Chapter 3. Ground Survey and Aerial Photography

3.1. Ground Control Point Survey

3.1.1. Installation of aerial signals

(1) Preliminary work in the office

Landmarks set up at the existing control points are indicated with red circles in Figure 3.1.1. Some points were altered from the initially-proposed control points due to the accessibility or snow coverage. In doing so, consideration was given that the new ground control points, shifted control points, remain in the vicinity of the edges of the Study Area.

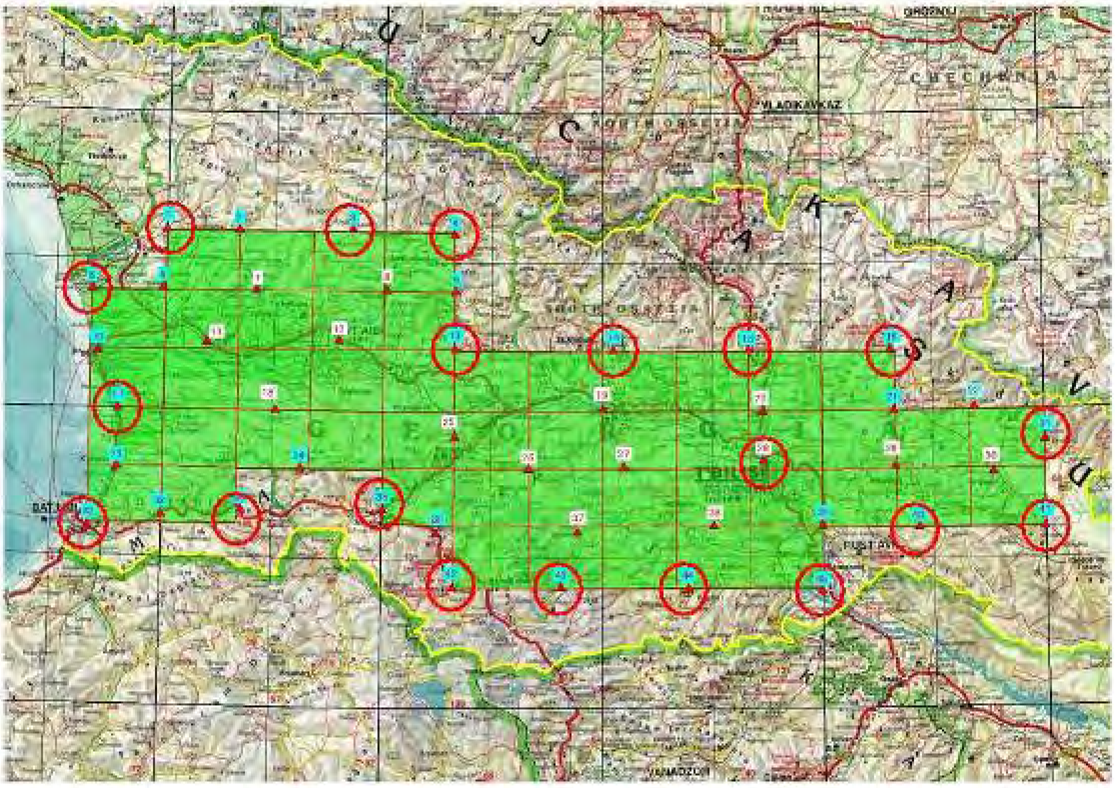


Figure 3.1.1 Landmarks selected at the existing control points

(2) Selection of landmarks

The landmarks were strictly selected at such sites where they were easy to recognize on the aerial photograph. In the field all points were chosen on suitable grounds, open space where there was no obstacle to aerial photograph shooting. Although 35 points were planned in the preliminary selection in the office, 33 points were set up for aerial signals eventually because of snow coverage over the proposed area.

The coordinates of the peripheral ground objects from each signal were observed with the use of a total station, a transit compass with measuring tape and/or a handy-type GPS in order to draft the "Point Description" (refer to Figure 3.1.5).

A white-painted aerial signal, which consisted of three rectangles (3m×1m) made of stone, wood or other suitable materials and placed in different directions centering the control point, was set up before the aerial photography commencement.

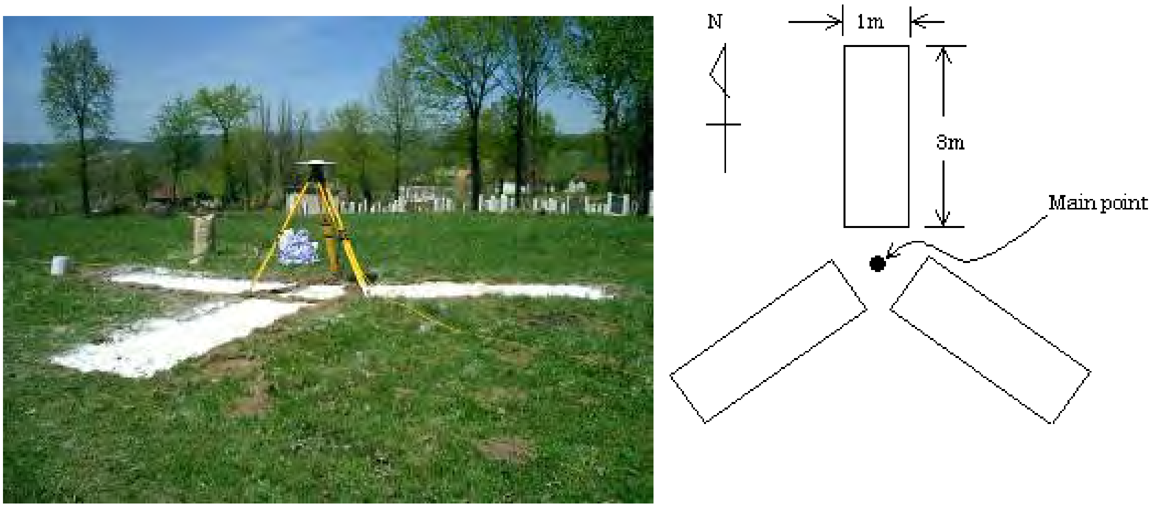


Figure 3.1.2 Specifications and installation of aerial signals (landmarks)

3.1.2. Geodetic control network survey

A geodetic control network survey using GPS was conducted on the entire landmark centers that had been installed previously.

(1) urvey datum

The following datum employed in the Study;

a. Coordinate system:	UTM
	Zone 37 and/or Zone 38
b. Horizontal datum:	WGS 84
c. Vertical datum:	The Baltic mean sea level in the system of 1977
d. Measurement unit	Metric system

(2) GPS observation

GPS observation via long distances within a short time was considered difficult in the light of the vast coverage of areas to be studied, the pavement conditions of access roads, and the complicated topographic conditions. It was impossible to complete observation over the entire planned area by an ideally-planned observation network within the scheduled study period, and hence it was decided to implement the work by dividing the area into blocks and organizing observation networks with ideal observation methods for respective blocks.

Fortunately, a large number of triangulation points being already present and well-maintained in the country enabled a local GPS observation network combining these control points as reference points given and newly-installed aerial signals as GCPs. By organizing an observation network per block, the accuracy of survey of newly-installed GCPs for topographic map generation was maintained. In other words, the GPS observation over several GCPs was carried out by organizing an independent observation network per session in place of setting up a comprehensive observation network over the entire Study Area. (Refer to Figure 3.1.3)

- **Coordinates computation**

The loop closing error was designed as not to exceed plus or minus 10mm + 2ppm x D (distance of baseline) in any closed polygonal route on the network after the baseline processing.

The computation results were finalized in the geographical and UTM coordinates (Table 3.1.1). In consideration of the geoid height difference, the elevation based on the M.S.L datum was carefully adjusted as to the new control points through the process of the baseline analysis and the polygonal network adjustment.

