A Technical Manual on the

Geocentric Datum of Malaysia (GDM2000)

Department of Survey and Mapping Malaysia
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JUPEM

A TECHNICAL MANUAL ON THE GEOCENTRIC DATUM OF MALAYSIA (GDM2000)

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PREFACE

The Department of Survey and Mapping Malaysia (JUPEM) holds more than a century-old proud record of serving the needs of the Government, the military, the industry and the general public. It is promoting itself to be a centre of excellence for all survey and mapping activities in Malaysia. It also aims to provide an efficient and high quality land survey and mapping services that include the dissemination of geodetic information in line with the national requirements.

Current national mapping in Malaysia relates to the old systems of the Malaysian Revised Triangulation 1968 (MRT68) in the peninsula and the Borneo Triangulation 1968 (BT68) in Sabah and Sarawak. These traditional survey control systems were referenced to a non-geocentric datum, based on Modified Everest ellipsoids. Both fit well regionally but not globally. In order to fully support Global Positioning System (GPS) activities and modern positioning infrastructures, a more accurate control system in the form a geocentric datum is needed.

The establishment of the Malaysia Active GPS System (MASS) in 1999 has provided the impetus for the adoption of the geocentric datum in all the geodetic activities. With the data products obtained from the International GPS Service (IGS) stations, the coordinates of the MASS stations have been derived using 4-year continuous GPS data. Following this, the passive GPS networks were strengthened and now superseded the old networks. The final outcome from this exercise is an accurate set of coordinates for all the 238 GPS stations in Peninsular Malaysia and 171 GPS stations in East Malaysia referred to the International Terrestrial Reference Frame 2000 at epoch 2 January 2000. Collectively these coordinates represent the basis for the Geocentric Datum of Malaysia 2000 (GDM2000).

This Technical Manual is produced to assist users in understanding the concept, strategies and procedures involved in the move towards the adoption of GDM2000. With the country enjoying vigorous development and the government supporting the growth of the spatial information industry, the challenge is for the JUPEM to evolve strategies and structure such that it is well positioned to continue to serve the needs of the nation. It is hoped that in this new millennium of an ever-increasing demand for geodetic products, JUPEM will continuously formulate and undertake its modernisation programmes by introducing more innovative strategies in areas of surveying and mapping. Undoubtedly, with this effort JUPEM will be in position to achieve its mission and objectives in line with Malaysia's Vision 2020.

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AUGUST 2003

Chapter 1

INTRODUCTION

1

1.0 Preamble

Malaysia covers an area of about 329,758 square kilometers, consisting of 12 states in Peninsular Malaysia and 3 states in the Borneo Island. South China Sea separates the two regions by about 540 km. Peninsular Malaysia, covering 131,598 sq. km. has its frontiers with Thailand and Singapore while the states in Borneo Island covering 198,160 sq. km, borders the territory of Indonesia's Kalimantan to the South and The Philippines to the North. Malaysia lies close to the equator between latitudes of 1° and 7°N and longitudes of 100° and 119°E.

The Department of Survey and Mapping Malaysia (JUPEM) is a government agency under the Ministry of Land and Co-operative Development which acts as the technical advisor to the Government of Malaysia on all matters pertaining to surveys and mapping in the country. It is the sole governmental body which maintain the Malaysian Spatial Reference Frame for various works such as for geodesy, mapping, engineering, cadastral, scientific, geodynamics and creations of Geographical/Land Information Systems.

The Department of Survey and Mapping, Malaysia (JUPEM) traces its origin back in 1886. The 1880s also marked an important phase with the commencement of more widespread trigonometrical works in various parts of Malaya. The first attempt at triangulation survey was made in Penang in 1832 by Lieutenant Woore of the Royal Navy.

In 1885, H.G. Deanne, a contract surveyor from Ceylon, was appointed by the Public Works Department, Perak, to carry out the Trigonometrical survey of Perak. He measured the 4.6 mile Larut baseline and carried out astronomical determinations for latitude and azimuth near Taiping.

This Trigonometrical Survey in Perak together with the Penang and Province Wellesley triangulations and Malacca Triangulation (1886-1888), laid the foundation of the existing control framework. These foundations were still primitive, progress was frequently sporadic and much of the work was found to be substandard. However, by the end of 1901, the Major Triangulation of Perak and Selangor had been completed and work had been in progress in Negeri Sembilan since 1899.

This period also witnessed the commencement of trigonometrical surveys in various parts of the country. However, the quality of the early works were so inconsistent that it was decided to re-observe the principal triangles of the general triangulation with the object of bringing the work up to modern standards. This triangulation scheme in Peninsular Malaysia was known as the Primary or Repsold Triangulation which was completed in 1916. In 1948, it was replaced by a new system known as the Malayan Revised Triangulation (MRT). This was followed by a lengthy process of additional measurements and recomputation until 1968. As a result, this system is then referred to as MRT68. On the other hand, the geodetic network used in Borneo is called the Borneo Triangulation (BT68).

The labour intensive traditional methods of conventional geodetic surveys have basically ceased with the advent of GPS. No major field activities have been undertaken except for monitoring of subsidence and building structures in urban areas particularly the cities and major towns. In the subsequent years, there have been numerous geodetic projects implemented by JUPEM on a nation wide scale. Collectively, these projects were and are executed with the final aim of providing horizontal and vertical controls for the development of various infrastructures across the country.

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1.1 EXISTING GEODETIC NETWORKS

1.1.1 Peninsular Malaysia Geodetic Network

The Malaysian Revised Triangulation (MRT) has been used for geodetic, mapping, cadastral and several other activities since 1948 in Peninsular Malaysia. This network consists of 77 geodetic, 240 primary, 837 secondary and 51 tertiary stations. This network is based on the conventional observations with many of the triangulation points are dated as far back as 1885. The MRT has been adopted as a result of the re-computations of the earlier network together with the Primary (Repsold) Triangulation (Figure 1.1) carried out between 1913 and 1916. The reference ellipsoid used for MRT is in Table 1.1 below. The map projection used for mapping in Peninsular is Rectified Skew Orthomorphic (RSO) and Cassini Soldner for cadastral. Table 1.2 tabulates the parameters for map projection used in Peninsular Malaysia.

Table 1.1 Reference Ellipsoids for MRT and BT68

No.	Parameter	MRT	BT68
1.	Reference Ellipsoid	Modified Everest	Modified Everest
2.	Origin	Kertau, Pahang	Timbalai, Labuan
3.	Semi-major axis (a)	6 377 304.063	6 377 298.556
4.	Semi-Minor Axis (b)	6 356 103.039	6 356 097.550
5.	Flattening (f)	1/300.8017	1/300.8017

Figure 1.1: Malayan Revised Triangulation 1948

1.1.2 East Malaysia Geodetic Network

The geodetic network in Sabah and Sarawak known as Borneo Triangulation, 1968 (BT68) was established with the station at Bukit Timbalai, in the Island of Labuan as the origin. For the vertical control, three different datums were adopted and based on the datums at Pulau Lakei, Kota Kinabalu (1975) and Belfry(1918).

BT68 results from the readjustment of the primary control of East Malaysia (Sabah, Sarawak plus Brunei) made by the Directorate of Overseas Surveys, United Kingdom (DOS). This network consists of the Borneo West Coast Triangulation of Brunei and Sabah (1930-1942), Borneo East Coast Triangulation of Sarawak and extension of the West Coast Triangulation in Sabah (1955-1960) and some new points surveyed between 1961 and 1968. This geodetic network is shown in Figure 1.2. The reference ellipsoid used is given in Table 1.1. The map projection used for mapping and cadastral surveys is RSO and Table 1.2 shows the various parameters used.

Table 1.2 Map Projections for Peninsular Malaysia, Sabah and Sarawak

No.	Parameter	Peninsular Malaysia	Sabah & Sarawak
1.	Projection Name	Malayan RSO	Borneo RSO
2.	Datum	Kertau N 3° 27” 50”.71 E 102° 37’ 24”.55	Timbalai N 5° 17’ 03”.55 E 115° 10’ 56”.41
3.	Conversion Factor	1 chain = 20.11678249 m (Chaney & Benoit, 1896)	1 chain= 20.11676512m (Sears, Jolly & Johnson, 1927)
4.	Origin of Projection	N 4° 00’ E 102° 15’ of Greenwich	N 4° 00’ E 115° 00’ of Greenwich
5.	Scale Factor (Origin)	0.99 984	0.99 984
6.	Basic or Initial Line Of Projection	Passes through the Skew Origin at an azimuth of Sin (-0.6) or 323° 01’ 32”.8458 from North	Passes through the origin in an azimuth of 53° 19’ 56”.9537 east of True North

Figure 1.2: Borneo Triangulation 1968 (BT68)

1.2 EXISTING GPS NETWORKS

1.2.1 Peninsular Malaysia Primary GPS Network

A GPS network of 238 stations as in Figure 1.3 have been observed in Peninsular Malaysia using four Ashtech LX II dual frequency receivers. The acquired data was processed and adjusted in 1993.

The main objectives are to establish a new GPS network, analyse the existing geodetic network and obtain transformation parameters between WGS84 of GPS and MRT. In the network adjustment, a minimally constrained

adjustment was made with Kertau, Pahang, held fixed. The coordinates of Kertau are in approximate WGS84 and derived from Doppler coordinates of NSWC 9Z-2 reference frame. The Ashtech processing software with broadcast ephemeris was used for the determination of the baseline solutions. The relative accuracy of the network is 1-2 ppm for horizontal coordinates and 3-5 ppm for vertical. Summary of the results of the network adjustment made using Geolab network adjustment software is tabulated in Table 1.3.

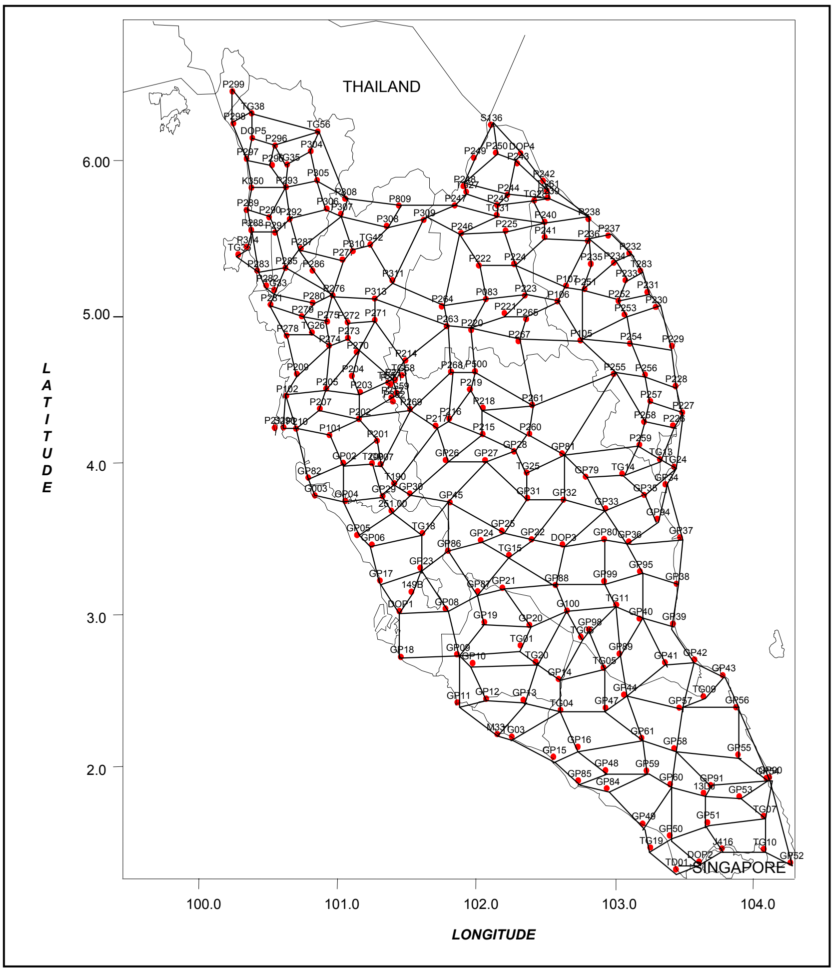

Figure 1.3 Peninsular Malaysia GPS Network (PMGN)

Table 1.3 Results of Minimally Constrained Adjustment For PMGN

Network Adjustment Software Used	Geolab Network Adjustment
Fixed Point in 3D	Kertau, Pahang
Approximate Positions	237
Number of Parameters	711
No. of observations	3594
Redundancy	2883
Weights used	σ_N = 5mm ± 0.5 ppm σ_E = 5mm ± 0.7 ppm σ_U = 7mm ± 1.1 ppm
Variance Factor Used	0.9952
Chi-Square Test	Pass
Station Error Ellipses	Hort: 0.038 – 0.094 Vert: 0.032 – 0.080
Relative Error Ellipses	Hort: 0.013 – 0.031 Vert: 0.011 – 0.030
Average Baseline Accuracies	Hort: < 1.5 ppm Vert: < 2.0 ppm

1.2.2 East Malaysia Primary GPS Network

In 1994, GPS observations were made using Trimble 4000SSE L1/L2 receivers to establish a new GPS network. In the network adjustment, a constrained adjustment was made with coordinates of STRE fixed. Broadcast ephemeris was used for baseline determinations. The relative accuracy of the network as shown in Figure 1.4 is found to be better than 1 ppm for horizontal coordinates and 2-3 ppm for vertical.

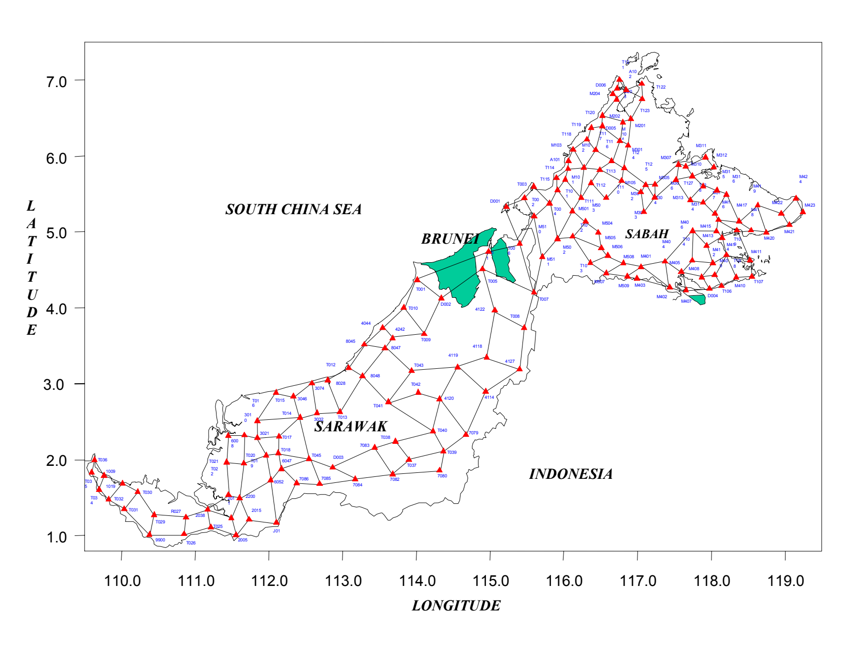

Figure 1.4 Sabah/Sarawak GPS Network (SSGN)

Chapter 2

REALISATION OF GDM2000

2

2.0 INTRODUCTION

JUPEM is responsible for the establishment and maintenance of horizontal and vertical control points for geodetic applications. Originally, this was achieved with the use of traditional surveying equipment such as theodolites and chains, followed by total stations and EDMs. Nowadays, the advent of Global Positioning System or GPS has prompted JUPEM to explore the possibilities of using this new technology in order to keep abreast with the latest development in surveying.

GPS had been introduced at JUPEM in 1987. To date, it has been used in the establishment of GPS networks in the Peninsular Malaysia, Sabah and Sarawak. The presence of these ‘passive’ networks served their purpose relatively well, especially in mapping and engineering applications. However, nowadays most precise applications of GPS make use of ‘active’ GPS networks.

2.1 MALAYSIAN ACTIVE GPS SYSTEM (MASS) NETWORK

Originally, the concept of having a network of unstaffed, permanently configured GPS facilities that collect GPS data in an automatic manner has been evolving at the JUPEM since 1996 (Abu & Mohamed, 1996). MASS is the latest venture of JUPEM in providing 24 hours GPS data for GPS users in Malaysia. This network was completed two years later under the ‘Sea Level Monitoring Using GPS’ project.

One of the primary objectives of the MASS is to act as the provider of GPS observational data and its related products (Abu & Mohamed, 1997; Abu *et. al.*, 1998). The MASS data are made available to the public by JUPEM either through the Internet or on request. The data are available in daily observation batches (i.e. from 0000 to 24 hours) and in compressed form to save disk space and transfer time.

2.1.1 Objectives of MASS

MASS is established with the following objectives:

- To monitor sites which are determined to cm-accuracy and provide local users ties to the global and national spatial reference systems
- To allow JUPEM to perform its survey more efficiently

- To permit maintenance of the National Coordinate System at the cm-level
- To monitor vertical and horizontal crustal motion
- To standardise aspects of reference station operation
- To provide observational data and corrections to users
- For non-positioning applications such as ionospheric and atmospheric water vapour determination
- Geodynamic and other scientific studies

2.1.2 MASS Data Products

The core products of the MASS is the data collected from the permanent GPS stations:

- Daily 24 hours GPS carrier phase and code observations, on both frequencies, for all satellites in view
- GPS navigation messages and status information

Products to be generated by MASS include:

- MASS station GPS observation data
- GPS satellite ephemerides
- MASS station coordinates and velocities
- Earth rotation parameters
- GPS satellite and MASS station clock information
- Inospheric and atmospheric information

2.1.3 Hardware Configuration

Figure 2.2 shows the hardware configuration of the network and the processing centre. Connected via telephone lines, all MASS stations are in direct link-up to the Kuala Lumpur Processing Centre (KLPC), situated at Geodesy Section of JUPEM. All functions of the MASS stations such as receiver control, tracking schedules, data acquisition and uploading times are accomplished by the software residing in the PC. The system is also capable of alerting and engaging onsite personnel of any abnormal conditions occurring at each MASS station such as power failure, system breakdown etc. The current design of the MASS system allows external interrogation by the System Manager in Kuala Lumpur for status reports and if the need arises, override certain functions at any MASS station.

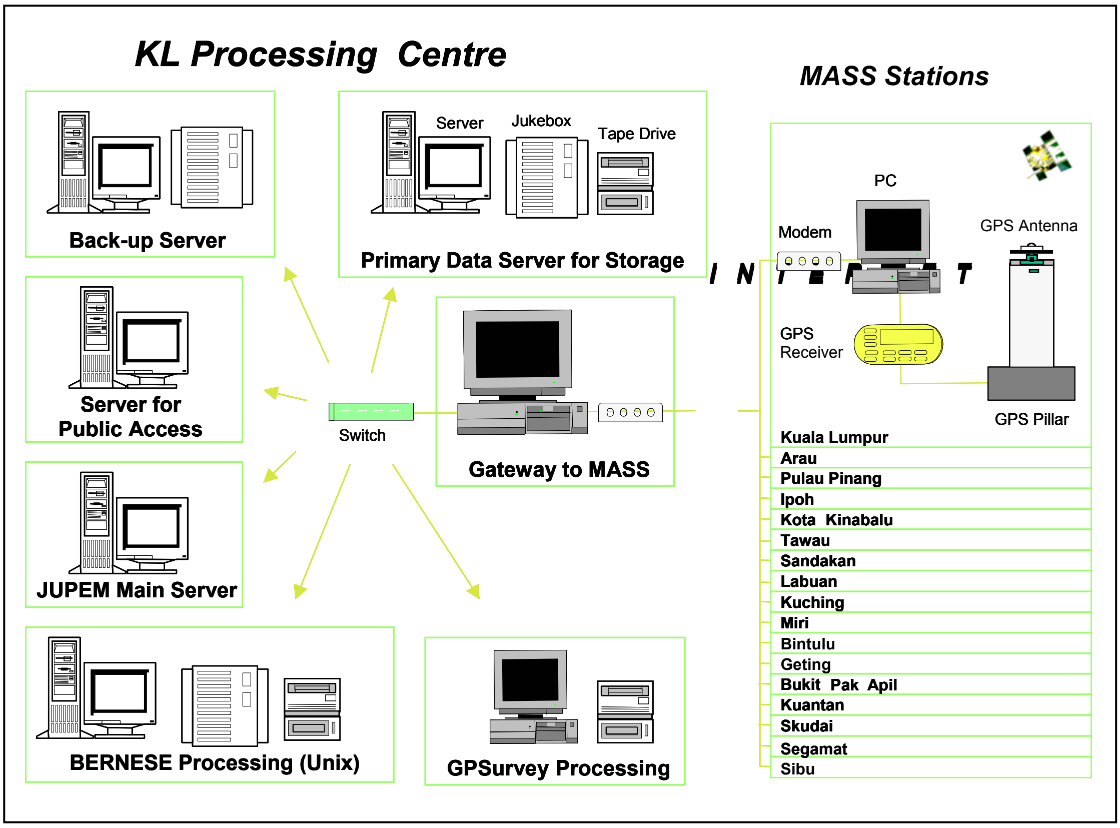

Figure 2.2 The hardware configuration of the Malaysian Active GPS System and the Processing Centre

At the heart of the system are the GPS receivers, which are dual frequency Trimble 4000 of either SSI or SSE geodetic models. The receivers have 24 channels, which are set to record GPS signals at a 15 seconds recording interval. The receivers are also equipped with either geodetic antennas with ground plane or choke ring antennas. To ensure that the system operates continuously, an uninterrupted power supply (UPS) will maintain power for at least three hours in the event of any power failure. The software is also designed to have an auto-start capability once the power is resumed.

The stations track GPS data 24 hours a day continuously. The data are stored and archived at an hourly interval in the site computers. The GPS data at each MASS site are then suitably compressed into an hourly batches before they are uploaded automatically twice daily to the central processing facility (KLPC) in Kuala Lumpur.

The processing centre is situated at the JUPEM headquarters. Its function is to monitor the 18 remote stations, to download the data on a daily basis and to provide all the information to users. At the KLPC, the GPS data are prepared in daily (24 hours) RINEX files, both for observations and broadcast navigation messages. The daily observation files from each MASS station contain the observations collected between 00:00:00 and 23:59:30 GPS time.

The data editing and validation process is performed using a quality check program, UNAVCO's QC program which was obtained from the IGS Central Bureau Information System. The GPS data are validated and edited for quality control by checking:

- the header-file information (station name, receiver/antenna information, antenna height;
- the number of GPS observations;
- the number of observed satellites; and
- the date and times of first and last observation record.

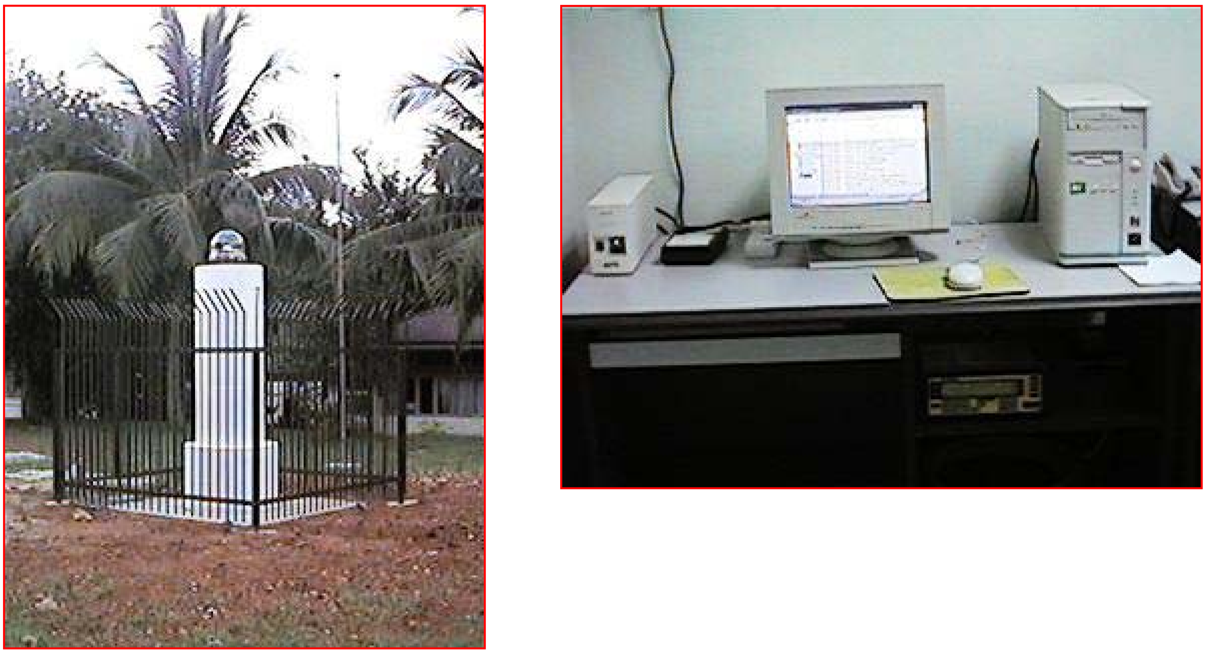

Figure 2.3 A typical MASS station (Arau, Perlis)

Next the data are archived in the RINEX format before it is made available to registered users via on-line on the Internet the following day. (*http:www.geodesi.jupem.gov.my/mass.htm*). The data will remain on the departmental Internet server for a period of 30 days. After this period has passed, the data will be archived inside the Primary Data Server CD jukebox and would only be made available on user's request. Presently, the MASS data products are available to users without charge.

2.2 ITRF2000 REALISATION OF MASS NETWORK

The MASS network is a homogeneous and coherent network that covers the whole of Malaysia. The data from fifteen MASS stations, excluding Segamat and Sibu, between January 1999 and December 2000 have been processed along with those from eleven IGS stations as part of the realisation of the Zero Order Geodetic Network for Malaysia (DSMM, 2002). The long-term objective is to integrate the network into the International Terrestrial Reference Frame (ITRF) based on the International Terrestrial Reference System (ITRS), (Abu & Mohamed, 1997; Abu & Mohamed, 1998).

