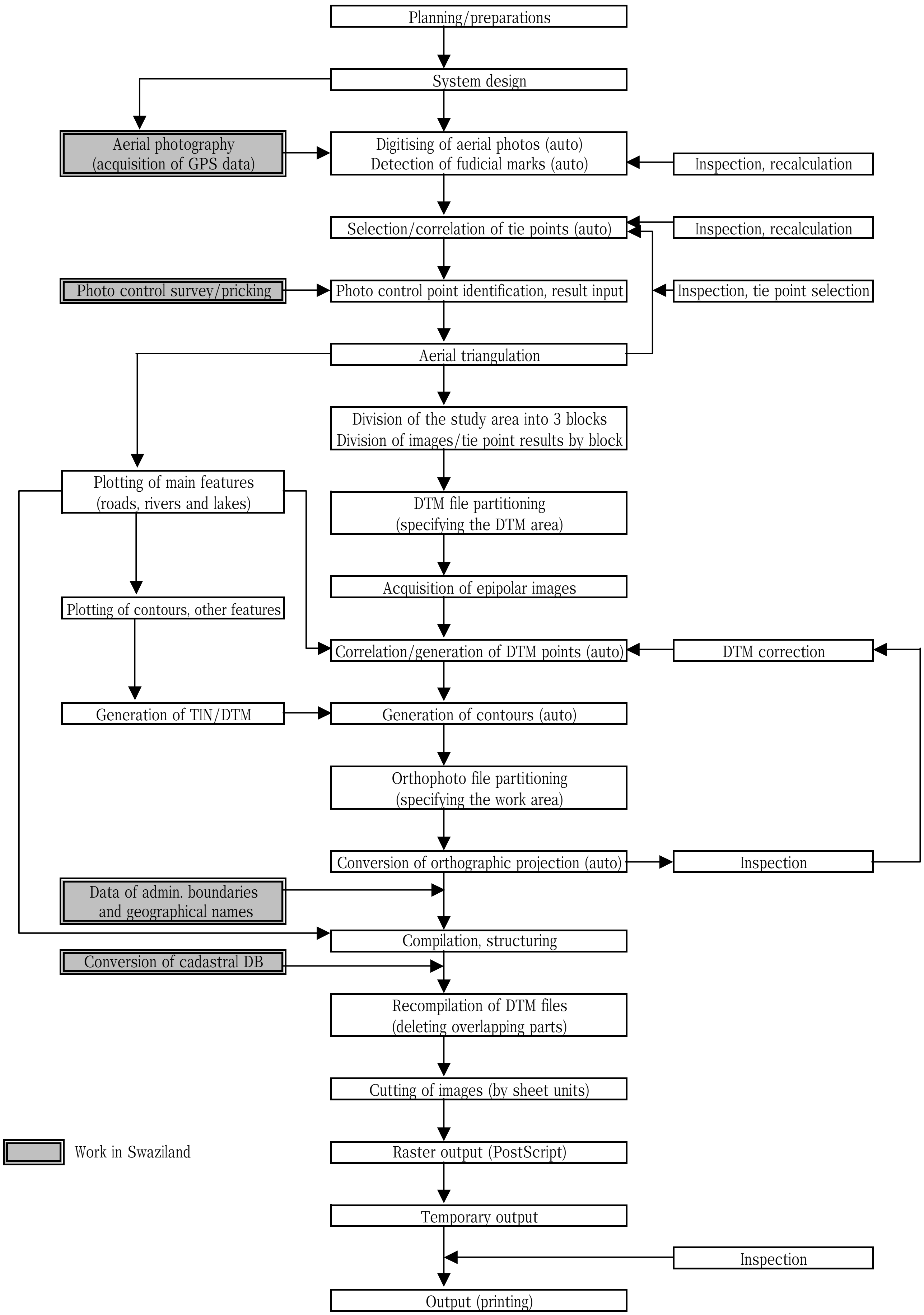


Fig. 3-5 Work Flow

(1) Code System for Graphic Data

Based on the specifications for annotation and graphic data, a feature code system (draft) for all graphic data, including cadastral data and marginal information data, was decided. Map symbols (draft), such as special lines, corresponding to each code were created

(2) Choice of File Archiving Configuration

The data file archiving configuration consists of 5 types of data files for each sheet: orthophoto image, cadastral data (Cadastral), annotations (Text), topography (Landform) and marginal information (Marginal).

(3) Scheduling of Automatic Processing

The necessary times for automatic processing and manual processing per unit (ex: stereomodel) were measured in a pilot area for each task, taking into consideration the balance between manual processing during the day and automatic processing during the night for each operator.

(4) Creation of Accuracy Control Forms

Accuracy control forms for each important task were established, striving to maintain high accuracy and uniformity.

