2.5 Field Identification

The field identification work was conducted to identify the unclear points in the photo interpretation and to collect the information available only from the field. In addition, the secular changes in the roads and power transmission lines that had been newly constructed were also surveyed.

(1) Preparation of overlays

Polyester-based overlays were attached to the two times enlarged photos used in the photo interpretation and the results of photo interpretation were transferred on the overlays. These overlays were brought to the field for field identification.

1) The administrative boundaries, major terrains, names of rivers, and public facilities were transferred from the existing materials onto the overlays.
2) The categories of road, and the names and categories of villages and hamlets were transcribed.

(2) Field identification

1) Examination of the unclear points in the photo interpretation.
2) Identification of the results of photo interpretation
3) Identification of public and governmental facilities
   If the position displayed was unclear, the coordinates were measured using a handy GPS unit.
4) Survey of displayed positions and names of villages
   Village names were surveyed using a voice recorder and the spelling checked later.
5) Confirmation of categories of cultivated land and land covered with weeds

(3) Arrangement of the results of field identification

In the field identification, additions, deletions and corrections to the items filled onto the overlays were made and arranged.

(4) Checking and inspection

The field identification maps were checked and inspected to make sure that there was no oversight or loss in each acquired item. The results were compiled into a quality control sheet in the same way as for photo interpretation.

2.6 Geoid Survey

In this Study, the survey using the GPS was made. The GPS is configured adopting the earth ellipsoid centering the gravity center of the earth (WGS-84). However, the topographic maps produced in this Study adopted the reference ellipsoid (CLARKE 1880) as specified by Mali. As the latitude and longitude values obtained in the GPS survey were the coordinate values on WGS-84, those values had to be transformed into the coordinate values on the CLARKE 1880 ellipsoid for practical use. For elevation values, topographic survey should have been implemented by direct leveling in the entire area, however the area was too extensive. Thus, the topographic survey was made using the GPS sensor.

For this purpose, the parameters to obtain the orthometric elevations from the coordinate transformation between ellipsoids and the ellipsoidal elevation measured by the GPS were required. The survey to obtain these parameters is called “geoid survey”.

2.6.1 Transformation of Ellipsoid

To obtain the parameter for transformation of two ellipsoids, the ground control point having the 3-dimensional coordinate values of both ellipsoids are required. In this Study, the point P272 located at approximately 5 km northwest of the Kita City that was used in the 12th parallel survey was adopted as the ground control point for coordinate transformation. The coordinate values of both ellipsoids around the point P272 are shown below.

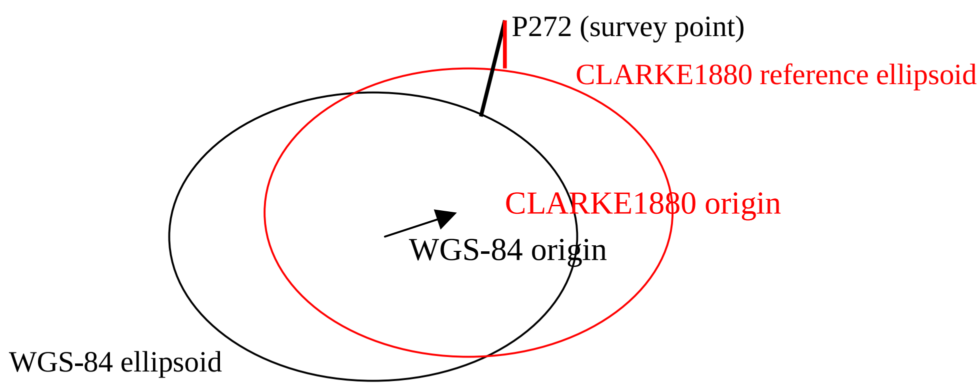


Fig. 2.6.1 Model diagram of transformation between ellipsoids

The steps to obtain the parameters for transformation between the ellipsoids will be described below.

① Obtain the 3-dimensional coordinates of the earth center from the latitude, longitude and ellipsoid elevation as measured on the WGS-84 ellipsoid.

② Obtain the 3-dimensional coordinates of the same point from the latitude, longitude and elevation values on the CLARKE 1880 ellipsoid.

③ Obtain the difference between both 3-dimensional coordinate values, which are the shift values of origins (ΔX, ΔY, ΔZ).

Table 2.6.1 Calculations of parameters for transformation between ellipsoids

Item	WGS-84	CLARKE1880
Semi major axis (m)	6378137.000	6378249.145
Flattering	1/298.257223563	1/293.465
Latitude	13° 5’ 41.5754”	13° 5’ 40.629”
Longitude	-9° 30’ 43.2326”	-9° 30’ 38.238”
Elevation (m)	453.399	393.87
X (m)	6128357.0205	6128456.1142
Y (m)	-1026855.7584	-1026719.7991
Z (m)	1435733.8248	1435563.5443
ΔX (m)	99.094	
ΔY (m)	135.960	
ΔZ (m)	-170.281	

2.6.2 Geoid Elevation

As shown in Fig. 2.6.2, the elevation measured by the GPS survey is the height above the ellipsoid. As the ellipsoidal plane is not coincident with the geoidal plane in principle, it is impossible to obtain the orthometric elevation that can be obtained in leveling. Thus, it is necessary to make the geoid survey to know how far the geoidal plane is from the ellipsoidal plane. In this Study, the height above the ellipsoid measured by GPS survey and the elevation measured by leveling are obtained and the undulation on the geoid from the CLARKE 1880 ellipsoid were presumed.