- **Observation**

The following observation method and coordinates computation were applied to the geodetic network with the use of such GPS networks.

- Survey method:	Simultaneous data receiving with three observation points or more (static observation)
- Type of GPS receiver:	Dual or single frequency type for geodetic survey
- Number of GPS receiver:	Not less than 3
- Observation time:	Not less than 2 hours
- Number of satellites received at one time:	More than 5
- Number of existing control points to be connected:	Not less than 2

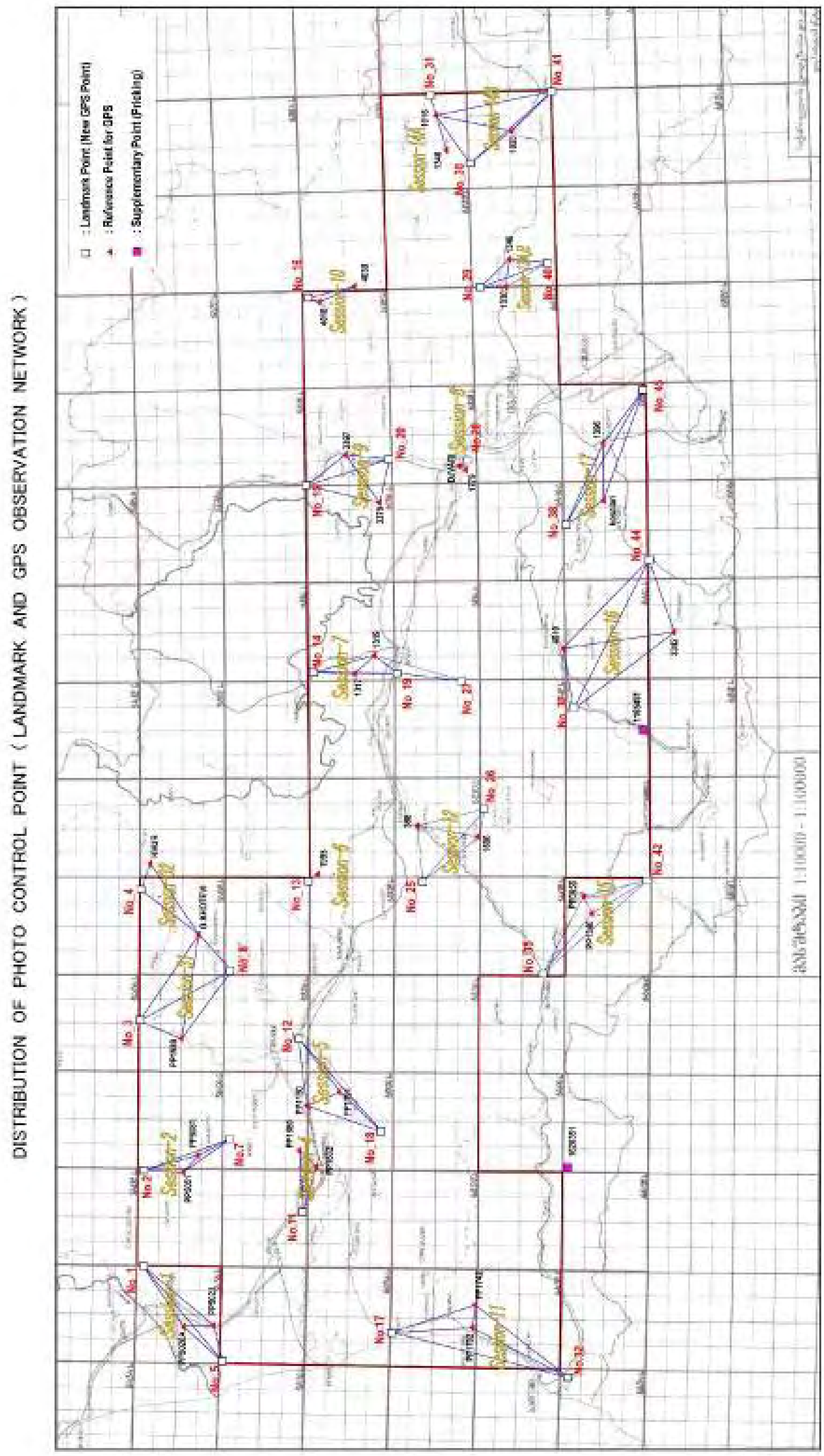


Figure 3.1.3 GPS observation network

Trimble

Loop Closure

www.trimble.com

Session-5

Number of Points	4
Start position (WGS-84)	N: 42° 12' 33.00760"
	E: 42° 33' 06.19351"
	H: 92.2120m

Results

Total length	73956.9937m
North	-0.0030m
East	-0.0190m
Height	0.0050m
Misclosure Vector Length	0.0198m
Precision	0.268 ppm
Ratio	1 / 3727928

From	To	Distance	ΔX	ΔY	ΔZ	ΔHeight	Session
PP1150	No_18	20833.9472m	14490.8490m	3743.3336m	-14493.3124m	78.8408m	S1 05:43 - 07:43
No_18	PP1191	15560.3905m	-12938.4522m	3186.7446m	8035.3510m	-91.9775m	S1 05:43 - 07:43
PP1191	No_12	18474.5140m	-15437.5858m	6059.3803m	8140.7942m	102.2604m	S1 05:40 - 07:42
No_12	PP1150	19088.1420m	13885.2055m	-12989.4692m	-1682.8315m	-89.1190m	S1 05:40 - 07:42
	Result	73956.9937m	0.0167m	-0.0107m	0.0012m	0.0050m	
	Limit	0.0400m	0.0400m	0.0400m	0.0400m		