① FILM SCANNING
② AERIAL TRIANGULATION
③ DTM GENERATION
④ DIGITAL PLOTTING
⑤ ORTHO PHOTO GENERATION
⑥ MOSAICING AND OUTPUT OF IMAGES BY NEAT LINE UNITS
⑦ MAP OUTPUT
⑧ EDITING

3-1-6 Film Scanning

Image data were acquired using a dedicated scanner for rolls of negative aerial films. Attention was paid to keep the films free of dust and dirt.

(1) Sample Scanning

Prior to data acquisition, samples of typical topographic features, such as urban areas, grasslands, mountains and bare lands, were selected and scanned in order to determine the various settings for brightness, contrast, etc.

(2) Normalization

The image data were digitised with a density of 10 µm or 14 µm, according to the scanner used. In order to eliminate the mechanical error specific to each scanner used, normalization of image data was conducted using a correction value previously calculated.

(3) Accuracy Control

A reference image was displayed next to each scanned image for comparison of quality. In case of disparity, fine adjustment of the settings was conducted immediately.

(4) Format Conversion

The image data obtained were stored in a widely used format (TIFF). They were later converted into a dedicated image format.

Each file was about 260 MB at 14 µm, and 480 MB at 10 µm, for a total data size of about 500 GB.

3-1-7 Automatic Aerial Triangulation

Using the conventional method (bundle adjustment method), aerial triangulation was carried out on 1526 models covering the whole country, which were split into 3 blocks of approximately 500 models. Automatic processing was applied at every step in order to boost work efficiency.

Because of hard disk space limitations, work blocks of approximately 150 models were created, with each work block overlapping other work blocks.

(1) Production of initial data

The GPS data obtained in the plane were analysed and the approximate XYZ values of each photographed point were acquired. By entering these values in the digital plotter, the subsequent work volume could be significantly reduced.

(2) Inner orientation

This work was carried out mainly at night by automatic processing, using a digital plotter. The fiducial marks of the photos were calculated automatically, to allow the computation of the positions of the principal points, shrinkage, and rotation of the photos.