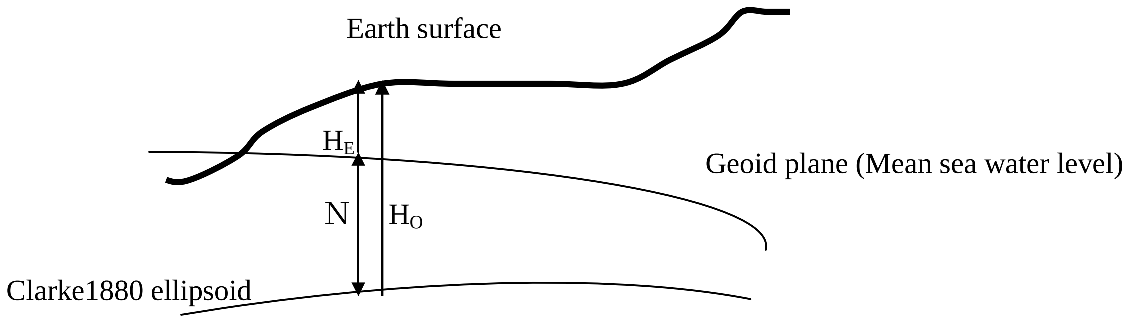
The steps for this procedure are as follows:

① Make the GPS survey on the benchmark and obtain the 3-dimensional coordinates on WGS-84.

② Transform the coordinates from WGS-84 into CLARKE 1880 and obtain the height above the ellipsoid (H_E) on the CLARKE 1880 ellipsoid.

③ Obtain the geoid elevation (N) at the point from the difference between the height above the ellipsoid and the orthometric elevation (H_0) measured by leveling.

④ Conduct this measurement in the entire target area, plot the geoid elevation at each point on the 1/50,000 topographic map and represent the undulation as the contour line to create the geoid map.



H_0: Orthometric height

N: Geoid elevation

H_E: Height above ellipsoid

$H_O = H_E + N$

Fig. 2.6.2 Height above ellipsoid and geoid elevation

The actual work was conducted in the following steps:

(1) Reconnaissance of existing benchmark (first-year work)

The railway runs from east to west through the Kita area located at the center of the study area. Along this railroad, the first order leveling route extends and the second order leveling route runs outside the study area in the north, and the third order leveling route passes around Manantali dam in the west of the study area. Therefore, it was decided to set the leveling routes in the north and the south where the road extends to the north from Kita and along the road running in the southwest direction. There was a benchmark Mle103 in the vicinity of the planned leveling route around Kita. As the result of measuring this point and the adjacent benchmark Mle104, the measuring error was only 1 mm. Therefore, the point Mle103 was adopted as the origin for this area. The route bound for Diéma in the north was set as Route 1 and the benchmark 28-T on the leveling route passing through Diéma was set as the end of the route. As the result of measuring the benchmark 28-T and the adjacent benchmark 27-T, the measuring error was 21 mm. The route connecting from Kita to the southwest was set as Route 2 with the end set to the third order benchmark 36 in Bantakoto. The adjacent benchmark 37 to this point 36 was measured, resulting in the measuring error of 7 mm. The route from Kita to Gale in the south was set as Route 3. There was no existing benchmark at the end of this route so that the route could not be enclosed at any benchmark. As this survey was aimed at obtaining the geoid undulation, the benchmark obtained by round-trip survey was adopted.

(2) Monumentation of benchmarks (first-year work)

On Route 1 from Kita to Diéma in the north, 21 benchmarks were established in about 10-km intervals over the distance of 200.1 km, 9 benchmarks in about 10-km intervals over the distance of 55.6 km on Route 2 up to Bantakoto, and 6 benchmarks over the distance of 88.4 km on Route 3 up to Galé. The specifications of monument of stones as the benchmarks are shown as follows. In addition, 4 benchmarks were laid each in Kita City and in the City of Diéma for the purpose of use for the future city development.

