HIS MAJESTY'S GOVERNMENT
OF NEPAL

Ministry of Land Reform
and Management

THE REPUBLIC OF
FINLAND

Ministry for Foreign Affairs,
Department of International
Development Cooperation

WESTERN NEPAL TOPOGRAPHIC
MAPPING PROJECT
Phase I

FINAL REPORT
OF
GROUND CONTROL SURVEYS

VOLUME I: REPORT

HMG Survey Department of Nepal
FM-International FINNMAP

June 1997

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EXECUTIVE SUMMARY

The Western Nepal Topographic Mapping Project (WNTMP) consists of Western, Mid-Western and Far-Western Regions of the Kingdom of Nepal (except Lumbini Zone). The purpose of the Project is to produce maps in scale 1:25 000 over Terai and Middle Mountains and in scale 1:50 000 over High Mountains and High Himalayas. Phase I (1995 - 1999) includes ground control surveys, aerial photography and aerial triangulation over the whole area as well as 1:25 000 scale mapping. The Project is implemented in cooperation with HMG Survey Department of Nepal (SD) and FM-International Oy (FINNMAP).

Ground control surveys were carried out over the whole WNTMP area in order to provide sufficient ground control for aerial triangulation. Totally 51 primary stations and 76 secondary stations were monumented, premarked and observed. GPS - observations of I and II order stations were done simultaneously at sessions. Two first order stations of the Eastern Nepal Topographic Mapping Project (ENTMP) and 22 old primary stations were included in the survey. Gravimetric observations were carried out on 52 of these stations and orthometric height was levelled for 24 stations.

Field works were carried out in two parts. First part was completed during January - April 1996 and second part during September - November 1996. The area was extremely difficult for survey operations. Helicopter was used for transportation of survey teams on most of the area. In addition 4WD vehicles and local airline services were needed for logistics.

Ground control survey was based on GPS (Global Positioning System) measurements. Observations were made by dual frequency GPS receivers using static relative positioning. Transformation from WGS-84 coordinates to Nepal Datum was computed by affine transformation based on above mentioned common points. Computations of GPS - observations and transform to Nepal datum were carried out in FINNMAP's head office.

Gravimetric geoid was determined over whole Nepal based on the new observations, observations made during ENTMP and global geoid model EGM96. Geoid computation was done in Finnish Geodetic Institute. The digital grid and interpolation software was produced to compute geoid height to any given point in Nepal. Final orthometric heights for all new stations, except those with levelled heights, were computed from their ellipsoidal (GPS) heights based on this model.

This report consists of three volumes:

VOLUME I: REPORT

VOLUME II: COMPUTATIONS

VOLUME III: DEFINITION OF GRAVIMETRIC GEOID.

1. GENERAL

This report consists of ground control surveys i.e. planning and monumentation of control points, GPS- and gravity survey, control levelling and computations as well as premarking of the points for aerial photography. Purpose of ground control survey was to provide ground control for aerial triangulation based on modern airborne-GPS aerial triangulation. Totally 51 primary GPS-stations and 76 secondary GPS-stations were established. Gravimetric observations were carried out on 52 of these stations and orthometric height was levelled for 24 stations. Ground control points were premarked before commencement of aerial photography in order to ensure sufficient control for aerial triangulation.

Ground control surveys were carried out in two parts. First part was completed during January - April 1996 and second part during September - November 1996. During first part 62 and during second part 65 GPS - stations were monumented, premarked and observed. Gravimetric observations were carried out on 25 and 27 stations correspondingly. Control levelling to connect the GPS - stations with existing Bench Marks was carried out during May - July 1996 and February 1997. Totally 202 km was levelled.

Field computations of GPS - observations were carried out immediately after each session, or few sessions depending on transportation of survey teams. Final computations were done after all measurements were completed and checked. First order net was computed as free network using one existing point of ENTMP as initial station. Second order points were then computed using first order points as fixed points. WGS-84 coordinates were transformed to Nepal Datum by affine transformation. Orthometric heights were computed by geoid model, which was computed for the whole Nepal by the Finnish Geodetic Institute.

The following data has been delivered to SD in addition to this report:

- station descriptions cards
- field records
- digital geoid model

2. PLANNING

Planning of ground control net was based on the flight plan of aerial photography. Points were located according to flight lines (east - west direction) and crossing strips (north - south direction) so that both horizontal and vertical control for aerial triangulation were provided. Other criteria for planning was:

- connecting new measurements with existing first order network,
- connecting new measurements with GPS-points of ENTMP,
- accessibility of the point,
- possibility to connect GPS-net with existing Bench Marks with ordinary levelling.

The exact location of each new point was decided during monumentation to fulfill the requirements of GPS - measurements. On mountainous areas accessibility of the site paid remarkable role. For GPS - survey points were numbered ascending starting from 0001. SD's Geodetic Survey Branch

decided the final number of each point by using its official numbering system.

3. MONUMENTATION AND PREMARKING

3.1.1 Survey methods

All new points were monumented according to the Specifications of HMG Survey Department. For each monument a description card was drafted during monumentation.

The points were premarked prior to aerial photography. Monumentation and premarking were completed at the same time. Because aerial photography was carried out during two separate flight missions, some points were premarked twice. The points were premarked with centric signals, whenever possible, located on top of the monument. For each premarked point a signal description was drawn.

3.1.2 Time schedule

First part: Jan - Feb 1996
Second part: Sept - Oct 1996

4. OBSERVATIONS

4.1 GPS - survey

4.1.1 Survey methods

The survey of ground control points was based on the use of Global Positioning System (GPS). Observations were made by four dual frequency GPS receivers, Ashtech L-XII, using static relative positioning. Observation time for all sessions was planned to 180 minutes due to difficult conditions. First and second order stations were observed mainly during the same sessions and separated only for final computations. Only few second order points were observed separately with shorter observation time, which was anyhow 90 minutes. The observation time used was longer than required in the specifications. Longer observation time was used in order to minimize the risks caused by coverage of high mountains as well as possible logistic problems, which might have caused delays in starting times of observations. Actual observation times at each point were anyhow longer than required in the Technical Specifications (90 min and 60 min).

Receivers were down loaded into micro computer and field computations were carried out immediately after each session, or few sessions depending on transportation of survey teams. Ashtech Inc.'s Geodetic Post Processing Software (GPPS), version 4.4.01 was used.

4.1.2 Resources

HMG Survey Department assigned four survey teams (2 surveyor in one team) and supervisors for

both survey missions. All the surveyors as well as supervisors had earlier experience in GPS - surveys, either during ENTMP or SD's other GPS - works. Two days training was arranged in using of Ashtech receivers and software. Consultant's Field Survey Expert was supervising and advising during the whole operation and he also controlled the quality of observations in the field.

Other resources:
- 5 four wheel drive vehicles,
- helicopter,
- 4 Ashtech Z-XII GPS receivers,
- portable micro computer with data editing and Ashtech's computing software,
- minor field survey equipment, camping facilities etc.