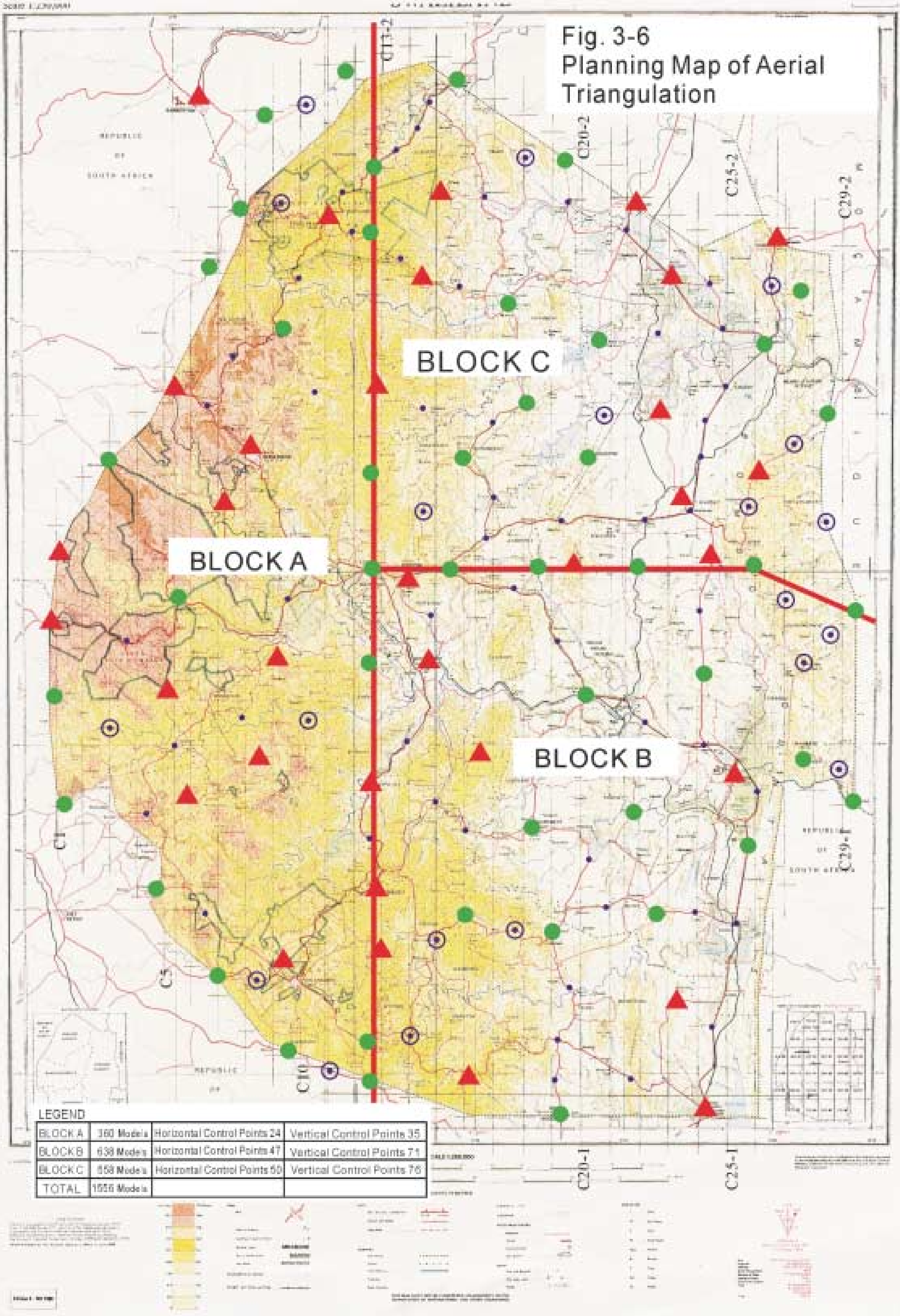


Fig. 3-6
Planning Map of Aerial Triangulation

LEGEND

BLOCK A	360 Models	Horizontal Control Points 24	Vertical Control Points 35
BLOCK B	638 Models	Horizontal Control Points 47	Vertical Control Points 71
BLOCK C	558 Models	Horizontal Control Points 50	Vertical Control Points 76
TOTAL	1556 Models		

(3) Tie point observations

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.

Between several tens and 100 points were acquired per model.

(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.

(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.

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

(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.

① Generation of epipolar images and epipolar hierarchical images

② Optimisation of automatic DTM generation parameters

③ Image correlation (stereo-matching)

④ DTM output

⑤ Manual additions/revisions of DTMs, re-calculations

(2) Automatic Generation of Orthophotos

Fig. 3-7 Orthophoto

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

The adjoining lines within overlapping parts were fixed in areas with the least distortion, then the orthophotos were divided by neat lines (411 sheets of 80 cm in width and 60 cm in height) using automatic processing.

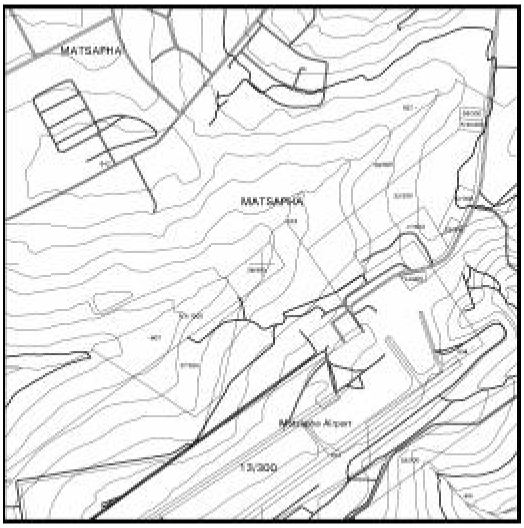
The images output by neat line units were in TIFF format (uncompressed), the output resolution was 600 dpi with a ground resolution of 42.3333 cm. The data size was approximately 260 MB, for a total of approximately 100 GB.

(4) Generation of Contour Data

TIN models were prepared from the DTMs, and the contours lines were generated by automatic processing with a 5m interval and thinned out in areas, such as mountains, where they became too dense in consideration of the overall balance.

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

(1) Plotting of Feature Data



Using a digital plotter, river centrelines, river banks, lakeshores, road centrelines, road sides, railroad centrelines, rail/road bridge centrelines, and rail/road tunnel centrelines were acquired in accordance with the map symbols, with due consideration of efficient use in GIS such as network analysis. As these acquired items do not appear on printed maps, they were assigned the non-display attribute.

Fig. 3-8 Contours, Topographic Data, Cadastral Data

(2) Plotting of Contours

Contour data for wooded areas were acquired by an operator on the digital plotter using stereoscopy. As forests cover 36% of the national territory of Swaziland, it was faster and more accurate to acquire contour data through direct plotting rather.

(3) Creation of Final DTMs and Contour Data

TIN models were generated from the contour data acquired by direct plotting, 40m DTMs were generated for these areas to complete the 40m DTMs for the whole area.

Contour data were divided into index, normal, and intermediate contours for regular features and for depressions, and DTM points, then they were archived as 3-dimensional data.

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

Administrative boundary data were 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 were divided by neat line units and saved as cadastral data files, based on the file configuration (draft).

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

3-1-11 Map Output for Field Survey

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

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 these 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 of 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 were divided into 7 categories.

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

The administrative boundaries and geographical names which had been corrected and input were overlaid on the orthophotos, cadastral and topographic data, and the final distribution was compiled.