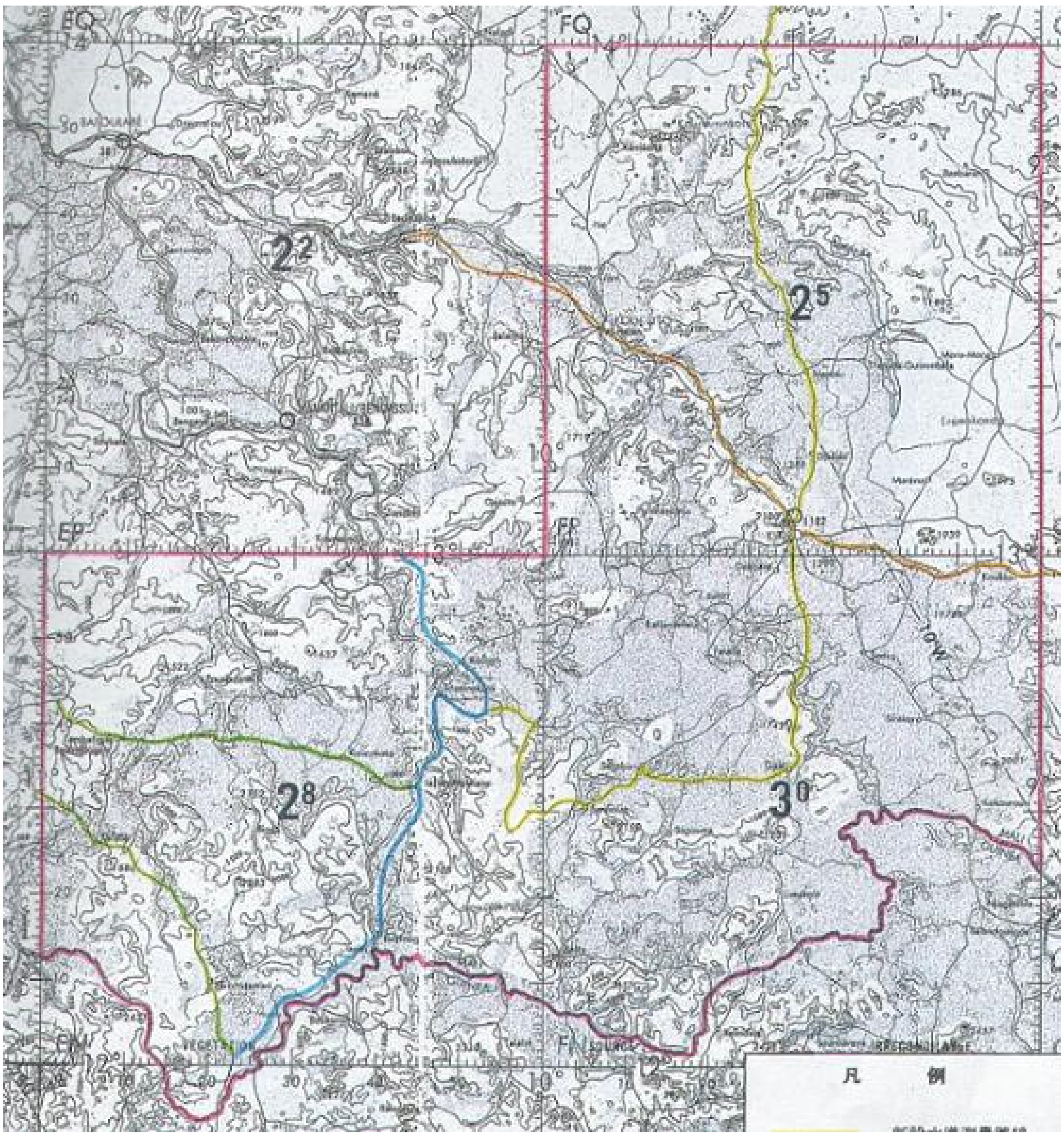


Fig. 2.6.3 Index of new and existing benchmarks

(3) Third order leveling (first-year work)

On three routes Route 1, Route 2 and Route 3 on which benchmark stones were laid, the third order leveling was conducted over the total distance of 376.9 km.

Fig. 2.6.4 Leveling

Table 2.6.2 New benchmarks and elevations

Route	Benchmark	Orthometric Elevation	Remarks
Route 1	Mle103	332.845	Existing benchmarks
	B101	314.126	
	B102	332.548	
	B103	354.737	
	B104	330.653	
	B105	324.403	
	B106	334.053	
	B107	290.039	
	B108	192.043	
	B109	230.188	
	B110	268.129	
	B111	279.962	
	B112	244.853	
	B113	255.639	
	B114	275.066	
	B115	296.005	
	B116	292.879	
	B117	298.416	
	B118	290.719	
	B119	273.965	
	B120	261.771	
	B121	253.373	
	28-T	252.713	Existing benchmarks

Route	Benchmark	Orthometric Elevation	Remarks
Route 2	Mle103	332.845	Existing benchmarks
	B201	305.620	
	B202	317.709	
	B203	281.206	
	B204	283.408	
	B205	319.444	
	B206	292.234	
	B207	275.831	
	B208	266.471	
	B209	266.537	
	36	273.027	Existing benchmarks
Route 3	Mle103	332.845	Existing benchmarks
	B301	313.644	
	B302	302.365	
	B303	302.435	
	B304	285.347	
	B305	322.126	
	B306	309.257	
	B1001	331.390	in Kita City
	B1002	329.793	in Kita City
	B1003	352.146	in Kita City
	B1004	352.409	in Kita City
	B2001	251.307	in Diéma City
	B2002	252.416	in Diéma City
	B2003	251.826	in Diéma City
	B2004	251.717	in Diéma City

(4) GPS survey on benchmarks and pricking (second-year work)

The GPS survey was conducted on the points where leveling was made to obtain their geoidal elevations and on the existing benchmarks.

Fig. 2.6.5 GPS survey

Table 2.6.3 Benchmarks and heights above ellipsoid (Clarke 1880 ellipsoid) by GPS survey