ITRF is realised through a set of station coordinates of global terrestrial fiducial points. The coordinates of the points are published by the International Earth Rotation Service (IERS) in its annual reports. At the time of writing, the coordinates of the IGS stations were available in the ITRF2000, released in March of 2001. This is the latest realisation of the ITRF and thus the most accurate to date. It has the reference epoch on 1997 January 1 0h UTC. This means that the station coordinates are based on data recorded up to the year 2000 but mapped using a plate motion or velocity field to their coordinates at a time of 1997.0.

The 2000 realisation of the ITRF is based on fifty-four sites and it combines solutions from a number of space techniques including GPS, Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR), Doppler Orbitography by Radio-positioning Integrated on Satellite (DORIS). The present estimated accuracy of the ITRF2000 coordinates is about 2 to 5mm in position and 1 to 2mm/yr in velocity. The stability of the frame over 10 years is reported to be accurate to better than 0.5 ppb in scale or equivalent to a shift of about 3mm in station height and 4mm in origin.

2.2.1 Data Acquisition

The data from 15 MASS stations and 11 IGS stations for 1999 and 2000 have been used in the data processing. However, only 8 stations in Peninsular Malaysia with 11 IGS station were used in the processing to establish the Zero Order Geodetic Network.

Eleven permanent GPS tracking stations of the International GPS Service (IGS) world-wide network in ITRF2000 Epoch 1997 were used as fiducial points in the processing to obtain the MASS set of station coordinates with two years (1999 to 2000) of continuous GPS data. These IGS stations are illustrated in Figure 2.5. Processing was done in a Digital-Unix environment using the Bernese Post Processing Software version 4.2.

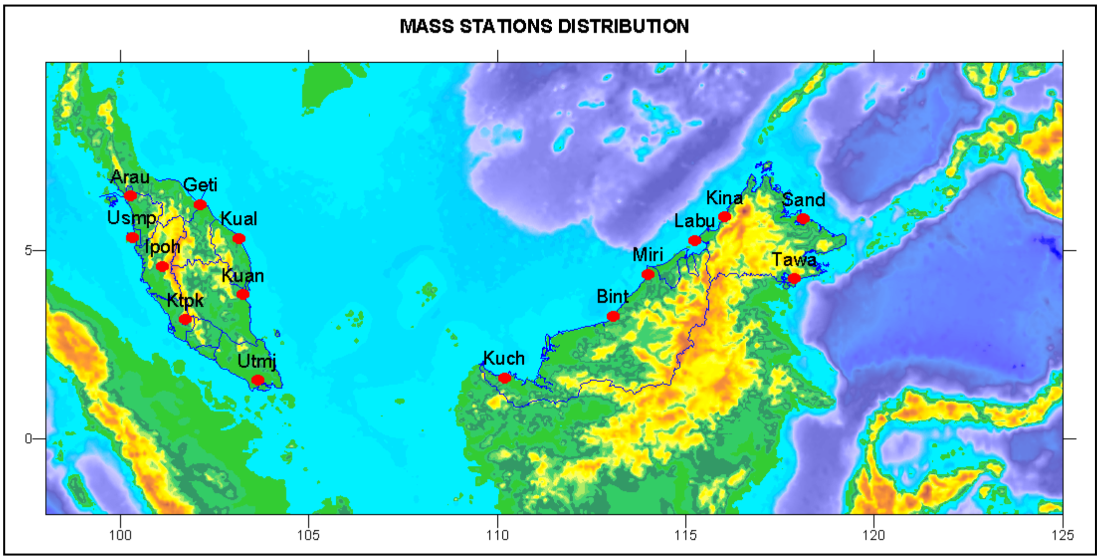

Figure 2.4 Distribution of MASS stations

2.2.2 GPS Processing Strategy

Bernese is a scientific software written by a team of geodetic scientists at the Astronomical Institute University of Berne (AUIB) in Switzerland. The software is the latest offering and a revised version of its predecessor developed by the geodetic team at the University of Berne. It combines specialised surveying knowledge with advanced software techniques. Data input and output is achieved via keyboard interface within Unix environment, allowing one to select commands and performs tasks with relative ease. The main features of the software are as follows:

- All GPS observables (code and phase) on L1 and L2 carrier frequencies and their different linear combinations may be used;
- All mathematical correlations and the combinations among the observables may be modeled;
- Baseline, session and network processing can be performed.

The Bernese software consists of a collection of batch and interactive programs that are executed for the following operations:

Transfer	-	to decode GPS observational data and satellite navigation data in RINEX into the Bernese format
Orbit	-	to create, improve and update satellite orbits
Pre-Processing	-	to perform single point station positioning and correct cycle slips
Processing	-	to estimate parameters in baseline or network modes

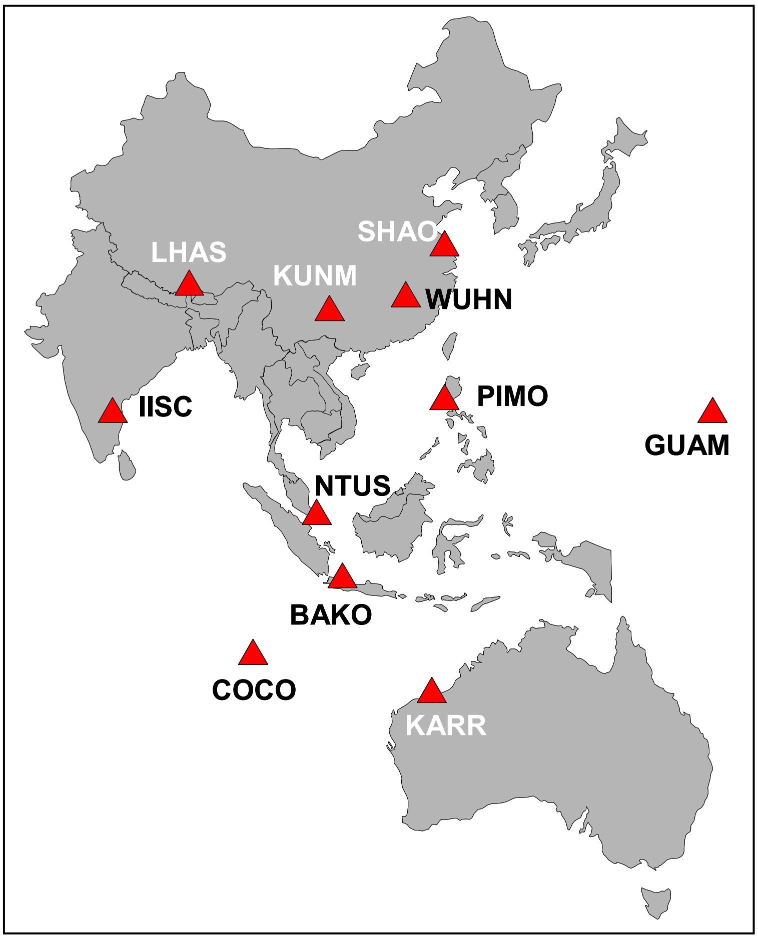

Figure 2.5 IGS stations used to derive MASS coordinates in ITRF2000

Automation in the routine GPS processing in order to obtain the MASS set of station coordinates was achieved using the Bernese Processing Engine (BPE) that runs on Red Hat Linux version 6.2. Following are the main highlights of the GPS processing (DSMM, 2002):

a) Pre-processing

The general strategy used for daily pre-processing is as follows:

- Use of IGS Final orbit referred to ITRF97 and C04 earth rotation parameter (ERP) series.
- The apriori coordinates of IGS stations (Official IERS release version) and MASS stations (APRGP Campaign).
- Antenna phase center offset - Phas_IGS.01 table.
- Rinex to Bernese Conversion : 30 second data sampling.

- Conversion: IGS SP3 ephemeris - tabular format - Bernese format. Ocean tides correction - OT-SCRC model is introduced with development planetary ephemeris (DE200).

- Single Point Positioning using the L3 code pseudo-range measurement - estimate the receiver clock correction.

- Satellite clock biases - eliminated by forming double-difference observations.

- Forming single difference observation by using “shortest” method.

- Phase check using triple difference for data screening - to fix the cycle-slips and to mark the short data interval, gaps, unpaired observations and ambiguity setup.

b) Daily Adjustment

The computation of baseline and daily solutions is as follows:

- Adjustment of double difference carrier phase and ionosphere effect eliminated by the L3 linear combination.

- Zenith delay parameters were estimated once per 2-hours interval relative to Saastamoinen model with apriori constraint of 5.0/5.0 m absolute/relative sigma.

- Ambiguity resolution : QIF (Quasi Ionosphere Free) [Mervart, 1995] ambiguity fixing strategy in baseline-by-baseline mode. Ionosphere for baseline specific model was used for baseline longer than 500 km.

- About 85 % of the ambiguities were fixed using the above strategy.

- The daily solutions (session) of the independent baselines were loosely constrained with 1 m apriori sigma and no coordinates in the network adjustment were fixed.

C) Weekly Solution

The weekly solution was carried out as follows:

- Weekly solution: Combination of seven (7) normal equations of the daily solution.

- 11 IGS stations were held fixed with the coordinates transformed to an epoch of the middle of the week.

- Two strategies had been applied for the weekly solution adjustment and the strategies:

  - Free Network adjustment with the introduction of Helmert Transformation
  - Heavily constrained

- Both results were analysed statistically for coordinate repeatability and RMS of residuals.
- Bad solutions were excluded at this stage and the final weekly normal equation was stored with fiducial free network of 1 m apriori sigma for all coordinates.
- A total of 52 and 53 weekly solutions for 1999 and 2000 were obtained.
- The RMS of weekly solution for 1999 and 2000 is less than 10 mm in the horizontal component and 15 mm in the height component.

2.2.3 Results and Analyses

The final combined solution for the year 1999 & 2000 consists of 105 weekly solutions and 26 stations (11 IGS stations and 15 MASS stations). Two strategies were employed to obtain optimum results and to check for outliers in the final adjustment. The two strategies were as follow:

Free Network Adjustment

The objective of the free network adjustment with the introduction of Helmert Transformation was to adjust the weekly normal equation freely and transform them using eleven (11) IGS station. This process will allow for the internal reliability investigation and to detect outliers.

With the introduction of reference velocity for the fixed stations, the final coordinates for all stations were transformed to the middle of the observation epoch. i.e 2 January 2000.

It shows that MASS station UTMJ has a slightly bigger RMS value in the northing and height components but the value is not significant. It can be concluded that the internal accuracy of the MASS stations from the free network adjustment is 5 to 11 mm in the horizontal component and 5 to 12 mm in the height component.

Comparison of IGS stations coordinates has been made in order to determine the accuracy of the network with respect to the IGS stations. With the final combined coordinate from the network adjustment projected to 2 January 2000 (IGS and MASS stations), the reference coordinates (ITRF2000 Epoch 1997.0) for the IGS stations were transformed on the same epoch as the adjusted coordinates.

It can be concluded that the accuracy for MASS stations with respect to the ITRF2000 reference frame with free network strategy is 9 to 15 mm in the horizontal component and 12 to 19 mm in height.

Heavily Constrained Adjustment

The heavily constrained adjustment was to adopt the specific reference frame in ITRF2000. It shows that the RMS in easting component is larger than the northing and height components. This is a normal scenario due to the MASS station location in the equatorial belt and the development of velocity in IGS stations. The figures also show that the accuracy of station coordinates is between 3 to 16 mm in horizontal component and 8 to 13 mm for the height.

Comparison between coordinates from free network adjustment and heavily constrained adjustment is also made. The RMS of residuals are 2.0, 1.7 and 4.4 mm for the northing, easting and height component respectively.

The translations component shows that the coordinates between two strategies were almost identical. With the above statistic, the coordinates of the heavily constrained adjustment was adopted as the final coordinates (Epoch 02.01.2000).

2.3 SRENGTHENING OF GPS NETWRORKS

2.3.1 PENINSULAR MALAYSIA PRIMARY GPS NETWORK (PMPGN)

The existing PMPGN consist of 238 GPS stations in Peninsula Malaysia (Figure 2.6). These GPS geodetic network together with its reference frame must be continually upgraded to provide accessibility to high accuracy GPS control. Thus, a GPS campaign was carried out from October 2000 to November 2000 to re-observe 36 stations of the Peninsular Malaysia Primary Geodetic Network (PMPGN) for a period of 48 hours to form the strengthening network (Figure 2.7). These stations were selected to ensure even distribution through out the GPS Network. The aim is to connect the existing PMPGN to the Zero Order Geodetic Network and thus defining a new PMPGN based on GDM2000 reference frame.

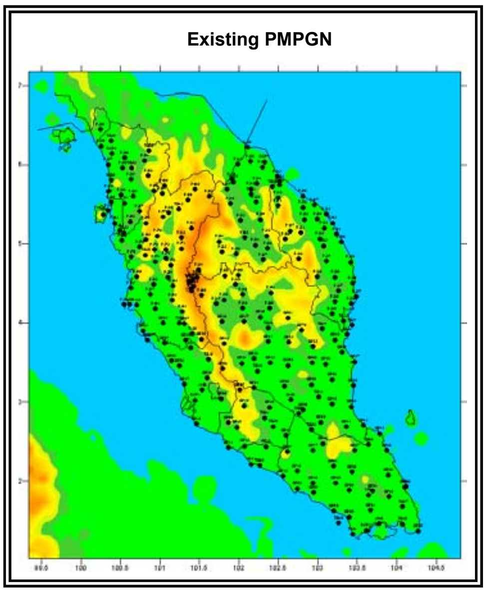

Figure 2.6: Existing PMPGN Stations

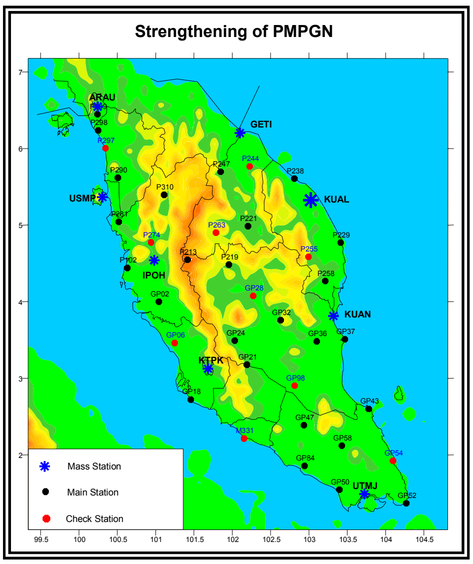

Figure 2.7: Link Stations Distribution

Bernese GPS processing software has been used in the data processing with the help of Bernese Processing Engine (BPE). Baseline wise approach has been used with all selected baseline produced separate normal equation (See Figure 2.8). Processing strategies being used by MASS Network were adopted and percentage of resolved ambiguities are 80% (See Figure 2.9**)**.

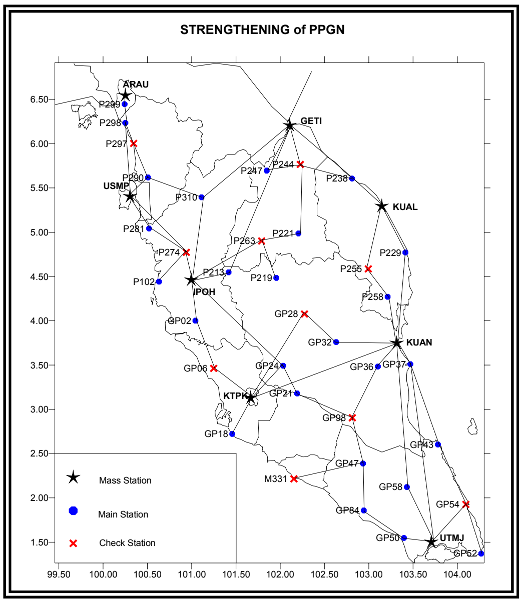

Figure 2.8: Baseline Formation of Link Stations

File Res	Length (km)	#Amb	RMS0 (mm)	Max/RMS L5 Amb (L5 Cycles)		Max/RMS L3 Amb (L3 Cycles)		#Amb	RMS0 (mm)	#Amb (%)
C1S12991	42.8	180	2.5	0.419	0.100	0.093	0.034	22	2.6	87.8
GEC12991	52.7	184	2.3	0.465	0.117	0.093	0.033	24	2.4	87.0
IPC22991	81.1	226	2.3	0.486	0.148	0.098	0.037	64	2.5	71.7
IPUS2991	124.7	204	2.4	0.490	0.186	0.100	0.034	52	2.6	74.5
KLS22991	48.4	206	2.1	0.445	0.124	0.095	0.029	36	2.2	82.5
KLS52991	67.8	220	2.2	0.496	0.151	0.100	0.036	50	2.4	77.3
KNS52991	103.7	198	2.4	0.490	0.148	0.099	0.034	30	2.5	84.8
S2C12991	67.0	176	2.2	0.468	0.122	0.098	0.034	14	2.3	92.0
S3C12991	86.2	176	2.2	0.416	0.118	0.099	0.035	22	2.3	87.5
S3C22991	47.1	196	2.2	0.419	0.103	0.096	0.033	38	2.4	80.6
S4C22991	49.7	204	2.3	0.483	0.122	0.100	0.034	40	2.4	80.4
Tot: 11	70.1	2170	2.3	0.496	0.133	0.100	0.034	392	2.4	81.9

Figure 2.9: Summary of Ambiguity Resolution (DOY 299)

The strengthening of the network involved two stages of network adjustment, and is divided into:

- Network Adjustment 1

  Heavily constrained adjustment with MASS stations held fixed to adjust the observed baseline vectors to obtain the link station's coordinates to conform to GDM2000.

- Network Adjustment 2

  Re-adjustment of all the old PMPGN and EMPGN vectors by free network adjustment strategy by constraining selected link stations with their respective standard deviation (stations with low RMS) from network adjustment 1.

Network Adjustment 1

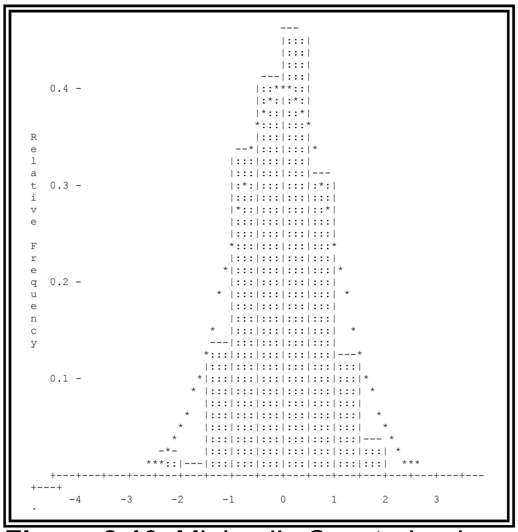

Figure 2.10: Minimally Constrained

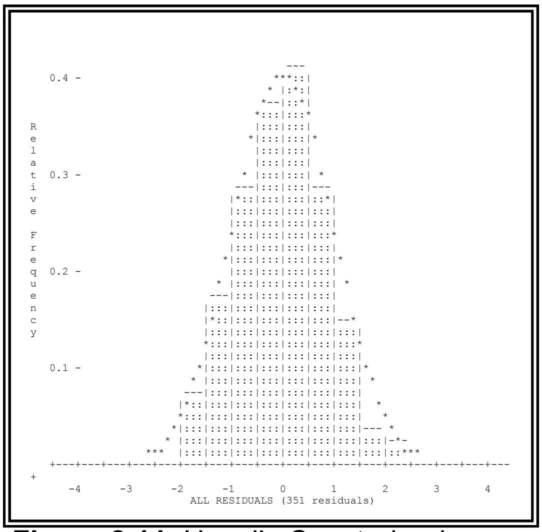

Figure 2.11: Heavily Constrained

The 2D and 1D error ellipses shows that the semi-major axis value is between 0.003 – 0.008 m with the average of 0.004 m and the vertical component is between 0.006 to 0.013 m with the average of 0.008 m. From this figure it shows that the average size of error ellipses and vertical bars are less than 1 cm. The RMS of residuals for their respective components are 0.002, 0.003 and 0.008 m.

Network Adjustment 2

Iterative adjustment with old PMPGN vectors with one fixed station and followed by the increment of number of fixed stations. This process will detect any outliers in the baseline components and to check any deformation in the network. The bad baselines (i.e flag residuals) were eliminated at this stage.

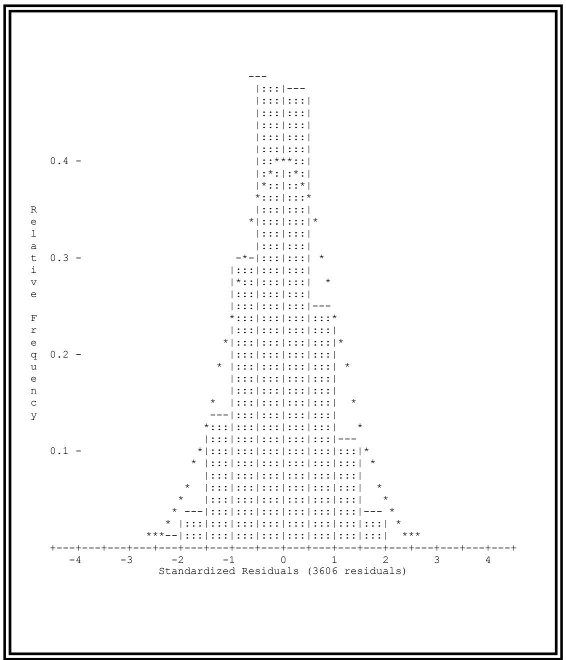

Figure 2.12: Histogram with 25 fixed points

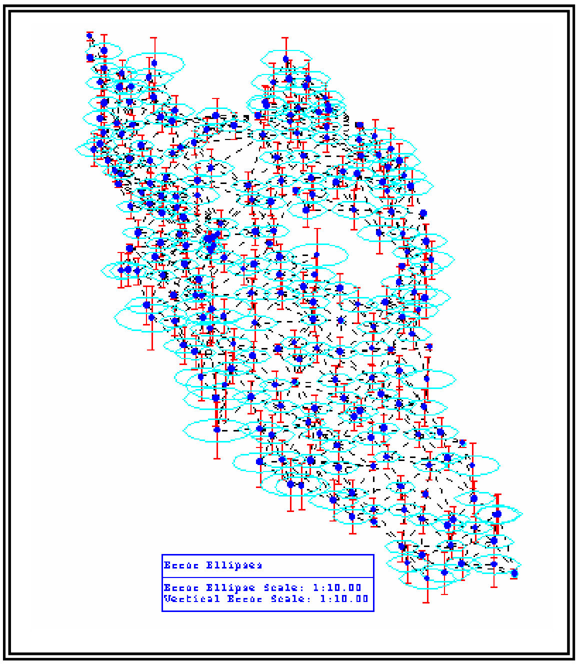

Figure 2.13: Error Ellipses

Comparisons were made at check stations (link stations not utilized in network adjustment 2) from both adjustments were made to verify and analyze the accuracy of PMPGN.

Station	Differences		
	Lat (m)	**Long(m)**	**Hgt(m)**
GP06	-0.00090	0.00000	-0.019
GP18	-0.00450	0.02670	0.112
GP28	-0.00600	0.01080	0.015
GP54	0.01500	-0.00990	0.019
GP98	0.01110	-0.01260	-0.006
M331	-0.01350	0.01050	-0.052
P244	-0.00060	0.00120	0.016
P255	-0.00210	-0.00900	-0.029
P263	0.01800	0.01530	-0.011
P274	-0.00240	0.01110	-0.007
P297	-0.01680	-0.00750	0.006

Figure 2.14: Coordinates Differences in North, East and Up

Quality assessment for the existing network shows that differences less than 3 cm is achieved. Only two stations in PMPGN show bigger differences.

The final adjustment eas carry out with no stations held fixed but by constraining the station with apriori standard deviation taken from Adjustment 1 and treated as an input. This will allow the old vectors in WGS84 to rotate in ITRF2000 (GRS80 ellipsoid).