3-1-14 Input of Cadastral Database

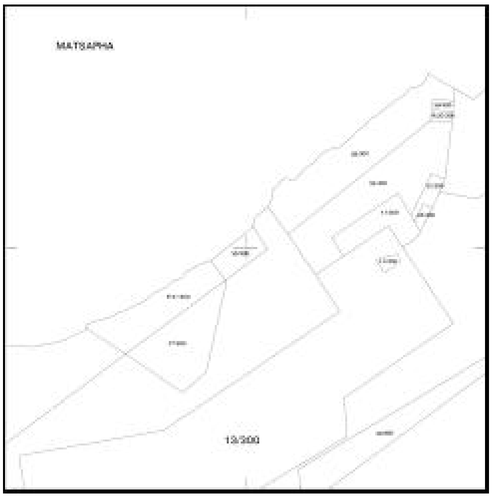


Fig. 3-9 Cadastral data

Many cadastral numbers had to be revised in the cadastral data files. As a result, the original data for printing from the cadastral database had to be reprocessed.

First, the revised original data for printing were 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 were conducted using the cadastral data, data of administrative boundaries and geographical names, and digital plotting data, in accordance with the map symbol specifications.

(1) Work Content

Fig. 3-10 Finished Orthophoto Images

The combined compilation of the cadastral data, data of administrative boundaries and geographical names, and digital plotting data was conducted using a compilation device.

(2) Flaws and Revisions of Digital Compilation

The main problems were as follows:

- Elevation points: A number of neat lines were found to have too many data compared with the acquisition standards.
- 5m intermediate contours: A number of neat lines were found to have too many 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 many data were often acquired.

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

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 were converted into Postscript files for printing, and the font consistency and appearance of the characters were adjusted.

(2) Inspection and Revisions

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 0.1 mm lines used to show the main contours appeared too thin on the outputs, and were therefore changed to 0.36pt.

3-1-17 Production of CD-ROMs

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 created in the past by the SGD using UNIGIS, an older software, were converted into a format accepted by the latest GIS software that JICA has granted as part of the procured equipment, to enable the representation of cadastral data on printed maps and the reconstruction of the database for future GIS use.

(2) SGD Cadastral Data

① Layer configuration

The original SGD data consist of layers ranging from LEVEL 1 to LEVEL 100.

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..

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

① Detection of errors

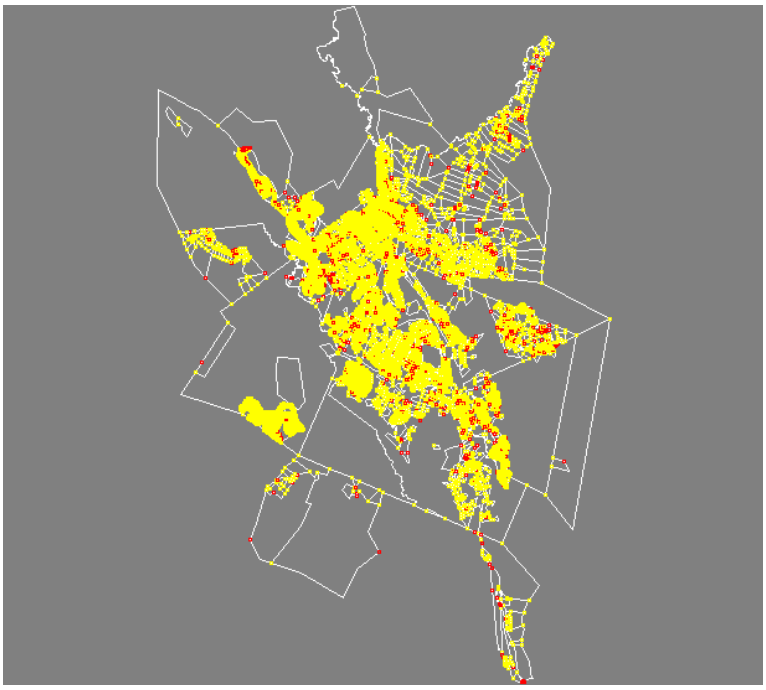
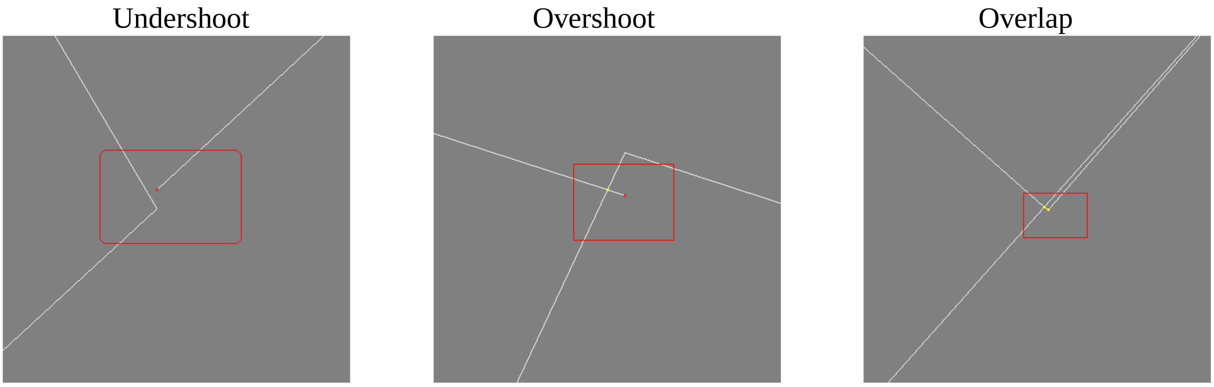