Benchmark	X (Easting)	Y (Northing)	Height above Ellipsoid	Remarks
BM005	299,003.648	1,398,294.512	263.510	Existing benchmark
BM007	309,817.658	1,397,209.149	257.975	Existing benchmark
BM019	319,903.252	1,342,724.406	463.145	Existing benchmark
BM020	320,764.248	1,336,809.783	401.775	Existing benchmark
BM034	374,422.342	1,414,248.804	230.759	Existing benchmark
BM036	379,908.067	1,403,535.144	273.027	Existing benchmark
BM038	368,819.073	1,407,485.633	219.481	Existing benchmark
BM042	364,827.717	1,390,501.105	227.377	Existing benchmark
BM043	363,957.774	1,387,061.646	237.802	Existing benchmark
BM059	323,926.457	1,323,090.225	339.491	Existing benchmark
BM082	404,822.828	1,486,859.129	179.571	Existing benchmark
BM087	419,911.775	1,480,196.342	218.770	Existing benchmark
BM092	429,205.099	1,467,682.524	297.251	Existing benchmark
BM096	434,675.265	1,455,541.879	291.936	Existing benchmark
BM114	475,817.357	1,433,537.911	329.710	Existing benchmark
B101	447,463.541	1,450,768.163	314.126	New benchmark
B102	451,103.641	1,459,236.707	332.584	New benchmark
B103	449,476.682	1,466,689.831	354.737	New benchmark
B104	449,597.482	1,476,922.896	330.653	New benchmark
B105	445,855.506	1,485,695,107	324.403	New benchmark
B106	444,626.701	1,493,596.013	334.053	New benchmark
B107	438,715.000	1,501,473.783	290.039	New benchmark
B108	437,356.805	1,514,616.427	192.043	New benchmark
B109	436,516.819	1,522,985.770	230.188	New benchmark
B110	437,922.484	1,532,242.483	268.129	New benchmark
B111	441,332.017	1,541,397.468	279.962	New benchmark
B112	440,603.188	1,546,753.034	244.853	New benchmark
B113	441,567,200	1,554,476.020	255.639	New benchmark
B114	445,899.778	1,561,082.362	275.066	New benchmark
B115	451,689.547	1,570,512.179	296.005	New benchmark
B116	458,939.194	1,576,505.359	292.879	New benchmark
B117	464,540.427	1,582,906.614	298.416	New benchmark
B118	467,410.629	1,587,441.819	290.719	New benchmark
B119	471,799.722	1,593,574.248	273.965	New benchmark
B120	476,318.524	1,594,263,828	261.771	New benchmark
B121	481,066.384	1,601,772.035	253.373	New benchmark
B201	437,030.491	1,440,357.843	305.620	New benchmark
B202	430,151.678	1,440,150.044	317.709	New benchmark
B203	420,968.604	1,434,685.517	281.206	New benchmark
B204	413,298.857	1,434,794.670	283.408	New benchmark
B205	405,118.900	1,433,487.675	319.444	New benchmark
B206	397,569.363	1,423,913.352	292.234	New benchmark
B207	395,669.188	1,416,235.815	275.831	New benchmark
B208	391,843.092	1,413,375.100	266.471	New benchmark
B209	390,113.591	1,400,755.677	266.537	New benchmark
B301	447,268.479	1,433,331.681	313.644	New benchmark
B302	448,629.920	1,425,601.485	302.365	New benchmark
B303	451,477.742	1,417,685.452	302.435	New benchmark
B304	446,248.038	1,408,103.317	285.347	New benchmark

Benchmark	X (Easting)	Y (Northing)	Height above Ellipsoid	Remarks
B305	447,018.454	1,401,402.809	322.126	New benchmark
B306	445,441.261	1,391,404.812	309.257	New benchmark

(5) Calculations and indication of geoidal elevations (second-year work)

The results of the GPS survey made on the benchmarks were transformed into the CLARKE 1880 reference ellipsoid as specified by Mali and the geoidal elevations were obtained from the elevation difference between the heights above the ellipsoid and those measured by leveling.

Table 2.6.4 Calculations of geoidal elevations from height difference between height above ellipsoid and leveled elevations

Benchmark	Height above Ellipsoid	Leveled Elevations	Geoidal Elevations
P272	453.399	393.870	59.529
BM017	537.995	478.015	59.980
BM019	523.200	463.145	60.055
BM020	462.159	401.775	60.384
BM034	290.543	230.759	59.784
BM036	332.612	273.027	59.585
BM038	279.261	219.481	59.780
BM042	287.262	227.377	59.885
BM043	297.626	237.802	59.824
BM82	238.742	179.571	59.171
BM87	277.581	218.770	58.811
BM92	356.548	297.251	59.297
BM96	351.384	291.936	59.448
BM114	389.350	329.710	59.640
B101	373.653	314.126	59.527
B102	392.109	332.584	59.525
B103	414.228	354.737	59.491
B104	390.032	330.653	59.379
B105	383.684	324.403	59.281
B106	393.154	334.053	59.101
B107	348.973	290.039	58.934
B108	250.762	192.043	58.719
B109	288.878	230.188	58.690
B110	326.807	268.129	58.678
B111	338.588	279.962	58.626
B112	303.425	244.853	58.572
B113	314.165	255.639	58.526
B114	333.561	275.066	58.495
B115	354.395	296.005	58.390
B116	351.178	292.879	58.299
B117	356.613	298.416	58.197
B118	348.848	290.719	58.129
B119	332.003	273.965	58.038
B120	319.780	261.771	58.009
B121	311.302	253.373	57.929
B201	365.137	305.620	59.517
B202	377.182	317.709	59.473
B203	340.682	281.206	59.476

Benchmark	Height above Ellipsoid	Leveled Elevations	Geoidal Elevations
B204	342.837	283.408	59.429
B205	378.873	319.444	59.429
B206	351.726	292.234	59.492
B207	335.413	275.831	59.582
B208	326.068	266.471	59.597
B209	326.149	266.537	59.612
B301	373.217	313.644	59.573
B302	361.931	302.365	59.566
B303	361.989	302.435	59.554
B304	344.928	285.347	59.581
B305	381.727	322.126	59.601
B306	368.954	309.257	59.697
B1001	390.969	331.390	59.579
B2003	309.834	251.826	58.008
B2004	309.814	251.717	58.097

It was clear that the geoidal plane in the study area was located 60 m in average above the CLARKE 1880 ellipsoid.