4.1.3 Final results

All observation data was stored in hard disk of portable micro computer in the field and also copied into diskettes, from which it was then transferred for final computations. During the observations written report was drawn of each session with information of circumstances during the observation. Vectors observed during each session were marked on the index map. Totally 127 points were observed, of which 52 were first order and 76 second order station.

4.1.4 Time schedule

First part: Feb - Apr 1996
Second part: Oct - Nov 1996

4.2 Gravimetric observations

4.2.1 Survey methods

Gravimetric observations were done on the selected stations simultaneously with GPS - observations. Observations were done by gravimeter using the small dial of the meter where gravity range of the meter (about 200 mgal) was enough. In high mountains where this range was not enough an extra dial, 'geodetic dial', was used, which reduced some accuracy.

4.2.2 Resources

Gravimetric observations were done with same resources as GPS. In addition 1 WORDEN gravimeter was used. Observations were done by SD's supervisor specialized in gravimetric survey.

4.2.3 Final results

Observed gravity values were reported in mgal:s for geoid computation. Gravimetric observations were done on 52 stations (Annex C).

4.3 Levelling

4.3.1 Survey methods

Selected GPS - stations were connected with existing Bench Marks with levelling. The level survey was carried out according to the third order levelling specifications of SD's Geodetic Survey Branch as mentioned in the project document. The main specification for third order levelling are the following:

- length of sight (max) 35 m,
- double levelling,
- max difference between backward and forward readings $\sqrt{5.0\ \text{km}}$ mm

4.3.2 Resources

Two survey teams of SD carried out the work.

Other resources:

- two 4WD vehicles for transportation,
- level instrument wild N2 or NA2 with parallel plate micrometer,
- invar staffs,
- minor field survey equipment, camping facilities etc.

4.3.3 Final results.

Final heights of each levelled point were calculated manually after observations. Levelled heights were used as input data for geoid computation. They were also used as final heights of the points. Orthometric heights were levelled to 24 GPS - points starting from existing Bench Marks. Totally 202 km (including both backward and forward levelling) was levelled as shown in Annex D.

4.3.4 Time schedule

Levelling was carried out during May - July 1996 and in February 1997.

5. COMPUTATIONS

5.1 GPS

First order (primary) network consists of 121 baselines and 51 stations. The adjustment was done as "free network adjustment", using only one point as fixed point (first order point of ENTMP). Adjustment was computed by using Ashtech Inc.'s FILLNET software, version 3.0.00. The accuracy of adjustment was controlled by comparing horizontal and vertical 1-Sigma accuracies of the baselines in the output list with requirements given in the Technical Specifications. These varied mainly between 0.9 - 2.2 ppm, only one short baseline gave 4.6 ppm as lowest value. Specification for the first order is 1:100 000, i.e. 10 ppm.

Second order network consists of 76 points, which were adjusted separately in 47 sub-networks. First order points were kept as fixed points. Adjustments were done as in first order. The lowest 1-Sigma accuracy was 6.7 ppm. Specification for second order is 1:50 000, i.e. 20 ppm.

Coordinates in WGS-84 system with ellipsoidal heights are in Annex A1 of this report. Final lists of all GPS-computations are in Volume II of this report.

5.2 Geoid computation

The geoid was determined over the whole Nepal by combining the gravimetric observations and other data of ENTMP and WNTMP. The computation of gravimetric geoid was done by the Finnish Geodetic Institute. In computation the latest global international data, EGM96 was also utilized. As a final result digital grid with interpolation software, "NEPAL97", was developed. This software was then used to compute differences between surfaces of ellipsoid and geoid. Final heights of ground control points were then calculated from their ellipsoidal (GPS) heights based on this difference (except levelled point).

The report "Geoid computation for Nepal" by Dr. M. Vermeer from the Finnish Geodetic Institute is in Volume III of this report.

5.3 Nepal Datum

The horizontal Nepal Datum comprises following:

Spheroid Everest 1830:	a: 6377276.345 m 1/f: 300.8017
Initial Station Nagarkot:	lat. 27° 41' 32.956" N lon. 85° 31' 24.941" E

The first order GPS network includes 22 stations of old primary geodetic network of Nepal, observed in 1982 - 84. This network was checked and readjusted during ENTMP in 1993. Also 2 first order GPS - points of ENTMP were included in first order network of WNTMP. Horizontal coordinates were transformed from WGS-84 system to Nepal datum by affine transformation based on those 24 common points:

- geographical and WGS-84 coordinates of common points and WGS-84 coordinates of other new points were transformed to projection plane,
- affine transformation was computed on projection plane,
- RMS of differences between transformed and old coordinates of common points was 0.300 m.
- transformed coordinates were then converted from projection plane to geographical coordinates.

Orthometric heights of 103 GPS - points were calculated from their ellipsoidal heights as described in para 5.2 and 24 GPS - points had levelled heights.

Coordinates in Nepal Datum with orthometric heights are in Annex A2 of this report. Final lists of transform computations are in Volume II of this report.

5.4 Grid coordinates

Latitudes and longitudes of all stations were converted to grid coordinates in 3 degree zones:

Projection:	Modified Universal Transverse Mercator
Scale factor of origin:	0.9999
Unit:	meter
Origins:	longitudes: 81°E, 84°E, 87°E
	latitude: Equator, 0°N
False easting of origin:	500 000 m
False northing of origin:	0 m

Grid coordinates in 81° and 84° zones with orthometric heights are in Annex A3 of this report. Final lists of computations are in Volume II of this report.