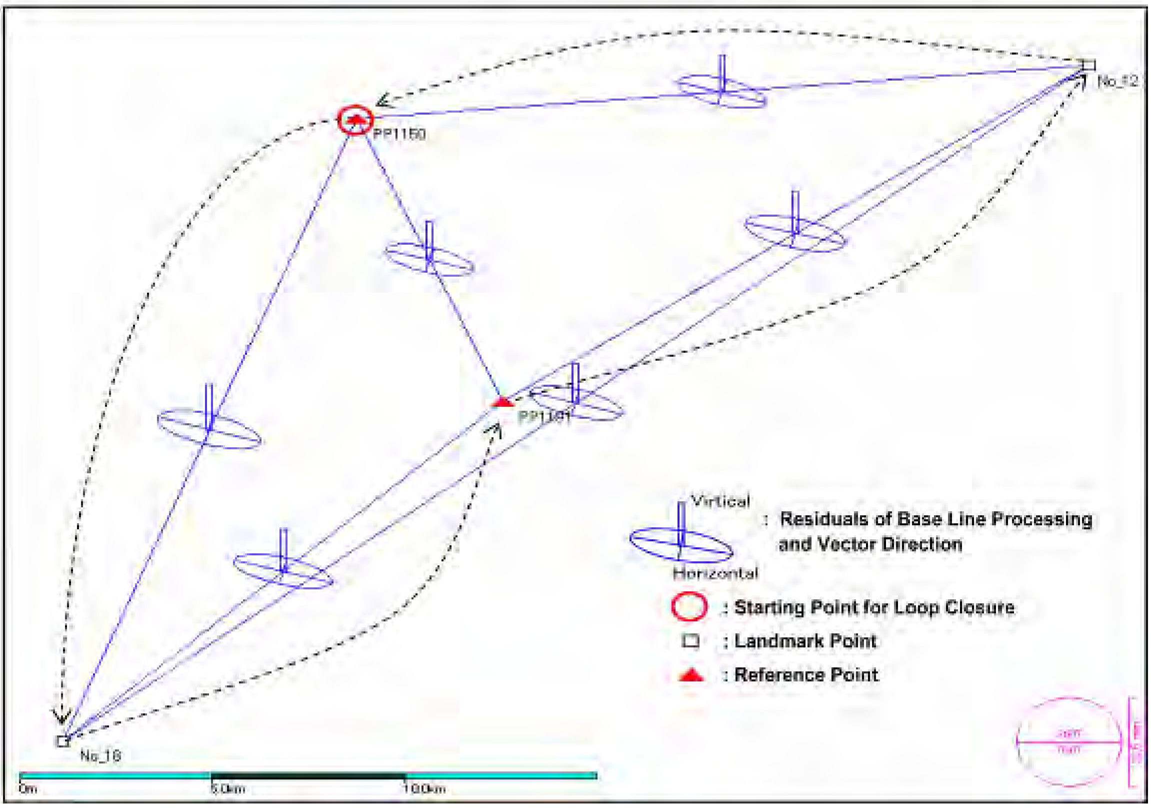


Figure 3.1.4 A sample loop closing error in coordinate computation

Table 3.1.1 List of GPS coordinates obtained by the computation

Final Coordinates in UTM (WGS84)				
Point No.	N	E	Ortho Height	Zone
No_1	4,719,397.135	745,782.274	241.371	37
No_2	4,718,936.574	280,292.125	350.405	38
No_3	4,719,304.655	322,614.465	507.000	38
No_4	4,717,012.219	359,786.138	735.275	38
No_5	4,697,595.171	719,543.892	7.930	37
No_7	4,696,279.338	288,069.980	158.089	38
No_8	4,694,785.058	336,438.984	1,195.695	38
No_11	4,677,644.260	267,847.284	21.337	38
No_12	4,677,573.999	316,913.865	161.826	38
No_13	4,673,749.694	361,438.195	718.365	38
No_14	4,671,242.116	420,152.911	846.650	38
No_15	4,672,064.097	473,009.748	896.741	38
No_16	4,670,413.841	525,989.933	682.529	38
No_17	4,652,817.759	730,284.114	7.764	37
No_18	4,656,502.713	290,296.749	151.794	38
No_19	4,649,528.308	419,442.963	598.456	38
No_20	4,650,212.794	479,996.071	588.359	38
No_25	4,644,309.731	360,661.028	520.576	38
No_26	4,627,549.705	381,024.954	1,164.660	38
No_27	4,632,729.490	416,959.495	1,289.500	38
No_28	4,630,584.535	478,672.967	475.540	38
No_29	4,625,536.329	528,249.398	1,590.611	38
No_30	4,627,665.743	563,227.351	373.819	38
No_31	4,637,554.894	582,514.152	367.575	38
No_32	4,607,027.393	720,009.105	19.250	37
No_35	4,613,567.925	334,178.287	1,032.116	38
No_37	4,603,830.079	408,847.055	1,555.923	38
No_38	4,604,765.769	460,669.010	801.573	38
No_40	4,607,959.592	534,846.531	542.733	38
No_41	4,605,532.462	583,328.999	280.569	38
No_42	4,585,584.362	360,172.494	1,243.805	38
No_44	4,583,334.242	450,520.317	737.106	38
No_45	4,583,552.539	499,029.760	312.862	38
1620351	4,608,193.450	279,132.180	1,384.200	38
1165451	4,585,622.930	402,572.920	2,103.230	38

Table 3.1.2 Verification of GPS observation accuracy

Verification of GPS observation accuracy (Loop Closure Check)

Loop No.	Observation Point in Loop	Total Length in Loop (m)	Misclosure (m)		Diff.	acceptance criteria
			Vector Length	Closure Limit		
1	No_1 → PP5020A → No_5 → PP5021 → No_1	69,825.582	0.179	0.369	-0.190	○
2	No_2 → PP5051 → No_7 → PP5081 → No_2	49,271.458	0.118	0.266	-0.148	○
31	No_3 → PP1986 → No_8 → G_KHOTEV → No_3	77,529.736	0.120	0.408	-0.288	○
32	No_4 → G_KHOTEVI → KHUR → No_4	50,086.988	0.059	0.270	-0.211	○
4	PP1632 → No_11 → PP1680 → PP1632	37,078.421	0.019	0.205	-0.187	○
5	PP1150 → No_18 → PP1191 → No_12 → PP1150	73,956.994	0.020	0.390	-0.370	○
7	No_14 → PP1317 → No_19 → PP1319 → No_14	46,205.475	0.033	0.251	-0.218	○
8	DJVARI → 1779 → No_28 → DJVARI	4,217.351	0.038	0.041	-0.004	○
9	No_15 → 3370 → No_20 → 3397 → No_15	57,435.997	0.069	0.307	-0.238	○
10	No_16 → PP4018 → PP4038 → No_16	25,782.400	0.071	0.149	-0.078	○
11	No_17 → PP1792 → No_32 → PP1742 → No_17	102,730.847	0.143	0.534	-0.391	○
12	No_25 → 1886 → No_26 → PP368 → No_25	61,739.684	0.057	0.329	-0.272	○
13A	No_29 → PP1330 → PP1340 → No_29	25,704.032	0.086	0.149	-0.063	○
13B	No_29 → No_40 → PP1340 → No_29	39,800.573	0.012	0.219	-0.208	○
14A	PP1016 → gr_rep-0918 → No_31 → PP1016	32,075.078	0.028	0.180	-0.152	○
14B	PP1016 → No_30 → PP1093 → No_41 → PP1016	77,370.571	0.036	0.407	-0.371	○
15	No_35 → PP3140 → No_42 → PP3056 → No_35	80,586.013	0.022	0.423	-0.401	○
16	No_37 → 3342 → No_44 → 4010 → No_37	106,518.829	0.023	0.553	-0.530	○
17	No_38 KOSALARI → No_45 → 1396 → No_38	89,613.363	0.029	0.468	-0.439	○

○ : All accuracy of the GPS observations were less values from the limitation (2cm+5ppm) of Loop Closur Error, and these filled accuracy enough.

- **Preparation of point description**

  A description of each point shown in Figure 3.1.5 was prepared after completion of the observation.

DESCRIPTION OF PHOTO SIGNAL POINT

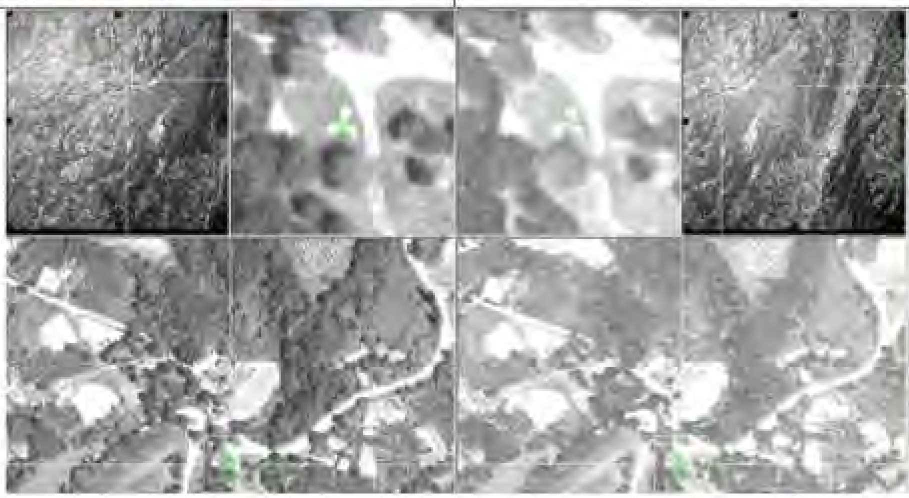
Station No.	1:50,000 Map Sheet No.	District	Preparerd by	Date
No. 1	K-37-60-B	Zugdidi	Gonjilashvili	Apr. 2005

U.T.M (WGS84 Ellipsoid)

Point	Northing (x)	Easting (y)	H
Zone 38			
Zome37	4719937.1348	745782.2739	241.371

Location Map (1:50000)

Sketch-map of Station and Neighborhood



1-1384 1-1383

Figure 3.1.5 An example of "point description"

Figure 3.1.6 GPS observation at one of landmark

3.1.3. Leveling

The presence of benchmarks on the existing leveling routes of approximately 920 km within the Study Area was investigated. 63 points of benchmarks confirmed then in the survey were pricked with an eccentric replacement at the apparent position on the aerial photo which was used for height correction in the aerial triangulation. Since most of the existing leveling routes in Georgia are placed along the railroads or were installed during the former Soviet era, they are largely damaged. In particular, those control points alongside the roads are mostly installed under the ground or metal signs riveted on rocks roadsides. The positions of these are not accurately mentioned in the point descriptions, and hence it is hard to find them. Quite a few of these were found already destroyed apparently due to road expansion works, etc.