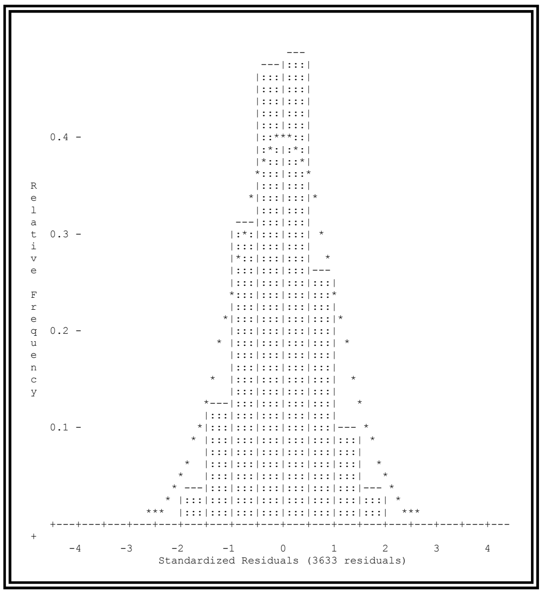

Figure 2.15: Histogram with 34 fixed points

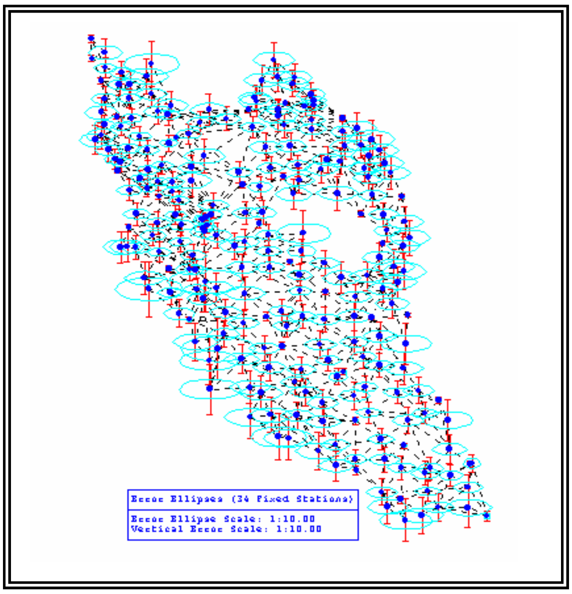

Figure 2.16: Error Ellipses

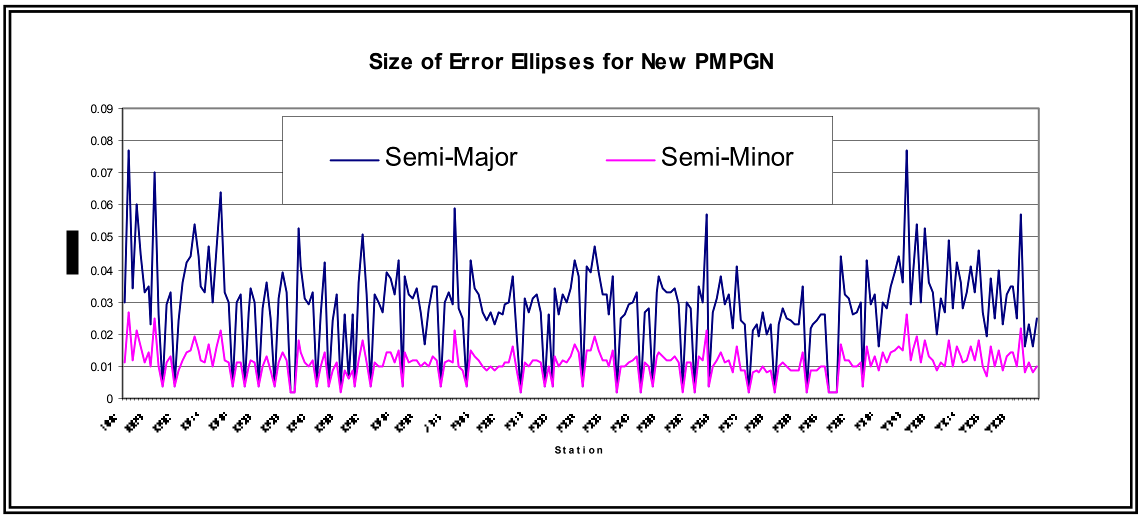

Figure 2.17: Stations Error Ellips Size

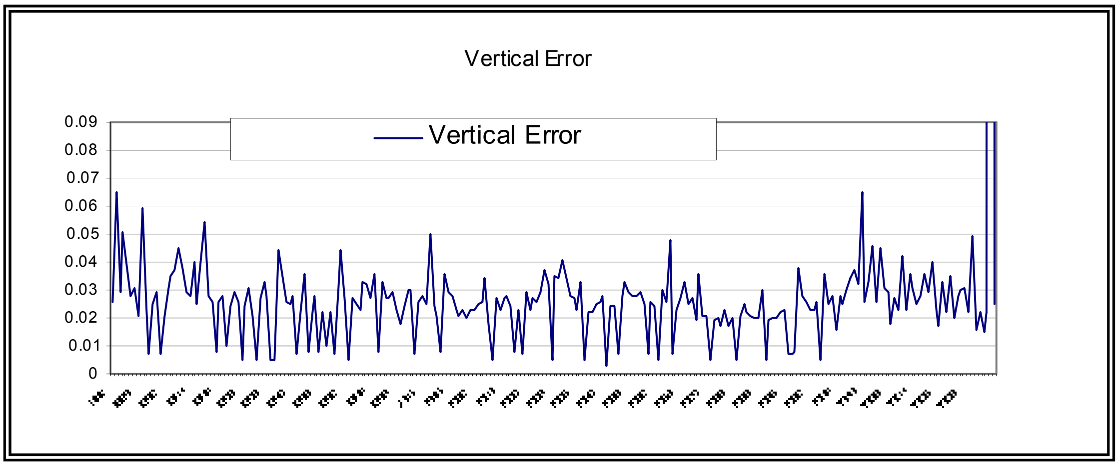

Figure 2.18: Stations Vertical Error Bars

	Semi Major Axis (m)	Semi Minor Axis (m)	Vertical
Maximum	0.077	0.026	0.065
Minimum	0.002	0.002	0.005
Average	0.029	0.011	0.025

Figure 2.19: Size of Error Ellipses and Vertical Error Bars

The final over constrained adjustment is derived by fixing 34 stations and the statistic as can be seen in above figures shows that, the average size of error ellipses and vertical bars achieved for both adjustment are less than 3cm. A complete set of new coordinates for 238 GPS stations in Peninsular Malaysia that referred to ITRF2000 Epoch 00.0 are succesfully computed.

2.3.2 EAST MALAYSIA PRIMARY GPS NETWORK (EMPGN)

The data sets from 8 MASS stations and 30 GPS stations from existing GPS Network in East Malaysia that were observed between 12 February (DoY 043) to 01 March (DoY 060) 2002 have been used in the data processing. The Bernese GPS processing software version 4.2 [Hugentobler, Schaer and Fridez, 2001] was used in the processing. The tedious routine processing is automated by using the Bernese Processing Engine (BPE) running on Red Hat Linux version 7.1.

Baseline wise strategy was used in the establishment of independent normal equation for the daily processing. Ionosphere for baseline specific model was not applied in the baseline processing scheme and this due to the baseline length is less than 500 km. A total off 97 baselines were produced that include the data from MASS stations. The formation of baseline between the station is shown in Figure 2.20 and the percentage of resolved ambiguities are between 50 - 75 % shown in Figure 2.21.

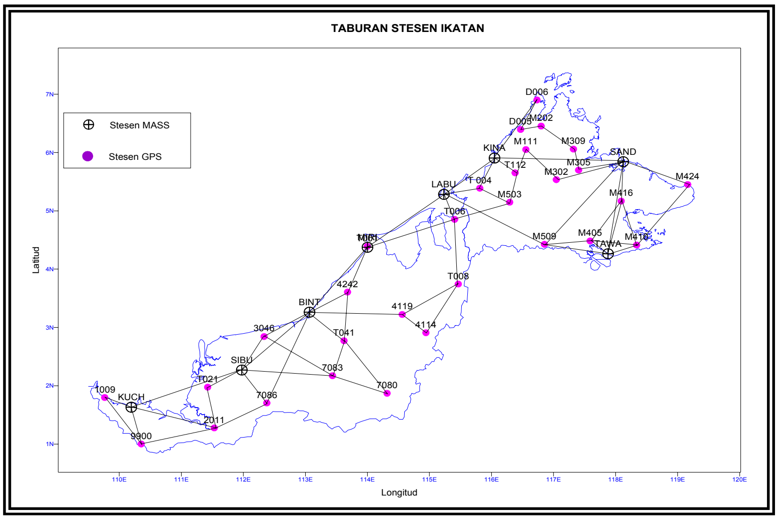

Figure 2.20: Baselines Formation

File	Length (km)	#Amb	RMS0 (mm)	Max/RMS L5 Amb (L5 Cycles)		Max/RMS L3 Amb (L3 Cycles)		#Amb	RMS0 (mm)	#Amb Res (%)
12M10431	50.0	164	2.5	0.444	0.122	0.096	0.033	46	2.6	72.0
44T80431	109.0	152	2.7	0.477	0.201	0.094	0.035	24	2.9	84.2
BIMI0431	160.8	210	2.7	0.497	0.188	0.099	0.041	60	2.9	71.4
KCSI0431	196.4	192	3.6	0.492	0.210	0.100	0.035	112	3.7	41.7
KI120431	46.4	152	2.5	0.482	0.132	0.099	0.034	46	2.7	69.7
KIT40431	62.8	104	2.5	0.471	0.109	0.099	0.039	30	2.7	71.2
LAT40431	63.5	116	2.9	0.472	0.154	0.099	0.040	28	3.1	75.9
LAT60431	50.7	224	2.4	0.495	0.134	0.099	0.035	44	2.5	80.4
M1M30431	78.7	180	2.6	0.460	0.169	0.100	0.040	68	2.8	62.2
M3530431	93.3	216	2.8	0.475	0.147	0.094	0.040	138	3.0	36.1
MIT10431	2.1	216	2.1	0.076	0.013	0.091	0.027	18	2.1	91.7
MIT60431	164.6	222	2.8	0.497	0.192	0.100	0.040	52	3.0	76.6
MTM30431	168.5	208	3.1	0.498	0.180	0.099	0.040	66	3.2	68.3
SAM30431	123.9	236	3.0	0.499	0.175	0.099	0.039	88	3.2	62.7
SIBI0431	174.8	170	3.2	0.494	0.181	0.096	0.034	38	3.3	77.6
T6T80431	122.9	204	2.5	0.485	0.193	0.098	0.035	48	2.7	76.5
Tot: 16	104.3	2966	2.8	0.499	0.162	0.100	0.036	906	2.9	69.5

Figure 2.21: Percentage Of Ambiguity Resolution - DoY 043

The GPS network adjustment may be divided into two parts :

1. Fixed MASS stations as reference station (Zero Order)
2. Fixed Link stations as reference station.

GPSEnv 7.0 (Geolab 3.9) from BitWise Inc. was used in the importing of baselines variance-covariance component from Bernese 4.2 format. For Adjustment 1, minimally Constrained adjustment was used with MIRI station as reference station to detect outliers in baseline components and followed by heavily constrained adjustment. At this stage, seven (7) MASS stations were held fixed with the reference coordinates is in the International Terrestrial Reference Frame (ITRF2000) Epoch 1 Jan 2000.

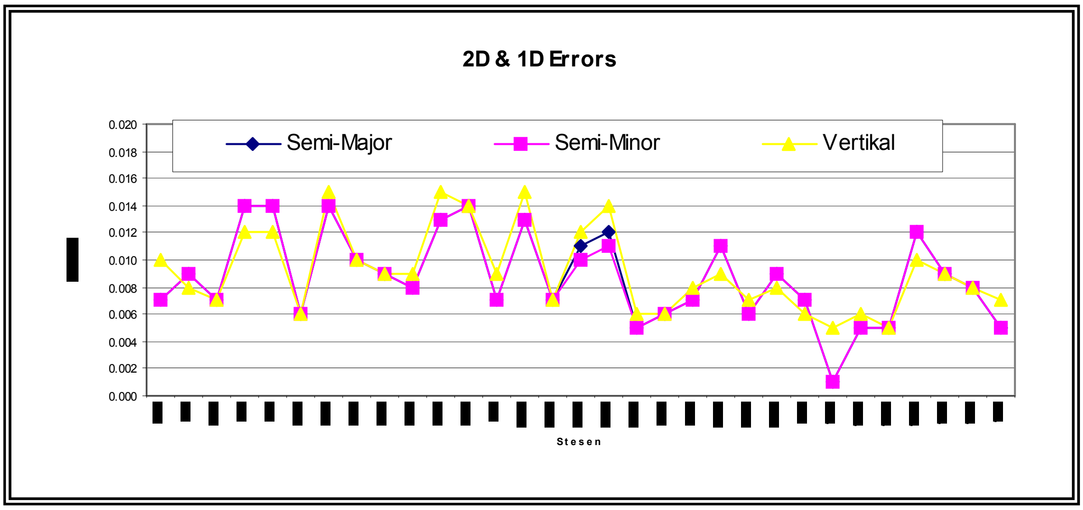

Figure 2.22: 2D and 1D Errors

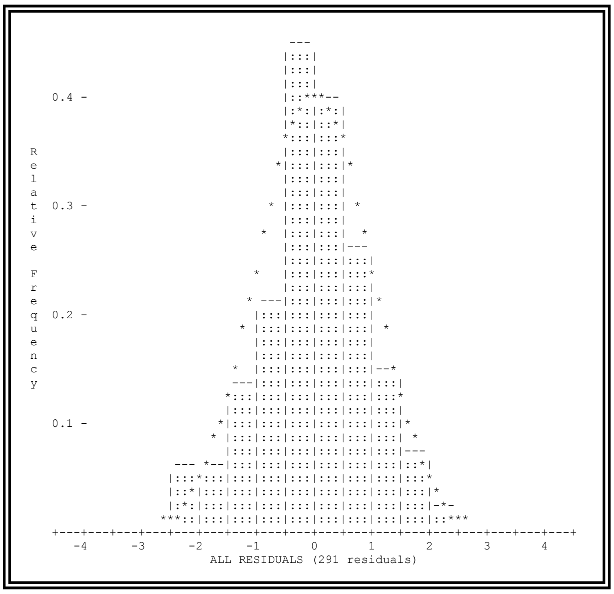

Figure 2.23: Hisstogram

Results from Figure 2.22 and Figure 2.23 shows that Heavily Constrained adjustment has produced high accuracy stations coordinates. It can be concluded that accuracy of stations in horizontal and vertical components is less than 14 mm. Chi-Square test for Heavily Constrained adjustment was pass and Aposteriori Variance Factor is 0.8760

Quality check for existing East Malaysia GPS Network start with the minimally constrained adjustment.with GPS station T006 was held fixed used in the processing with all the baseline produced from East Malaysia GPS campaign in 1994 - 1996. The old independent vectors were used with the original variance-covariance components.

The adjustment included 29 existing GPS stations, new MASS station (SIBU) and a new GPS station (Gunung Kinabalu - M111). From the 29 observed stations, 10 of them were used as check stations for Quality Check (QC) and 19 stations as a link stations (Figure 2.24).
A series of heavily constrained adjustment was done, by increasing the number of fixed stations in order to detect any deformation on the old GPS vectors. Down weighting of the old GPS vectors were introduced in order to estimate the error scheme as well as to propagate the error into the stations coordinate.

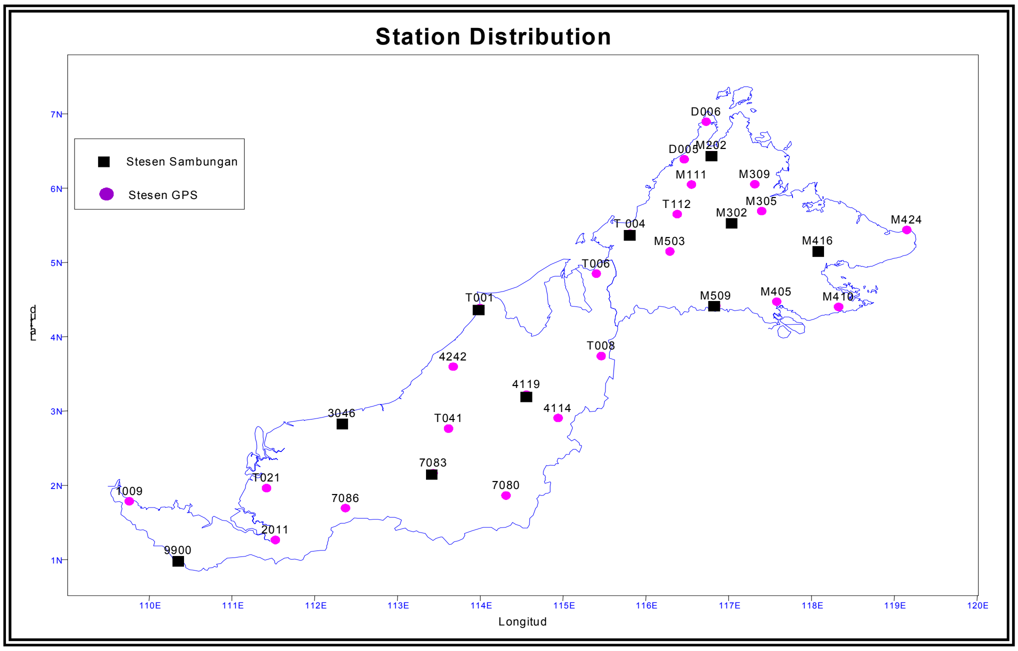

Figure 2.24 : Check Stations and Link Stations

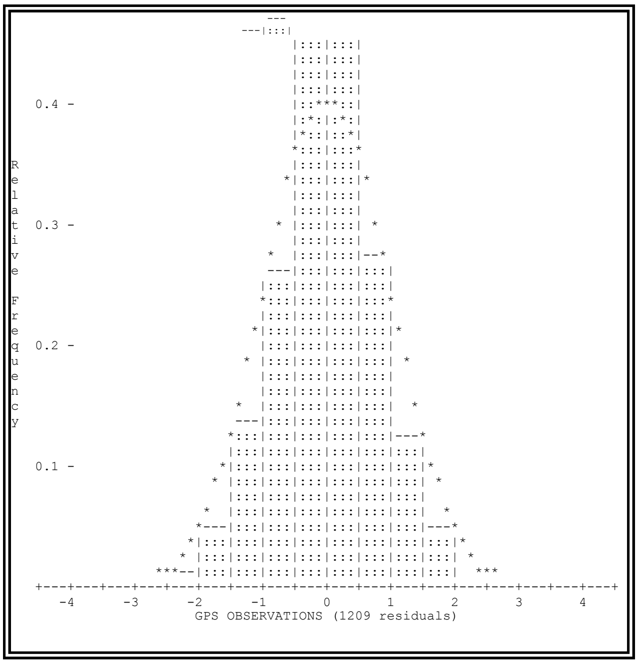

Figure 2.25 : Histogram With 19 Fixed Stns

Comparisons were made at check stations (link stations not utilized in network adjustment 2) from both adjustments were made to verify and analyze the accuracy of EMPGN.

Station	Differences (m)		
	Lat	Long	Hgt
3046	-0.0021	-0.0174	-0.0550
4119	0.0051	0.0120	-0.0400
7083	0.0030	0.0003	-0.0030
9900	0.0162	0.0006	-0.0850
M202	-0.0051	-0.0054	-0.0180
M302	0.0057	0.0315	-0.0260
M416	-0.0108	-0.0060	-0.0260
M509	0.0066	0.0147	0.0400
T001	-0.0123	0.0255	0.0060
T004	0.0057	0.0132	0.0080

Figure 2.26 : Coodinates Comparison For 10 Check Stations

Quality assessment for the existing network shows that differences less than 3 cm is achieved. Only two stations in PMPGN show bigger differences.

The final heavily constrained adjustment is using 26 GPS stations as fixed with the introduction of their respective standard deviation from the previous adjustment (Fixed Mass Stations). This strategy will allow the old GPS vectors to rotate throughout the network.

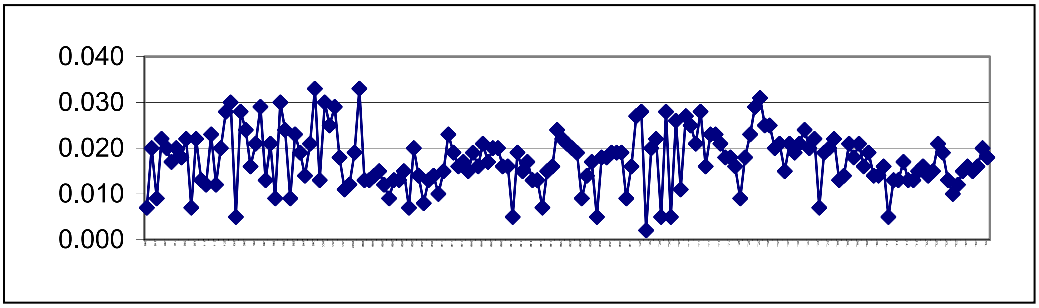

Figure 2.27: Semi-Major Axis (Error Ellips)

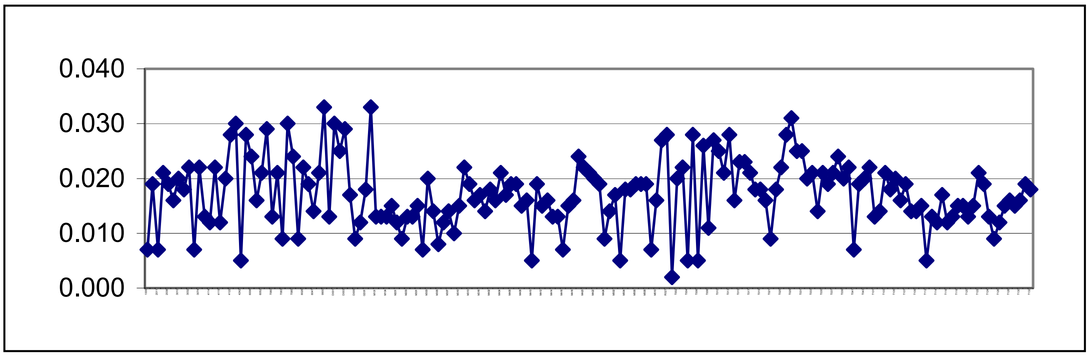

Figure 2.28: Semi-Minor Axis (Error Ellips)

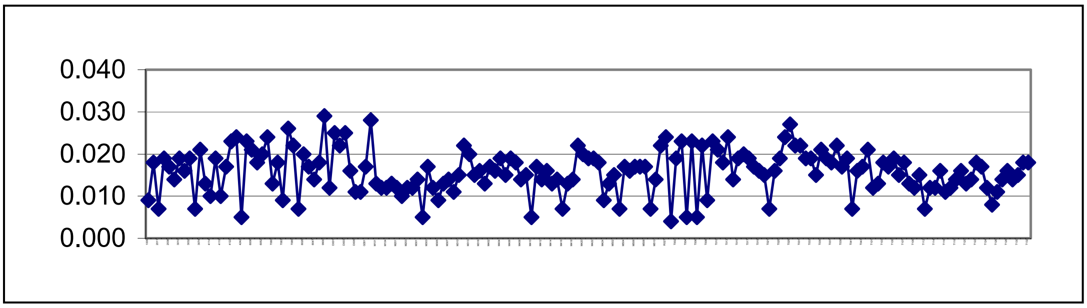

Figure 2.29: Vertical Error

From Figure 2.27, 2.28 and 2.29 it shows that the stations accuracy for the final adjustment is around 3 cm and the stations coordinate is of the high accuracy. The adjustment of the new East Malaysia Primary Geodetic Network using the old vectors has achieved the primary target to have the 3 cm accuracy station coordinate and referred to the ITRF2000 Epoch 1 Jan 2000.

2.4 POTENTIAL APPLICATIONS

The main concern in establishing the network is in the determination and maintenance of precise local reference frame and at the same providing a three dimensional surveying system for geodetic control. Although the primary concern is in the field of geodetic survey, the products from this project will find its way into many other applications. These include:

- **Products**

  As the MASS system matures, KLPC is expected to be able to meet all levels of users by:
  - producing a highly precise reference frame connected to the International Terrestrial Reference Frame (ITRF),
  - monitoring deformations of the solid earth, earth rotation and variations in the sea-level, and
  - determining GPS satellite orbits

- **Single receiver positioning**

  In this concept, a user can carry out a survey with only one receiver for the purpose of survey and mapping work such as GIS systems Integration, Map completion etc. Here, the user can avoid the setting-up of a base station, thus saving time, money and energy. The MASS Station will act as a reference point and will provide data for measurements in the differential and relative mode.

- **Establishing a Global Reference Frame**

The MASS Station GPS data will be contributed to IGS so as to realise a precise reference frame for the country. Through this continuous observations, the reference frame could be constantly refined, yearly coordinates by epoch and velocities could be produced, and thus a consistent and stable national reference frame of international standard is maintained.

- **Transportation and Recreation**

With an active reference system, one can think of many applications where the GPS data could be used to provide reference for various kind of transportation and recreation activities. With the ultimate goal of providing data in real time, transportation monitoring is of great potential by providing real time positioning, vehicle tracking and reporting and setting up of the intelligent transport system. Fishing, boating, bike touring and hiking could be more enjoying just by knowing that you are constantly on course.

- **Navigation**

It is envisaged that MASS will also support users in areas of navigation. These users are quite unique in their needs as they are particularly interested in knowing their positions in real time. In order to meet their demands, MASS is expected to be able to broadcast both the differential corrections (for DGPS applications) and raw GPS data (for RTK applications) to registered users.

- **Environmental and Deformation Monitoring**

Sea level could be monitored over the years to provide environmental assessment so as to allow our coast and marine activities to be protected and preserved. Deformation monitoring will contribute to a better maintenance of our infrastructure and land use.

- **Support for Regional GPS Campaigns**

With the availability of MASS data combined with that of the region, a time series of the dynamics can be produced for geodynamical studies.

- **Aerial Photography Surveys**

Currently JUPEM is conducting a study into the use of GPS as control in aerial photography. One of the components of the project is the use of reference GPS station for post-mission DGPS relative to the on-board GPS. MASS data can be used to achieve this by supplying post-mission GPS data in RINEX format. As such, aircraft conducting aerial photography work will be able to fly at any specified time without having to initiate the ground reference station.

2.5 CONCLUSION

JUPEM has proposed the establishment of MASS which comprises of 15 permanent GPS stations throughout Malaysia. The tracking, collecting and disseminating of the GPS data will be performed by KLPC which will also acts as the processing centre. This ambitious infrastructure is hoped to support various GPS surveying activities and meet the requirements of all types of users, ranging from the novice to the scientists.

Chapter 3

TRANSFORMATION OF COORDINATES

3

3.0 INTRODUCTION

Today, the modern geodetic datums range from flat Earth models used for plane surveying to very complex models used for global applications which completely describe the size, shape, orientation, gravity field, angular velocity of the Earth and others. With satellite positioning that is especially GPS with rapidly increasing applications, the relationship between various geodetic datums become very necessary and important. With the widespread use of GPS, there is a trend for working datum to be consistent with the ITRF and WGS84. Therefore, accurate positioning using satellite-based systems needs the full understanding of reference frame conversions or transformations.

Datum conversion can be accomplished by many different methods. A simple three parameter conversion between geodetic co-ordinates in different datums can be accomplished by conversion through Earth-Centred, Earth Fixed (ECEF) XYZ cartesian co-ordinates in one reference datum and three origin offsets that approximate differences in rotation, translation and scale. Therefore, the complete datum conversion is usually based on seven parameter transformations, which include three translation parameters, three rotation parameters and a scale. Veis (1960), Bursa-Wolf (1963), Molodensky (1962), Vanicek and Wells (1974) and many others have developed the transformation of 3-D co-ordinate system, for transforming geodetic datum. The method of transformation between co-ordinate systems using seven transformation parameters can guarantee transformed results to be quite consistent with the required co-ordinate system in a certain and quite large area. But , gaps will still exist between the transformed results and the given results in the required co-ordinate system.