ANNEX A1

LIST OF THE COORDINATES IN WGS-84 SYSTEM

Geodetic WGS-84 Coordinates of The Stations
Elevations are Ellipsoidal

Stat no	L (dms)	B (dms)	h (m)
1	80 04 35.76717	28 51 04.47988	150.424
2	80 08 52.52088	28 57 48.27939	180.414
3	80 56 09.65313	29 15 47.29786	549.935
4	80 31 14.39230	28 49 20.59777	161.984
5	80 34 55.22517	28 45 12.08214	149.633
6	80 30 59.90893	28 33 58.04518	121.190
7	80 19 47.44671	28 40 39.52406	130.648
8	80 14 40.92240	28 47 43.58879	140.100
9	80 49 27.46263	28 33 08.83908	114.266
10	81 05 44.57402	28 25 45.38878	104.891
11	81 16 06.12062	28 19 49.33608	119.035
12	81 20 39.39069	28 12 21.80472	110.529
13	81 27 10.84308	28 09 11.13156	100.415
14	81 27 56.52879	28 18 20.20293	131.541
15	81 38 06.61177	28 35 09.28953	645.624
16	80 58 44.23374	28 40 23.80079	141.153
17	80 08 24.86110	29 03 53.19385	224.830
18	80 19 01.26019	29 03 14.97640	1375.997
19	80 19 33.66823	29 18 56.07436	766.640
20	80 15 48.64738	29 25 58.36379	1240.347
21	80 25 11.50957	29 29 03.54946	2510.936
22	80 45 44.21037	29 28 29.90767	2829.196
23	80 56 38.42013	28 53 47.59744	1275.971
24	81 00 20.57316	29 02 20.95325	1390.063
26	80 42 28.22846	29 11 30.65815	2658.768
27	81 12 56.32650	29 14 10.40956	572.635
29	81 20 05.28247	28 59 31.17623	2225.058
31	81 13 43.91364	28 36 40.54971	153.388
32	81 28 30.72743	28 32 26.64284	1550.539
33	81 48 52.85814	28 43 12.23375	2763.493
34	82 03 37.98125	28 41 55.35116	2151.125
35	82 15 35.66252	28 40 41.01085	1848.373
36	80 37 38.26793	29 00 56.84126	1308.913
37	82 03 09.53306	28 20 23.20469	2375.257
38	82 23 30.68394	27 44 35.08077	233.606
036/22 39	82 06 30.57911	28 12 09.79064	628.670
40	81 53 33.78115	28 03 21.47548	124.567
41	81 36 50.22402	28 20 14.72429	985.493
42	81 43 00.27842	27 59 02.75660	91.831
43	81 55 14.74863	27 52 05.11413	89.654
44	81 55 13.22792	27 56 45.18310	408.588
45	82 15 05.00281	27 51 22.02749	821.926
46	82 31 42.52829	27 41 29.05096	189.860
47	82 48 11.64941	27 45 19.68986	938.823
097/22 48	82 47 15.67453	27 50 50.17105	274.898
097/23 49	82 31 24.83394	27 52 18.39260	218.034
50	82 34 22.80332	28 03 45.70394	1672.743
036/23 53	82 17 33.20946	28 06 43.71064	598.478
54	82 57 15.87589	28 21 36.10579	3604.071
55	83 09 00.48442	28 18 53.61340	1714.513
56	83 00 55.33961	28 05 12.61378	1985.568
57	83 08 11.18634	27 55 09.20254	1816.405
59	83 23 17.35952	28 14 53.48982	3138.994
60	83 26 23.71054	27 56 26.20088	588.154
61	83 39 29.67712	27 55 18.86823	515.838
62	83 49 29.88368	27 50 52.80554	1270.104
63	83 47 18.69630	28 02 11.86489	881.685
64	83 48 00.08773	28 09 52.78737	983.404
65	83 58 53.96119	28 11 59.79051	791.699
66	84 05 20.52748	28 01 21.98434	472.948
67	84 11 05.93119	28 05 02.59240	1252.002
68	84 15 18.43413	27 59 46.66279	334.943

69	84	10	46.69781	27	46	03.69450	1896.329
72	84	27	42.89769	28	24	04.30409	3921.863
73	84	29	31.03106	28	13	36.59552	1888.355
74	84	36	02.71912	28	05	02.58816	1946.339
75	85	03	05.10134	28	29	21.28592	3005.323
76	80	36	13.25575	29	19	52.23626	1657.162
77	82	40	02.33821	28	16	14.71183	2058.608
78	81	34	28.72304	28	08	03.29470	107.890
79	82	37	04.75474	28	27	17.85937	2518.765
80	80	22	54.57463	29	44	16.40428	1101.504
81	80	32	28.11376	29	50	38.86965	873.339
82	80	43	54.84875	29	58	41.93252	2494.559
83	80	58	49.12124	30	08	03.04696	3630.251
84	80	52	16.57861	29	47	40.63674	2448.405
85	80	55	23.93415	29	37	41.91093	2553.242
86	81	01	24.27380	29	29	32.08227	1871.223
87	81	12	51.40031	29	32	26.75302	1790.717
88	81	17	09.19640	29	45	11.88064	2525.495
89	81	31	13.25347	30	04	52.94624	3175.439
91	82	02	33.68326	30	06	41.72782	3899.411
92	81	49	08.15270	29	58	15.85616	2962.089
93	81	23	12.08174	29	42	06.96353	2799.651
94	81	20	51.04679	29	37	05.69977	2626.225
95	81	40	05.62593	29	30	12.51175	1386.267
96	81	25	45.00820	29	29	44.66489	2246.892
97	81	27	21.25537	29	12	29.33735	2450.917
98	81	43	06.73039	29	08	28.74056	3048.567
99	82	01	56.04103	28	53	55.46634	2275.345
100	82	05	07.00850	29	04	55.38713	3027.046
101	81	55	19.92099	29	12	58.36840	2541.241
102	82	11	23.38167	29	16	26.18374	2358.176
103	82	04	48.43527	29	32	21.58779	2961.997
104	81	57	06.82934	29	38	16.97930	2623.715
105	82	18	14.47442	29	54	43.76256	3531.669
106	82	15	27.88932	29	35	06.17956	2768.353
107	82	27	14.65809	29	34	54.39305	2950.779
108	82	22	04.62172	29	17	21.91137	3117.754
109	82	35	20.52549	29	07	16.83097	3018.479
110	82	33	14.34877	29	01	30.45290	2133.611
112	82	26	57.67340	28	38	14.21276	1554.975
113	82	55	24.59205	28	31	03.35145	2812.509
114	82	52	56.73318	28	40	20.42119	2412.009
115	82	49	08.92510	28	59	08.60527	2486.548
117	82	53	48.41702	29	26	34.56825	3933.397
118	83	10	47.14324	29	27	01.10733	3887.175
119	82	59	35.08947	28	52	22.29864	2816.699
120	83	18	40.06176	28	52	19.91410	3952.458
121	83	20	05.15516	28	29	31.11477	2017.508
122	83	40	57.67593	28	25	09.95224	2536.851
123	83	37	58.08910	28	38	13.40530	2447.280
124	83	43	20.75340	28	46	51.55232	2723.621
125	83	51	37.71330	29	00	08.34168	3471.242
126	84	00	43.52432	29	02	30.95064	3923.632
127	83	57	33.97119	29	10	57.26590	3795.031
128	84	05	20.90776	28	38	29.48590	3370.314
129	84	20	20.13869	28	32	09.91031	2149.732
130	84	28	14.24157	28	38	06.51555	3693.244
131	84	38	18.46123	28	35	29.89332	3547.570
133	84	49	54.28392	28	31	29.71209	2391.756
134	85	06	20.28912	28	36	47.53277	3810.687
136	83	11	16.71329	29	07	49.50078	4084.033
137	83	17	07.70543	29	22	15.32717	4159.886
138	82	56	18.34509	29	10	22.57591	3617.642
139	84	06	59.78365	28	20	08.71560	1756.364
333	81	47	36.07758	28	43	55.97399	2616.267

ANNEX A2

LIST OF THE GEOGRAPHICAL COORDINATES IN NEPAL DATUM

Geodetic Coordinates of The Stations in The Nepal Datum
Elevations are Orthometric