Verification of the heights of leveling by GPS was not carried out in the Study because they can be corrected by referring to the height values of neighboring benchmarks. (Refer to Figure 3.1.8 and Table 3.1.3)

Figure 3.1.7 Leveling along the existing route

3.1.4. Collection of existing control point coordinate data

The coordinates of existing control points covering the entire area under the Study were collected. The finalized coordinates were compiled into digital files by the Study Team during the first-phase field survey from the existing data book created by the former DGC. The coordinate list contained 1,447 points in total consisting of triangulation points and control points of 1st to 4th orders. These points without exception had altitude values and could be used, as well as the results obtained in the leveling, in height correction in the aerial triangulation. They could also be used for checking the altitudes in the final products.

Table 3.1.3 List of existing benchmarks

1/100,000 Sheet No.	Location	Catalog No.	Mark Point No.	Type of BM	Elevation from Catalog	ID No.	U.T.M N	U.T.M E	Ortho H	Gauss X	Gauss Y
K-38-78	Mckheta	27400	1	Ground	456.754	201p	4,631,262	476,832	458.13	4,633,202	8,476,924
K-38-78	Nataxtari	27394	6568	Wall	518.520	202p	4,640,913	477,427	516.78	4,642,857	8,477,519
K-38-66	Ananuri	27385	6532	Wall	823.032	203p	4,668,428	475,162	818.68	4,670,383	8,475,253
K-38-66	Cixisdziri	27383	803	Rock	861.861	204p	4,671,842	473,239	861.85	4,673,798	8,473,329
K-38-76	Likhi	27208	18324	Wall	762.288	205p	4,648,170	376,496	759.20	4,650,117	8,376,547
K-38-75	Kvishxeti	27206	4	Wall	778.109	206p	4,649,182	375,467	776.22	4,651,129	8,375,518
K-38-75	Cipa	27201	1606	Wall	671.052	207p	4,650,721	370,660	669.79	4,652,669	8,370,709
K-38-63	Haragauli	27186	1973	Wall	283.476	208p	4,652,558	351,757	281.99	4,654,506	8,351,798
K-38-75	Marelisi	27192	1449	Wall	381.687	209p	4,648,480	358,884	360.22	4,650,427	8,358,928
K-38-75	Moliti	27195	No#	Wall	501.323	210p	4,648,980	364,575	500.18	4,650,927	8,364,621
K-38-75	Moliti	27196	15406	Wall	504.357	211p	4,649,076	364,893	499.67	4,651,023	8,364,940
K-38-63	Lashe	27181	1001	Wall	236.616	212p	4,656,575	349,483	236.44	4,658,525	8,349,523
K-38-63	dzirula	27181	no/#	Wall	201.586	213p	4,660,228	347,805	201.25	4,662,179	8,347,845
K-38-63	Sorapani	27174	18361	Wall	170.986	214p	4,662,438	341,000	169.36	4,664,390	8,341,037
K-38-63	Zestafoni	27171	15594	Wall	159.931	215p	4,663,631	337,905	158.67	4,665,584	8,337,941
K-38-62	Sviri	27166	1734	Wall	130.312	216p	4,669,799	326,794	129.24	4,671,754	8,326,825
K-38-62	Adjamety	27160	20724	Wall	102.194	217p	4,673,777	317,966	102.50	4,675,734	8,317,994
K-38-102	Shulaveri	28107	310	Wall	359.539	T1	4,579,741	486,780	356.88	4,581,660	8,486,876
K-38-90	Orjonikidze	28402	327	Bridge	341.658	T2	4,583,768	485,840	342.93	4,585,689	8,485,935
K-38-90	Marneuli	28401	3	Wall	417.273	T3	4,592,878	483,840	417.07	4,594,802	8,483,935
K-38-90	Kumisi	28101	23	Wall	502.627	T4	4,599,227	483,435	501.59	4,601,154	8,483,529
K-38-90	Kumisi	28099	no/#-1910	Wall	493.154	T5	4,602,385	487,355	492.09	4,604,313	8,487,451
K-38-90	Fonichala	28095	756	Bridge	384.291	T6	4,611,734	491,159	385.05	4,613,666	8,491,257
K-38-91	Gardabani	28055	899	Wall	301.234	T7	4,591,092	508,590	301.05	4,593,016	8,508,695
K-38-91	Ruisbolo	28053	140	Wall	283.013	T8	4,586,472	511,878	284.40	4,588,394	8,511,984
K-38-90	Gashiani	28063	225	Wall	343.222	T9	4,605,914	499,142	343.17	4,607,844	8,499,243
K-38-90	Veli	28065/66	1392/20362	Wall	373.027/372.960	T10	4,610,212	495,714	372.22	4,612,143	8,495,813
K-38-78	Dzegvi	27412	20584	Wall	487.857	T20	4,632,540	468,829	486.29	4,634,480	8,468,918
K-38-77	Kaspi	27422	740	Wall	529.108	T21	4,641,116	451,759	528.66	4,643,060	8,451,841
K-38-77	Kavtishevi	27418	1753	Wall	508.466	T22	4,638,985	456,690	507.55	4,640,928	8,456,774
K-38-77	Grakali	27426	20531	Wall	550.011	T23	4,644,165	440,067	549.25	4,646,110	8,440,144
K-38-76	Hashuri	27455	512	Wall	705.888	T24	4,645,814	433,017	561.25	4,647,760	8,433,091
K-38-77	Gori	27434	20621	Wall	586.038	T25	4,647,133	426,194	538.97	4,649,079	8,426,265
K-38-77	Skra	27439	20426	Wall	603.516	T27	4,649,990	418,743	601.56	4,651,937	8,418,811
K-38-64	Kareli	27443	889	Wall	622.521	T28	4,652,698	409,182	622.18	4,654,646	8,409,246
K-38-64	Kareli	27448	15741	Wall	639.203	T29	4,654,170	403,231	637.68	4,656,119	8,403,293
K-38-64	Gomi	27451/52	57/2067	Wall	661.216/662.308	T30	4,652,799	394,648	660.48	4,654,747	8,394,707
K-38-76	Hashuri	27455	512	Wall	705.888	T32	4,650,655	384,418	704.78	4,652,603	8,384,472
K-38-62	Kutaisi	26994	1763	Wall	202143	T40	4,687,814	310,719	202.41	4,689,776	8,310,744
K-38-50	Gumati	26993	13	Rock	351.774	T41	4,688,965	308,661	352.96	4,690,928	8,308,685
K-38-50	Joneti	26991	1271	Rock	212.861	T42	4,695,558	310,168	211.12	4,697,524	8,310,192
K-38-50	Tvishi	26980	6542	Wall	342.177	T43	4,709,605	319,386	341.14	4,711,576	8,319,414
K-38-50	Tvishi	26979	1055	Rock	347.76	T44	4,710,991	318,988	347.29	4,712,963	8,319,016
K-38-50	Chrebalo	26975	336	Wall	459.338	T45	4,714,859	333,544	475.88	4,716,832	8,333,578
K-38-61	Samtredia	27041	15846	Wall	24.905	T46	4,674,348	301,274	83.70	4,676,305	8,301,295
K-37-72	Djumati	27127	no/#	Wall	17.541	T47	4,662,158	740,536	16.87	4,664,117	7,740,740
K-38-61	Samtredia	27041	15846	Wall	24.905	T48	4,671,033	280,548	22.61	4,672,989	8,280,560
K-37-72	Poti	27146	63-49	Wall	3.664	101P	4,669,036	720,803	2.83	4,670,998	7,720,999
K-37-72	Kvalovani	27138	No number	Wall	15.285	102p	4,681,650	743,335	14.14	4,683,617	7,743,540
K-37-72	Kolhida	27142	2518	Ground	0.587	103p	4,675,065	723,652	0.89	4,677,030	7,723,849
K-37-72	Ureki	27214	20145	Wall	10.159	104p	4,654,407	730,173	9.39	4,656,363	7,730,373
K-37-84	Oczhamuri	27220	20684	Wall	12.864	105p	4,637,902	734,942	10.84	4,639,852	7,735,144
K-37-84	Kobuletti	27222	1368	Wall	5.831	106p	4,632,550	731,026	4.06	4,634,497	7,731,226
K-37-84	Czihisdziri	27224	20578	Wall	22.431	107p	4,626,670	728,213	21.31	4,628,615	7,728,412
K-37-84	Czakvi	27022	No number	Wall	8.289	108p	4,623,833	727,261	7.20	4,625,777	7,727,460
K-37-96	Batumi	27231	54	Wall	5.656	109p	4,613,700	719,492	4.28	4,615,640	7,719,688
K-38-85	Dandalo	27248	754	Ground	327.231	110p	4,614,475	258,649	327.73	4,616,408	8,258,653
K-38-85	Hulo	27309	468	Wall	874.202	111p	4,613,636	276,275	873.98	4,615,568	8,276,286
K-38-62		27274	408	Ground	964.102	112p	4,613,630	336,380	964.40	4,615,563	8,336,415
K-38-75	Borjomi	27287	No number	Wall	782.965	114p	4,634,089	367,958	781.91	4,636,030	8,368,006
K-38-76	Kvishheti	27292	539	Wall	724.887	115p	4,646,203	376,283	724.73	4,648,149	8,376,334
K-38-91		28057	2160	Wall	317.1	P3	4,596,059	504,892	317.76	4,597,985	8,504,995
K-38-102		28110	380	Wall	386.104	P5	4,572,956	482,911	384.89	4,574,872	8,483,005