Fig. 3-11 Display of Errors

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*



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. Polygon data were restored and the database for map printing was created.

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

③ Defining cadastral line data

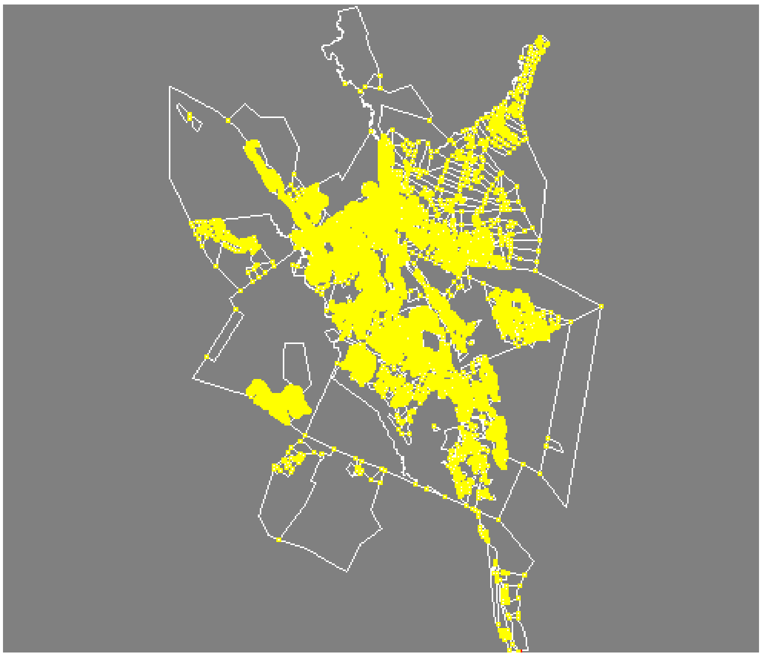


Fig. 3-12 Corrected Data

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 were 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

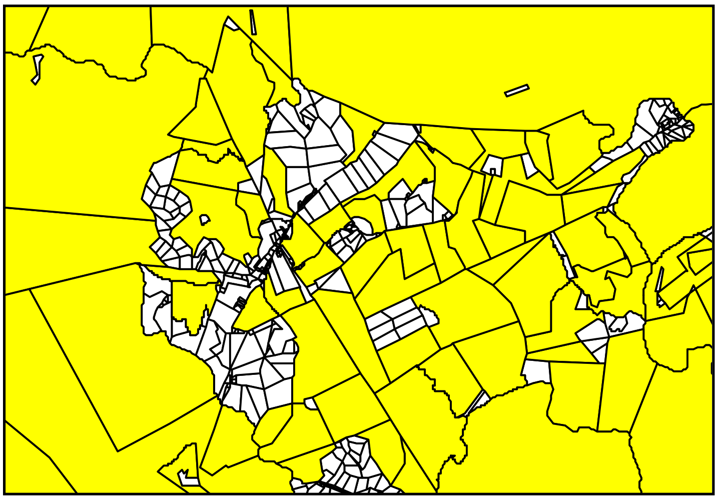


Fig. 3-13 Classification by Area

Figure 3-13 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 were returned to the CAD software belonging to the SGD. Based on discussions with the SGD, 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, it was decided that the PIDs of parcels equal or under 1.5 ha would not be displayed.

Figure 3-14 shows the display of text over all parcels, and Figure 3-15 shows the result when the PIDs of parcels equal or under 1.5 ha are not displayed.