Stat no	L (dms)	B (dms)	H (m)
1	80 04 41.8691	28 51 03.7960	187.191
2	80 08 58.6652	28 57 47.6315	216.465
3	80 56 16.2094	29 15 46.7160	577.146
4	80 31 20.7138	28 49 19.8824	199.002
5	80 35 01.5730	28 45 11.3395	187.525
6	80 31 06.2128	28 33 57.2401	160.520
7	80 19 53.6644	28 40 38.7672	169.657
8	80 14 47.1048	28 47 42.8773	175.114
9	80 49 33.9185	28 33 08.0141	152.900
10	81 05 51.1570	28 25 44.5069	144.067
11	81 16 12.7830	28 19 48.4108	159.873
12	81 20 46.0829	28 12 20.8320	152.453
13	81 27 17.5857	28 09 10.1347	142.910
14	81 28 03.2873	28 18 19.2588	171.464
15	81 38 13.4719	28 35 08.4343	678.247
16	80 58 50.7740	28 40 23.0103	178.533
17	80 08 31.0078	29 03 52.5820	257.238
18	80 19 07.4945	29 03 14.3522	1408.745
19	80 19 39.9233	29 18 55.5415	794.202
20	80 15 54.8785	29 25 57.8751	1265.813
21	80 25 17.8221	29 29 03.0712	2534.059
22	80 45 50.6935	29 28 29.4089	2850.072
23	80 56 44.9570	28 53 46.8869	1306.705
24	81 00 27.1498	29 02 20.2895	1417.670
26	80 42 34.6664	29 11 30.0630	2684.712
27	81 13 03.0203	29 14 09.8038	596.770
29	81 20 12.0197	28 59 30.4788	2252.632
31	81 13 50.5740	28 36 39.7247	190.148
32	81 28 37.5055	28 32 25.7803	1586.124
33	81 48 59.8159	28 43 11.4156	2790.963
34	82 03 45.0593	28 41 54.5121	2177.940
35	82 15 42.8377	28 40 40.1534	1870.828
36	80 37 44.6546	29 00 56.1884	1340.296
37	82 03 16.5838	28 20 22.2409	2407.815
38	82 23 37.8634	27 44 33.8903	275.978
39	82 06 37.6485	28 12 08.7760	664.365
40	81 53 40.7348	28 03 20.4214	164.766
41	81 36 57.0578	28 20 13.7834	1023.412
42	81 43 07.1407	27 59 01.6869	134.552
43	81 55 21.7043	27 52 03.9930	132.465
44	81 55 20.1883	27 56 44.0891	449.559
45	82 15 12.1204	27 51 20.8842	863.086
46	82 31 49.7716	27 41 27.8349	232.953
47	82 48 19.0316	27 45 18.4805	981.000
48	82 47 23.0550	27 50 48.9945	314.283
49	82 31 32.0864	27 52 17.2396	257.352
50	82 34 30.0924	28 03 44.6146	1707.492
53	82 17 40.3637	28 06 42.6543	634.027
54	82 57 23.3722	28 21 35.0976	3626.878
55	83 09 08.0738	28 18 52.5779	1740.309
56	83 01 02.8476	28 05 11.5072	2018.415
57	83 08 18.7425	27 55 08.0307	1852.530
59	83 23 25.0612	28 14 52.4169	3163.246
60	83 26 31.4168	27 56 25.0182	621.599
61	83 39 37.4888	27 55 17.6658	549.683
62	83 49 37.7718	27 50 51.5673	1304.833
63	83 47 26.5795	28 02 10.6941	912.704
64	83 48 07.9853	28 09 51.6601	1011.178
65	83 59 01.9500	28 11 58.6640	819.083
66	84 05 28.5564	28 01 20.7899	504.637
67	84 11 14.0112	28 05 01.4130	1281.642
68	84 15 26.5422	27 59 45.4486	367.460

69	84 10 54.7534	27 46 02.4063	1933.445
72	84 27 51.1352	28 24 03.2160	3939.144
73	84 29 39.2708	28 13 35.4454	1911.670
74	84 36 11.0017	28 05 01.3817	1972.741
75	85 03 13.6324	28 29 20.1885	3016.457
76	80 36 19.6505	29 19 51.6952	1682.450
77	82 40 09.6873	28 16 13.6894	2088.777
78	81 34 35.5246	28 08 02.2849	149.882
79	82 37 12.0918	28 27 16.9038	2545.625
80	80 23 00.8842	29 44 16.0168	1119.674
81	80 32 34.5100	29 50 38.5115	886.297
82	80 44 01.3495	29 58 41.6117	2498.211
83	80 58 55.7568	30 08 02.7678	3625.761
84	80 52 23.1370	29 47 40.2444	2457.501
85	80 55 30.5077	29 37 41.4576	2568.457
86	81 01 30.8885	29 29 31.5762	1889.822
87	81 12 58.1134	29 32 26.2539	1807.493
88	81 17 15.9593	29 45 11.4520	2533.899
89	81 31 20.1559	30 04 52.6195	3176.242
91	82 02 40.8488	30 06 41.3822	3908.908
92	81 49 15.1967	29 58 15.4743	2970.863
93	81 23 18.8916	29 42 06.5115	2810.529
94	81 20 57.8315	29 37 05.2206	2640.530
95	81 40 12.5628	29 30 11.9751	1404.447
96	81 25 51.8255	29 29 44.1385	2264.912
97	81 27 28.0669	29 12 28.7091	2474.542
98	81 43 13.6681	29 08 28.0747	3072.230
99	82 02 03.1183	28 53 54.6985	2299.060
100	82 05 14.1243	29 04 54.6802	3048.158
101	81 55 26.9649	29 12 57.7174	2562.174
102	82 11 30.5623	29 16 25.5378	2375.019
103	82 04 55.5796	29 32 21.0406	2979.053
104	81 57 13.9166	29 38 16.4738	2640.300
105	82 18 21.7561	29 54 43.3323	3545.965
106	82 15 35.1250	29 35 05.6381	2783.973
107	82 27 21.9911	29 34 53.8390	2964.877
108	82 22 11.8917	29 17 21.2606	3132.690
109	82 35 27.8934	29 07 16.1088	3034.768
110	82 33 21.6927	29 01 29.6993	2151.741
112	82 27 04.9395	28 38 13.3303	1579.813
113	82 55 32.0838	28 31 02.3998	2834.821
114	82 53 04.2152	28 40 19.5257	2431.327
115	82 49 16.3974	28 59 07.8224	2502.884
117	82 53 55.9597	29 26 33.9395	3946.510
118	83 10 54.8265	29 27 00.4638	3900.914
119	82 59 42.6398	28 52 21.4662	2832.340
120	83 18 47.7687	28 52 19.0621	3965.130
121	83 20 12.8473	28 29 30.1295	2037.334
122	83 41 05.5337	28 25 08.9204	2557.462
123	83 38 05.9377	28 38 12.4519	2461.698
124	83 43 28.6561	28 46 50.6430	2736.401
125	83 51 45.6997	29 00 07.5001	3484.175
126	84 00 51.5880	29 02 30.1129	3936.773
127	83 57 42.0193	29 10 56.4801	3809.443
128	84 05 28.9803	28 38 28.5049	3381.121
129	84 20 28.3258	28 32 08.8768	2162.518
130	84 28 22.5002	28 38 05.5074	3703.323
131	84 38 26.7986	28 35 28.8590	3558.746
133	84 50 02.7107	28 31 28.6418	2403.915
134	85 06 28.8557	28 36 46.4741	3819.804
136	83 11 24.3777	29 07 48.7458	4097.348
137	83 17 15.4352	29 22 14.6495	4173.634
138	82 56 25.8893	29 10 21.8509	3631.283
139	84 07 07.8479	28 20 07.6274	1776.695
333	81 47 43.0255	28 43 55.1613	2645.138