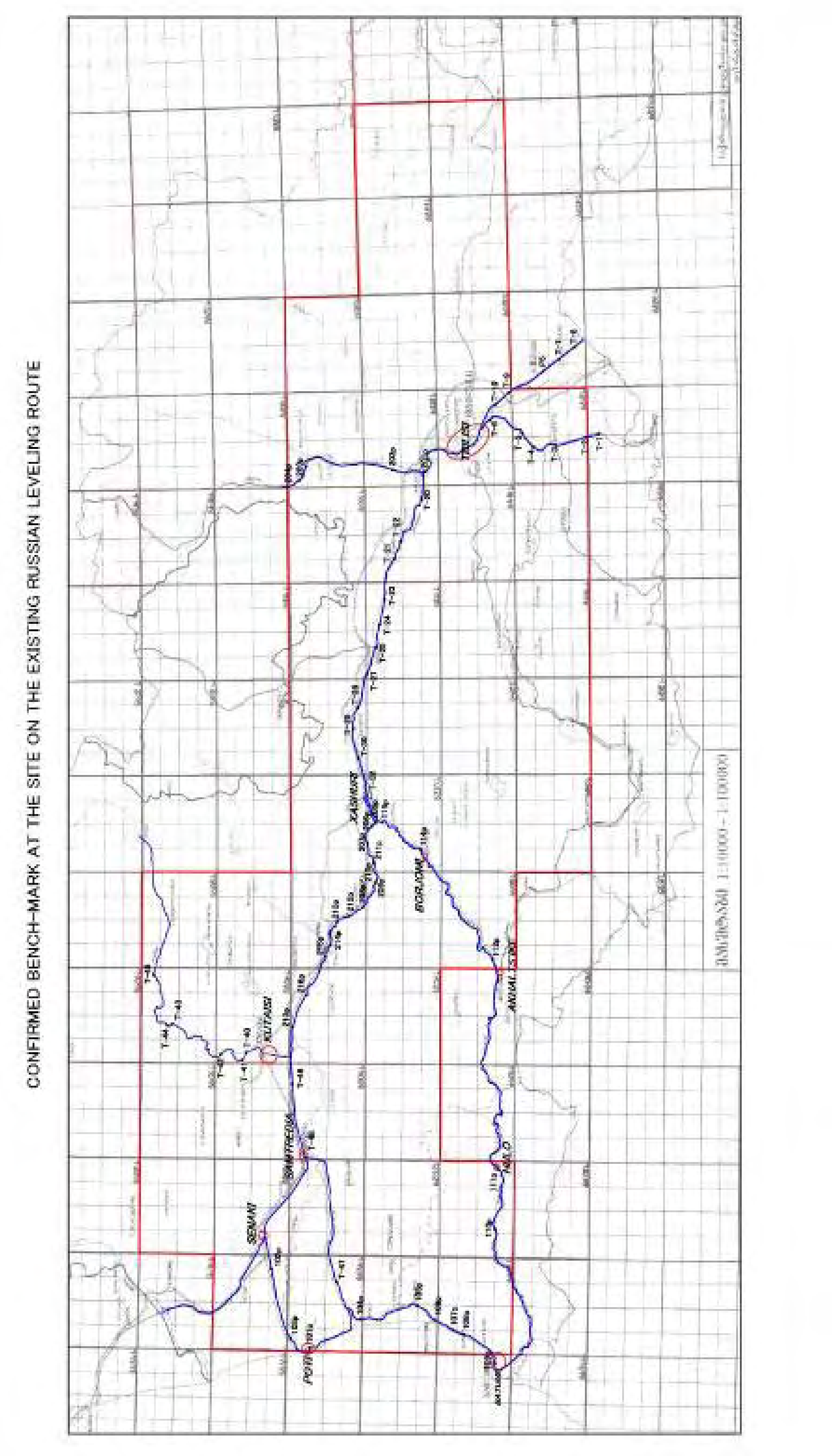


Figure 3.1.8 Existing leveling route with benchmarks

3.2. Aerial Photography

Aerial photography took place in May 2005 under the control of Pasco Europe. An area of approximately 30,000 km2 was completely photographed with a scale of 1: 40,000. A total of 1,447 black and white aerial photographs were taken during this mission.

Figure 3.2.1 Aircraft used for the aerial photography

The aerial photography in this study adopted the GPS Kinematic method so that surveying works on the ground, including surveying GCPs, was drastically reduced compared with traditional methods. The method to install GPS benchmarks on the ground around the photography stations and perform observation simultaneously with the GPS receivers installed onboard the aircraft was adopted to derive the photo center coordinate.