This chapter will present the transformation models used by Bursa-Wolf. It will also describe the technique for least-squares estimation of transformation parameters.

3.1 DATUM TRANSFORMATION

Three-dimensional co-ordinates could be converted from Cartesian to curvilinear or vice versa through the knowledge of the parameters of an adopted reference ellipsoid. The forward transformation from geodetic co-ordinates (ϕ, λ, h) to Cartesian co-ordinates (X, Y, Z) is given in Heiskanen and Moritz (1967), p182 as:

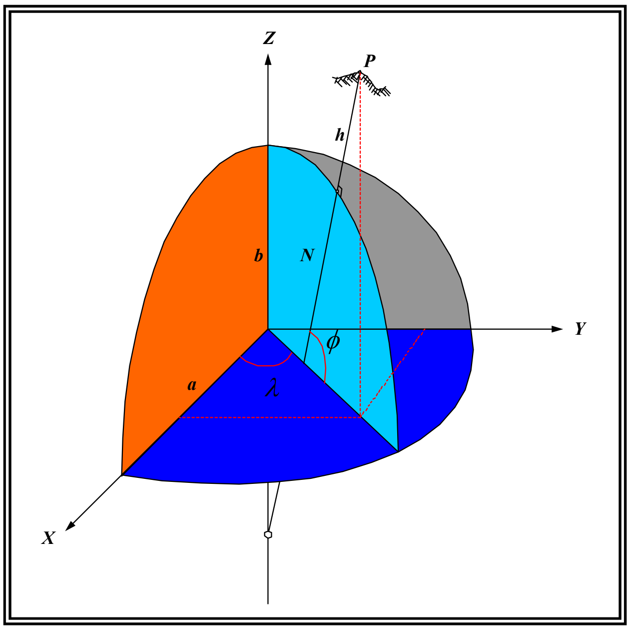

Figure 3.1: Coordinates Conversion

$$X = (N + h)\cos\phi\cos\lambda$$
$$Y = (N + h)\cos\phi\sin\lambda$$
$$Z = \left(\frac{b^2}{a^2}N + h\right)\sin\phi$$

where the prime vertical radius of curvature (N) is:

$$N = \frac{a^2}{(a^2\cos\phi + b^2\sin^2\phi)^{\frac{1}{2}}}$$

with:

a : the semi-major axis of the reference ellipsoid;
e : the first eccentricity of the reference ellipsoid.

The non-iterative reverse transformation from Cartesian co-ordinates (X, Y, Z) to geodetic co-ordinates (ϕ, λ, h) is given in Bowring (1985) as:

$$\phi = \arctan\left[\frac{Z + \varepsilon^2 b \sin^3 u}{P - e^2 a \cos^3 u}\right]$$

$$\lambda = \arctan\left[\frac{Y}{X}\right]$$

$$h = P\cos\phi + Z\sin\phi - a\sqrt{1 - e^2\sin^2\phi}$$

With:

$$u = \arctan\left[\frac{aZ}{bP}\right]$$

$$P = \sqrt{X^2 + Y^2}$$

$$\varepsilon = \frac{e^2}{1 - e^2}$$

Where,

u : the parametric latitude;
b : the semi-minor axis of the reference ellipsoid;
ε : the second eccentricity of the reference ellipsoid.

The Bursa-Wolf is a seven-parameter model for transforming three-dimensional Cartesian co-ordinates between two datums (see **Figure 3.2**). This transformation model is more suitable for satellite datums on a global scale (Krakwisky and Thomson, 1974). The transformation involves three geocentric datum shift parameters ($\Delta X, \Delta Y, \Delta Z$), three rotation elements (R_X, R_Y, R_Z) and scale factor ($1 + \Delta L$).

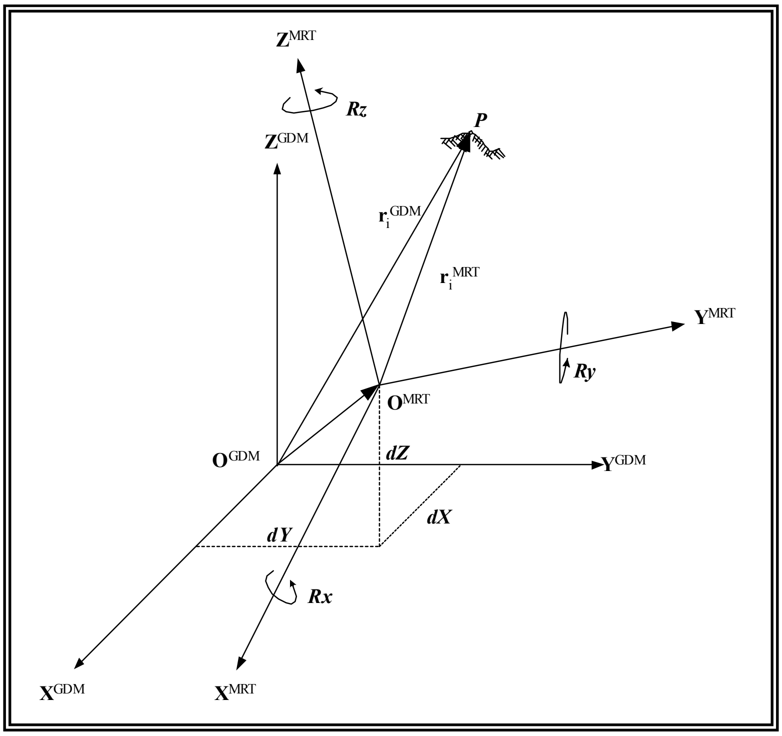

Figure 3.2: Bursa-Wolf 3-D Model Transformation

The model in its matrix-vector form could be written as (see Burford 1985) :

$$\begin{bmatrix} X_{WGS84} \\ Y_{WGS84} \\ Z_{WGS84} \end{bmatrix} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + \begin{bmatrix} 1+\Delta L & R_Z & -R_Y \\ -R_Z & 1+\Delta L & R_X \\ R_Y & -R_X & 1+\Delta L \end{bmatrix} \begin{bmatrix} X_{MRT} \\ Y_{MRT} \\ Z_{MRT} \end{bmatrix}$$

where;

$X_{WGS84}, Y_{WGS84}, Z_{WGS84}$: are the global datum (WGS84) Cartesian co-ordinates;

$X_{MRT}, Y_{MRT}, Z_{MRT}$: are the local datum (MRT) Cartesian co-ordinates.

In order to convert the geocentric coordinates of XYZ to the geodetic coordinate of PLH, ellipsoid properties for the respective datums are listed below:

No.	Ellipsoid	a (m)	1/f (m)	Ref. Frame
1	GRS80	6378137.000	298.2572221	ITRF91 - 2000
2	WGS84	6378137.000	298.2572236	WGS84
3	Mod. Everest (Pen. Mal)	6377304.063	300.8017	MRT48
4	Mod. Everest (East Mal)	6377298.565	300.8017	BT68

Table 3.1: Ellipsoid Properties

3.1.1 GDM2000 TO WGS84

The flowchart of deriving transformation parameters between GDM2000 to PMPGN and EMPGN are as in **Figure 3.3**:

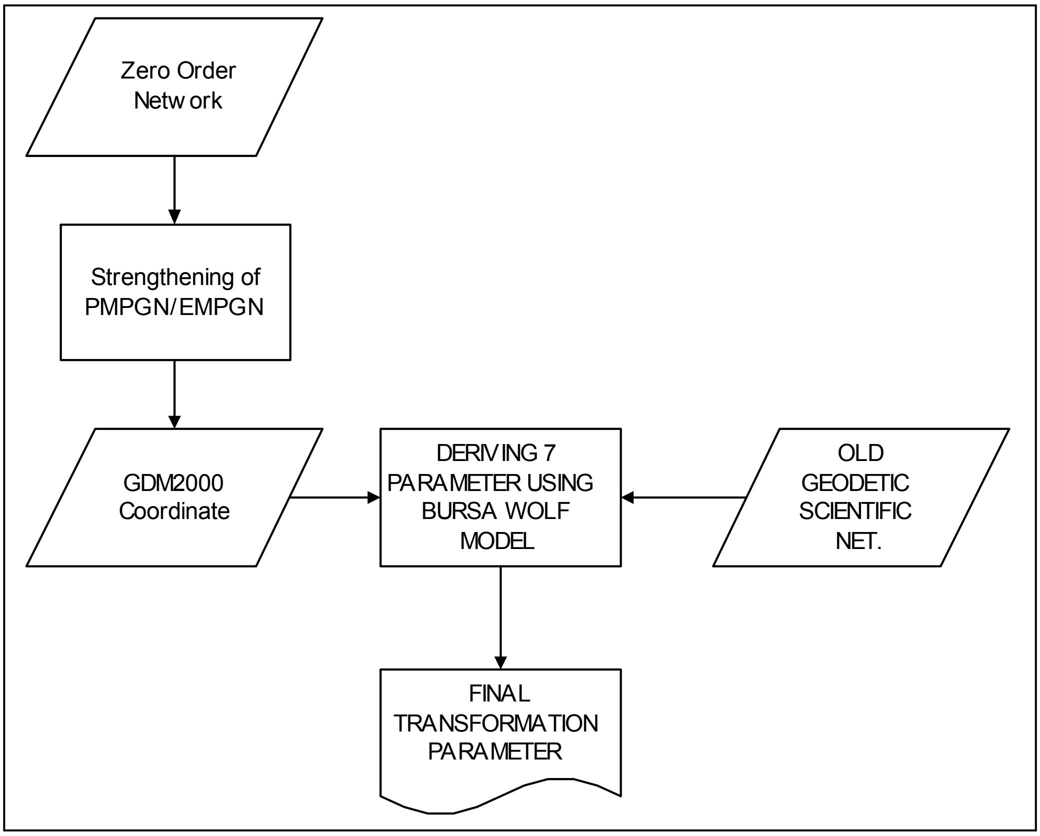

FIGURE 3.3: Flowchart of Deriving Transformation Parameter

Transformation parameter from GDM2000 to WGS84 (PPGN) and GDM2000 to WGS84(EMPGN) are listed in **APPENDIX G-1** and **APPENDIX H-1** respectively.

3.2 MAP PROJECTION

The RSO is an oblique Mercator projection developed by Hotine in 1947 (Snyder, 1984). Hotine called the projection as "rectified skew orthomorphic". This projection is orthomorphic (conformal) and cylindrical. All meridians and parallel are complex curves. Scale is approximately true along a chosen central line (exactly true along a great circle in its spherical form). It is thus a suitable projection for an area like Switzerland, Italy, New Zealand, Madagascar, and Malaysia as well.

The RSO provide an optimum solution in the sense of minimizing distortion whilst remaining conformal for Malaysia. Table 3.2 tabulates the new *geocentric RSO* parameters for Peninsular Malaysia and East Malaysia

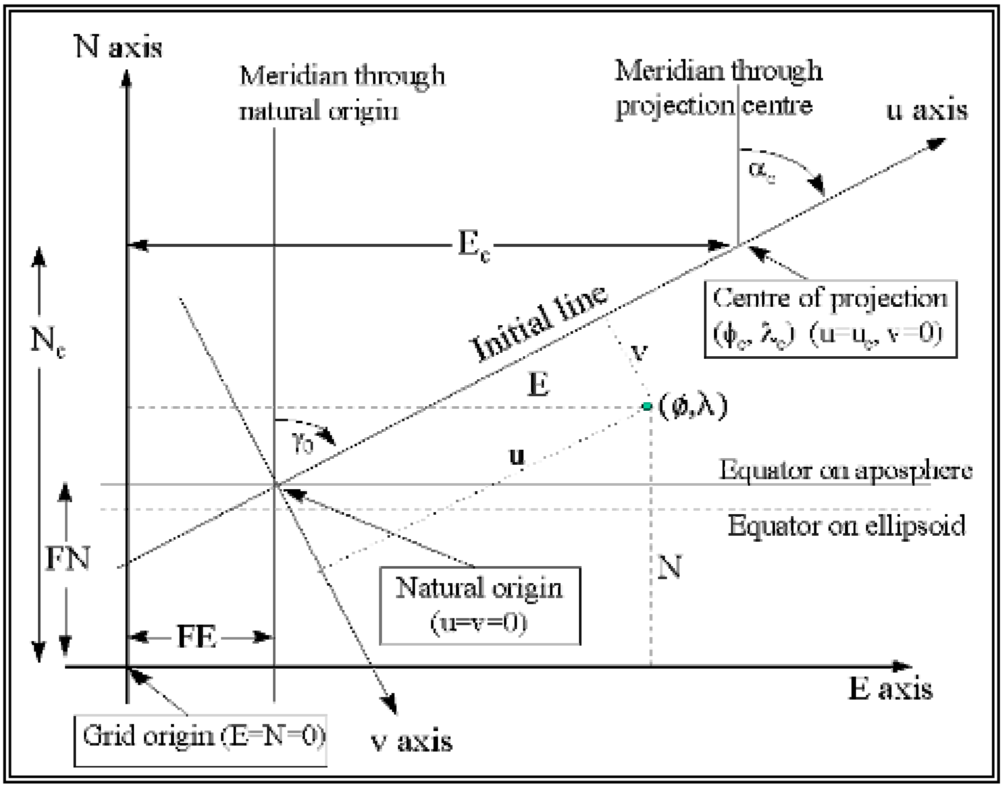

FIGURE 3.4: Hotine, 1947 (Snyder, 1984), Oblique Mercator (Source:EPSG)

	Peninsular RSO	**East Malaysia BRSO**	**Remark**
Ellipsoid Parameters			
Ellipsoid	GRS 80	GRS 80	
Major axis, a	6378137.000 Meters	6378137.000 Meters	
Flattening, 1/f	298.2572221	298.2572221	
Defined Parameters.			
Latitude of Origin, ϕ_o	4^o 00' 00" N	4^o 00' 00" N	
Longitude of Origin, λ	102^o 15' 00" E	115^o 00' 00" E	
Rectified to Skew Grid, γ_o	- $\sin^{-1}$ (0.6)	$\sin^{-1}$ (0.8)	
Azimuth of Central Line, α_c	323^o 01' 32.86728"	53^o 18' 56.91582"	
Scale factor, k	0.99984	0.99984	
False Origin (Easting)	804,671 Meters E	Nil	
False Origin (Northing)	Nil	Nil	

Table 3.2: The New Geocentric RSO Projection Parameters

3.2.1 Rectified Skew Orthomorphic Projection (RSO)

Notation:

The notation adopted for use in this section is as follows :

ϕ_c = latitude of center of the projection.

λ_c = longitude of center of the projection.

α_c = azimuth (true) of the center line passing through the center of the projection.

γ_c = rectified bearing of the center line.

k_c = scale factor at the center of the projection.

ϕ = geographical latitude

λ = geographical longitude

t_o = isometric latitude for ϕ= 4°

$$t_o = \log\theta \tan\left(\frac{\pi}{4}+\frac{\phi_c}{2}\right)-\frac{k}{2}\log\theta\frac{1+e\sin\phi_c}{1-e\sin\phi_c}$$

or

$$t_0 = \frac{\tan(\frac{\pi}{4}-\frac{\phi_c}{2})}{\left[(1-e\sin\phi_c)/(1+e\sin\phi_c)\right]^{e/2}}$$

t = isometric latitude

λ_o = basic longitude

a = semi major axis of ellipsoid

b = semi minor axis of ellipsoid

f = flattening of ellipsoid

$$f = (a-b)/a$$

e = eccentricity of ellipsoid

$$e^2=(a^2-b^2)/a^2$$

$$e_1^2=(a^2-b^2)/b^2$$

ρ = radius of curvature in the meridian

$$\rho = a\left(1-e^2\right)/\left(1-e^2.Sin^2\phi\right)^{3/2}$$

ν = radius of curvature in the prime vertical

$$\nu = \rho\left(1 + e_1^2.Cos^2\phi\right)$$

m = scale factor

m_o = scale factor at the origin

γ = skew convergence at meridians

p = distance from polar axis, $p = \upsilon \cos\varphi$

γ_R =rectified convergence of meridians

$$\gamma_R = \gamma + 36°52'11.6314"$$

u = skew coordinate parallel to initial line

v = skew coordinate at right angles to initial line

N = Northing map coordinate

E = East map coordinate

FE = False Easting at the natural origin.

FN = False Northing at the natural origin.

Constants of the projection

$$B = \left(1 - e_1^2.\cos^4\phi_c\right)^{1/2}$$

or

$$B = [1 + e^2\cos^4(\phi_c)/(1 - e^2)]^{0.5}$$

$$A = a \cdot B \cdot k_c(1 - e^2)^{0.5}/(1 - e^2\sin^2(\phi_c))$$

$$A' = B\left(\rho_o \nu_o\right)^{1/2}$$

$$C = \cosh^{-1}\left(A/p_o\right) - Bt_o$$

$$D = \frac{B\sqrt{1 - e^2}}{\cos\phi_c \cdot \sqrt{1 - e^2\sin^2\phi_c}}$$

To avoid problems with computation of F, if D<1, make $D^2 = 1$.

$$F = D + \mathrm{sgn}(\phi_c) \cdot \sqrt{Dsq - 1}$$

$$H = F \cdot t_0^{B}$$

$$G = \frac{F - 1/F}{2}$$

$$\sin \gamma_o = -0.6 \text{ or}$$

$$\gamma_0 = \arcsin[\sin(\alpha_c / D)]$$

Basic Longitude:

$$\lambda_0 = \lambda_c - \frac{\arcsin(G \cdot \tan \gamma_0)}{B}$$

Constant of Projection		
	Peninsular Malaysia	East Malaysia
Parameter A	6377117.000138081Meters	6377117.000138081Meters
Parameter A'	6378137.502 Meters	6378137.502 Meters
Parameter B	1.003331484621	1.003331484621
Parameter C	0.000003016721	0.000003016721
Basic Longitude. λ_o	105° 14' 10.58664"	109°41' 08.95525"

Table 3.3: Constant of Projection

- **Projection Formulas**

a) <u>Conversion of Geographicals to Rectangulars and vice versa</u>

<u>Forward Case: To compute (E, N) from a given (φ, λ):</u>

$$t = \frac{\tan(\frac{\pi}{4} - \frac{\phi}{2})}{[(1 - e\sin\phi)/1 + e\sin\phi)]^{e/2}}$$

$$Q = H / t^{B}$$

$$S = \frac{Q - 1/Q}{2}$$

$$T = \frac{Q + 1/Q}{2}$$

$$V = \sin[B(\lambda - \lambda_0)]$$

$$U = \frac{S \sin \gamma_0 - V \cos \gamma_0}{T}$$

$$v = \frac{A \ln\left(\frac{1-U}{1+U}\right)}{2 \cdot B}$$

For the Hotine Oblique Mercator (where the FE and FN values have been specified with respect to the origin of the (u, v) axes):

$$u = \frac{A}{B} \arctan\left(\frac{S \cos \gamma_0 + V \sin \gamma_0}{\cos[B(\lambda - \lambda_0)]}\right)$$

The rectified skew co-ordinates are then derived from: $E = v \cos \gamma_c + u \sin \gamma_c + (FEorE_c)$

$$N = u \cos \gamma_c - v \sin \gamma_c + (FNorN_c)$$

<u>Reverse case: Compute (ϕ, λ) from a given (E, N):</u>

For the Hotine Oblique Mercator:

$$v' = (E - FE) \cos \gamma_c - (N - FN) \sin \gamma_c$$

$$u' = (N - FN) \cos \gamma_c + (E - FE) \sin \gamma_c$$

Then the other parameters can be calculated.

$$Q' = \exp[-(Bv'/A)]$$

$$S' = \frac{Q' - 1/Q'}{2}$$

$$T' = \frac{Q' + 1/Q'}{2}$$

$$V' = \sin\left(\frac{B \cdot u'}{A}\right)$$

$$U' = \frac{V' \cos \gamma_c + S' \sin \gamma_c}{T'}$$

$$t' = \left[\frac{H}{\sqrt{(1+U')/(1-U')}}\right]^{1/B}$$

$$\chi = \pi / 2 - 2 \cdot \arctan(t')$$

$$\varphi = \begin{array}{l} \chi + \sin(2\chi)\left(e^2/2 + 5e^4/24 + e^6/12 + 13e^8/360\right) + \\ \sin(4\chi)\left(7e^4/48 + 29e^6/240 + 811e^8/11520\right) + \\ \sin(6\chi)\left(7e^6/120 + 81e^8/1120\right) + \\ \sin(8\chi)\left(4279e^8/161280\right) \end{array}$$

$$\lambda = \lambda_0 - \arctan\left(\frac{S' \cos \gamma_c - V' \sin \gamma_c}{\cos(Bu'/A)}\right) \Big/ B$$

b) <u>Convergence of Map Meridians</u>

The convergence of the map meridians is defined as the angle measured clockwise from True North to the Rectified Grid North, and is denoted γ_R :

$$\begin{aligned} \gamma_R &= \gamma - \sin^{-1}(-0.6) \\ &= \gamma + 36°52'11.6314'' \end{aligned}$$

where

$$\tan \gamma = \frac{\tan \gamma_O - \sin B(\lambda_O - \lambda)\sinh(Bt + C)}{\cos B(\lambda_O - \lambda)\cosh(Bt + C)}$$

$$= \frac{\sin \frac{Bv}{A' m_o} \sinh \frac{Bu}{A' m} + \tan \gamma_o}{\cos \frac{Bv}{A' m_o} \cosh \frac{Bu}{A' m_o}}$$

c) Scale Factor at any Point

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The formulas giving the scale factor " m " at any point in terms of isometric latitude and longitude and coordinates (v,u) are:

$$m = \frac{A' m_o}{p} \frac{\cosh \frac{Bu}{A' m_o}}{\cosh(Bt + C)}$$

$$= \frac{A' m_o}{p} \frac{\cos \frac{Bv}{A' m_o}}{\cos B(\lambda_o - \lambda)}$$

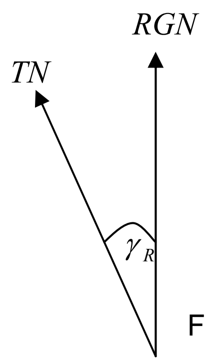

Figure 3.5

It can be shown that the initial line of the projection has a scale factor that is nearly constant throughout its length.

d) Scale Factor for a Line

The Scale factor for a line can be computed from the formula :

$$m = \frac{1}{6}(m_1 + 4m_3 + m_2)$$

where m_1, m_2 are the scale factors at the ends of the line and m_3 the scale factor at its mid-point. The scale factor for a line also may be evaluated from the following formula :

$$m = \frac{A' m_o}{v_m \cos\varphi_m \cosh(B\varphi_m + C)} \left[1 + \frac{B^2}{6 A'^2 m_o^2} \left(u_1^2 + u_1 u_2 + u_2^2 \right) \right]$$

where

φ_m and ψ_m are evaluated for the mid-latitude of the line

u_1 and u_2 are the u - coordinates of the points :

e) Arc-to-Chord Correction

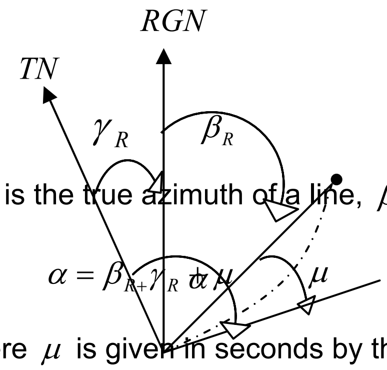

Figure 3.6: Arc-to-Chord

If α is the true azimuth of a line, β_R is the rectified grid bearing, then

$$\alpha = \beta_R + \gamma_R \pm \mu$$

where μ is given in seconds by the formula

$$\mu = \frac{B}{2A' m_o \sin 1''}(v_2 - v_1)\tanh\left\{\frac{B}{2A' m_o}\frac{2u_1 + u_2}{3}\right\}$$

$$+ k_1^2 \frac{\rho_o}{v_o} \sin\phi_o (\sin\phi_3 - \sin\phi_o)^2 (\lambda_1 - \lambda_2)$$

where $\phi 3 = \frac{1}{3}(2\phi_1 + \phi_2)$ and $(\lambda_1 - \lambda_2)$ is measured in seconds.

For a line not exceeding 70 miles in length, the maximum value of the second term of the formula is 0.007", it can therefore be safely neglected.

3.2.2 Cassini Coordinate in GDM2000

The mapping equations can be given as (Richadus and Adler, 1974) and the formulas to derive projected Easting and Northing coordinates are:

Forward Computation

*E = FE + v[A – T(A³/6) - (8 –T + 8C)T * A⁵/120]* ….(3.1)

$$E = FE + v[A - T(A^3/6) - (8 - T + 8C)T * A^5/120] \quad \text{….(3.1)}$$

$$N = FN + M - Mo + v*\tan\phi[A^2/2 + (5 - T + 6C)A^4/24] \quad \text{….(3.2)}$$

where,

N, E	=	Computed Cassini coordinate
FE, FN	=	Cassini State origin coordinates
A	=	$(\lambda - \lambda_o)Cos\phi$

where,

λ	=	Longitude of computation point
λ_o	=	Longitude of state origin
ϕ	=	Latitude of computation point

T = $Tan^2\phi$

C = $$\frac{e^2}{(1-e^2)}Cos^2\phi$$

V = Radius of curvature in prime vertical

= $$\frac{a}{(1-e^2 Sin^2\phi)^{1/2}}$$

M = Meridianal arc distance

= $a[1 - e^2/4 - 3e^4/64 - 5e^6/256 - ..)\phi - (3e^2/8 + 3e^4/32 + 45e^6/1024 + \ldots)sin2\phi + (15e^4/256 + 45e^6/1024 + \ldots)sin4\phi - (35e^6/3072 + \ldots)sin6\phi ..]$

with ϕ in Radians.