(6) Production of geoid maps (second-year work)

The geoidal elevations obtained as above were plotted on the 1/50,000 topographic maps. The maximum value of the geoidal elevations was 60.384 m and the minimum value was 57.929 m, and the distance between both points was about 280 km. As described above, it was clear that the geoidal undulation in this study area rose gradually by 2.5 m over 280 km, namely about 10 cm in 10 km intervals. Therefore, the contour lines were depicted in 10 cm intervals to complete the geoid map. The heights above the ellipsoid that were obtained by GPS survey could be corrected with the geoidal correction values that were easily obtained by plotting the measuring points and could also be transformed into the elevation values obtained by leveling.

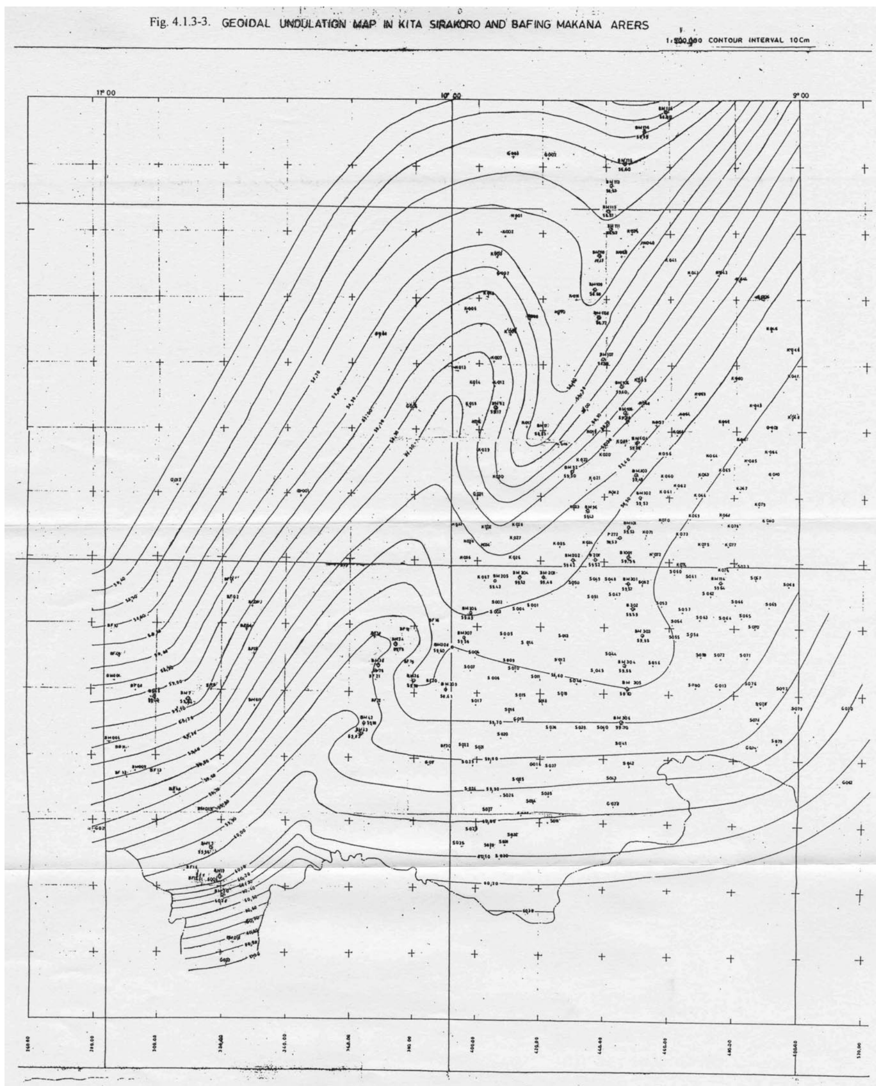


Fig. 2.6.6 Geoidal undulating map (contour lines at 10 cm intervals)

2.7 Ground Control Point Survey

The ground control points were set at the adequate positions to conduct the spatial triangulation using the SPOT images and the coordinates of these ground control points were measured by GPS survey. The steps of this work will be outlined below.

(1) Reconnaissance of existing ground control points

As the existing ground control points in this study area, there are the astronomic points and the traversing points set by the 12th parallel survey. However, the astronomic points had a low accuracy so that it was decided not to use them in this Study. The 12th parallel circle survey was conducted jointly by the U.S.A, France and Mali in 1973 in the area along latitude 12 degrees north from the border with Egypt and Sudan to Dakar in Senegal. By combining a traverse survey with astronomical observation, a highly accurate position can be obtained with a probable error of the mean of 0.3 sec. for the latitude, longitude and azimuth. These traverse stations were therefore used. Thus, the benchmarks set in the first-year work were used as part of the ground control points and new ground control points were established in the area of lack of ground control points.

(2) Selection of ground control points

It was planned to distribute the ground control points uniformly in the surrounding area of each block covered by the SPOT image in order to ensure the accuracy of spatial triangulation to be kept so high as to implement the spatial triangulation using the SPOT satellite images. In the control point distribution plan, the ground control points were selected in considering that the GPS survey could be made, that the access to those points by car was easy and that pricking could be made.

(3) GPS survey and pricking

The ground control point survey was made by GPS survey in accordance with the control point distribution plan. The benchmarks capable of pricking were also adopted as the ground control points and 24 new control points were added. The descriptions of points were prepared for the new benchmarks and ground control points, which were pricked on the SPOT images.