ANNEX A3

LIST OF THE GRID COORDINATES

Modified UTM Grid Coordinates of The Stations in The Nepal Datum Belt 81 Degrees, Elevations are Orthometric

Stat no	N (m)	E (m)	H (m)	
026 → 1 —10	3192519.856	410081.451	187.191	
020 — 2 —10	3204899.196	417129.889	216.465	
021 — 3 —11	3237819.507	493959.657	577.146	
027 — 4 —11	3189065.930	453396.726	199.002	
027 — 5 — 3	3181392.995	459356.671	187.525	
027 — 6 —12	3160667.827	452889.036	160.520	
026 — 7 —11	3173114.955	434683.040	169.657	
026 — 8 — 1	3186219.411	426444.175	175.114	
027 — 9 —13	3159070.333	482985.830	152.900	
034 — 10 — 1	3145411.015	509553.999	144.067	
34/ 034 — 11 — G.P.S-138	3134476.571	526491.319	159.873	
034 — 12 — 2	3120719.706	533973.420	152.453	— Ordinary a Cross house
034 — 13 — 35	3114885.602	544669.535	142.910	
034 — 14 — 36	3131791.672	545850.943	171.464	
029 — 15 — 21	3162930.232	562307.524	678.247	
027 — 16 —14	3172447.267	498120.892	178.533	
020 — 17 —11	3216139.063	416462.784	257.238	
020 — 18 — 2	3214849.898	433669.314	1408.745	
014 — 19 —13	3243818.040	434712.179	794.202	
2636 / 014 — 20 —14	3256855.932	428722.633	1265.813	— Urth order Triga point
014 — 21 — 1	3262471.680	443920.730	2534.059	
015 — 22 — 1	3261319.284	477123.708	2850.072	
027 — 23 — 4	3197192.160	494716.914	1306.705	
022 — 24 —15	3212994.263	500734.393	1417.670	
021 — 26 — 1	3229952.340	471765.740	2684.712	Lapilas station
022 — 27 —17	3234854.279	521140.097	596.770	
022 — 29 — 2	3207813.887	532799.730	2252.632	First order St.
028 — 31 —11	3165596.135	522558.847	190.148	Titaura Lekh
028 — 32 — 2	3157850.908	546679.753	1586.124	— First order St.
029 — 33 — 1	3177903.833	579765.937	2790.963	→ Bamspani danda
030 — 34 — 32	3175725.797	603807.630	2177.940	→ First order St. Matte Ko Lekh
030 — 35 — 1	3173626.505	623313.076	1870.828	
021 — 36 —12	3210462.187	463871.083	1340.296	
036 — 37 — 1	3135939.859	603384.414	2407.815	— First order St.
042 — 38 —11	3070145.810	637400.604	275.978	Origal Chula
036 — 39 —22	3120799.363	608999.411	664.365	
035 — 40 —55	3104361.518	587934.829	164.766	
035 — 41 — 2	3135381.871	560372.576	1023.412	
041 — 42 —10	3096283.481	570682.339	134.552	
041 — 43 —11	3083562.154	590848.926	132.465	
041 — 44 — 1	3092182.910	590742.506	449.559	— First order St.
042 — 45 — 1	3082524.292	623423.042	863.086	Tilwa Lekh.
097 — 46 —21	3064578.693	650943.096	232.953	→ First order St. Rewa Ko Thapla.
097 — 47 — 1	3072045.818	677945.027	981.000	→ First order St.
097 — 48 —22	3082198.217	676263.804	314.283	Shivagadi danda
097 — 49 —23	3084562.902	650210.387	257.352	
036 — 091 — 50 — 3	3105784.344	654806.744	1707.492	— First order St.
036 — 53 —23	3110939.881	627177.569	634.027	Dhim Dhim danda
091 — 54 — 1	3139286.307	691775.646	3626.878	— Gravati St.
092 — 55 —26	3134609.237	711057.158	1740.309	
092 — 56 —12	3109101.298	698257.307	2018.415	— 2nd order St.
098 — 57 — 2	3090724.049	710484.907	1852.530	Chauriati Ko Lekh
092 — 59 — 1	3127653.195	734554.846	3163.246	— 1st order St.
098 — 60 — 3	3093654.309	740321.045	621.599	Ghumti pahar
099 — 61 —25	3092028.941	761862.518	549.683	
090 — 62 —14	3084202.170	778471.722	1304.833	
093 — 63 —20	3105035.266	774402.841	912.704	
093 — 64 — 2	3119258.164	775206.955	1011.178	
094 — 65 —27	3123595.807	792959.977	819.083	— British G.P.S
095 — 66 —28	3104212.095	804009.287	504.637	
094 — 67 — 1	3111251.503	813273.816	1281.642	
~~095~~ 68 ~~—28~~ 100 —29	3101700.986	820433.175	367.460	