Mo = The value of **M** calculated for the latitude of the chosen origin.

Reverse Computation

$$\phi = \phi_1 - \frac{v_1 Tan\phi_1}{\rho_1}\left[\frac{D^2}{2} - (1+3T_1)\frac{D^4}{24}\right] \qquad \ldots.(3.3)$$

$$\lambda = \lambda_0 + \left[D - T_1\frac{D^3}{3} + (1+3T_1)T_1\frac{D^5}{15}\right] / Cos\phi_1 \qquad \ldots.(3.4)$$

where,

ϕ_1 = $\mu_1 + (3e_1/2 - 27e_1^3/32 + ..)Sin2\mu_1 + (21e_1^2/16 - 55e_1^4/32 + ..)Sin4\mu_1 + (151e_1^3/96 + \ldots)Sin6\mu_1 + (1097e_1^4/512 - \ldots)Sin8\mu_1 + \ldots$

$$\rho_1 = \frac{a(1-e^2)}{(1-e^2 Sin^2\phi_1)^{3/2}}$$

$$\nu_1 = \frac{a}{(1-e^2 Sin^2\phi_1)^{1/2}}$$

where,

$$e_1 = \frac{1-(1-e^2)^{1/2}}{1+(1-e^2)^{1/2}} \qquad \text{3-14}$$

$$\mu_1 = \frac{M_1}{a(1-e^2/4-3e^4/64-5e^6/256-...)}$$

$M1 = M_o + (N - FN)$

$=$ M_o is the value of M calculated for the latitude of the origin

$T1 = Tan^2\phi_1$

$D = (E - FE)/\nu_1$

Scale and Arc-to-Chord Correction for Cassini Projection

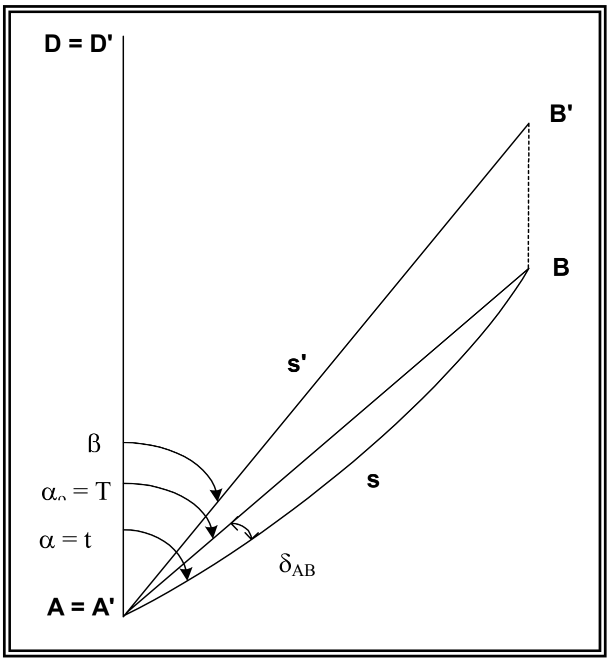

Figure 3.7: Scale and Arc-to-Chord

$\delta AB \quad = \; (t - T)'' \; = \; ((N_b - N_a)(E_b + 2E_a))/(6R^2.Sin1'')$

where,

N_a, N_b, E_a, E_b = Cassini Coordinates 3-15

$(t - T)''$ = Arc-to-Chord

Bearing correction:-

$(\beta - \alpha)'' = -((Sin\alpha_o.Cos\alpha_o)/(6R^2.Sin1''))E^2_\mu$

where,

$E^2_\mu \quad = (E^2_a + E_aE_b + E^2_b)$

Linear correction:-

$s' \quad = s + [((Cos^2\alpha_o)/(6R^2))E^2_\mu]s$

Projected Coordinate on Cassini:-

$E_b \quad = E_a + s'.Sin\beta$

$N_b \quad = N_a + s'.Cos\beta$

Computation of Station's Convergence (as in Solar Observation's Form)

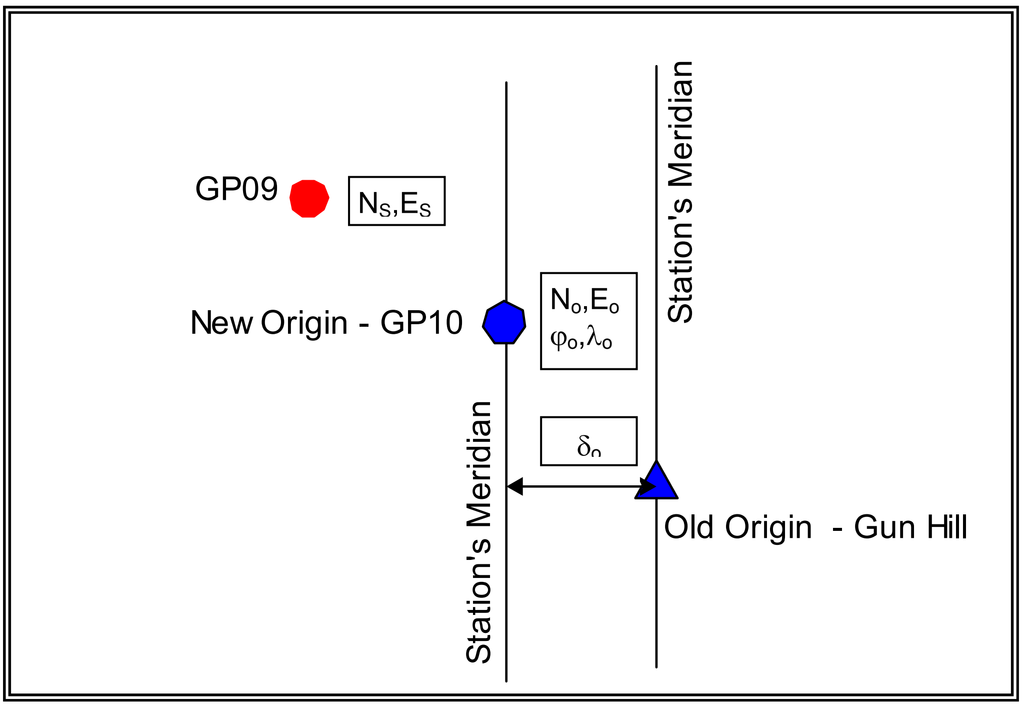

Figure 3.8 : Old and New Origin for Negeri Sembilan

Notation:

φ_O	-	Latitude of State Origin
λ_O	-	Longitude of State Origin
φ_S	-	Latitude of Station
λ_S	-	Longitude of Station
N_O	-	Cassini-Soldner North Coordinate of State Origin
E_O	-	Cassini-Soldner East Coordinate of State Origin
N_S	-	Cassini-Soldner North Coordinate of Station
E_S	-	Cassini-Soldner North Coordinate of Station
δ_o	-	Offset Between Old and New Origin (East Component)
γ_S	-	Station's Convergence

COMPUTATION:

Station's Latitude

$\varphi_S = \varphi_O + \delta_\varphi$

where,

$\delta_\varphi = [(N_S - N_O) * 0.03256] / 3600$

Station's Convergence

$\gamma_S = \Delta\lambda * \mathrm{Sin}(\varphi_S)$

where,

$\Delta E \;=\; E_S - E_O$

$\Delta\lambda \;=\; (\Delta E \;+\; \delta_o) * 0.03246$ (in second)

If $(\Delta E \;+\; \delta_o)$ is –ve, station's convergence (γ_S) is +ve (west of old origin) and if $(\Delta E \;+\; \delta_o)$ is +ve, station's convergence (γ_S) is -ve (east of old origin).

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Kordinat Origin	N_O m [U(+) S(-)]	Kordinat Origin	E_O m [T(+) B(-)]
Stesen	N_S m [U(+) S(-)]	Stesen	E_S m [T(+) B(-)]
Jumlah/Sel.	$N_S - N_O$ m	Jumlah/Sel.	ΔE m
Jumlah/Sel. x 0.03256	δ_φ (in Degree, Min, Sec)	Jumlah/Sel + Offset =	$(\Delta E \;+\; \delta_o)$ m =
G. Lintang Origin U	φ_O (in Degree, Min, Sec)		
G. Lintang Stesen U	φ_S (in Degree, Min, Sec)	Sel. G. Bujur	$(\Delta E \;+\; \delta_o)$ x 0.03246 ± $\Delta\lambda$ "
		Sel. G. Bujur x Sin G. Lintang =	$\Delta\lambda * \mathbf{Sin}(\varphi_S)$ "
		T(-) B(+) Tirusan =	γ_S "

JUPEM

Re-defination of States Origin in GDM2000

State	GPS Station	Station Location	Coordinates of State Origins					
			GDM2000		Cassini		Offset	
			Latitude (N)	Longitude (E)	Northing (m)	Easting (m)	Northing (m)	Easting (m)
Johor	GP58	Institut Haiwan Kluang	2°07'18.04708"	103°25'40.57045"	8758.320	-14810.562	8758.320	-14810.562
N.Sembilan & Melaka	GP10	K. Perindustrian Senawang, Seremban	2°40'56.45149"	101°58'29.65815"	-4240.573	3673.785	-3292.026	3915.790
Pahang	GP31	Sek. Ren. Keb. Kuala Mai, Jerantut	3°46'09.79712"	102°22'05.87634"	6485.858	-7368.228	6485.858	-7368.228
Selangor	251D	Felda Soeharto, K. Kubu Baharu	3°41'04.73658"	101°23'20.78849"	56464.049	-34836.161	503.095	-13076.704
Terengganu	P253	Kg. Matang, Hulu Terenganu	4°58'34.62672"	103°04'12.99225"	3371.895	19594.245	3371.895	19594.245
P.Pinang & S. Perai	P314	TLDM Georgetown	5°25'17.46315"	100°20'39.75707"	62.283	-23.414	62.283	-23.414
Kedah & Perlis	TG35	Gunung Perak, Kuala Muda	5°57'52.82177"	100°38'10.93600"	0	0	0	0
Perak	TG26	Gunung Larut Hiijau, Taiping	4°51'32.62688"	100°48'55.47811"	133454.779	-1.769	0.994	-1.769
Kelantan	P243	B. Polis Melor, Kota Bharu	5°58'21.15717"	102°17'42.87001"	8739.894	13227.851	8739.894	13227.851

Table 3.4 : Re-defination of State's Origin Coordinates

Chapter 4

TEST EXAMPLES

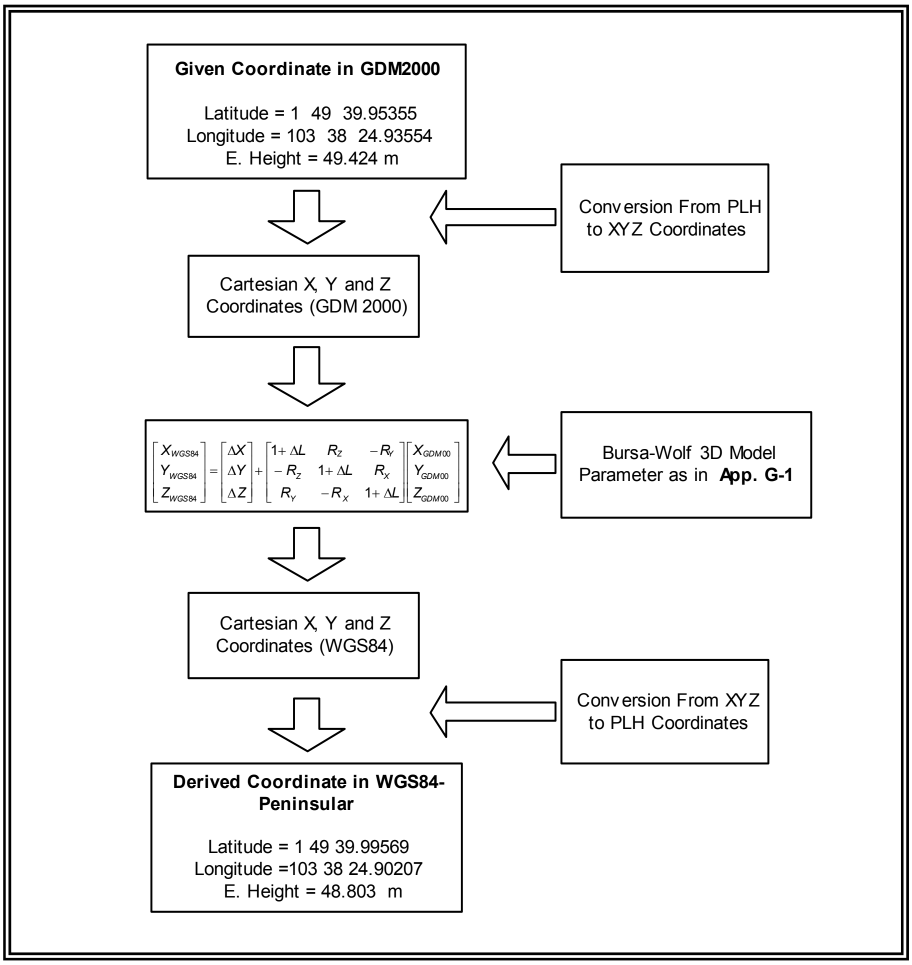
4

4.0 INTRODUCTION

This chapter provides examples of 3D Coordinates Transformation and Map Projection Computation, which are based on the algorithms and parameters given in Chapter 3.

4.1 GDM2000 AND WGS84

4.1.1 GDM2000 – WGS84 (Peninsular)



4.1.2 GDM2000 – WGS84 (East Malaysia)

Given Coordinate in GDM2000

Latitude = 6 52 42.45022
Longitude = 116 50 47.58835
E. Height = 52.620

Conversion From PLH to XYZ Coordinates

Cartesian X, Y and Z Coordinates (GDM 2000)

$$\begin{bmatrix} X_{WGS84} \\ Y_{WGS84} \\ Z_{WGS84} \end{bmatrix} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + \begin{bmatrix} 1+\Delta L & R_Z & -R_Y \\ -R_Z & 1+\Delta L & R_X \\ R_Y & -R_X & 1+\Delta L \end{bmatrix} \begin{bmatrix} X_{GDM00} \\ Y_{GDM00} \\ Z_{GDM00} \end{bmatrix}$$

Bursa-Wolf 3D Model Parameter as in **App. H-1**

Cartesian X, Y and Z Coordinates (WGS84)

Conversion From XYZ to PLH Coordinates

Derived Coordinate in WGS84-East Malaysia

Latitude = 6 52 42.47394
Longitude =116 50 47.59024
E. Height = 52.760 m

4.2 GDM2000 TO RSO PROJECTION

4.2.1 GDM2000 – MRSO (Peninsular)

Given

φ = 1° 49′ 39.95355″ N
λ = 103° 38′ 24.93554″ E

by using parameters from Table 3.2 and 3.3 and their respective formula in Chapter Three, the computed parameters are;

Parameter	Computed Value
t	9.688045322767098E-001
Q	1.032312063031939
S	3.180636836132084E-002
T	1.000505694670618
V	-2.794486508151413E-002
U	3.270417215188204E-003
v	-20786.657147808510000
u	268242.570959949100000

Computed RSO Coordinates

Component	RSO Coordinates
Easting	627096.132 m
Northing	202122.062 m

4.2.2 GDM – BRSO (East Malaysia)

Given

φ = 6° 52′ 42.45022″ N
λ = 116° 50′ 47.58835″ E

by using parameters from Table 3.2 and 3.3 and their respective formula in Chapter Three, the computed parameters are;

Parameter	Computed Value
t	8.873290516924147E-001
Q	1.127429941554232
S	1.202284342117319E-001
T	1.007201507342500
V	1.250663475664954E-001
U	2.099176646726154E-002
v	-133442.058848890000000
u	1092212.332832247000000

Computed RSO Coordinates

Component	RSO Coordinates
Easting	793704.631 m
Northing	762081.047 m

4.3 RSO PROJECTION TO GDM2000

4.3.1 MRSO – GDM2000

Given

Northing (N) = 202122.062 m
Easting (E) = 627096.132 m

by using parameters from Table 3.2 and 3.3 and their respective formula in Chapter Three, the computed parameters are;

Parameter	Computed Value
v'	-20786.648605748150000
u'	268242.571819490500000
Q'	1.003275781213841
S'	3.270433360956837E-003
T'	1.000005347852885
V'	4.219090390177289E-002
U'	3.179029226263264E-002
t'	9.688045321968283E-001
χ	3.168710457523694E-002
φ (Rad)	3.190051510359386E-002
λ (Rad)	1.808863772439700

Computed GDM2000 Coordinates

Component	GDM2000 Coordinates
φ	1° 49′ 39.95357″ N
λ	103° 38′ 24.93555″ E

4.3.2 BRSO – GDM2000

Given

Northing (N) = 762081.047 m
Easting (E) = 793704.631 m

by using parameters from Table 3.2 and 3.3 and their respective formula in Chapter Three, the computed parameters are;

Parameter	Computed Value
v'	-133442.080700309500000
u'	1092212.330348744000000
Q'	1.021216796535431
S'	2.099639649072310E-002
T'	1.000220400044708
V'	1.709966552263680E-001
U'	1.193687989721469E-001
t'	8.873290516543988E-001
χ	1.192557105410228E-001
φ (Rad)	1.200517464858845E-001
λ (Rad)	2.039357057571987

Computed GDM2000 Coordinates

Component	GDM2000 Coordinates
φ	6° 52′ 42.45023″ N
λ	116° 50′ 47.58835″ E

4.4 GDM2000 – STATE CASSINI AND VICE VERSA

4.4.1 GDM2000 TO STATE CASSINI

Example No. 1

Given: Geographical (GDM2000) Coordinates for Johor

φ = 1° 49′ 39.95355″ N
λ = 103° 38′ 24.93554″ E

by using ellipsoid parameters from Table 3.2 and their respective formula 3.1 and 3.2 in Chapter Three, the computed parameters are;

Parameter	Computed Value
FN	8758.320000000000000
FE	-14810.562000000000000
A	3.703861126596332E-003
T	1.018333654939246E-003
C	6.732640700889340E-003
V	6378158.718233293000000
M	202104.465696800700000
Mo	234604.277755942500000

Computed Cassini-Soldner Coordinates

Component	Cassini-Soldner Coordinates
Northing	-23740.095940690840000
Easting	8813.252080720971000

Example No. 2

Given: Geographical (GDM2000) Coordinates for N. Sembilan & Melaka

φ = 2° 26′ 53.59844″ N
λ = 102° 04′ 19.67919″ E

by using ellipsoid parameters from Table 3.2 and their respective formula 3.1 and 3.2 in Chapter Three, the computed parameters are;

Parameter	Computed Value
FN	-4240.573000000000000
FE	3673.785000000000000
A	1.695400967940158E-003
T	1.828037519001000E-003
C	6.727199202960864E-003
V	6378175.955619241000000
M	270712.005162894400000
Mo	296600.822302555900000

Computed Cassini-Soldner Coordinates

Component	Cassini-Soldner Coordinates
Northing	-30128.998213340740000
Easting	14487.350679379540000

4.4.2 STATE CASSINI TO GDM2000

Example No. 1

Given: Cassini-Soldner Coordinates for Johor

N = -23740.096 m
E = 8813.252 m

by using ellipsoid parameters from Table 3.2 and their respective formula 3.3 and 3.4 in Chapter Three, the computed parameters are;

Parameter	Computed Value
ϕ_1	3.190073537522443E-002
ρ_1	6335482.473439429000000
ν_1	6378158.718533233000000
e_1	1.679220394634369E-003
μ_1	3.174047520831971E-002
$M1$	202105.861755942500000
$T1$	1.018347732903464E-003
D	3.703861105142379E-003
φ (Rad)	3.190051501024879E-002
λ (Rad)	1.808863772380172

Computed GDM2000 Coordinates

Component	GDM2000 Coordinates
φ	1° 49′ 39.95355″ N
λ	103° 38′ 24.93554″ E

Example No. 2

Given: Cassini-Soldner Coordinates for for N. Sembilan & Melaka

N = -30128.998 m
E = 14487.351 m

by using ellipsoid parameters from Table 3.2 and their respective formula 3.3 and 3.4 in Chapter Three, the computed parameters are;

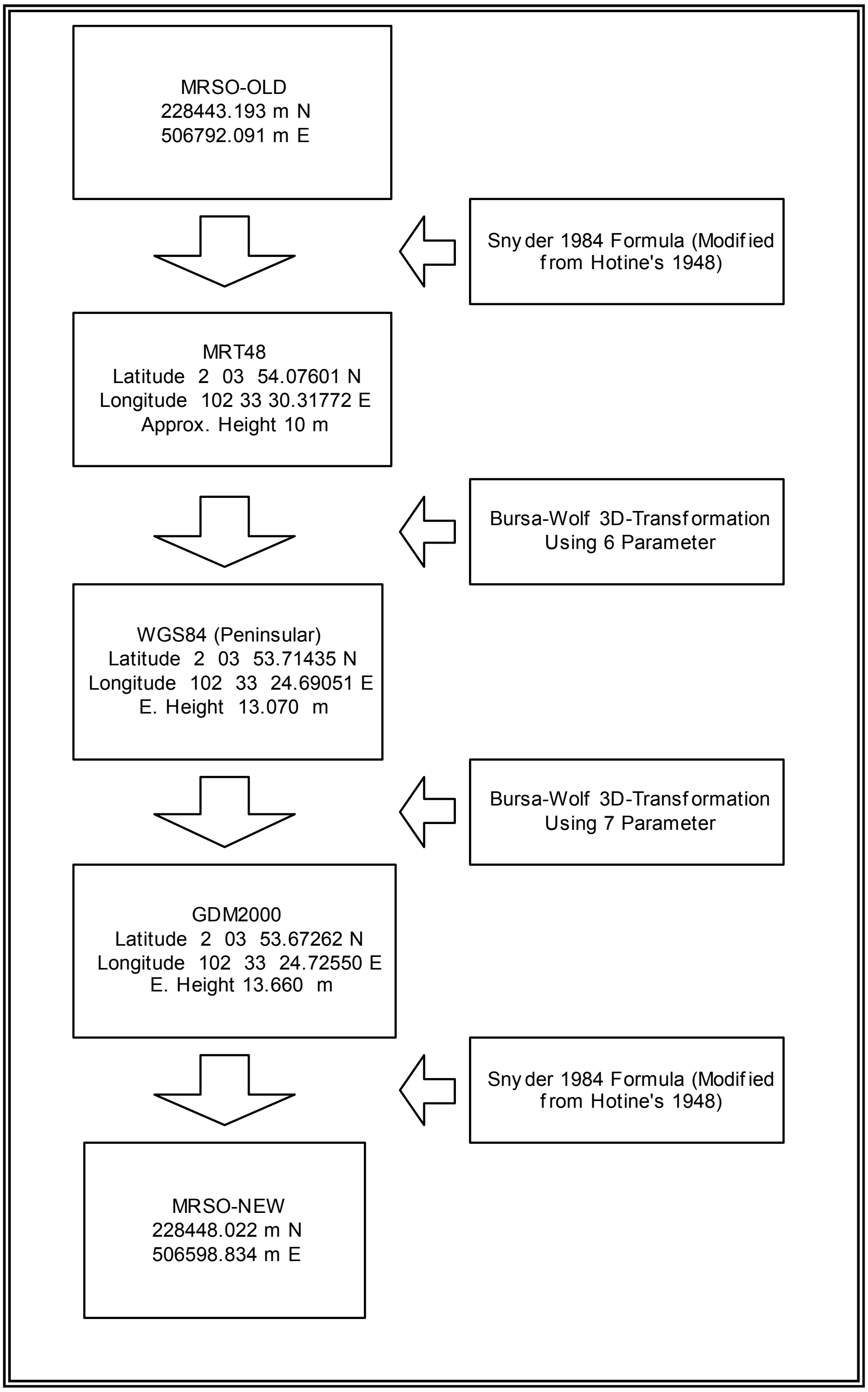
Parameter	Computed Value
ϕ_1	4.272959292932023E-002
ρ_1	6335516.717215179000000
v_1	6378175.955732029000000
e_1	1.679220394634369E-003
μ_1	4.251504662216422E-002
M1	270712.397302555900000
T1	1.828042821316970E-003
D	1.695401016693795E-003
φ (Rad)	4.272953106753976E-002
λ (Rad)	1.781494797324647