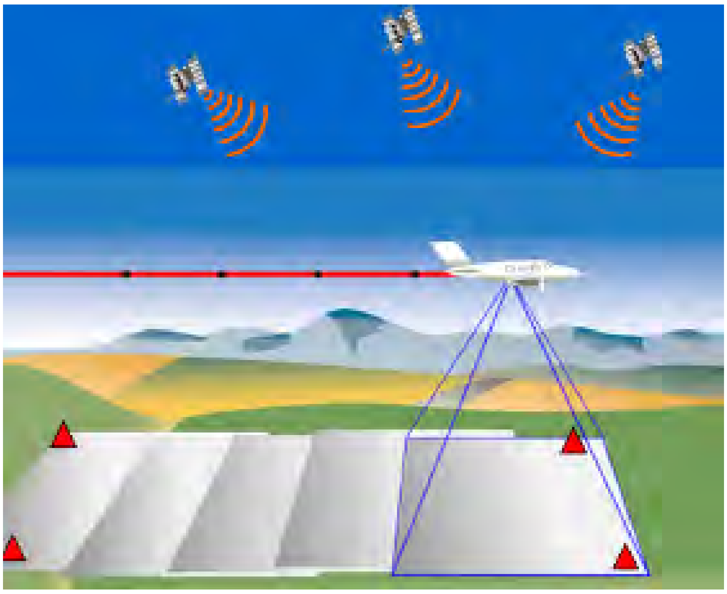


Figure 3.2.2 Diagram of aerial photography by GPS Kinematic Method

3.2.1. Planning and implementation

- **Preparation:** The tentative flight plan was checked and necessary adjustment was made prior to the installation of data in the navigation system.
- **Flight Plan** :All the flight lines were planned using the Tracker flight planning software.
- **Shooting** : All the aerial shootings took off from Tbilisi International Airport. The first flight was carried out on May 21, 2005 and photography of the entire project area was completed on May 24, 2005.
- **Condition of photography**: The aerial photography was performed only when the angle of the sun above the horizon was 30 degrees or more.
- **Security Check**: All the films were checked by Security Officer, Colonel Zurab Tateshvili, the Ministry of Defense, the Government of Georgia to remove the confidential objects.

3.2.2. Specifications

The shooting was made on the following specifications. The aerial photographs were inspected if required specifications were fulfilled after the shooting.

- **Used specification for aerial photography**

Scale of Photography	1:40,000
Camera specifications:	LaicaRC-30 or equivalent (f= 152 mm, 23 cm ×23 cm)
Flight altitude to planned elevation:	within 6,000m ± 5% from the ground
Overlap	Overlap 60 ± 5%
	Sidelap 30 ± 10%
Tolerable cloud cover:	Within 3% of successive 5 frames of photographs (excluding parts necessary for plotting orientation)
Condition	The coordinates of the principal points were measured using ADGPS.

- **Used equipment, materials and navigation system:**

Aircraft	Camera type	Lens type	Calibration Date	Navigation system
Piper PA31-T N700RG	ZEISS RMK TOP 15	PLEOGON- A3	03.03.2003	Tracker

- **Film type used**: KODAK LX 2405 black and white aerial photography film was used for the entire project.

- **Airborne GPS**: Differential GPS registration is as follows.

Location	Model	Options	Recording interval	Cut off angle
Base station Afrika	Leica	10 mb memory	1 second	10 degrees
Aircraft N700RG	Ashtech Z-Surveyor	16 mb memory	1 second	0 degrees

The reference station was located in the vicinity of the Tbilisi International Airport. All the data were downloaded daily after the aerial photography flights. Leica SKI-Pro V3.0 software was used for photo center coordinate computations using the backward and forward processing method. The processed data and final coordinates of each photo center, were saved on CD-ROM.

3.2.3. Inspection of Photographs

The Study Team carried out a quality control of the photographs using the rush prints. All the photographs were inspected and checked for overlapping and image quality in accordance with Specification. As the results of inspection, all photographs were found satisfied with the above-mentioned specifications. A flight index map was prepared in the AutoCAD format and saved on CD-ROM for a total number of 73 strips with 1,447 photographs (Figure 3.2.3).

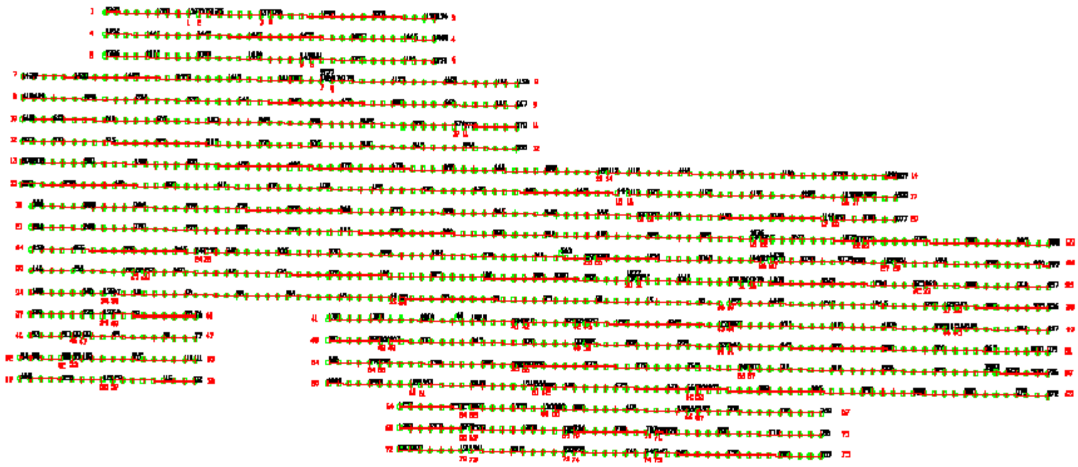


Figure 3.2.3 Flight index map

3.2.4. Scanning of aerial photographic films

All the frames of aerial film were scanned according to the following conditions.

Mode	:	Grayscale
Resolution	:	20 micrometer
File format	:	Tiff (un-tiled, uncompressed)
Scanner	:	Vexcel Ultrascan5000

Figure 3.2.4 Scanning of a roll film by Ultrascan 5000

Scanning direction was designed in such a way that the film rotation with respect to the ground was reversed in alternate strips because the airplane was flying in the opposite direction in alternate strips.

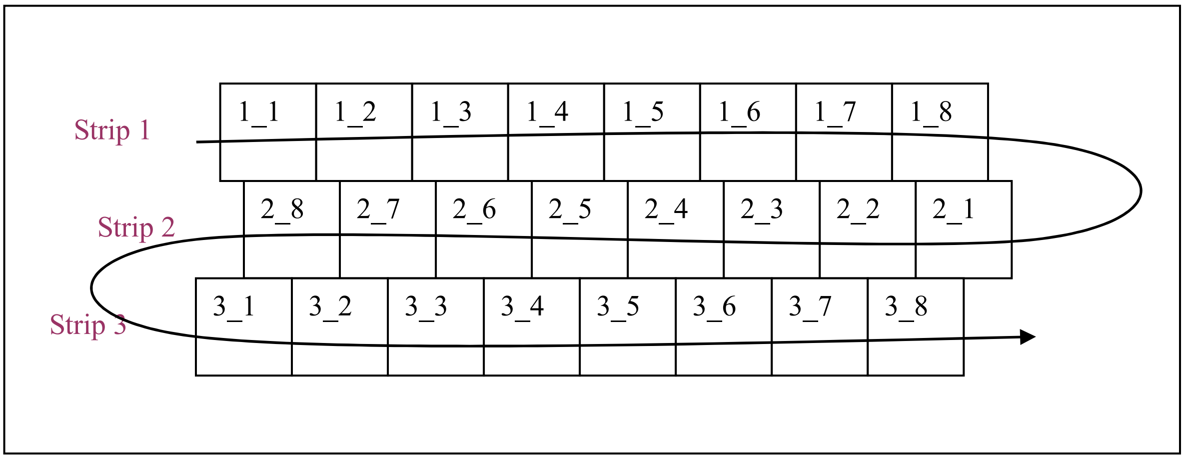


Figure 3.2.5 Rotation needed for reversed flight direction

Each scanned aerial photo was opened with Adobe Photoshop 8.0 for checking on the brightness and contrast and also for deletion of confidential objects such as military facilities.