100- 69 -1	3076152.184	813661.172	1933.445	1st order St. Dev Check	
095-72 -29	3147175.122	839508.334	3939.144		
095-73 -2	3127918.551	843014.345	1911.670		
095-74 -1	3112392.849	854174.493	1972.741		
099-75 -1 (1)	3158751.965	897009.697	3016.457		
021-76 -13	3245423.709	461688.535	1682.450		
091-77 -27	3128968.276	663762.665	2088.777		
035-78 -3	3112848.013	556625.605	149.882		
091-79 -4	3149319.866	658648.181	2545.625		
014-80 -15	3290595.939	440381.923	1119.674		
009-81 -2	3302299.707	455839.645	886.297		
009-82 -23	3317114.507	474307.059	2498.211		
009-83 -3	3334360.823	498280.906	3625.761		
015-84 -18	3296730.780	487733.090	2457.501		
015-85 -19	3278292.794	492752.115	2568.457		
016-86 -29	3263210.122	502447.687	1889.822		
016-87 -30	3268606.610	520945.136	1807.493		
016-88 -3	3292178.111	527827.294	2533.899		
011-89 -20	3328621.644	550338.504	3176.242		
012-91 -11	3332315.515	600662.862	3908.908		
011-92 -1	3316563.481	579209.669	2970.863		
016-93 -21	3286513.215	537595.370	2810.529		
016 94 -22	3277225.899	533832.329	2640.530		
017-95 -2	3264640.605	564965.504	1404.447		
016-96 -23	3263673.975	541790.450	2264.912		
022 97 -19	3231809.488	544507.084	2474.542		
(4110) / 023-98 -3	3224530.010	570089.629	3072.230	4th order St.	
030-99 -27	3197871.279	600848.111	2299.060		
024-100 -4	3218234.803	605835.336	3048.158		
023-101 -17	3232969.347	589841.302	2562.174		
024-102 -28	3239601.927	615798.998	2375.019		
018-103 -2	3268914.897	604865.199	2979.053		
017-104 -12	3279748.568	592347.089	2640.300		
012-105 -12	3310465.793	626101.265	3545.965		
018-106 -27	3274156.030	622027.491	2783.973		
018-107 -3	3274015.362	641053.806	2964.877		
024-108 -29	3241506.759	633089.543	3132.690		
079 109	3223146.492	654825.267	3034.768	No description card	
079 110 -11	3212435.632	651554.386	2151.741		
030-112 -33	3169316.936	641885.323	1579.813		
085-113 -30	3156703.985	688465.221	2834.821		
085-114 -31	3173793.410	684174.134	2431.327		
079-115 -2	3208436.774	677455.673	2502.884		
073-117 -10	3259242.305	684203.579	3946.510		
074-118 -1	3260540.040	711649.394	3900.914		
085-119 -32	3196198.252	694619.920	2832.340		
086-120 -1	3196687.957	725658.075	3965.130		
086-121 -2	3154578.141	728789.800	2037.334		
093-122 -23	3147246.400	763049.513	2557.462		
087-123 -12	3171268.953	757629.475	2461.698		
087 124 -1	3187425.502	766032.906	2736.401		
081-125 -10	3212286.962	778926.761	3484.175		
081-126 -11	3217047.955	793596.245	3936.773		
081-127 -1	3232516.035	788072.272	3809.443		
088 128 -1	3172833.594	802262.057	3381.121		
088-129 -16	3161796.207	827029.442	2162.518		
088 130 -22	3173151.112	839610.837	3703.323		
089-131 -1	3168813.511	856184.493	3558.746		
089-133 -10	3162002.346	875348.477	2403.915		
090 134 -10	3172688.676	901853.376	3819.804		
080 136 -10	3225088.121	713109.438	4097.348		
086-137 -13	3251934.845	722080.387	4173.634		
079-138 -12	3229376.054	688740.855	3631.283		
094-139 -29	3138991.652	805830.095	1776.695		
029-333 -19	3179236.327	577673.328	2645.138		

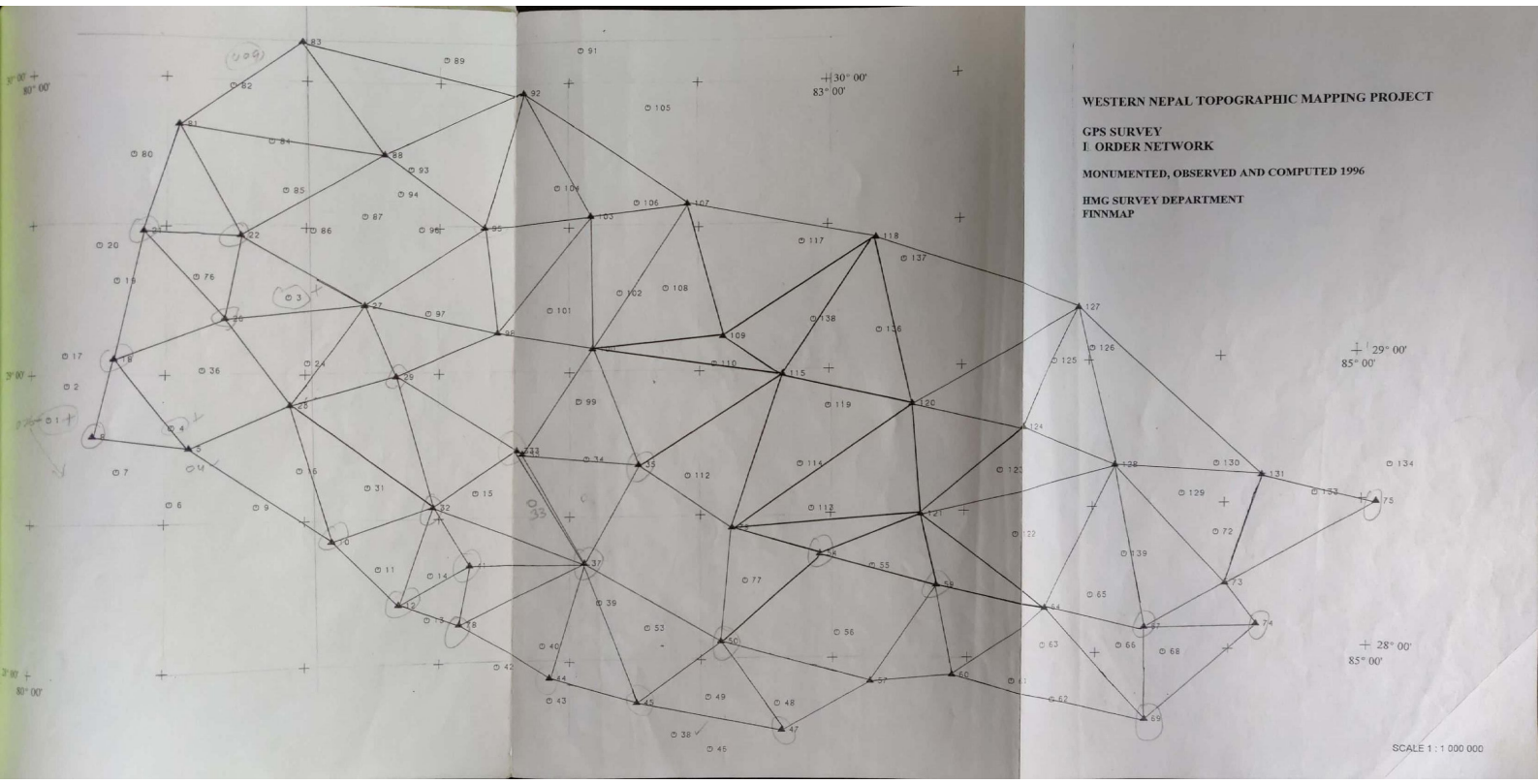
Modified UTM Grid Coordinates of The Stations in The Nepal Datum Belt 84 Degrees, Elevations are Orthometric