Computed GDM2000 Coordinates

Component	GDM2000 Coordinates
φ	2° 26′ 53.59845″ N
λ	102° 04′ 19.67920″ E

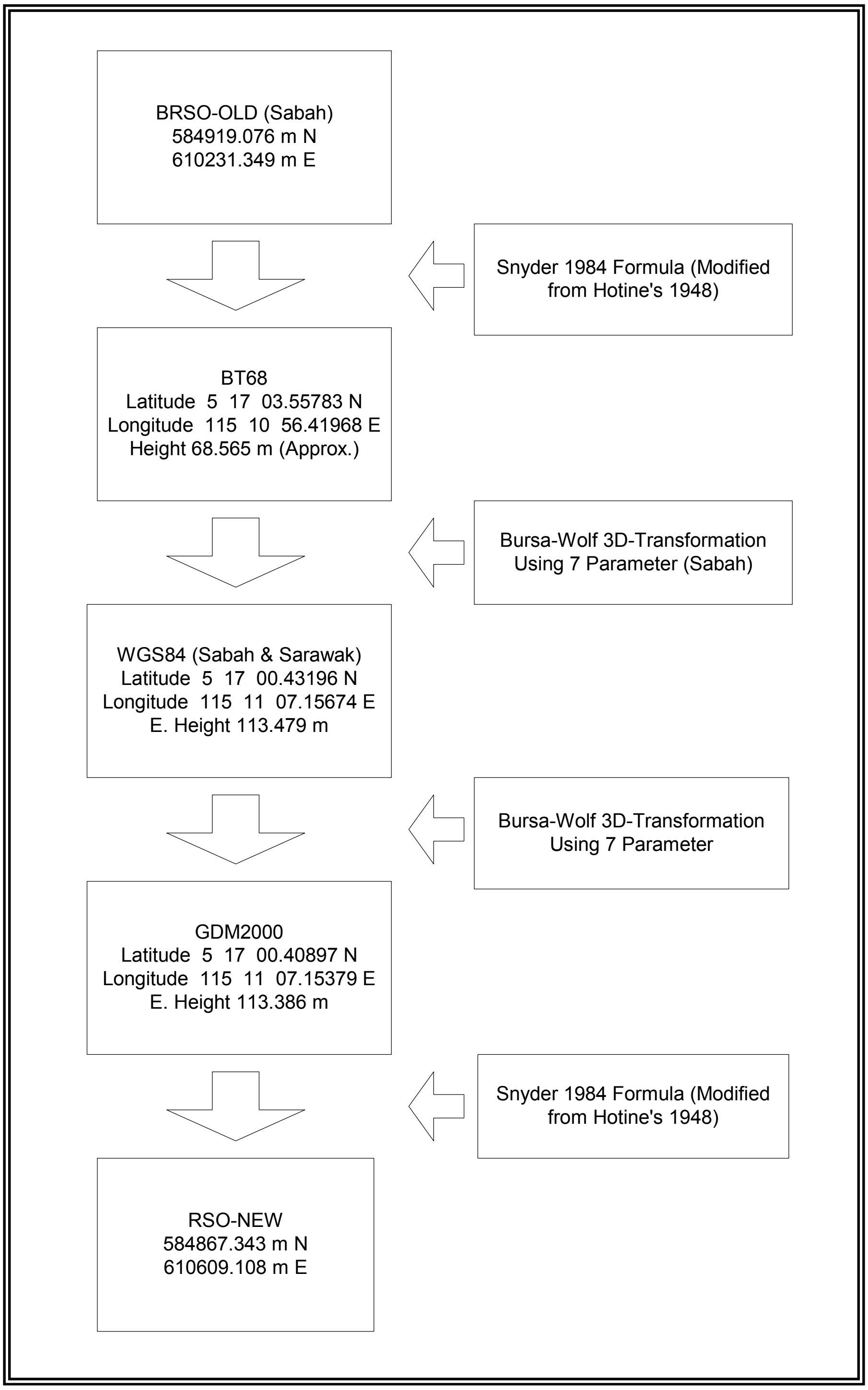
4.5 MRSO$_{OLD}$ - MRSO$_{NEW}$

4.5.1 MRSO$_{OLD}$-MRT48-WGS84-GDM2000-MRSO$_{NEW}$



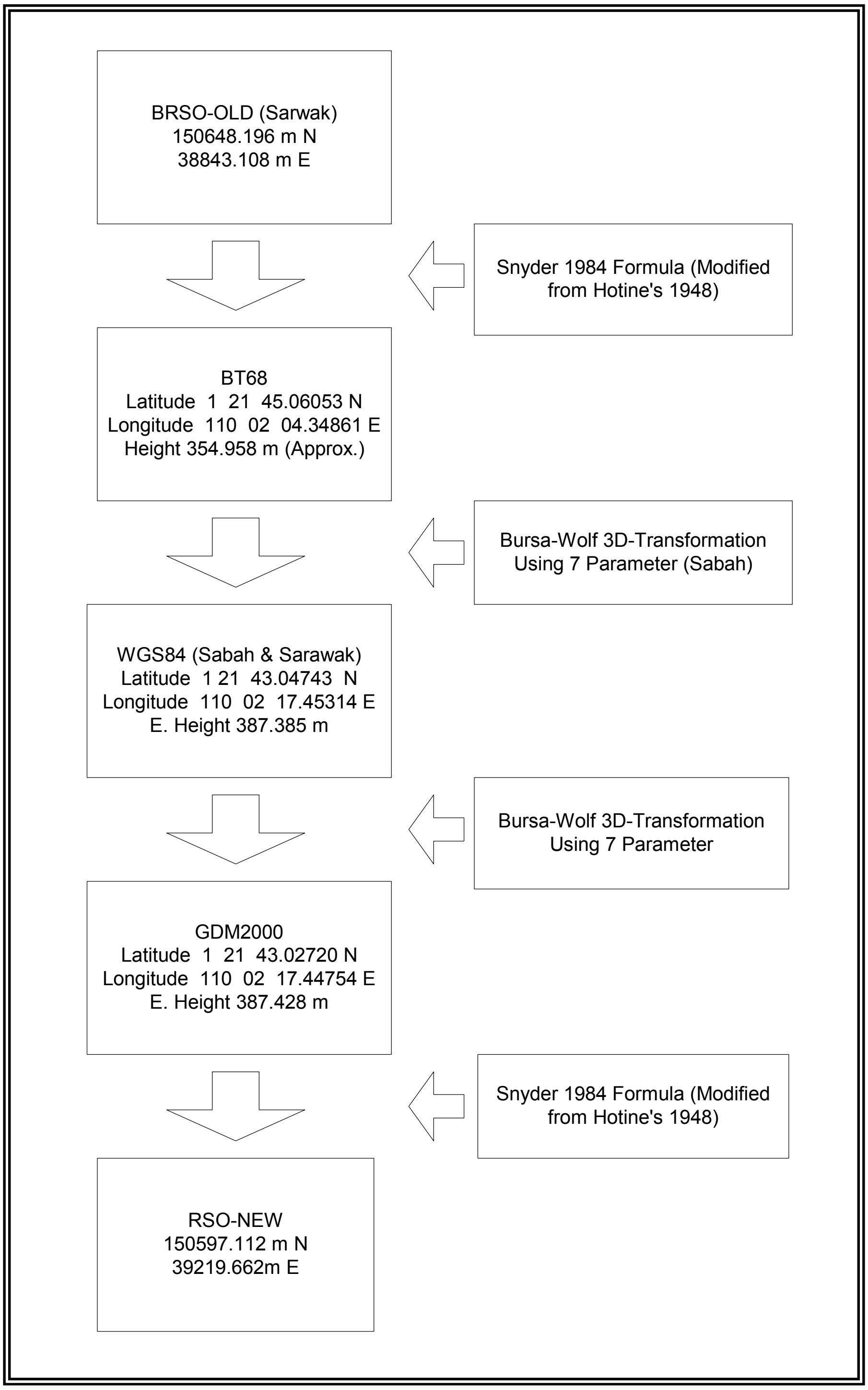
4.6 BRSO$_{OLD}$ - BRSO$_{NEW}$ (Sabah)

4.6.1 BRSO$_{OLD}$-BT68-WGS84-GDM2000-BRSO$_{NEW}$



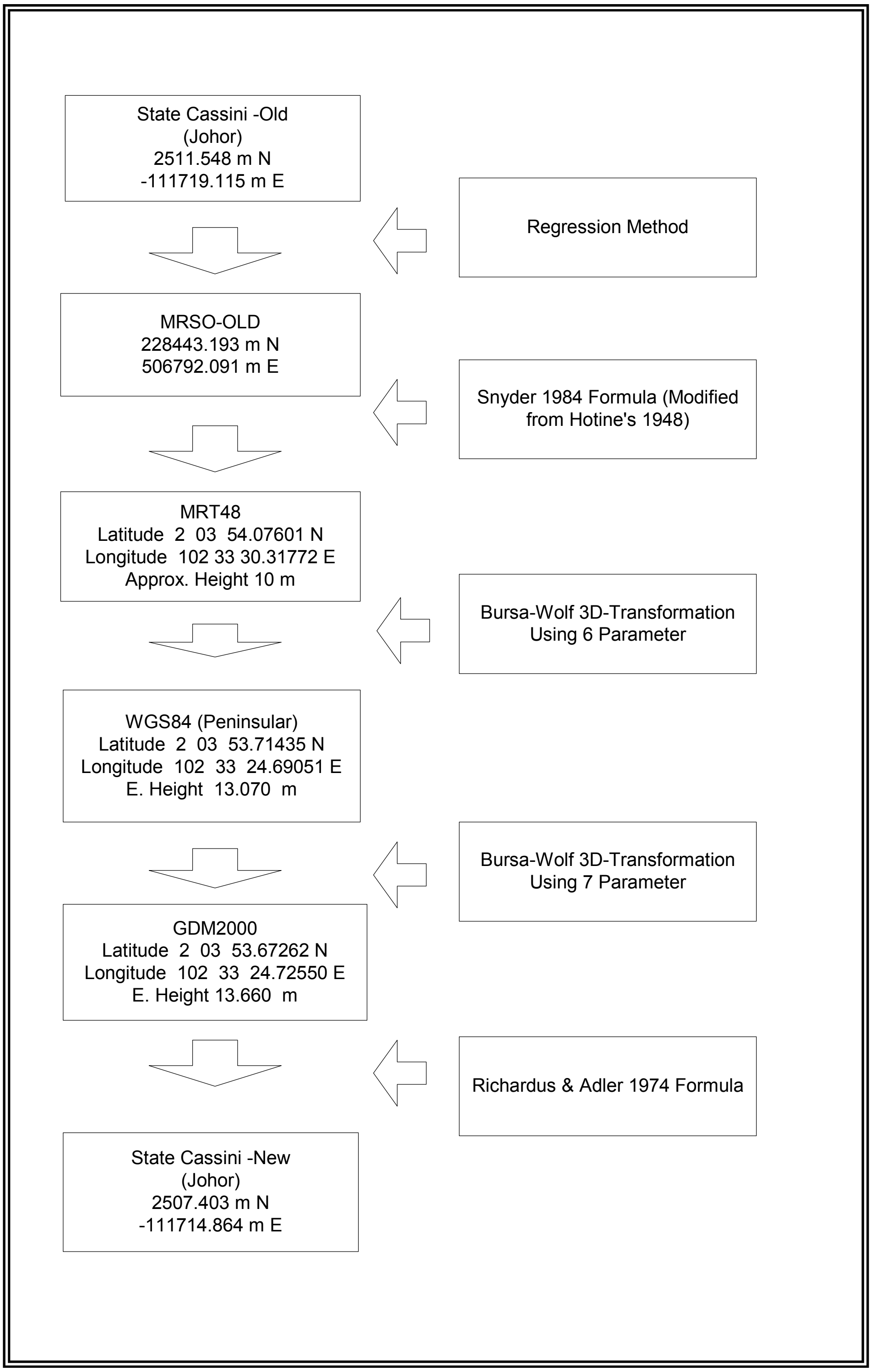
4.7 BRSO_{OLD} - BRSO_{NEW} (Sarawak)

4.7.1 BRSO_{OLD}-BT68-WGS84-GDM2000-BRSO_{NEW}



4.8 CASSINI$_{OLD}$ - CASSINI$_{NEW}$ (Peninsular)

4.8.1 CAS$_{OLD}$ -MRSO$_{OLD}$-MRT48-WGS84-GDM2000-CAS$_{NEW}$



4.9 COMPUTATION ON CASSINI-SOLDNER'S MAP CONVERGENCE

4.9.1 State of Johor (Cassini-Soldner Origin = Cassini-Soldner Offset)

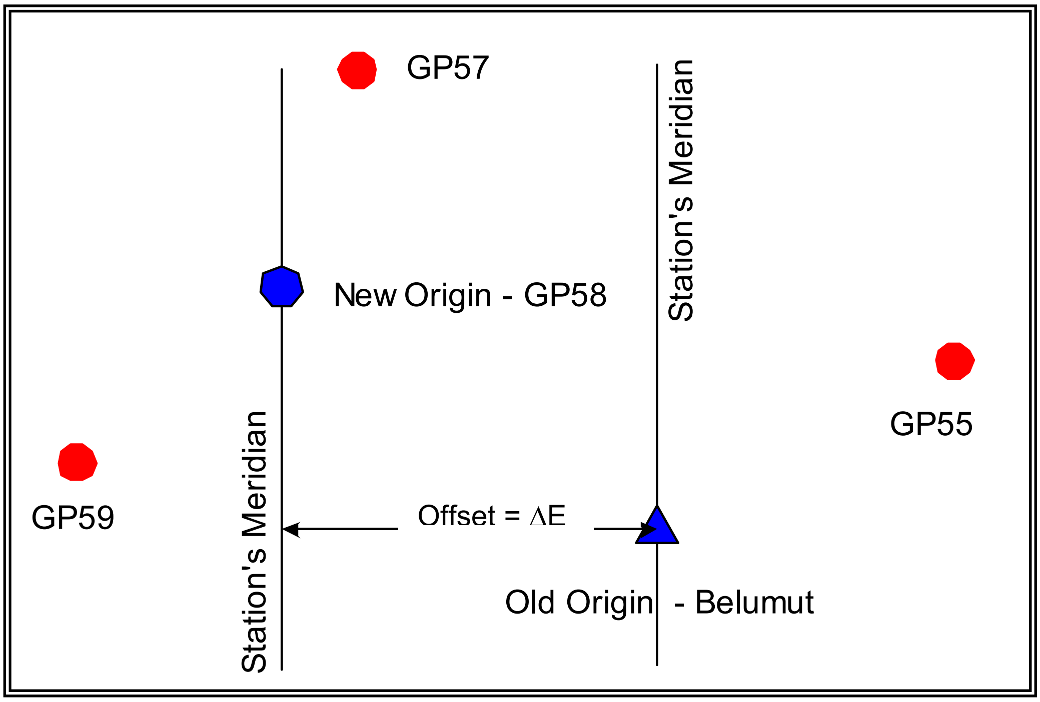


Figure 4.1: New and Old Origin for State of Johor

Example No. 1

Given:

New State's Origin (as in Chapter 3):

Stn	Latitude (N)	Longitude (E)	Cass-N	Cass-E	Offset-N	Offset-E
GP58	2°07'18.04708"	103°25'40.57045"	8758.320	-14810.562	8758.320	-14810.562

Station's Information:

Stn	Latitude (N)	Longitude (E)	Cass-N	Cass-E
GP55	2°04'47.27886"	103°53'21.71083"	4134.902	36521.743

COMPUTATION:

Note:

North and East coordinates sign are +ve and for South and West coordinates are –ve.

Computation on Station Latitude:

"*Jumlah/Sel.*" for Latitude = 4134.902 – 8758.320 = - 4623.420 m

"*Jumlah/Sel.*" in Geographical Sys. = -4623.420 * 0.03256 = - 150.539 "

= - 0° 02’ 30.54"

"*G. Lintang Stesen*" = 2°07’18.05 + (- 0° 02’ 30.54") = 2° 04’ 47.5"

Computation on Convergence:

Offset ∆**E** = -14810.562 m

"*Jumlah/Sel.*" for Longitude = 36521.743 - (- 14810.562) = 51332.305 m

"*Jumlah/Sel. + Offset* " for Longitude = 51332.305 + (- 14810.562) = 36521.743 m

"*Jumlah/Sel. + Offset* " in Geographical Sys. = 36521.743 * 0.03246 = 1185.496 "

"*Sel. G. Bujur x Sain G. Lintang*" = 1185.496 x Sin(2° 04’ 47.5")= 43.0"

"*Tirusan*" is –ve if "*Jumlah/Sel. + Offset*" is +ve (east of old origin) and vice versa.

∴ "*Tirusan*" = -43.0"

Kordinat Origin	**8758.320**		m [U(+) S(-)]	Kordinat Origin **-14810.562** m
Stesen	**4134.902**		m [U(+) S(-)]	Stesen **36521.743** m
Jumlah/Sel.	**- 4623.420**		m	Jumlah/Sel. **51332.305** m
Jumlah/Sel. x 0.03256	**-0°**	**02'**	**30.54"**	Jumlah/Sel + Offset = 51332.305 - 14810.562 = 36521.743 m
G. Lintang Origin U	**2°**	**07'**	**18.05"**	
G. Lintang Stesen U	**2°**	**04'**	**47.5"**	Sel. G. Bujur = Jum/Sel x 0.03246 ± **1185.496** "
				Sel. G. Bujur x Sain G. Lintang = **43.0** "
				T(-) B(+) Tirusan = - **43.0"**

Example No. 2

Given:

Station's Information:

Stn	Latitude (N)	Longitude (E)	Cass-N	Cass-E
GP57	2°23'21.87363	103°27'53.15111''	38362.842	-10714.433

COMPUTATION:

Note:
North and East coordinates sign are +ve and for South and West coordinates are –ve.

Computation on Station Latitude:

"*Jumlah/Sel.*" for Latitude = 38362.842 - 8758.320= 29604.522 m

"*Jumlah/Sel.*" in Geographical Sys. = 29604.522 * 0.03256 = 963.923 "

= 0° 16' 03.92"

"*G. Lintang Stesen*" = 2°07'18.05 + (+ 0° 16' 03.92") = 2° 23' 22.0"

Computation on Convergence:

Offset Δ**E** = -14810.562 m

"*Jumlah/Sel.*" for Longitude = -10714.433 - (- 14810.562) = 4096.129 m

"*Jumlah/Sel. + Offset*" for Longitude = 4096.129 + (- 14810.562) = -10714.433 m

"*Jumlah/Sel. + Offset*" in Geographical Sys. = 10714.433 * 0.03246 = 347.790 "

"*Sel. G. Bujur x Sain G. Lintang*" = 347.790 x Sin(2° 23' 22.0")= 14.5"

"*Tirusan*" is –ve if "*Jumlah/Sel. + Offset*" is +ve (east of old origin) and vice versa.

∴ "*Tirusan*" = 14.5"

Kordinat Origin **8758.320** m [U(+) S(-)]				Kordinat Origin **-14810.562** m
Stesen **38362.842** m [U(+) S(-)]				Stesen **-10714.433** m
Jumlah/Sel. **29604.522** m				Jumlah/Sel. **4096.129** m
Jumlah/Sel. x 0.03256	**0°**	**16'**	**03.92"**	Jumlah/Sel + Offset = 4096.129 - 14810.562 = -10714.433 m
G. Lintang Origin U	**2°**	**07'**	**18.05"**	
G. Lintang Stesen U	**2°**	**23'**	**22.0"**	Sel. G. Bujur = Jum/Sel x 0.03246 = **347.790** "
				Sel. G. Bujur x Sain G. Lintang = **14.5** "
				T(-) B(+) Tirusan = **14.5"**

Example No. 3

Given:

Station's Information:

Stn	Latitude (N)	Longitude (E)	Cass-N	Cass-E
GP59	1°58'24.61353"	103°13'41.57267"	-7625.009	-37030.370

COMPUTATION:

Note:
North and East coordinates sign are +ve and for South and West coordinates are –ve.

Computation on Station Latitude:

"*Jumlah/Sel.*" for Latitude = -7625.009 - 8758.320 = -16383.329 m

"*Jumlah/Sel.*" in Geographical Sys. = -16383.329 * 0.03256 = -533.441 "

= - 0° 08' 53.44"

"*G. Lintang Stesen*" = 2°07'18.05 + (- 0° 08' 53.44") = 1° 58' 24.6"

Computation on Convergence:

Offset ΔE = -14810.562 m

"*Jumlah/Sel.*" for Longitude = -37030.370 - (- 14810.562) = -22219.808 m

"*Jumlah/Sel. + Offset*" for Longitude = -22219.808 + (- 14810.562) = -37030.370 m

"*Jumlah/Sel. + Offset*" in Geographical Sys. = 37030.370 * 0.03246 = 1202.006 "

"*Sel. G. Bujur x Sain G. Lintang*" = 1202.006 x Sin(1° 58' 24.6")= 41.4"

"*Tirusan*" is –ve if "*Jumlah/Sel. + Offset*" is +ve (east of old origin) and vice versa.

∴ "*Tirusan*" = 41.4"

Kordinat Origin **8758.320** m [U(+) S(-)]				Kordinat Origin **-14810.562** m
Stesen **-7625.009** m [U(+) S(-)]				Stesen **-37030.370** m
Jumlah/Sel. **-16383.329** m				Jumlah/Sel. **-22219.808** m
Jumlah/Sel. x 0.03256	**-0°**	**08'**	**53.44"**	Jumlah/Sel + Offset = -22219.808 - 14810.562 = -37030.370 m
G. Lintang Origin U	**2°**	**07'**	**18.05"**	
G. Lintang Stesen U	**1°**	**58'**	**24.6"**	Sel. G. Bujur = Jum/Sel x 0.03246 = 1202.006 "
				Sel. G. Bujur x Sain G. Lintang = **41.4** "
				T(-) B(+) Tirusan = **41.4"**

4.9.2 State of N. Sembilan & Melaka (Cassini-Soldner Origin ≠ Cassini-Soldner Offset)

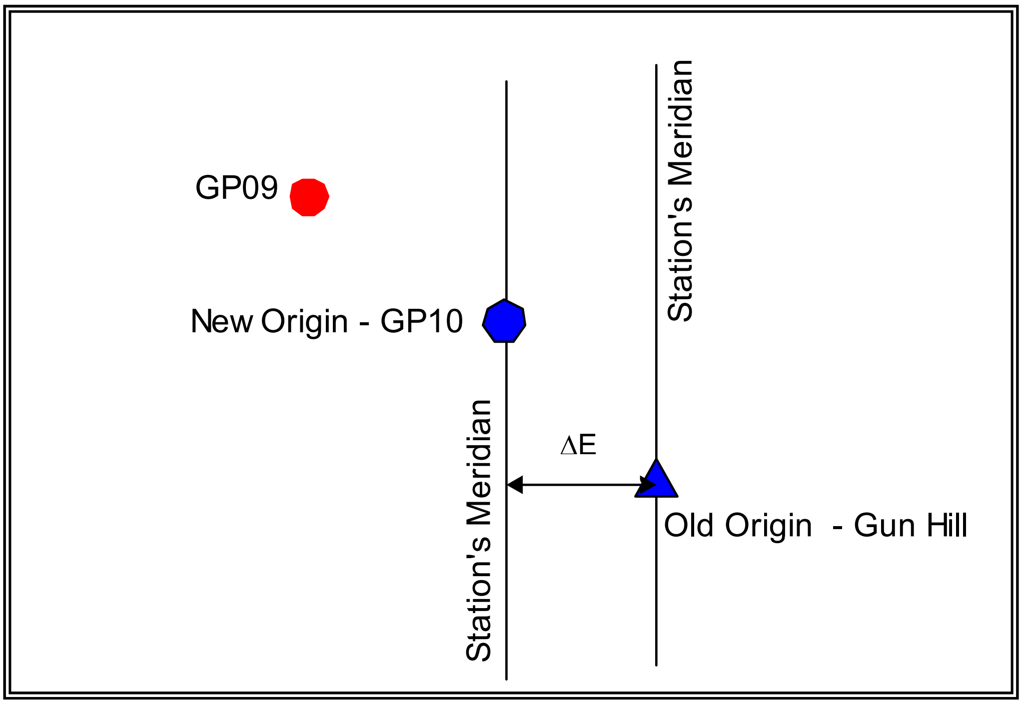


Figure 4.2: New and Old Origin for State of N. Sembilan & Melaka

<u>Example No. 1</u>

Given:

New State's Origin (as in Chapter 3):

Stn	Latitude (N)	Longitude (E)	Cass-N	Cass-E	Offset-N	Offset-E
GP10	2°40'56.45149"	103°58'29.65815''	-4240.573	3673.785	-3292.026	3915.790

Station's Information:

Stn	Latitude (N)	Longitude (E)	Cass-N	Cass-E
GP09	2°44'26.29311"	101°51'39.86533''	2205.474	-8983.465

COMPUTATION:

Note:

North and East coordinates sign are +ve and for South and West coordinates are –ve.

Computation on Station Latitude:

"*Jumlah/Sel.*" for Latitude = 2205.474 - (-4240.573) = 6446.047 m

"*Jumlah/Sel.*" in Geographical Sys. = 6446.047 * 0.03256 = 209.883 "

= 0° 03’ 29.88"

"*G. Lintang Stesen*" = 2°40’56.45 + (+ 0° 03’ 29.88") = 2° 44’ 26.3"

Computation on Convergence:

Offset Δ**E** = 3915.790 m

"*Jumlah/Sel.*" for Longitude = -8983.465 - (+ 3673.785) = -12657.250 m

"*Jumlah/Sel. + Offset* " for Longitude = -12657.250 + (+3915.790) = -8741.460 m

"*Jumlah/Sel. + Offset* " in Geographical Sys. = 8741.460 * 0.03246 = 283.748 "

"*Sel. G. Bujur x Sain G. Lintang*" = 283.748 x Sin(2° 44’ 26.3")= 13.6"

"*Tirusan*" is –ve if "*Jumlah/Sel. + Offset*" is +ve (east of old origin) and vice versa.