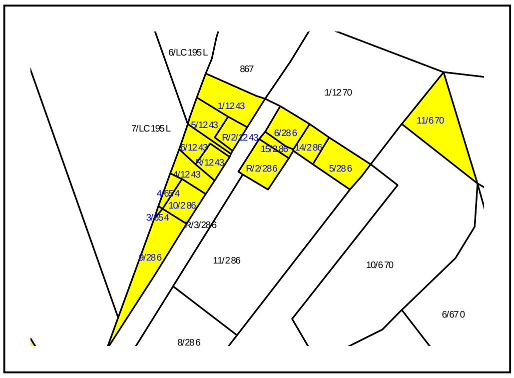


Fig. 3-14

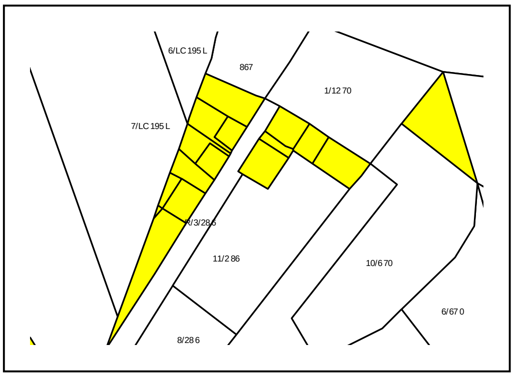


Fig. 3-15

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

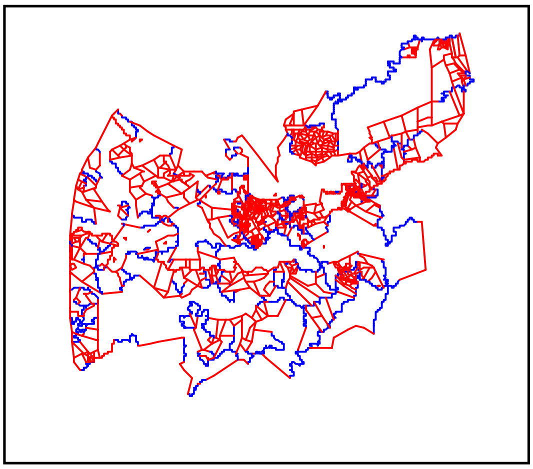


Fig. 3-16 River Centreline Data

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

These river data were created a long time ago and have not been surveyed since.

Fig. 3-17 Deletion of River Centreline Data

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 3-16 were deleted.

Fig. 3-18 Results of Coordinate Conversion

As the original cadastral data used an original coordinate system for GIS/CAD, they 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)

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 3-19 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.

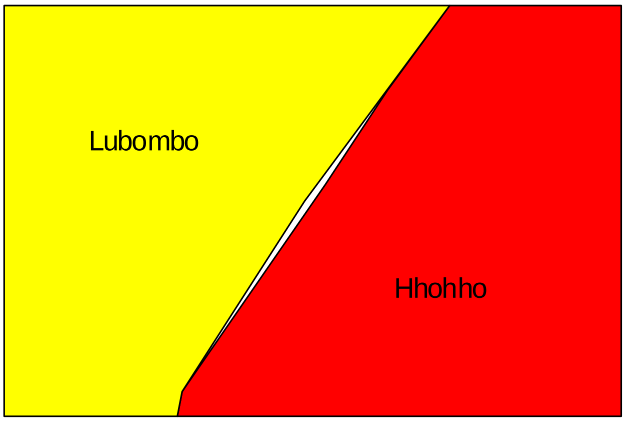


Fig. 3-19 Error Found When Adjoining 2 Regions

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 3-20 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 orthophotos.

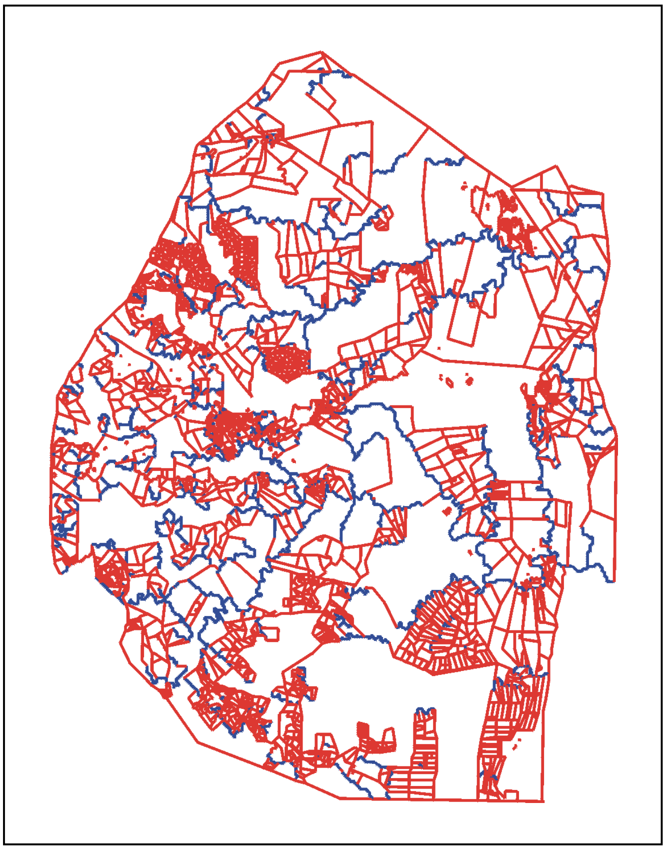


Fig. 3-20 Cadastral Data for the Whole Territory of Swaziland

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

The data were transferred into GIS so that the cadastral data 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 were converted into Arc/View so that GIS could be used for data management.