Stat no order	N (m)	E (m) +3	H (m)
II -026-1	3198497.735	117258.668	187.191
II - 020-2	3210714.953	124630.986	216.465
II -021- 3	3241707.880	202381.871	577.146
II -027- 4	3193942.631	160539.827	199.002
I -027- 5	3186110.965	166312.139	187.525
II -027- 6	3165526.559	159315.949	160.520
II -027-7	3178445.865	141401.937	169.657
I -026- 8	3191774.617	133483.627	175.114
II -027- 9	3163172.494	189402.223	152.900
II -034- 10 -1	3148837.799	215649.346	144.067
II -034- 11-G.P.S-138	3137474.385	232324.752	159.873
I - 034- 12 -2	3123524.296	239469.337	152.453
II -034- 13	3117422.621	250026.155	142.910
II -034-14	3134306.735	251627.224	171.464
II -027-15	3165045.741	268867.113	678.247
II -027-16	3176180.151	204885.660	178.533
II -020-17	3221986.779	124249.305	257.238
I -020-18	3220257.119	141444.802	1408.745
II -014-19	3249233.271	143230.539	794.202
II -014- 20 -2636	3262441.155	137569.535	1265.813
I -014-21 -1	3267671.078	152930.409	2534.059
II -015- 22 -1	3265660.069	186136.678	2850.072
I -027-23	3201029.976	202104.022	1306.705
II -22- 24	3216691.068	208527.410	1417.670
I -021-26 -1	3234402.552	179967.668	2684.712
I -022-27	3238044.223	229504.464	596.770
I -022- 29 -2	3210692.012	240480.556	2252.632
II -028-31	3168710.139	229167.810	190.148
II -028-32 -2	3160356.225	253106.519	1586.124
II -029-33 -1	3179584.154	286705.793	2790.963
II -030 34	3176800.923	310694.586	2177.940
II -030-35	3174211.357	330145.741	1870.828
II -027-36	3215095.188	171568.008	1340.296
I -036-37 -1	3137025.552	309276.321	2407.815
II -042-38	3070400.946	341668.923	275.978
II -036-39	3121745.902	314515.623	664.365
II -035-40	3105827.473	293043.996	164.766
I -035-41 -2	3137537.201	266243.551	1023.412
II -041-42	3098172.532	275589.327	134.552
II -041-43	3084953.981	295447.512	132.465
I -041- 44 -1	3093578.329	295552.463	449.559
I -042-45	3083118.702	327996.099	863.086
II -047-46	3064505.495	355072.177	232.953
I -047- 47	3071311.814	382244.711	981.000
48	3081500.066	380812.251	314.283
49	3084501.231	354827.442	257.352
50	3105602.641	359943.358	1707.492
53	3111438.047	332448.403	634.027
54	3138173.039	397723.089	3626.878
55	3133020.170	416874.828	1740.309
56	3107847.308	403453.250	2018.415
57	3089182.695	415220.429	1852.530
59	3125487.347	440179.866	3163.246
60	3091378.935	445102.528	621.599
61	3089227.174	466581.441	549.683
62	3081003.182	482979.261	1304.833
63	3101910.246	479426.328	912.704
64	3116095.819	480580.067	1011.178
65	3119989.021	498417.230	819.083
66	3100360.028	508973.039	504.637
67	3107161.017	518397.160	1281.642
68	3097449.020	525310.560	367.460

69	3072105.145	517923.630	1933.445
72	3142377.143	545479.194	3939.144
73	3123066.600	548501.151	1911.670
74	3107292.717	559258.129	1972.741
75	3152498.175	603159.103	3016.457
76	3250147.244	170277.600	1682.450
77	3128556.119	369468.766	2088.777
78	3115088.640	261936.608	149.882
79	3149026.529	364862.596	2545.625
80	3295918.665	150117.105	1119.674
81	3307231.859	165896.584	886.297
82	3321577.426	184769.069	2498.211
83	3338207.455	209214.852	3625.761
84	3300825.812	197673.431	2457.501
85	3282243.107	202216.998	2568.457
86	3266898.623	211529.355	1889.822
87	3271820.623	230177.807	1807.493
88	3295226.145	237674.906	2533.899
89	3331096.274	261148.191	3176.242
91	3333468.465	311577.037	3908.908
92	3318278.334	289709.723	2970.863
93	3289304.684	247300.290	2810.529
94	3280110.815	243294.647	2640.530
95	3266716.052	274113.432	1404.447
96	3266347.185	250905.832	2264.912
97	3234399.930	252804.890	2474.542
98	3226464.623	278209.445	3072.230
99	3199021.093	308293.895	2299.060
100	3219257.731	313798.031	3048.158
101	3234400.680	298179.625	2562.174
102	3240368.856	324306.582	2375.019
103	3269960.744	314127.497	2979.053
104	3281118.205	301889.599	2640.300
105	3310954.938	336439.991	3545.965
106	3274757.838	331423.420	2783.973
107	3274125.301	350441.616	2964.877
108	3241830.454	341642.895	3132.690
109	3222920.574	362902.703	3034.768
110	3212296.956	359360.529	2151.741
112	3169436.271	348605.780	1579.813
113	3155662.375	394848.950	2834.821
114	3172849.048	390988.628	2431.327
115	3207642.350	385148.513	2502.884
117	3258246.075	393190.677	3946.510
118	3258836.589	420650.466	3900.914
119	3194976.612	401992.403	2832.340
120	3194681.437	433018.713	3965.130
121	3152530.805	435089.779	2037.334
122	3144352.226	469131.402	2557.462
123	3168482.994	464317.977	2461.698
124	3184409.699	473117.933	2736.401
125	3208914.525	486624.582	3484.175
126	3213296.706	501395.402	3936.773
127	3228884.288	496272.839	3809.443
128	3168926.046	508932.717	3381.121
129	3157285.260	533385.809	2162.518
130	3168306.203	546230.621	3703.323
131	3163560.853	562666.219	3558.746
133	3156283.084	581623.391	2403.915
134	3166283.845	608341.115	3819.804
136	3223375.901	421201.464	4097.348
137	3249970.529	430851.484	4173.634
138	3228282.120	396959.797	3631.283
139	3135044.121	511650.769	1776.695
333	3180969.576	284646.376	2645.138