∴ "*Tirusan*" = 13.6"

<table>
<tr><td>Kordinat Origin</td><td colspan="3">-4240.573 m [U(+) S(-)]</td><td>Kordinat Origin 3673.785 m</td></tr>
<tr><td>Stesen</td><td colspan="3">2205.474 m [U(+) S(-)]</td><td>Stesen -8983.465 m</td></tr>
<tr><td>Jumlah/Sel.</td><td colspan="3">6446.047 m</td><td>Jumlah/Sel. - 12657.250 m</td></tr>
<tr><td>Jumlah/Sel. x 0.03256</td><td>+0°</td><td>03'</td><td>29.88"</td><td rowspan="2">Jumlah/Sel + Offset = -12657.250 + (+3915.790)
= -8741.460 m</td></tr>
<tr><td>G. Lintang Origin U</td><td>2°</td><td>40'</td><td>56.45"</td></tr>
<tr><td>G. Lintang Stesen U</td><td>2°</td><td>44'</td><td>26.3"</td><td>Sel. G. Bujur = Jum/Sel x 0.03246 ± 283.748 "</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Sel. G. Bujur x Sain G. Lintang = 13.6 "</td></tr>
<tr><td></td><td></td><td></td><td></td><td>T(-) B(+) Tirusan = 13.6 "</td></tr>
</table>

JUPEM

Appendix A

ZERO ORDER GPS NETWORK (MASS)

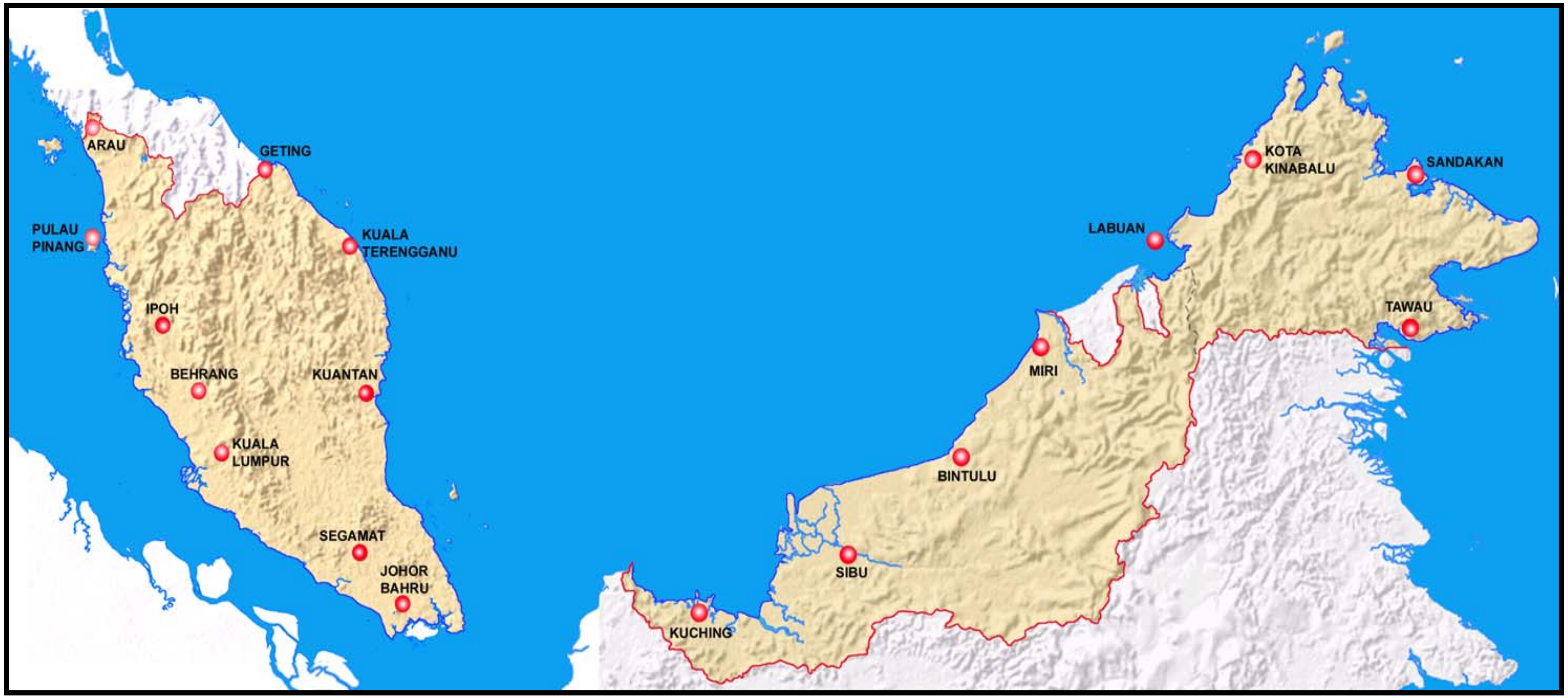


DIAGRAM AND DESCRIPTION FOR ZERO ORDER GPS NETWORK (MASS)

Stesen MASS *ARAU*, Kampus UITM, Perlis

Stesen MASS *USMP*, Kampus Universiti Sains Malaysia, Pulau Pinang

Stesen MASS *IPOH*, Kampus Politeknik Ungku Omar, Perak

Stesen MASS *BEHR*, Kampus Institut Tanah Dan Ukur Negara (INSTUT), Perak

Stesen MASS *KTPK*, Wisma Tanah, Kuala Lumpur Persekutuan

Stesen MASS *SEGA*, Kampus UITM, Segamat, Johor

Stesen MASS *UTMJ*, Kampus Universiti Teknologi Malaysia, Skudai, Johor

Stesen Mass *KUAN*, Jabatan Ukur dan Pemetaan Pahang, Kuantan, Pahang

Stesen MASS *KUAL*, Bukit Pak Apil, Kuala Terengganu, Terengganu

Stesen MASS *GETI*, Pangkalan Kubur, Kelantan

Stesen MASS *KUCH*, Kampus Politeknik Kuching, Kuching, Sarawak

Stesen MASS *SIBU*, Bangunan Jabatan Kerja Raya (JKR) Sibu, Sarawak

Stesen MASS *BINT*, Stesen Tolok Air Pasang-Surut, Pelabuhan Bintulu, Sarawak

Stesen MASS *MIRI*, Atas Bumbung Bangunan Gunasama Miri, Sarawak

Stesen MASS *KINA*, Kawasan Surau Tg. Dumpil, Kota Kinabalu, Sabah

Stesen MASS *SAND*, Jalan Istana, Sandakan, Sabah

Stesen MASS *MTAW*, Kawasan Rumah Kerajaan Tawau, Sabah

Stesen MASS *LABU*, Kawasan Rumah Kerajaan Jabatan Ukur Labuan, Sabah

Appendix B

LIST OF COORDINATES FOR ZERO ORDER GPS NETWORK (MASS) IN GDM2000

STATE	LOCATION OF GPS STATION	STN ID.	GDM2000 COORDINATES LATITUDE DD	LATITUDE MM	LATITUDE SS	LONGITUDE DD	LONGITUDE MM	LONGITUDE SS	E. HEIGHT (h) METRE
PERLIS	KAMPUS UITM, ARAU	ARAU	6	27	0.57078	100	16	47.05799	18.059
P. PINANG	KAMPUS UNIVERSITI SAINS MALAYSIA (USM), BUKIT JAMBUL	USMP	5	21	28.03730	100	18	14.53681	19.879
PERAK	KAMPUS POLITEKNIK UNGKU OMAR, IPOH	IPOH	4	35	8.49659	101	07	34.23736	41.834
PERAK	KAMPUS INSTITUT TANAH DAN UKUR NEGARA (INSTUN)	BEHR	3	45	55.33344	101	31	1.96370	68.690
W.PERSEKUTUAN (K. LUMPUR)	WISMA TANAH, KTPK , JLN SEMARAK	KTPK	3	10	15.39787	101	43	3.39045	99.767
JOHOR	KAMPUS UITM, SEGAMAT	SEGA	2	29	10.67041	102	43	55.34897	25.232
JOHOR	KAMPUS UNIVERSITI TEKNOLOGI MALAYSIA (UTM), SKUDAI	UTMJ	1	33	56.93325	103	38	22.43053	80.421
PAHANG	JABATAN UKUR DAN PEMETAAN PAHANG	KUAN	3	50	3.76134	103	21	1.26981	25.415
TERENGGANU	BUKIT PAK APIL, K. TERENGGANU	KUAL	5	19	8.00193	103	8	20.92585	54.978
KELANTAN	GETING, PENGKALAN KUBUR	GETI	6	13	34.29291	102	6	19.66793	-0.496
SARAWAK	KAMPUS POLITEKNIK KUCHING, MATANG	KUCH	1	37	56.63675	110	11	42.32830	79.401
SARAWAK	BANGUNAN JKR SIBU, SIBU	SIBU	2	16	12.13506	111	50	33.96178	46.768
SARAWAK	STESEN AIR PASANG-SURUT, PELABUHAN BINTULU	BINT	3	15	41.42519	113	4	1.99107	48.775
SARAWAK	ATAS BUMBUNG BANGUNAN GUNASAMA MIRI	MIRI	4	22	19.56375	114	0	6.27136	62.394
SABAH	KAWASAN SURAU TG. DUMPIL, KOTA KINABALU	KINA	5	54	16.57533	116	2	21.47206	51.734
SABAH	JALAN ISTANA , SANDAKAN	SAND	5	50	32.65585	118	7	14.10168	133.500
SABAH	KAWASAN RUMAH KERAJAAN TAWAU	MTAW	4	15	45.98900	117	52	53.93073	72.875
SABAH	KAWASAN RUMAH KERAJAAN JABATAN UKUR LABUAN	LABU	5	16	57.61609	115	14	41.23196	49.741

Appendix C

LIST OF PRIMARY GPS NETWORK STATION LOCATIONS IN PENINSULAR MALAYSIA

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS NO.	MONUMENT	TYPE OF STATION
JOHOR	KOTA TINGGI	FELDA PENGGELI	13DJ	TYPE-B	NEW
JOHOR	GELANG PATAH	TG KUPANG	DOP2	OLD PIPE	DOPPLER-30401
JOHOR	MUAR	SEK MEN SAINS MUAR	GP15	TYPE-B	NEW
JOHOR	PAGOH	PLUS PAGOH	GP16	TYPE-B	NEW
JOHOR	MERSING	KG. MAWAR	GP43	TYPE-B	NEW
JOHOR	LABIS	SRK AIR PANAS	GP44	TYPE-B	NEW
JOHOR	LABIS	FELDA CHEMPLAK	GP47	TYPE-B	NEW
JOHOR	BATU PAHAT	LOJI AIR SERI MEDAN	GP48	TYPE-B	NEW
JOHOR	PONTIAN	JPS BENUT	GP49	TYPE-B	NEW
JOHOR	PONTIAN KECHIL	SMK AIR PASONG	GP50	TYPE-B	NEW
JOHOR	KULAI	LPG. TERBANG SENAI	GP51	TYPE-B	NEW
JOHOR	KOTA TINGGI	TELUK RAMUNIA	GP52	TYPE-B	NEW
JOHOR	KOTA TINGGI	JPS KG LUKUT, SPG EMPAT	GP53	TYPE-B	NEW
JOHOR	KOTA TINGGI	SRK (AGAMA) KUALA SEDELI	GP54	TYPE-B	NEW
JOHOR	KOTA TINGGI	FELDA TENGGAROH	GP55	TYPE-B	NEW
JOHOR	MERSING	LPG. TERBANG MERSING	GP56	TYPE-B	NEW
JOHOR	KLUANG	BUKIT TAWAI	GP57	TYPE-B	NEW
JOHOR	KLUANG	INSTITUT HAIWAN KLUANG	GP58	TYPE-B	NEW
JOHOR	KLUANG	INSTITUT PERTANIAN AIR HITAM	GP59	TYPE-B	NEW
JOHOR	RENGGAM	SMK RENGGAM	GP60	TYPE-B	NEW
JOHOR	KLUANG	PADANG AWAM PALOH	GP61	TYPE-B	NEW
JOHOR	BATU PAHAT	SRK DATO' ONN	GP84	TYPE-B	NEW
JOHOR	BATU PAHAT	SRK LEBAI ALI TG TOHOR	GP85	TYPE-B	NEW
JOHOR	KOTA TINGGI	STAPS KUALA SEDELI	GP90	BRASS PLATE	NEW
JOHOR	KOTA TINGGI	FELCRA KG ASAM, HULU SEDELI	GP91	TYPE-B	NEW
JOHOR	JOHOR BAHARU	STAPS JETI JOHOR BAHARU	J416	BENCH-MARK	BENCH-MARK
JOHOR	PONTIAN KECHIL	STAPS KUKUP	TD01	TIDE HOUSE	TIDAL
JOHOR	MUAR	GUNUNG LEDANG, TANGKAK	TG04	TYPE-A	NEW

GEOCENTRIC DATUM OF MALAYSIA 2000

JUPEM

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS NO.	MONUMENT	TYPE OF STATION
JOHOR	MUAR	BUKIT BATU BERTARAH, LABIS	TG05	OLD PIPE	TRIG-P063
JOHOR	KOTA TINGGI	BUKIT TANGGA TUJUH	TG07	TYPE-A	TRIG-P072
JOHOR	KLUANG	BUKIT TANAH ABANG	TG09	OLD PIPE	TRIG-P006
JOHOR	KOTA TINGGI	BUKIT BELUNGKOR, SG RENGIT	TG10	OLD PIPE	TRIG-G006
JOHOR	PONTIAN	PULAU PISANG	TG19	TYPE-A	TRIG-P074
KEDAH	ALOR SETAR	ALOR SETAR SOUTH BASE	DOP5	OLD PIPE	DOPPLER-30404
KEDAH	YAN	BALAI POLIS YAN	K350	BENCH-MARK	BENCH-MARK
KEDAH	KULIM	SRK TERAP	P285	TYPE-B	NEW
KEDAH	BALING	SRK ULU SEDIM	P287	TYPE-B	NEW
KEDAH	ALOR SETAR	BUKIT PETERI, KUALA MUDA	P289	TYPE-B	NEW
KEDAH	SG PETANI	TAMAN KELADI BAKAR ARANG	P290	TYPE-B	NEW
KEDAH	KULIM	SRK PADANG SERAI II	P291	TYPE-B	NEW
KEDAH	SG PETANI	SMK KUALA KETIL	P292	TYPE-B	NEW
KEDAH	JENIANG	SRK TG SULONG	P293	TYPE-B	NEW
KEDAH	ALOR SETAR	SRK PADANG PUSING, K. SETAR	P295	TYPE-B	NEW
KEDAH	ALOR SETAR	SRK KUBUR PANJANG, K. SETAR	P296	TYPE-B	NEW
KEDAH	ALOR SETAR	SRK KANGKONG	P297	TYPE-B	NEW
KEDAH	ALOR SETAR	SRJK (CINA) JERLUN	P298	TYPE-B	NEW
KEDAH	BALING	BUKIT TERBIL, SIK	P304	TYPE-B	TRIG-S283
KEDAH	BALING	FELCRA BENDANG MAN	P305	TYPE-B	NEW
KEDAH	BALING	KOMPLEKS SUKAN BALING	P306	TYPE-B	NEW
KEDAH	ALOR SETAR	GUNUNG PERAK, KUALA MUDA	TG35	OLD PIPE	TRIG-G057
KEDAH	ALOR SETAR	BUKIT TUNJANG,KOTA SETAR	TG38	OLD PIPE	TRIG-G071
KEDAH	BALING	BUKIT BATU TAJAM,SIK	TG56	OLD PIPE	TRIG-S282
KELANTAN	PASIR PUTIH	BUKIT MARAK, PASIR PUTIH	DOP4	OLD PIPE	DOPPLER-30399
KELANTAN	GUA MUSANG	SEK REN KEB LIMAU KASTURI	P083	TYPE-B	NEW
KELANTAN	GUA MUSANG	SEK MEN KEB GUA MUSANG	P220	TYPE-B	NEW
KELANTAN	GUA MUSANG	FELDA CIKU V	P221	TYPE-B	NEW

GEOCENTRIC DATUM OF MALAYSIA 2000

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS NO.	MONUMENT	TYPE OF STATION
KELANTAN	GUA MUSANG	S. KERETAPI KEMUBU	P222	TYPE-B	NEW
KELANTAN	GUA MUSANG	KG LEPAR	P223	TYPE-B	NEW
KELANTAN	KUALA KERAI	RUMAH GURU KG LALOH	P224	TYPE-B	NEW
KELANTAN	KUALA KERAI	SM VOKASIONAL KUALA KERAI	P225	TYPE-B	NEW
KELANTAN	PASIR PUTIH	BUKIT PERAKSI	P242	TYPE-B	TRIG-P018
KELANTAN	KOTA BAHARU	BALAI POLIS MELOR	P243	TYPE-B	NEW
KELANTAN	MACHANG	HOSPITAL DAERAH MACHANG	P244	TYPE-B	NEW
KELANTAN	MACHANG	TEMANGAN BARU	P245	TYPE-B	NEW
KELANTAN	MACHANG	SRK KUBUR DATU, TANAH MERAH	P246	TYPE-B	NEW
KELANTAN	JELI	SEK REN KEB JELI	P247	TYPE-B	NEW
KELANTAN	MACHANG	KG NIBONG, TANAH MERAH	P248	TYPE-B	NEW
KELANTAN	PASIR MAS	SEK MEN KEB RANTAU PANJANG	P249	TYPE-B	NEW
KELANTAN	PASIR MAS	STESEN KERETAPI PASIR MAS	P250	TYPE-B	NEW
KELANTAN	GUA MUSANG	POST RPS KUALA BETIS	P263	TYPE-B	NEW
KELANTAN	GUA MUSANG	POST RPS KG TOHOI	P264	TYPE-B	NEW
KELANTAN	GUA MUSANG	FELDA ARING I	P265	TYPE-B	NEW
KELANTAN	GUA MUSANG	FELDA ARING V	P267	TYPE-B	NEW
KELANTAN	GUA MUSANG	RPS KG LEPAR	P268	TYPE-B	NEW
KELANTAN	PASIR MAS	STAPS GETTING,TUMPAT	S136	SBM	BM
KELANTAN	PASIR MAS	BUKIT KEMAHANG	TG27	OLD PIPE	TRIG-G032
KELANTAN	KUALA KERAI	BUKIT LUMUT	TG31	OLD PIPE	TRIG-G042
MELAKA	ALOR GAJAH	SMK LUBOK CINA	GP12	TYPE-B	NEW
MELAKA	ALOR GAJAH	SRJK (TAMIL), TEBUNG	GP13	TYPE-B	NEW
MELAKA	ALOR GAJAH	STAPS PELABUHAN TG KELING	M331	BENCH-MARK	BENCH-MARK
MELAKA	MELAKA	BUKIT CINA	TG03	TYPE-A	TRIG-P103
N. SEMBILAN	SEREMBAN	SM AGAMA PERSEKUTUAN, LABU	GP09	TYPE-B	NEW
N. SEMBILAN	SEREMBAN	K. PERINDUSTRIAN SENAWANG	GP10	TYPE-B	NEW
N. SEMBILAN	P. DICKSON	TANJUNG TUAN	GP11	TYPE-B	NEW
N. SEMBILAN	GEMAS	SEK MEN KEB GEMAS	GP14	TYPE-B	NEW
N. SEMBILAN	JELEBU	SEK MEN KEB UNDANG LUAK	GP19	TYPE-B	NEW
N. SEMBILAN	BAHAU	SEK REN KEB AIR HITAM	GP20	TYPE-B	NEW
N. SEMBILAN	JELEBU	RPS FELCRA KG ESOK, K.KLAWANG	GP87	TYPE-B	NEW
N. SEMBILAN	BAHAU	BUKIT GELUGOR, BATU KIKIR	TG01	TYPE-A	TRIG-G020

GEOCENTRIC DATUM OF MALAYSIA 2000

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS NO.	MONUMENT	TYPE OF STATION
N. SEMBILAN	TAMPIN	BUKIT JELAI BESAR	TG20	OLD PIPE	TRIG-G012
PAHANG	TEMERLOH	BUKIT KERTAU, KG NYAK	DOP3	OLD PIPE	DOPPLER-30398
PAHANG	TEMERLOH	RPS POST ISKANDAR, KEMAYAN	G100	TYPE-B	NEW
PAHANG	BENTONG	SEK MEN KEB SPG PELANGAI	GP21	TYPE-B	NEW
PAHANG	TEMERLOH	T. PERINDUSTRIAN SONGSANG	GP22	TYPE-B	NEW
PAHANG	BENTONG	SEK MEN KEB LKTP SERTIK	GP24	TYPE-B	NEW
PAHANG	BENTONG	KG TERIS, LANCANG	GP25	TYPE-B	NEW
PAHANG	JERANTUT	KG TERSANG	GP26	TYPE-B	NEW
PAHANG	JERANTUT	KG TG BESAR	GP27	TYPE-B	NEW
PAHANG	JERANTUT	BALAI POLIS MELA	GP28	TYPE-B	NEW
PAHANG	JERANTUT	SEK REN KEB KUALA MAI	GP31	TYPE-B	NEW
PAHANG	MARAN	FELDA SG JERIK	GP32	TYPE-B	NEW
PAHANG	MARAN	TASIK PAYA BUNGOR	GP33	TYPE-B	NEW
PAHANG	KUANTAN	BALAI POLIS BESERAH	GP34	TYPE-B	NEW
PAHANG	KUANTAN	LAPANGAN TERBANG KUANTAN	GP35	TYPE-B	NEW
PAHANG	PEKAN	RPS PALOH HINAI	GP36	TYPE-B	NEW
PAHANG	PEKAN	MASJID TG AGAS, NENASI	GP37	TYPE-B	NEW
PAHANG	PEKAN	TG BATU, KUALA ROMPIN	GP38	TYPE-B	NEW
PAHANG	PEKAN	KG BAGONG, LEBAN CONDONG	GP39	TYPE-B	NEW
PAHANG	MUADZAM SHAH	BUKIT GAYONG, MUADZAM SHAH	GP40	TYPE-B	NEW
PAHANG	PEKAN	FELDA SELENDANG TIGA, ROMPIN	GP41	TYPE-B	NEW
PAHANG	PEKAN	BALAIRAYA KG. JAWA, ROMPIN	GP42	TYPE-B	NEW
PAHANG	RAUB	POST UKK TERAS	GP45	TYPE-B	NEW
PAHANG	MARAN	FELDA LEPAR UTARA I	GP79	TYPE-B	NEW
PAHANG	MARAN	KG BELIMBING, TASIK CINI	GP80	TYPE-B	NEW
PAHANG	MARAN	FELDA KOTA GELANGGI V	GP81	TYPE-B	NEW
PAHANG	BENTONG	PERANGINAN G. HIGHLANDS	GP86	TYPE-B	NEW
PAHANG	TEMERLOH	RPS FELDA SEBERTAK	GP88	TYPE-B	NEW
PAHANG	MUADZAM SHAH	ESTATE HWA LEE KERATONG	GP89	TYPE-B	NEW
PAHANG	PEKAN	KG PENCHOR	GP94	TYPE-B	NEW
PAHANG	MUADZAM SHAH	RPS RUNCHANG,KUALA ROMPIN	GP95	TYPE-B	NEW
PAHANG	TEMERLOH	RPS BUKIT SEROK	GP98	TYPE-B	NEW
PAHANG	MUADZAM SHAH	BUKIT IBAM	GP99	TYPE-B	NEW

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS NO.	MONUMENT	TYPE OF STATION
PAHANG	C. HIGHLANDS	RINGLET	P212	TYPE-B	NEW
PAHANG	C. HIGHLANDS	KUALA TERLA	P213	TYPE-B	NEW
PAHANG	C. HIGHLANDS	POST BROOKS	P214	TYPE-B	NEW
PAHANG	K. LIPIS	INSTITUT PERTANIAN	P215	TYPE-B	NEW
PAHANG	K. LIPIS	SEK REN KEB KUALA MEDANG	P216	TYPE-B	NEW
PAHANG	K. LIPIS	POST BETAU	P217	TYPE-B	NEW
PAHANG	K. LIPIS	KG BANDAR	P218	TYPE-B	NEW
PAHANG	K. LIPIS	BALAI POLIS CHEGAR PERAH	P219	TYPE-B	NEW
PAHANG	JERANTUT	KG BATU GARANG	P260	TYPE-B	NEW
PAHANG	JERANTUT	BALAI POLIS KUALA TAHAN	P261	TYPE-B	NEW
PAHANG	C. HIGHLANDS	RPS POST LEMOI	P269	TYPE-B	NEW
PAHANG	C. HIGHLANDS	GUNUNG BERINCHANG	P351	TYPE-B	NEW
PAHANG	C. HIGHLANDS	GUNUNG GANDEK	P352	TYPE-B	TRIG-S046
PAHANG	KUALA LIPIS	SEKOLAH TABIKA KUBANG RUSA	P500	SBM	BENCH-MARK
PAHANG	TEMERLOH	BUKIT KERISEK	TG06	TYPE-A	TRIG-G039
PAHANG	MUADZAM SHAH	BUKIT AUR	TG11	TYPE-A	TRIG-S041
PAHANG	KUANTAN	BUKIT SAH	TG13	OLD PIPE	TRIG-S006
PAHANG	KUANTAN	BUKIT KENAU, SG LEMBING	TG14	OLD PIPE	TRIG-S051
PAHANG	TEMERLOH	BUKIT BESAR, MENTAKAB	TG15	OLD PIPE	TRIG-G009
PAHANG	KUANTAN	STAPS TG GELANG	TG24	SPIKE	NEW
PAHANG	JERANTUT	BUKIT KEREJUR, BDR. JERANTUT	TG25	TYPE-A	NEW
PAHANG	C. HIGHLANDS	GUNUNG IRAU	TG57	OLD PIPE	TRIG-S430
PAHANG	C. HIGHLANDS	GUNUNG SWETHENHAM	TG58	OLD PIPE	TRIG-S195
PAHANG	C. HIGHLANDS	GUNUNG CHANTEK	TG59	OLD PIPE	TRIG-S192
PERAK	TELUK INTAN	HOSPITAL DAERAH TELUK INTAN	GP02	TYPE-B	NEW
PERAK	BIDOR	SEK MEN KEB SUNGKAI	GP07	TYPE-B	NEW
PERAK	SLIM RIVER	JPS KUALA SLIM BATANG PADANG	GP29	TYPE-B	NEW
PERAK	SLIM RIVER	KG BEHRANG BATANG PADANG	GP30	TYPE-B	NEW
PERAK	BAGAN DATOH	PUSAT KESIHATAN SELEKOH	GP82	TYPE-B	NEW
PERAK	TELUK INTAN	KLINIK KG GAJAH	P101	TYPE-B	NEW
PERAK	SITIAWAN	JPS PANTAI REMIS	P102	TYPE-B	NEW
PERAK	TAPAH	PPH SENOI PRAAQ, BIDOR	P201	TYPE-B	NEW
PERAK	IPOH	SEK MEN KEB KAMPAR	P202	TYPE-B	NEW