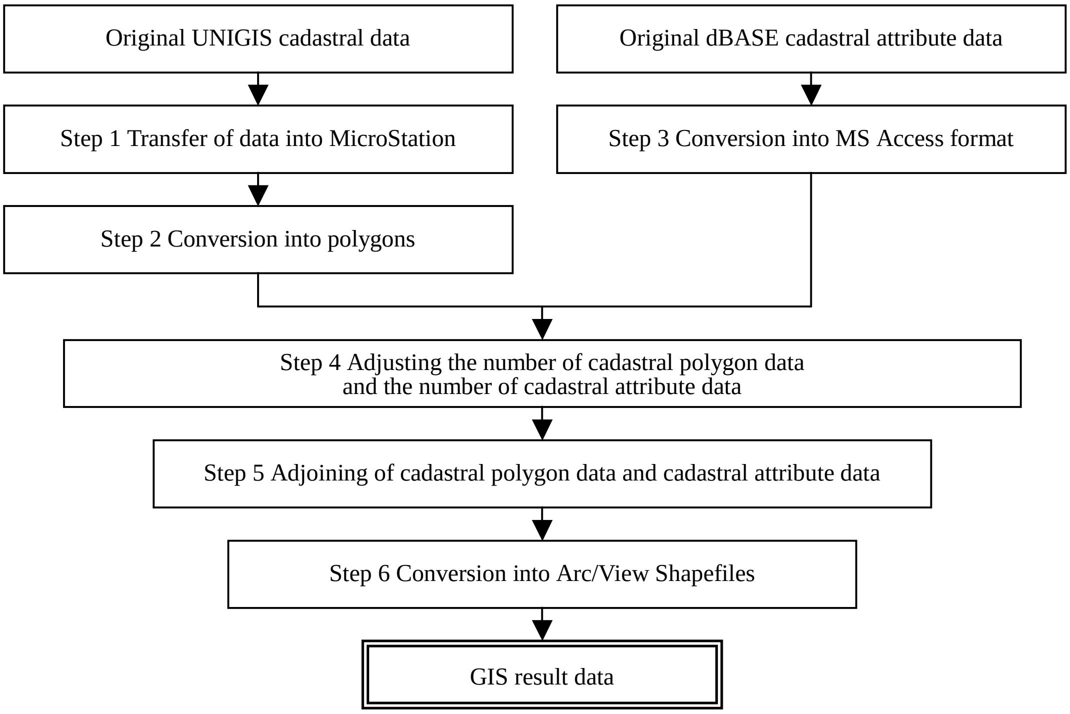


Fig. 3-21 Flowchart for the Creation of Cadastral Data for GIS

(1) Transfer of Data Into MicroStation

The first step for the construction of GIS cadastral data for this project 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 were changed into polygons by the SGD team. Figure 3-22 shows UNIGIS line data. Figure 3-23 shows cadastral data after they were transformed into polygons by MicroStation (M/S). The yellow code is used to represent polygons.

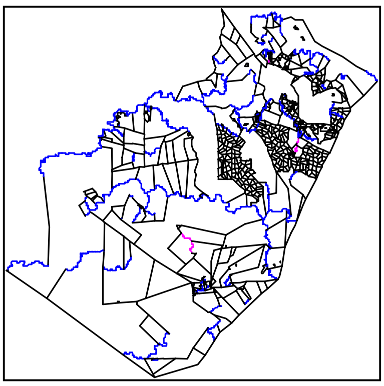


Fig. 3-22 Cadastral Line Data

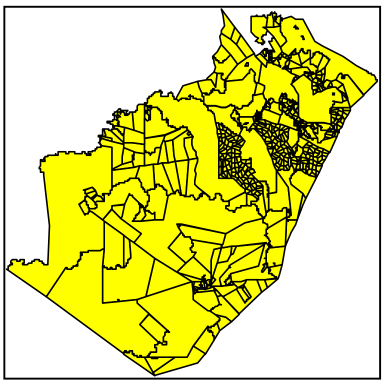


Fig. 3-23 Cadastral Polygon Data

(3) Conversion of Cadastral Attribute Data

In general, in GIS, graphic data as well as attribute data linked to these graphics must be managed. As cadastral data will ultimately be managed by Arc/View, all the cadastral attribute data created in UNIGIS were converted into Microsoft Access format with the cooperation of the SGD team.