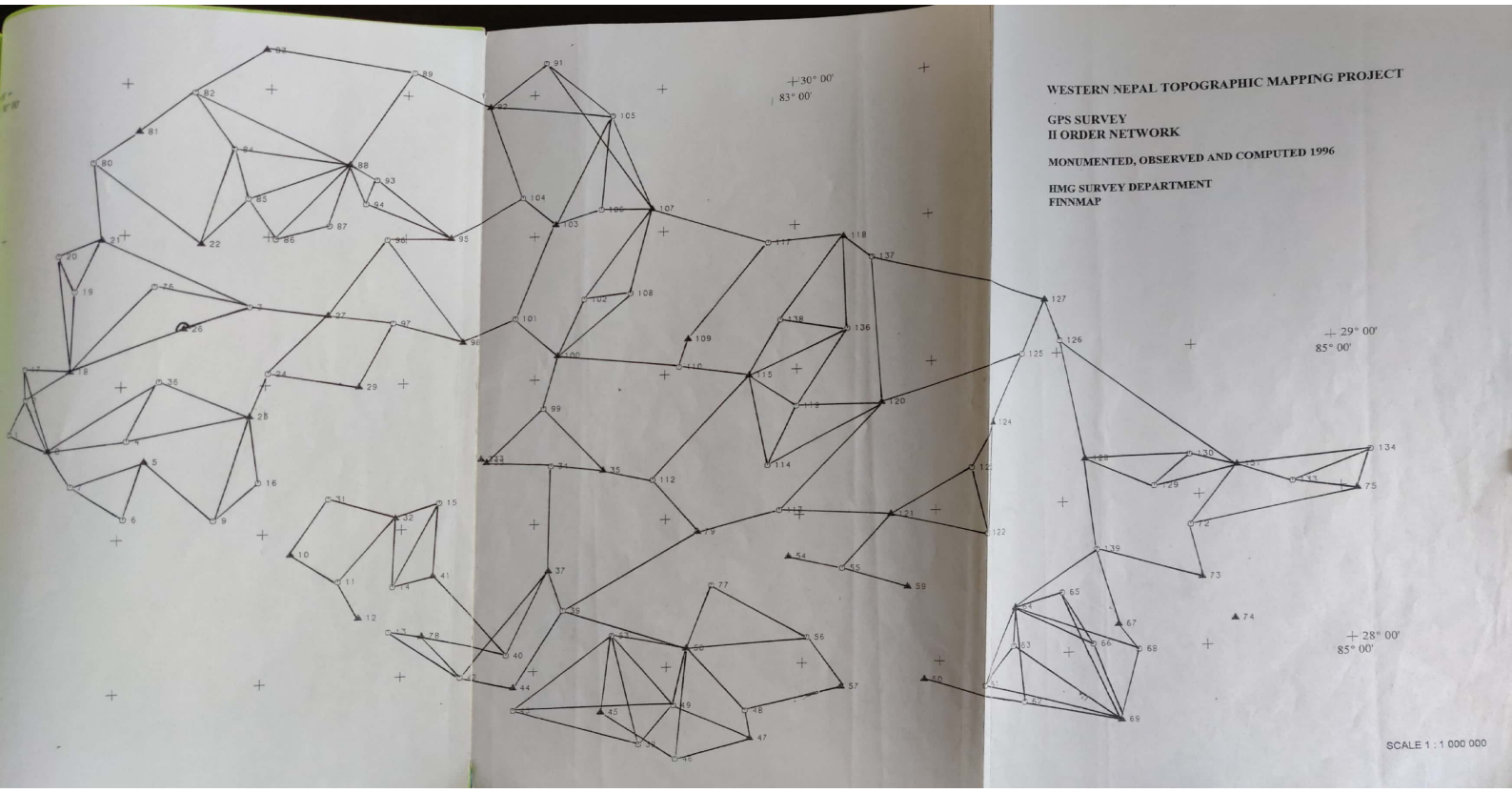
ANNEX B1

FIRST ORDER GPS - NET


30° 00'
83° 00'
29° 00'
85° 00'
28° 00'
85° 00'
80° 00'
WESTERN NEPAL TOPOGRAPHIC MAPPING PROJECT
GPS SURVEY
I. ORDER NETWORK
MONUMENTED, OBSERVED AND COMPUTED 1996
HMG SURVEY DEPARTMENT
FINNMAP
SCALE 1 : 1 000 000

ANNEX B2

SECOND ORDER GPS - NET


WESTERN NEPAL TOPOGRAPHIC MAPPING PROJECT
GPS SURVEY
II ORDER NETWORK
MONUMENTED, OBSERVED AND COMPUTED 1996
HMG SURVEY DEPARTMENT
FINNMAP
30° 00'
83° 00'
29° 00'
85° 00'
28° 00'
85° 00'
SCALE 1 : 1 000 000

ANNEX C

GRAVITY SURVEY DATA

WESTERN NEPAL TOPOGRAPHIC MAPPING PROJECT

GRAVITY SURVEY DATA

No.	GPS station no.	g-value (mgal)
1	2	979008.24
2	3	978929.06
3	4	978992.82
4	5	978990.55
5	6	979000.24
6	9	978990.82
7	11	978968.15
8	12	978971.72
9	13	978969.84
10	14	978966.83
11	15	978895.36
12	16	978980.71
13	17	979008.35
14	19	978918.40
15	20	978823.59
16	23	978786.51
17	27	978913.69
18	31	978979.14
19	35	978621.50
20	38	978933.03
21	40	978974.12
22	53	978877.63
23	54	978230.88
24	55	978640.38
25	60	978862.47
26	61	978958.41
27	63	978790.77
28	65	978785.58
29	66	978859.17
30	78	978968.09
31	79	978495.17
32	81	978858.75
33	84	978551.79
34	85	978531.90
35	95	978722.43

37	103	978340.61
38	109	978381.87
39	110	978538.60
40	112	978696.74
41	114	978500.61
42	117	978171.10
43	118	978139.27
44	120	978171.14
45	121	978557.43
46	122	978450.26
47	123	978445.06
48	124	978374.60
49	126	978114.63
50	127	978114.50
51	136	978140.24
52	137	978083.62

GRAVITY DATA ON FIRST ORDER POINTS

(COMMON TO WNTMP GPS STATIONS)

No.	GPS station no.	g-value (mgal)
1	74	978509.30
2	67	978675.50
3	32	978686.10
4	37	978519.80
5	78	978968.00

GRAVITY DATA ON FIRST ORDER POINTS

(NOT COMMON TO WNTMP GPS STATIONS)

No.	Name	φ	λ	H (m)	g (mgal)
1	Siraichuli	27°45′43.6″	84°38′00.6″	1945.3	978518.50
2	Kumari	27°30′37.5″	45°09′45.5″	2505.4	978400.40
3	Huwakot	27°45′53.1″	83°36′24.6″	1845.4	978579.40
4	Chaitidhuri	28°29′42.5″	82°38′32.7″	3052.3	978375.80
5	Ghartighara	28°40′40.1″	82°15′42.8″	1870.8	978621.50

ANNEX D

LEVELLING OF GPS POINTS

FINAL RESULTS OF CONTROL LEVELLING OF GPS-POINTS

GPS POINT		LEVELLED	
NO	HEIGHT	FROM BM	KM
2	216.465	BM 001	0.6
3	577.146	128-122	59.9
4	199.002	126-155	1.0
5	187.525	BM Dhangadhi	0.2
7	169.657	126-174	34.2
11	159.873	126-052	17.1
12	152.453	BM Khajura	28.6
13	142.91	121-017 (New)	5.4
14	171.464	126-028	4.7
15	678.247	121-100	2.7
16	178.533	126-108	1.7
17	257.237	126-198	10.2
31	190.148	126-083	1.0
36	1340.296	128-056	1.9
40	164.765	118-191	5.0
49	257.352	118-119	0.6
53	634.027	228-048-049	4.6
61	549.683	102-090	0.9
63	912.704	102-055	1.5
65	819.083	101-187	0.2
66	504.637	101-155	1.8
68	367.46	101-134	3.8
76	1682.451	128-132	3.4
78	149.882	121-001	11.1
TOTAL			202.1