(4) Calculations and arrangement

In calculations for the GPS survey, the SKI software made by Leica was used to obtain the positions on WGS-84 and convert these into the latitude and longitude values and the heights above the ellipsoid on the Clarke ellipsoid. The results of calculations were converted into the UTM coordinates and the orthometric heights for use in the spatial triangulation.

(5) Preparation of Quality control sheet

The survey results were evaluated and the points measured several times were compared with each another to check the measuring accuracy. The results of evaluation were arranged in the Quality control sheet.

(6) Preparation of resulting table

The resulting table of ground control points was prepared.

Table 2.7.1 Coordinate of ground control point and elevation

Point Name	Latitude	Longitude	UTM coordinates		Elevation
	Deg.min.sec	Deg.min.sec	Easting	Northing	
P272	13 5 40.629	9 30 38.238	444,646.753	1,447,525.712	393.870
B101	13 7 26.368	9 29 4.904	447,463.541	1,450,768.163	314.126
B102	13 12 2.282	9 27 4.512	451,103.641	1,459,236.707	332.584
B103	13 16 4.820	9 27 59.025	449,476.682	1,466,689.831	354.737
B104	13 21 37.961	9 27 55.647	449,597.482	1,47,922.896	330.653
B105	13 26 23.296	9 30 0.637	445,855.506	1,485,695.107	324.403
B106	13 30 40.420	9 30 42.048	444,626.701	1,493,596.013	334.053
B107	13 34 56.446	9 33 59.307	438,715.000	1,501,473.783	290.039
B108	13 42 4.177	9 34 45.543	437,358.805	1,514,616.427	192.043
B109	13 46 36.557	9 35 14.186	436,516.819	1,522,985.770	230.188
B110	13 51 37.999	9 34 28.113	437,922.484	1,532,242.483	268.129
B111	13 56 36.278	9 32 35.222	441,332.017	1,541,397.468	279.962
B112	13 59 30.560	9 32 59.925	440,603.188	1,546,753.034	244.853
B113	14 3 42.033	9 32 28.381	441,567.200	1,554,476.020	255.639
B114	14 7 17.397	9 30 4.389	445,899.778	1,561,082.362	275.066
B115	14 12 24.741	9 26 51.890	451,689.547	1,570,512.179	296.005
B116	14 15 40.253	9 22 50.335	458,939.194	1,576,505.359	292.879
B117	14 19 8.908	9 19 43.708	464,540.427	1,582,906.614	298.416
B118	14 21 36.668	9 18 8.094	467,410.629	1,587,441.819	290.719
B119	14 24 56.468	9 15 41.784	471,799.722	1,593,574.248	273.965
B120	14 25 19.069	9 13 10.896	476,318.524	1,594,263.828	261.771
B121	14 29 23.613	9 10 32.523	481,066.384	1,601,772.035	253.373
B201	13 1 46.746	9 34 50.614	437,030.491	1,440,357.843	305.620
B202	13 1 39.442	9 38 38.967	430,151.678	1,440,150.044	317.709
B203	12 58 40.743	9 43 43.309	420,968.604	1,434,685.517	281.206
B204	12 58 43.548	9 47 57.888	413,298.857	1,434,794.670	283.408
B205	12 58 0.128	9 52 29.237	405,118.900	1,433,487.675	319.444
B206	12 52 47.587	9 56 38.622	397,569.363	1,423,913.352	292.234
B207	12 48 37.436	9 57 40.713	395,669.188	1,416,235.815	275.831
B208	12 47 10.353	9 59 47.274	391,843.092	1,413,375.100	266.471
B209	12 40 12.835	10 0 42.976	390,113.591	1,400,755.677	266.537
B301	12 57 58.707	9 29 10.273	447,268.479	1,433,331.681	313.644
B302	12 53 47.129	9 28 24.610	448,629.920	1,425,601.485	302.365
B303	12 49 29.582	9 26 49.657	451,477.742	1,417,685.452	302.435
B304	12 44 17.317	9 29 42.533	446,248.038	1,408,103.317	285.347
B305	12 40 39.222	9 29 16.569	447,018.454	1,401,402.809	322.126
B306	12 35 13.628	9 30 8.223	445,441.261	1,391,404.812	309.257