GEOCENTRIC DATUM OF MALAYSIA 2000

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS NO.	MONUMENT	TYPE OF STATION
PERAK	IPOH	SEK MEN KEB GOPENG	P203	TYPE-B	NEW
PERAK	IPOH	TAMAN SRI RAPAT	P204	TYPE-B	NEW
PERAK	PARIT	TAMAN PARIT JAYA	P205	TYPE-B	NEW
PERAK	PARIT	SEK REN KEB BOTA KIRI	P207	TYPE-B	NEW
PERAK	SITIAWAN	BUKIT NAGA	P209	TYPE-B	NEW
PERAK	SITIAWAN	LPG. TERBANG LAMA SITIAWAN	P210	TYPE-B	NEW
PERAK	MANJUNG	PULAU PANGKOR	P211	PIPE	NEW
PERAK	K. KANGSAR	P. KESIHATAN KECIL TANAH HITAM	P270	TYPE-B	NEW
PERAK	K. KANGSAR	RPS POST LEGAP	P271	TYPE-B	NEW
PERAK	K. KANGSAR	FELDA LASAH	P272	TYPE-B	NEW
PERAK	K. KANGSAR	LOJI AIR SG SIPUT	P273	TYPE-B	NEW
PERAK	K. KANGSAR	SEK MEN KEB CHILFORD	P274	TYPE-B	NEW
PERAK	K. KANGSAR	KLINIK SAUK	P275	TYPE-B	NEW
PERAK	K. KANGSAR	SMK DATO' AHMAD LENGGONG	P276	TYPE-B	NEW
PERAK	GERIK	FELDA LAWIN UTARA, LENGGONG	P277	TYPE-B	NEW
PERAK	TAIPING	PADANG AWAM KUALA SEPETANG	P278	TYPE-B	NEW
PERAK	TAIPING	BUKIT HULU SEPETANG	P279	TYPE-B	TRIG-P215
PERAK	TAIPING	SRK. JEMERANG SETAR SELAMA	P280	TYPE-B	NEW
PERAK	BAGAN SERAI	JPS SG BOGAK, KRIAN	P281	TYPE-B	NEW
PERAK	TAIPING	SEK REN KEB SG SEPUTIH, SELAMA	P286	TYPE-B	NEW
PERAK	GRIK	M. TENTERA DARAT KELIAN INTAN	P307	TYPE-B	NEW
PERAK	GRIK	BANDING CAUSEWAY	P308	TYPE-B	NEW
PERAK	GRIK	POST 28 LEBUHRAYA TIMUR-BARAT	P309	TYPE-B	NEW
PERAK	GRIK	SMK TENGKU IDRIS SHAH	P310	TYPE-B	NEW
PERAK	GRIK	RPS KEMAR-TEMENGGOR	P311	TYPE-B	NEW
PERAK	K. KANGSAR	RPS POST PIAH, LENGGONG	P313	TYPE-B	NEW
PERAK	KEROH	PPH POST 8, NENERING KEROH	P808	NEW PIPE	NEW
PERAK	GRIK	H. SIMPAN BELUM, SG TIANG BANDING	P809	NEW PIPE	NEW
PERAK	MANJUNG	STAPS TLDM LUMUT	S290	SBM	BENCH-MARK
PERAK	TAIPING	BUKIT NARAN, BATANG PADANG	T190	OLD PIPE	TRIG-P153
PERAK	TAIPING	CHANGKAT KUNING	T200	OLD PIPE	TRIG-P148
PERAK	TAIPING	GUNUNG LARUT HIJAU	TG26	OLD PIPE	TRIG-G024
PERAK	GERIK	GUNUNG BUBU	TG42	OLD PIPE	TRIG-S252
PERLIS	KANGAR	SEK MEN KEB JEJAWI	P299	TYPE-B	NEW

GEOCENTRIC DATUM OF MALAYSIA 2000

JUPEM

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS NO.	MONUMENT	TYPE OF STATION
P. PINANG	SEB. PERAI	NIBONG TEBAL	P282	TYPE-B	NEW
P. PINANG	SEB. PERAI	P. KESIHATAN KECIL BATU KAWAN	P283	TYPE-B	NEW
P. PINANG	SEB. PERAI	KG PENAGA	P288	TYPE-B	NEW
P. PINANG	PULAU PINANG	TLDM GEORGETOWN	P314	TYPE-B	NEW
P. PINANG	SEB. PERAI	BUKIT PANCHOR	TG33	OLD PIPE	TRIG-G053
P. PINANG	PULAU PINANG	BUKIT RELAU, GEORGETOWN	TG36	OLD PIPE	TRIG-G063
SELANGOR	SHAH ALAM	SEK REN KEB KG MELAYU SUBANG	149B	TYPE-B	NEW
SELANGOR	K. KUBU BAHARU	FELDA SOEHARTO	251D	PIPE	NEW
SELANGOR	KLANG	BUKIT LIPAT KAJANG	DOP1	OLD PIPE	DOPPLER-30397
SELANGOR	SABAK BERNAM	BAGAN TELUK RHU	GP03	TYPE-B	NEW
SELANGOR	SABAK BERNAM	DEWAN ORANG RAMAI BGN. TERAP	GP04	TYPE-B	NEW
SELANGOR	SEKINCHAN	SEK REN JENIS KEB (C) KHIAN SIT	GP05	TYPE-B	NEW
SELANGOR	K. SELANGOR	JPS SRI TIRAM, TG KARANG	GP06	TYPE-B	NEW
SELANGOR	HULU LANGAT	LOJI PENAPIS AIR, BT 11, CHERAS	GP08	TYPE-B	NEW
SELANGOR	K. SELANGOR	BALAI NELAYAN, PANTAI JERAM	GP17	TYPE-B	NEW
SELANGOR	BANTING	RUMAH PERSEKUTUAN, MORIB	GP18	TYPE-B	NEW
SELANGOR	SELAYANG	KG MELAYU BT 16, RAWANG	GP23	TYPE-B	NEW
SELANGOR	TG MALIM	BUKIT PERABONG, K. KUBU BARU	TG18	TYPE-A	TRIG-G061
TERENGGANU	K. BERANG	SG CACHING, TASIK KENYIR	P105	TYPE-B	NEW
TERENGGANU	K. BERANG	KG BELIMBING, TASIK KENYIR	P106	TYPE-B	NEW
TERENGGANU	K. BERANG	KG SG TEMBAT, TASIK KENYIR	P107	TYPE-B	NEW
TERENGGANU	KEMAMAN	SEK REN KEB KEMAMAN	P226	TYPE-B	NEW
TERENGGANU	KEMAMAN	PUSAT KESIHATAN KECIL, KIJAL	P227	TYPE-B	NEW
TERENGGANU	KERTIH	PUSAT BANDAR BARU KERTIH	P228	TYPE-B	NEW
TERENGGANU	DUNGUN	KG MOLEK, KUALA DUNGUN	P229	TYPE-B	NEW
TERENGGANU	MARANG	SEK REN KEB MERCHANG	P230	TYPE-B	NEW
TERENGGANU	MARANG	SEK REN KEB PULAU KERENGGA	P231	TYPE-B	NEW
TERENGGANU	K. TERENGGANU	LPG. TERBANG TELAGA BATIN	P232	TYPE-B	NEW
TERENGGANU	K. TERENGGANU	DEWAN KG SRI RAWAI	P233	TYPE-B	NEW
TERENGGANU	K. TERENGGANU	KG TEKAH	P234	TYPE-B	NEW
TERENGGANU	BESUT	KG BUKIT GETING	P235	TYPE-B	NEW
TERENGGANU	SETIU	KG RAHMAT	P236	TYPE-B	NEW
TERENGGANU	BESUT	BUKIT BIDONG DARAT	P237	TYPE-B	TRIG-P020
TERENGGANU	SETIU	KG PENARIK	P238	TYPE-B	NEW

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS NO.	MONUMENT	TYPE OF STATION
TERENGGANU	BESUT	JPS JERTIH	P239	TYPE-B	NEW
TERENGGANU	BESUT	KG BUKIT PAYONG	P240	TYPE-B	NEW
TERENGGANU	BESUT	KG KERUAK	P241	TYPE-B	NEW
TERENGGANU	K. BERANG	PLANA 'A' TASIK KENYIR	P251	TYPE-B	NEW
TERENGGANU	K. BERANG	TAMAN REKRASI SEKAYU	P252	TYPE-B	NEW
TERENGGANU	K. TERENGGANU	KG MATANG, HULU TERENGGANU	P253	TYPE-B	NEW
TERENGGANU	DUNGUN	KG MINDA	P254	TYPE-B	NEW
TERENGGANU	DUNGUN	KG SYUKUR	P255	TYPE-B	NEW
TERENGGANU	DUNGUN	KG DURIAN MAS	P256	TYPE-B	NEW
TERENGGANU	KEMAMAN	KG PADANG KUBU	P257	TYPE-B	NEW
TERENGGANU	KEMAMAN	FELDA AIR PUTIH	P258	TYPE-B	NEW
TERENGGANU	KEMAMAN	FELDA CERUL I	P259	TYPE-B	NEW
TERENGGANU	MARANG	STAPS LKIM CHENDERING	T283	BENCH-MARK	BENCH-MARK
TERENGGANU	BESUT	BUKIT YONG	TG28	OLD PIPE	TRIG-G077
TERENGGANU	BESUT	BUKIT PETERI	TG61	TYPE-A	NEW

Appendix D

LIST OF COORDINATES IN GDM2000 FOR PENINSULAR MALAYSIA PRIMARY GPS NETWORK

Please contact :

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Appendix E

LIST OF PRIMARY GPS NETWORK STATION LOCATIONS IN EAST MALAYSIA

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS STATIONS NO
SABAH	KUDAT	JETI PELABUHAN KUDAT, TAPS KUDAT	A102
SABAH	LABUAN	BKT. TIMBALAI	D001
SABAH	TAWAU	BUKIT TINAGAT	D004
SABAH	KOTA BELUD	RUMOLOH	D005
SABAH	KUDAT	SIKUATI, KURIMA	D006
SABAH	TAWAU	BUKIT TINAGAT	GD01
SABAH	PAPAR	KAYAU	M101
SABAH	PENAMPANG	KG. TAGUDON, GUNUNG EMAS	M102
SABAH	RANAU	KG. MANGGIS	M104
SABAH	RANAU	PAUS	M105
SABAH	KOTA MARUDU	KG. SOROPON	M201
SABAH	KOTA MARUDU	KG. TIMBANG BATU	M202
SABAH	KUDAT	URUSETIA KECIL MATUNGGONG	M203
SABAH	KUDAT	KG. BINGOLON	M204
SABAH	LABUK SUGUT	KG. MURUD KURUD	M301
SABAH	KINABATANGAN	HULU TELUPID, ENTILIBON	M302
SABAH	KINABATANGAN	KG. MALIAU, BANGKULAT, IMBAK	M303
SABAH	KINABATANGAN	KG. TANGKULAP, BANGKULAT	M304
SABAH	LABUK SUGUT	ULU SAPA PAYAU	M305
SABAH	LABUK SUGUT	JLN. LABUK, BELURAN, TOPOD	M306
SABAH	LABUK SUGUT	DEWAN MASYARAKAT BELURAN	M307
SABAH	LABUK SUGUT	BASAI	M309
SABAH	LABUK SUGUT	KOLAYAK	M310
SABAH	SANDAKAN	KG. SUNGAI BERUANG	M311
SABAH	KINABATANGAN	KG. SANGAU, BUKIT GARAM, PINTASAN	M313
SABAH	KINABATANGAN	GOMANTONG JAYA	M315
SABAH	KINABATANGAN	SEKOLAH KAMPUNG BILIT	M316
SABAH	KINABATANGAN	KEM PANG BROTHERS, HULU KUAMUT	M401
SABAH	TAWAU	KG. SARUDONG	M402
SABAH	TAWAU	SG. SESUI, SIMPANG 9	M403

GEOCENTRIC DATUM OF MALAYSIA 2000

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS STATIONS NO.
SABAH	TAWAU	LUASONG, MEROTAI, MALANDOT	M404
SABAH	TAWAU	PEJABAT PERHUTANAN, BRANTIAN	M405
SABAH	LAHAD DATU	LEMBAH DANUM, BORNEO RAIN FOREST	M406
SABAH	TAWAU	BALAI POLIS WALLACE BAY	M407
SABAH	TAWAU	KG. KARITO	M408
SABAH	TAWAU	LDG. MAJU KOKO, SUNGAI BALUNG	M409
SABAH	SEMPORNA	SG.PINANG BESAR	M410
SABAH	SEMPORNA	PULAU TIMBUN MATA	M411
SABAH	TAWAU	ULU KELUMPANG	M412
SABAH	KUNAK	LADANG WEE FONG, ULU TINGKAYU	M413
SABAH	LAHAD DATU	PEJABAT YAYASAN SABAH, DIWATA	M414
SABAH	LAHAD DATU	TALIWAS FORESTRY	M415
SABAH	LAHAD DATU	PDG. BOLA LDG.MANSULI	M416
SABAH	TUNGKU L.DATU	SERI PUTATA, JLN. LAHAD	M417
SABAH	LAHAD DATU	LDG.MATAMBA, SILABUKAN	M418
SABAH	LAHAD DATU	KG. LITANG	M419
SABAH	LAHAD DATU	KG. MEMBATU	M420
SABAH	LAHAD DATU	FELDA SAHABAT 16	M421
SABAH	LAHAD DATU	FELDA SAHABAT 50	M422
SABAH	KINABATANGAN	TANJUNG HOG, DENT HAVEN	M423
SABAH	KINABATANGAN	TAMBISAN DARAT	M424
SABAH	KENINGAU	SEK. KEB. ANSIP	M501
SABAH	TENOM	PEKAN KEMABONG	M502
SABAH	PENSIANGAN	PEJABAT JKR SOOK	M503
SABAH	KENINGAU	KG. TAKUL	M504
SABAH	PENSIANGAN	KG. MATIKU, SEPULUT	M505
SABAH	PENSIANGAN	SRK LABANG	M506
SABAH	PENSIANGAN	KG. SIBUA	M507
SABAH	PENSIANGAN	KEM ATUR JAYA, SEPULUT	M508
SABAH	PENSIANGAN	SURAU SALIHA CAMP B	M509

JUPEM

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS STATIONS NO.
SABAH	BEAUFORT	SEK. KEB. WESTON	M510
SABAH	SIPITANG	SEK. KEB. MALIGAN	M511
SABAH	BEAUFORT	LIMBAYONG	T002
SABAH	BEAUFORT	BKT. BANTAYAN	T003
SABAH	BEAUFORT	ULU MEMBAKUT	T004
SABAH	MEMBAKUT	BKT. MANDAHAN	T101
SABAH	KENINGAU	MALAING	T102
SABAH	PENSIANGAN	LUMUTAN	T103
SABAH	TAWAU	UMAS-UMAS, BRUMAS SOFTWOOD	T104
SABAH	TAWAU	SEK. KEB. SG.PUKUL	T105
SABAH	TAWAU	KG. WAKUBA	T106
SABAH	TAWAU	SEMPORNA, CORNER	T107
SABAH	TAWAU	KUNAK, LORMARLONG	T108
SABAH	LAHAD DATU	CHELLATHUREY	T109
SABAH	KENINGAU	DOMPOI	T111
SABAH	TAMBUNAN	KG. KAINGARAN, PAPAYA	T112
SABAH	TAMBUNAN	KG. KEROKOT LAUT	T113
SABAH	PENAMPANG	KG. LOK KAWI BARU	T114
SABAH	PAPAR	PANTAI MANIS, KINANDUKAN	T115
SABAH	RANAU	RANAU	T116
SABAH	TUARAN	JLN. TUARAN-RANAU, KOKOHITAN	T117
SABAH	TUARAN	TENGHILAN	T118
SABAH	KOTA BELUD	KG. KUALA ABAI, PULAU USUKAN	T119
SABAH	KOTA BELUD	KG. TIMBANG MENGGARIS, RAMPAYAN	T120
SABAH	KUDAT	TIGA PAPAN	T121
SABAH	PITAS	KG. TIGA TAROK, BATU TIRAM	T122
SABAH	PITAS	SENAJA	T123
SABAH	RANAU	SAGINDI	T124
SABAH	LABUK SUGUT	DOJI, TELUPID	T125
SABAH	LABUK SUGUT	KG. BAKUNG, BELURAN, MORONGGO	T126
SABAH	SANDAKAN	KM-58 JLN. SANDAKAN, CPT. SANDAKAN	T127

GEOCENTRIC DATUM OF MALAYSIA 2000

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS STATIONS NO.
SABAH	KINABATANGAN	BRINCANG PLANTATION, SEKONG	T128
SABAH	TUARAN	TELIPOK, MENGATAL, LOK BUNO	T130
SABAH	SANDAKAN	PUSAT PEMULIHARAAN ORANG HUTAN	T131
SABAH	KINABATANGAN	KG. SG. PIN	T132
SARAWAK	MIRI	MARUDI WEST-BASE-P56	D002
SARAWAK	KAPIT	BKT GORAM, KAPIT - P42	D003
SARAWAK	LUBUK ANTU	BUKIT PERAYUNG	J01
SARAWAK	SERIAN	SURAU RITOH MAWANG	R027
SARAWAK	MIRI	BUKIT CANADA MIRI- N100	T001
SARAWAK	LIMBANG	BUKIT SAGAN RUNDANG- TT 454	T005
SARAWAK	LIMBANG	BUKIT LAWAS CT-15-T76	T006
SARAWAK	LIMBANG	LONG SEMADO, LAWAS- TT 1024	T007
SARAWAK	MIRI	BAREO, ULU BARAM - 946	T008
SARAWAK	MIRI	BUKIT MENTIGAI BELURU- P31	T009
SARAWAK	MIRI	BUKIT SERAWI, BEKENU - N 103	T010
SARAWAK	BINTULU	BUKIT NYABAU, BINTULU N106	T012
SARAWAK	BINTULU	BUKIT BUTIK,TATAU - TT174	T013
SARAWAK	SIBU	SG BULUH, SIBU- TT1037	T014
SARAWAK	MUKAH	MUKAH WATER TOWER - TT1354	T015
SARAWAK	SIBU	TRIG SG. TUTUS, SIBU-TT47	T016
SARAWAK	SIBU	BUKIT TANGGI, SIBU - P43	T017
SARAWAK	SIBU	BUKIT MALAU, KANOWIT -N88	T018
SARAWAK	SARIKEI	BUKIT KELINDANG, SARIKEI -N134	T019
SARAWAK	SARIKEI	BUKIT KAYU MALAM, PAKAN - T 143	T020
SARAWAK	SARIKEI	BKT SEBANKOI, SARIKEI -N53	T021
SARAWAK	BETONG	BUKIT SURI, DEBAK-N81	T022
SARAWAK	SRI AMAN	BUKIT BEGUNAN, SRI AMAN - N35	T025
SARAWAK	SAMARAHAN	BUKIT ABIT, - N28	T026
SARAWAK	SAMARAHAN	RITOH MAWANG, SERIAN - N20	T029
SARAWAK	KUCHING	KUCHING WEST BASE - 34	T030
SARAWAK	KUCHING	GUNUNG JAGOI, BAU - N07	T031

GEOCENTRIC DATUM OF MALAYSIA 2000

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS STATIONS NO.
SARAWAK	KUCHING	GUNUNG MUNTI,LUNDU	T032
SARAWAK	KUCHING	KG SEMPADI, LUNDU	T033
SARAWAK	KUCHING	BUKIT PERJUMPAAN , BIAWAK -TT6121	T034
SARAWAK	KUCHING	GUNUNG PUTTING, LUNDU	T035
SARAWAK	KUCHING	TG SERABANG, SEMATAN - N66	T036
SARAWAK	KAPIT	BKT TASU, KAPIT - 48	T037
SARAWAK	KAPIT	BKT BATU, KAPIT - 47	T038
SARAWAK	KAPIT	BKT KAYO, KAPIT - 49	T039
SARAWAK	KAPIT	BKT DEMA - 46	T040
SARAWAK	BINTULU	BKT LUMUT - 37 BINTULU	T041
SARAWAK	KAPIT	BKT SEMALONG,BELAGA - 53	T042
SARAWAK	KAPIT	BKT SKALAP, P34 BELAGA	T043
SARAWAK	KAPIT	BKT SONG, SONG - N89	T045
SARAWAK	KUCHING	SMK SEMATAN, LUNDU	1009
SARAWAK	SRI AMAN	SRK BATU LINTANG,SRI AMAN	2005
SARAWAK	BETONG	SRK LIDONG, BETONG	2011
SARAWAK	SRI AMAN	RH SEBELIAU, LEMANAK, LUBUK ANTU	2015
SARAWAK	SRI AMAN	SRK LELA PAHLAWAN,LINGGA	2038
SARAWAK	BETONG	RH UKING BATANG LAYAR,BETONG	2200
SARAWAK	SIBU	SRK BEKAKAP,SIBU	3010
SARAWAK	SIBU	SRB ST ELIZABERTH, SIBU	3021
SARAWAK	SIBU	RH. MALANG	3032
SARAWAK	SIBU	SIMPANG MUKAH-SELANGGAU	3046
SARAWAK	SIBU	SRK KUALA BALINGIAN,SIBU	3074
SARAWAK	MIRI	SRK KUALA SUAI	4044
SARAWAK	MIRI	LONG MENKABA, BARAM	4114
SARAWAK	MIRI	LONG TEBANGAN, MARUDI	4118
SARAWAK	MIRI	LONG SEBATANG, MARUDI	4119
SARAWAK	MIRI	LONG JAIK, BARAM	4120
SARAWAK	MIRI	LONG SERIDAN, MARUDI	4122
SARAWAK	MIRI	LPG. TERBANG LONG BANGA, BARAM	4127

GEOCENTRIC DATUM OF MALAYSIA 2000

JUPEM

STATE	DISTRICT	LOCATION OF GPS STATIONS	GPS STATIONS NO.
SARAWAK	BINTULU	GELASAH, SUAI-BINTULU	4242
SARAWAK	LIMBANG	MASJID BANDAR LIMBANG	5101
SARAWAK	MUKAH	SRK KG SEREDANG	6008
SARAWAK	SIBU	RH KEBUN ALOI, BTG. POI, KANOWIT	6047
SARAWAK	SIBU	RH ULU SKRANG, KANOWIT	6052
SARAWAK	KAPIT	LONG LIDAM/PUNAN BUSANG, BELAGA	7079
SARAWAK	KAPIT	SRK LONG BUSANG, BELAGA	7080
SARAWAK	KAPIT	SESCO ENTAWAU, KAPIT	7082
SARAWAK	KAPIT	SRK ULU BANGAN, KAPIT	7083
SARAWAK	KAPIT	SRK NANGA BALANG, KAPIT	7084
SARAWAK	KAPIT	SRK TUN JUGAH, SG. AYAT, SONG	7085
SARAWAK	KAPIT	SRK LUBUK IPOH, SONG	7086
SARAWAK	BINTULU	KG. KUALA TATAU, TATAU	8028
SARAWAK	BINTULU	T.T 31 - TG SIMALAJAU, TATAU	8045
SARAWAK	BINTULU	SIMPANG LDG. PEKAKA/SUAI/BINTULU	8047
SARAWAK	BINTULU	PEJ. DAERAH KECIL, SEBAUH	8048
SARAWAK	SAMARAHAN	GEREJA KG ENTUBOH, TEBEDU	9900

Appendix F

LIST OF COORDINATES IN GDM2000 FOR EAST MALAYSIA PRIMARY GPS NETWORK

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Appendix G

TRANSFORMATION PARAMETERS USED IN PENINSULAR MALAYSIA

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Appendix H

TRANSFORMATION PARAMETERS USED IN EAST MALAYSIA

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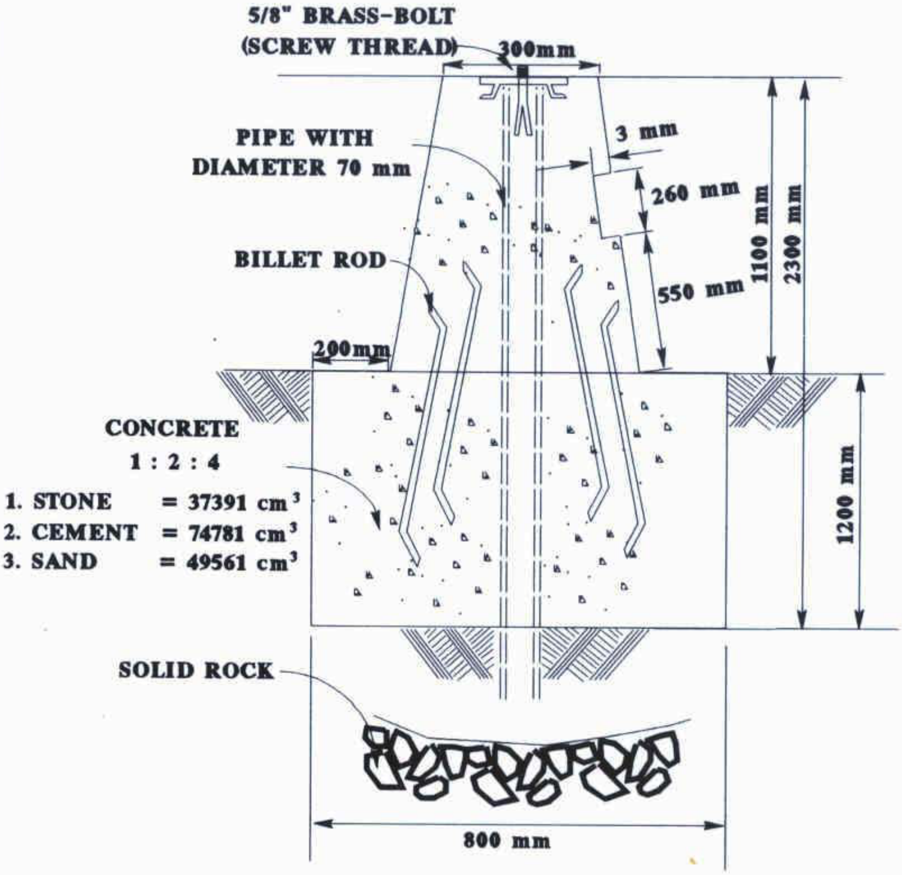
Appendix I

GPS MONUMENT TYPE A

SIDE VIEW



Appendix J

GPS MONUMENT TYPE B