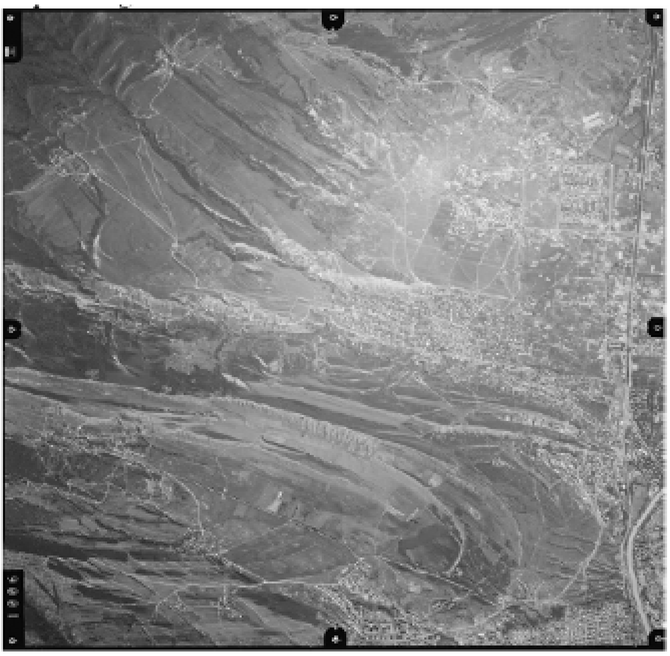


Figure 3.2.6 Scanned image opened with Adobe Photoshop

Each aerial photo was manually put in the scanning target. ⇨ **Brightness and contrast were adjusted for each photo individually** ⇨ **Rotation of the aerial photos was made in the way that all images have north up.**

Figure 3.2.7 Scanning process of aerial photographs

3.3. Aerial Triangulation

3.3.1. Outline of the work (Scope of the aerial triangulation)

Aerial triangulation was carried out over the entire Study Area of 30,000km^2. All the works were implemented using the MST model in the Socet Set software.

All 1,447 images were split into two blocks, east and west.

The triangulation was done based on WGS84 and coordinate system UTM, Zone 38.

Computation was successfully processed, and the results were used in digital plotting of maps to be newly created.

3.3.2. Method of triangulation

The scanned images of aerial photographs and the results of GCP observation and leveling were used in the aerial triangulation. Adjustment computations were carried out employing the bundle method by dividing the whole Study Area into two blocks, A and B.

All frame images were imported into the Socet Set software

↓

Interior orientation was conducted on all images manually, using the solution type of 6 parameters, with the RMS error less than one pixel

↓

All the project area was split into 2 portions, Block-Ⅰ and Block-Ⅱ

↓

As control points were used premark points and GPS points (Refer to Figure 3.3.2)

Block-Ⅰ : 64 points

Block-Ⅱ : 41 points

No. of models for B-1 : 790 models

No. of models for B-2 : 603 models

Figure 3.3.1 Process flow of adjustment

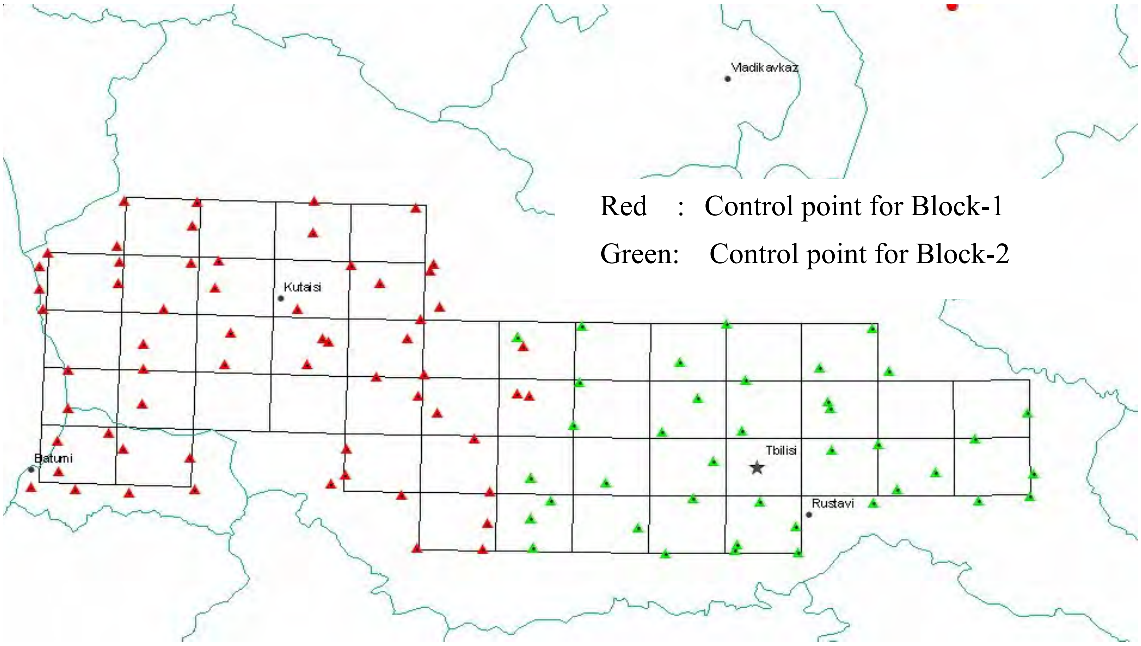


Figure 3.3.2 Allocation of control points in each block

3.3.3. Results

In the Multi-Sensor Triangulation Residual table, each control or tie point had a residual error less than one pixel, except a few points that were located in mountains or whose image quality is poor.

The average residual errors (RMS errors) and its maximum residual values, in the horizontal and vertical directions, of the control points used in the calculation are as follows:

In the Multi-Sensor Triangulation Residual table, each control or tie point had a residual error less than one pixel, except a few points that were located in mountains or whose image quality was poor.

In the horizontal and vertical directions, the resulted standard deviation of residual error computed as "RMS" and maximum residual errors of the control points are presented in Table 3.3.1 below :

Table 3.3.1 Results of adjustment computation of residual error

Block No.	X (Longitude)		Y (Latitude)		Z (Elevation)	
	Standard deviation	Max.	Standard deviation	Max.	Standard deviation	Max.
B1	0.237	+0.846	0.213	-0.643	0.088	-0.340
B2	0.358	+1.327	0.293	-0.866	0.047	+0.124

,. (in meter)

With the bundle method, the thresholds (accuracy standards) for the residual errors of control points in aerial triangulation were within the limitation values of 0.02% (1.2m), and 0.04% (2.4m) for average and maximum, respectively of aerial photography flight height, as mentioned in the Manual of Overseas Basic Map Production issued by the JICA, refer to Table 3.3.2,. Thus, the above adjustment computation results could be deemed as a satisfactory level of accuracy.

Table 3.3.2 Accuracy standards for standard deviation of residual errors

X:	less than 1.2 m (“altitude above ground level” x 0.02 %)
Y:	less than 1.2 m (“altitude above ground level” x 0.02 %)
Z:	less than 1.2 m (“altitude above ground level” x 0.02 %)

Table 3.3.3 Accuracy standards for maximum of residual errors

X:	less than 2.4 m (“altitude above ground level” x 0.04 %)
Y:	less than 2.4 m (“altitude above ground level” x 0.04 %)
Z:	less than 2.4 m (“altitude above ground level” x 0.04 %)

3.4. Creation of orthphotographs

3.4.1. Objective of the work

Considering the difficulty in field identification of the aerial photograph images, to avoid misinterpretation of information, Semi orthophotographs (produced at larger scale, 1:20,000) were prepared for the counterpart to conduct field verification speedily and efficiently.

More specifically, it is easier in this way, for the surveyors to confirm their position by referring to the positional information acquired using a handy GPS device as the 1:20,000 scaled orthophotographs displays the GPS coordinates “2 times enlargement compared to the original aerial photographs so taken at 1:40,000”, which is traditionally used for field verification.