Point Name	Latitude	Longitude	UTM coordinates		Elevation
	Deg.min.sec	Deg.min.sec	Easting	Northing	
BM001	12 40 45.734	10 57 41.038	286,991.280	1,402,353.800	215.3
BM005	12 38 36.499	10 51 2.037	299,003.648	1,398,294.512	263.510
BM006	12 30 45.747	10 58 25.669	285,505.856	1,383,925.461	177.880
BM007	12 38 3.601	10 45 3.486	309,817.658	1,397,209.149	257.975
BM009	12 26 1.635	10 53 48.656	293,808.239	1,375,133.502	182.070
BM019	12 8 32.567	10 39 18.115	319,903.252	1,342,724.406	463,145
BM020	12 5 20.244	10 38 48.459	320,764.248	1,336,809.783	401.775
BM034	12 47 29.923	10 9 25.096	374,422.342	1,414,248.804	230.759
BM036	12 41 41.963	10 6 21.660	379,908.067	1,403,535.144	273.027
BM038	12 43 48.949	10 12 29.869	368,819.073	1,407,485.633	219.481
BM042	12 34 35.496	10 14 39.519	364,827.717	1,390,501.105	227.377
BM043	12 32 43.408	10 15 7.802	363,957.774	1,387,061.646	237.802
BM059	11 57 54.344	10 37 1.225	323,926.457	1,323,090.225	339.491
BM082	13 26 57.450	9 52 45.274	404,822.828	1,486,859.129	179.571
BM087	13 23 22.172	9 44 22.835	419,911.775	1,480,196.342	218.770
BM092	13 16 35.656	9 39 12.764	429,205.099	1,467,682.524	297.251
BM096	13 10 0.876	9 36 10.008	434,675.265	1,455,541.879	291.936
BM114	12 58 6.712	9 13 22.688	475,817.357	1,433,537.911	329.710
G001	13 11 51.362	10 26 11.392	344,330.497	1,459,302.940	165.5
G002	14 8 12.430	9 43 30.987	421,720.139	1,562,836.156	243.0
G003	14 8 16.878	9 49 44.592	410,518.944	1,563,009.921	257.8
G005	14 1 29.800	10 8 24.264	376,886.121	1,550,643.819	210.6
G006	13 45 3.832	9 6 25.550	488,421.891	1,520,062.553	262.9
G007	13 48 23.789	9 51 25.192	407,370.286	1,526,367.549	189.8
G008	13 38 22.807	10 12 56.700	368,496.675	1,508,070.537	132.0
G009	13 23 23.074	9 5 7.723	490,745.053	1,480,105.922	335.7
G010	13 15 54.907	9 4 41.325	491,534.686	1,466,339.475	335.7
G012	13 13 14.988	10 47 23.581	306,043.233	1,462,119.051	117.1
G013	12 40 48.730	9 13 21.734	475,818.597	1,401,655.632	332.0
G014	12 30 45.073	9 7 18.676	486,760.354	1,383,107.134	327.2
G015	12 35 15.610	9 48 6.426	412,907.697	1,391,546.375	336.8
G016	12 27 29.241	9 44 48.996	418,824.598	1,377,203.332	419.7
G017	12 27 41.606	10 3 39.730	384,688.468	1,377,699.394	365.1
G021	12 15 45.262	11 1 0.514	280,620.853	1,356,287.252	182.2
G023	11 54 16.451	10 38 15.878	321,628.305	1,316,408.795	310.3
G025	12 14 8.758	9 57 31.877	395,705.000	1,352,687.879	388.8
G026	13 26 27.653	10 6 58.961	379,146.430	1,486,047.703	183.0
G027	12 26 3.981	8 44 25.809	528,203.266	1,374,484.217	502.7
G028	12 21 3.414	9 31 18.049	443,283.025	1,365,293.949	348.6
G030	12 37 28.103	8 51 22.316	515,617.428	1,395,487.369	384.1
G031	13 11 52.765	9 55 23.512	399,961.173	1,459,084.459	303.3
G262	12 24 53.424	8 52 42.131	513,220.256	1,372,306.357	428.2