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

The number of cadastral polygon data transferred into MicroStation did not coincide with the number of cadastral attribute data in MS Access format. This error results from the fact that graphic data and attribute data had not been properly updated at the same time.

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

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 polygon data and cadastral attribute data were combined using these ms-links as key fields in Arc/View.

(6) Conversion into Arc/View Shapefiles

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. 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.

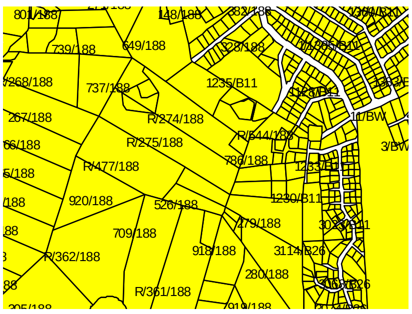


Fig. 3-24 Example of PID Display

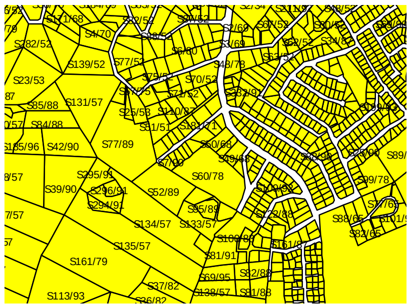


Fig. 3-25 Example of SG_NO Display

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 and is currently managed using MicroStation Geographics and Microsoft Access (MS Access). It contained a number of errors.

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

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.

The following describes database management using MS Access (new data, addition, revision, deletion, import of outside data, export as outside data).

① Creation of new data

When creating cadastral attribute information, the PID is input as the first item (Field), and the other necessary cadastral information are input starting from the second item.

② Addition, revision (update) and deletion of data

There are 2 types of tasks for adding data into an existing database.

When adding new cadastral boundary data, newly created PIDs are added into the existing database and their corresponding cadastral attribute information are input. When adding new attribute data related to existing cadastral boundary data, information are input into blank spaces in the existing database.

There are also 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 the existing database.

③ Import from an external database/export 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 format for importing/exporting databases.

4-2 Applications of Orthophoto Maps and the Cadastral Database

4-2-1 GIS Situation 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.

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.

(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 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 at the SGD, there are 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.

(2) Ministry of Agriculture

GIS is used at the Land Use Planning Section of the Ministry of Agriculture for the management of 7 types of databases. As they use Arc/View and Arc/Info, their data can be distributed not only in IDRISI format but also in Arc/View and Arc/Info formats.

(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. They would like 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.

(4) Ministry of Natural Resources and Energy

① Rural Water Supply Branch
This section manages the pipe network map using MicroStation. 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. They wish to apply GIS to create models for solar energy and small-scale hydroelectric power generation.

(5) Swaziland Water Services Corporation

They use MicroStation for CAD applications and are considering introducing GIS for the management of water fee, fee collection, pipe network, material, size, attributes, etc.

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

They currently use 1:250,000 and 1:50,000 maps and conduct ground surveys. However, operation/management of existing power lines and planning of new lines are 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.

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.

(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.

Using orthophoto images as background maps and cadastral boundary data, 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 devised in the field of urban planning.

(2) Agricultural Development (Selection of Appropriate Land)

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.

(3) Forestry Development (Protection, Reforestation)

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.

(4) Watershed Management (Dam Construction)

Orthophoto data, which show elevation, are extremely valuable information for dam construction. Elevation data enable to determine the area that must be flooded for the construction of a 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.

(5) Health Care, Education

Superimposing administrative boundary data and population data on orthophoto images, and comparing these data with the current situation of medical facility distribution, would enable 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.

(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, 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.

The efficient uses of orthophoto data 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

5-1 THE CURRENT ENVIRONMENT OF THE SGD

- Budget restrictions to low economic growth
- Technological stagnation (staff, equipment)
- Appropriation of income by the National Treasury

5-2 THE WORLD SURVEY AND MAPPING INDUSTRY

- Shift toward independence of government organizations (England, France, Finland, Sweden, Vietnam)
- Market development (from national services to international tenders)

5-3 SGD REOGANIZATION PROPOSAL

(1) Future Options

① Remain as a government department

② Become an independent agency

③ Become a public corporation

(2) Recommendations to the SGD

The SGD should be given independent agency status for the time being, and be allowed to secure its own revenue using the latest technologies and equipment. Then it could become an completely independent public corporation.

The SGD should be given the chance to become independent, following the examples of similar mapping organizations in other countries. This will depend on the following related factors:

- Ratio of national budget and technical services (including sales benefit)
- Entry into the national market and development of new markets
- Employment, wages, education, new product pricing