3.4.2. Method of creating orthophotos

Orthophotographs were created with ERDAS Imagine V.8.6. First, importing the SocetSet projects, DEM data was generated from the automatic DTM. This DEM data was employed to derive, semi orthophotographs covering the entire Study Area.

These photos were mosaicked per four images and output as 49 scenes were carried at the surveys. All these data were saved in Geo-Tiff files. Followings are the major steps involved in this work:

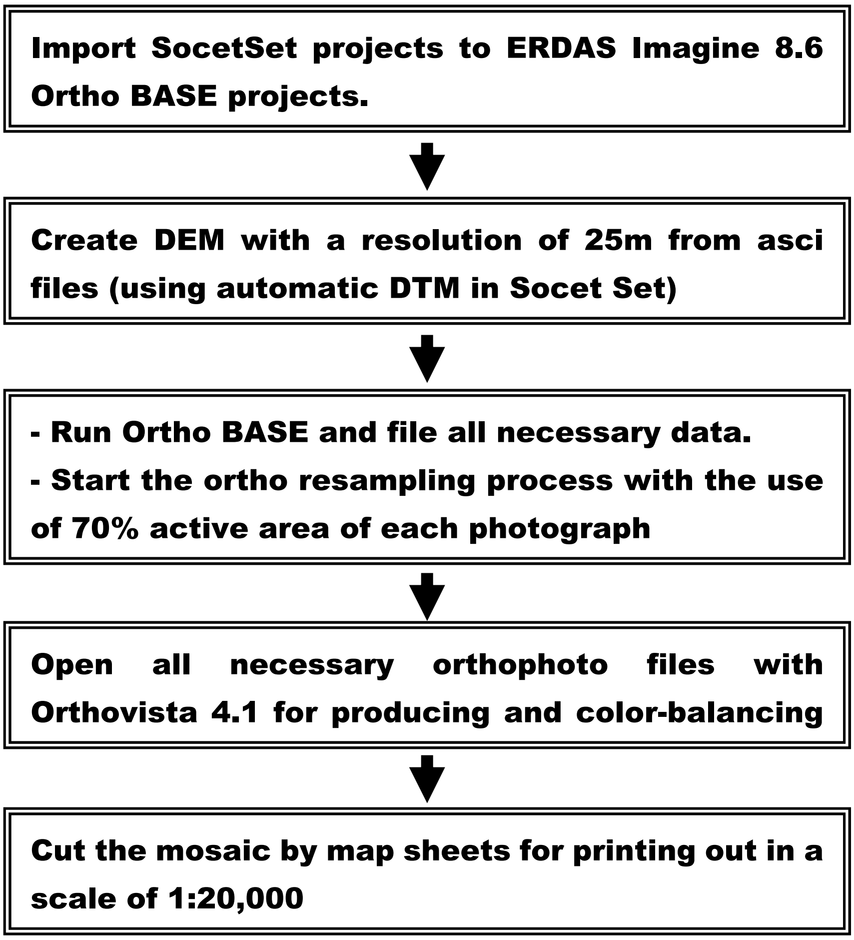


Figure 3.4.1 The process of generating semi orthphotos

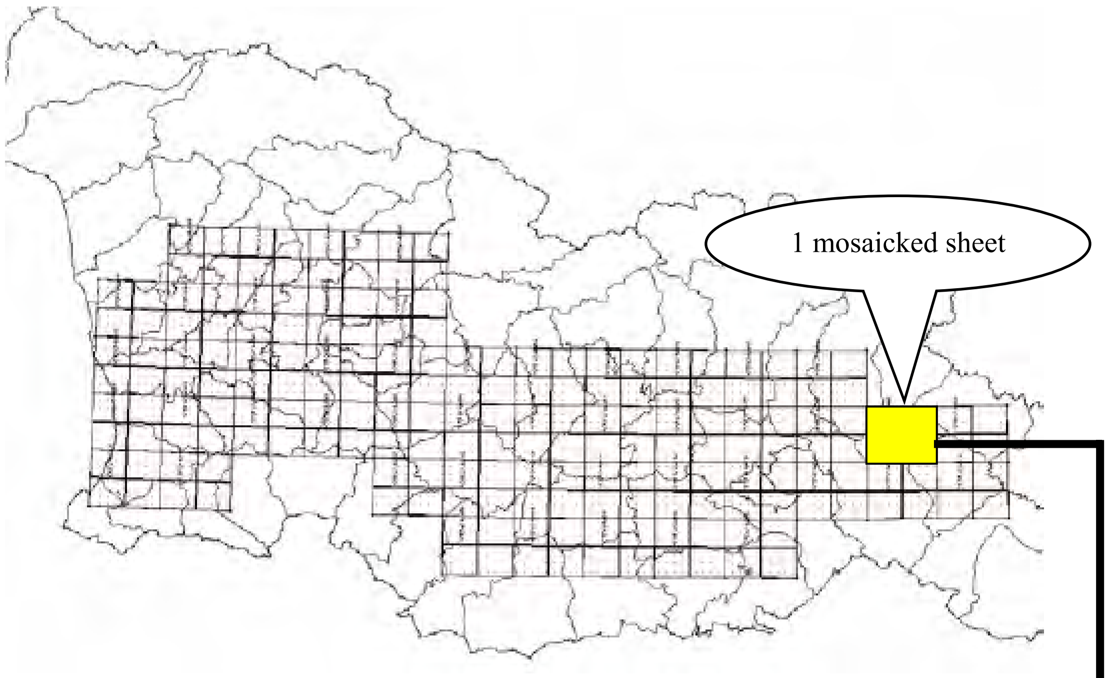


Figure 3.4.2 Sheet design of mosaicked orthophotos

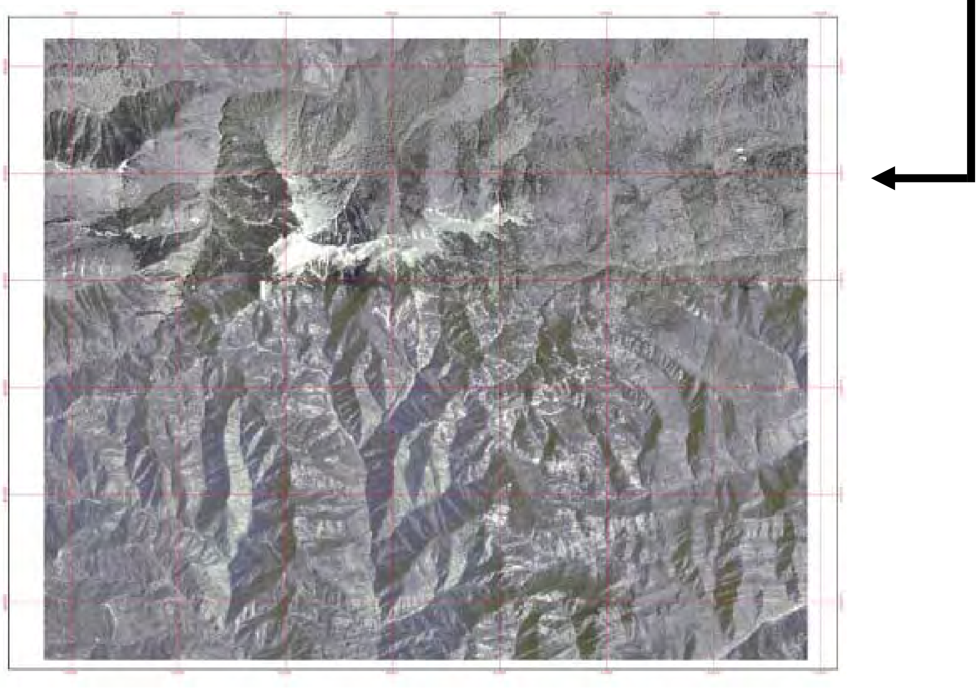


Figure 3.4.3 Output files, Geo Tiff, cutting off into the format of newly designed map sheet