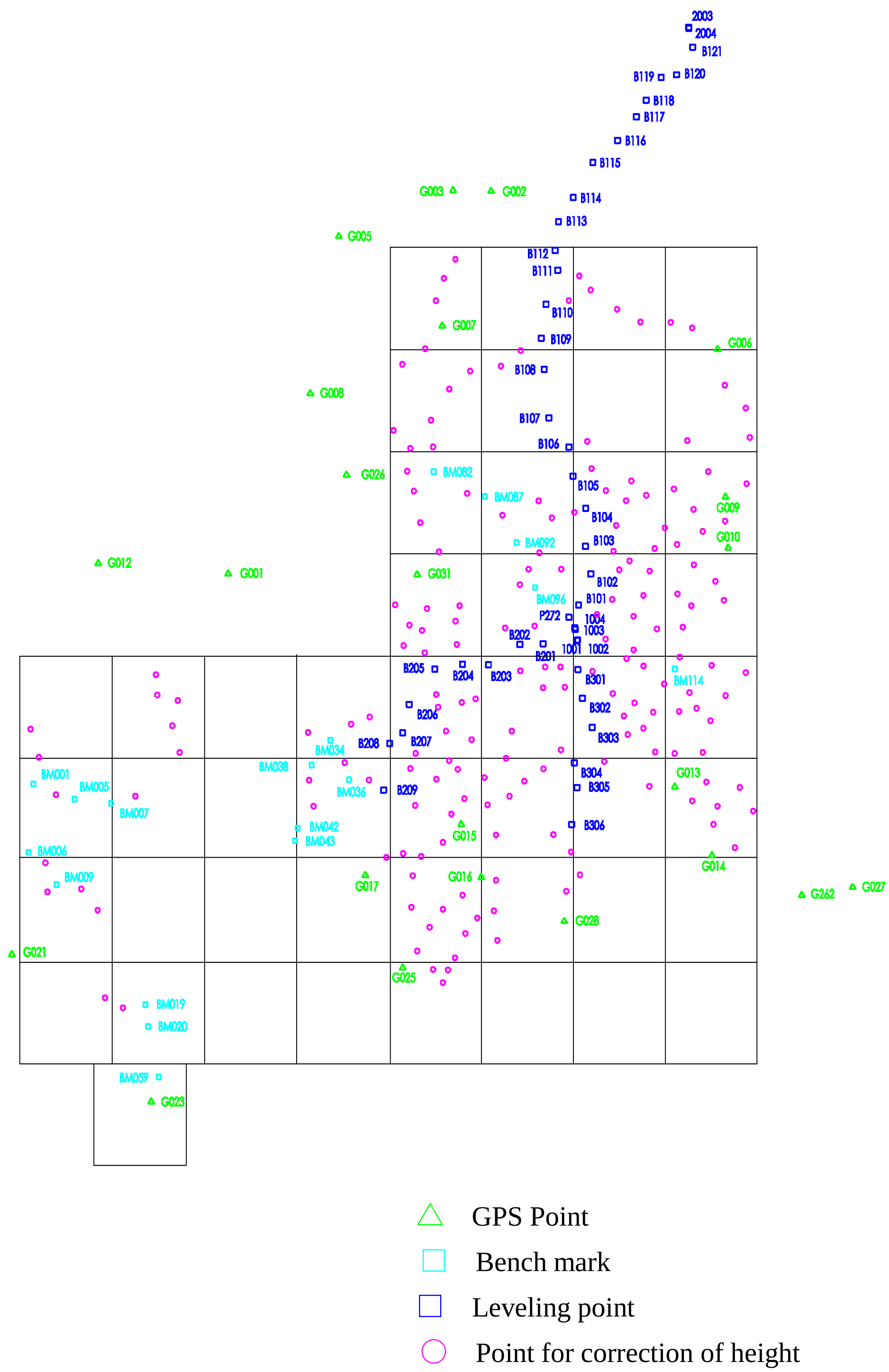


Fig. 2.7.1 Location map of ground control points

2.8 Survey of Supplementary Elevation Points

Since the elevation values in the SPOT images had no sufficient accuracy to depict the 13 m- and the 20m-contour lines according to the past research, about 273 additional elevation points (including 24 ground control points) were surveyed in order to enhance the elevation accuracy. Care was taken to distribute these supplementary elevation points uniformly across the entire study area. The results of GPS survey were transformed into the coordinates on the CLARKE ellipsoid and corrected using the geoid map in order to obtain the elevations. The obtained elevations were used as the check data for the contour lines depicted in the digital plotting process.

2.9 Spatial Triangulation

The index elements of each SPOT image were obtained to execute the digital plotting using the SPOT images. 20 scenes of stereo images were lent by JICA to the Study Team, of which it was confirmed that 19 scenes could cover the entire study area. Therefore, spatial triangulation for the 19 scenes of SPOT images was executed to determine the index elements of each image and the coordinates of pass points and tie points. The spatial triangulation was conducted in Japan.

The actual work of spatial triangulation was carried out in the following procedure:

(1) Preparation

First, the density of the satellite images was adjusted to standardize the density of each image scene using the filtering function of the image processing software PHOTOSHOP.

Then, the ground control point file was made up, in which the ground control points were divided into the control points with XYH coordinates obtained in the GPS observation and the benchmarks having only the heights.

(2) Point selection and observation

From the images for which the density was adjusted, the ground control points and pass points were selected and relative orientation was made using these points. For transcription of the ground control points, the satellite images on which the description of points (GPS points and benchmarks) and pricking were made were referred to. Furthermore, 3 or more tie points were added between courses to strengthen the connections of these.

(3) Adjustment

All the scenes of the satellite images were subject to the absolute orientation using the spatial triangulation software SOCET SET (Leica Helava, Switzerland) for satellite images to perform adjustment calculations.

The result of adjustment was verified and the ground control points with large residual errors were checked and re-measured, and it was verified that the residual errors were within the limits before the adjustment was finished.

The header of the satellite image data records the orbital elements. Some of the 19 scenes were acquired on the same orbit and these are called segments. A total of 11 segments were acquired in this study. Adjustment computation can be conducted for each scene, but the ground control points can be minimized if the same segment (two or more scenes) is treated as one scene. In this study, therefore, aerial triangulation software for satellite images was used to incorporate orbital elements into the adjustment computation.

The number of points used for the adjustment and the overall standard deviations are as follows:

Table 2.9.1 Results of adjustment computation by aerial triangulation

Input	Number of pass points		547
	Number of control points on plane		23
	Number of control points for height		43
	Number of tie points		102
Output	Standard deviation	X	9.558 m
		Y	14.228 m
		H	5.095 m

The table of final results and the quality control sheet were compiled based on these results.

2.10 Creation of Digital Terrain Models

The results of spatial triangulation and the SPOT satellite images were used to create the digital terrain models (DTMs) with 100m grids using the Supresoft (China) automatic DTM generation program. The steps to create the DTMs will be described below.

(1) Inner-model measurement

Automatic generation of elevations above the earth's surface was performed by stereo matching for each model. As the points are selected to enable image correlation, the elevation of random points (TIN) is measured.

Points where the image was unclear or the texture uniform were excluded from automatic elevation generation at first because their matching accuracy is low. In wooded areas where the elevation of the tree tops is measured, a 3-dimensional model was generated by a digital plotter and the elevation above the earth's surface was measured and corrected manually.

The parts of the satellite images that could not be subject to 3-dimensional observation due to the smoke of field burning and clouds were supplemented with the 3-dimensional data measured in aerial photography.

(2) DEM data integration

Square grid DEM data were created from the TIN data generated for each model and were merged into one to make a DEM file.

(3) Acquisition of break lines

Geographic lines such as main roads, rivers, ridges and swamp lines were acquired as break lines in order to create contour lines that accurately represent the topographic features.

(4) Creation of DTMs

The 100m-interval DTMs were created from the merged DEM file, and the break line data was combined to the DTMs to create the topographic data (rivers, contour lines, etc.).