

Current and Future Geodetic Activities In Malaysia

by

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Abstract

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 Brunei to the North. Malaysia lies close to the equator between latitudes of 1° and 7°N and longitudes of 100° and 119°E. The Dept. of Survey and Mapping, Malaysia (DSMM) traces its origin back in 1886. The 1880s also marked an important phase with the commencement of more widespread trigonometrically works in various parts of Malaya. Lieutenant Woore of the Royal Navy made the first attempt at triangulation survey in Penang in 1832. The intensive methods of conventional geodetic surveys have basically ceased with the advent of GPS. In the subsequent years, there have been numerous geodetic projects implemented by DSMM 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. In Malaysia, research in geodesy is undertaken through academic institutions, principally funded by the Ministry of Science, Malaysia. Information about the national geodetic infrastructure and databases can be obtained from the Geodesy Section, Geodetic Division, DSMM. This paper will describe the various geodetic activities that has been and currently undertaken by DSMM and Universiti Teknologi Malaysia.

1.0 Introduction

1.1 Existing Geodetic Networks

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**) carried out between 1913 and 1916. The reference ellipsoid used for MRT is in **Table 1** below. The map projection used for

mapping in Peninsular is Rectified Skew Orthomorphic (RSO) and Cassini Soldner for cadastral. **Table 2** tabulates the parameters for map projection used in Peninsular Malaysia.

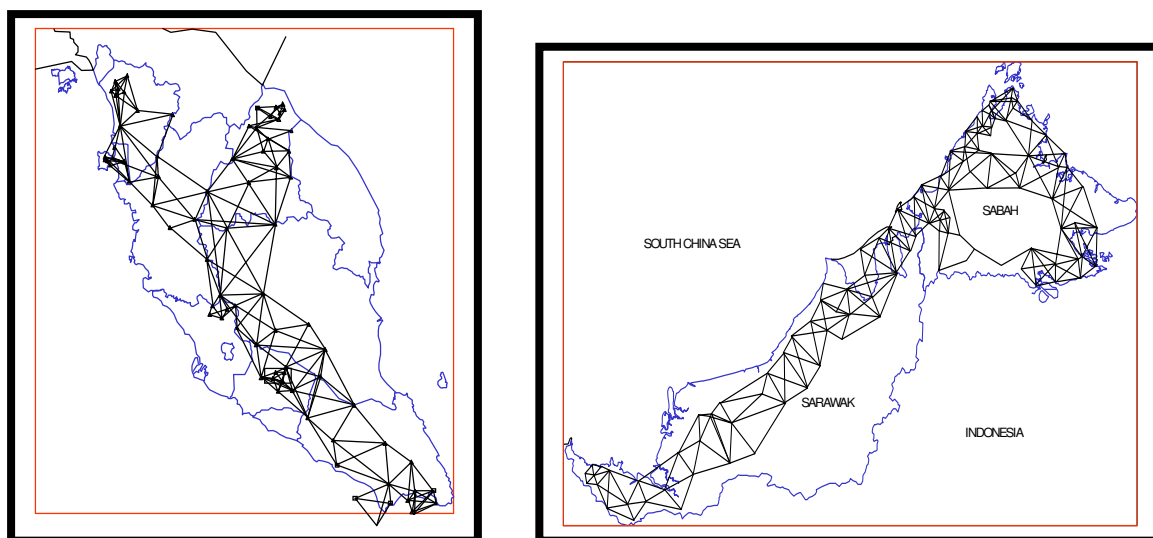


Figure 1 : Peninsular Malaysia and Borneo Triangulation

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

Table 1 : Reference Ellipsoids for MRT and BT68

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. 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**. The reference ellipsoid used is given in **Table 1**. The map projection used for mapping and cadastral surveys is RSO and **TABLE 2** shows the various parameters used.

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

Table 2 : Map Projections for Peninsular Malaysia, Sabah & Sarawak

1.2 EXISTING GPS NETWORKS

Peninsular Malaysia GPS Network

A GPS network of 238 stations as in **Figure 2** 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 NSW 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.

GPS Network in Sabah and Sarawak

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, were made. Broadcast ephemeris was used for baseline determinations. The relative accuracy of the network as shown in **Figure 2** is found to be better than 1 ppm for horizontal coordinates and 2-3 ppm for vertical.

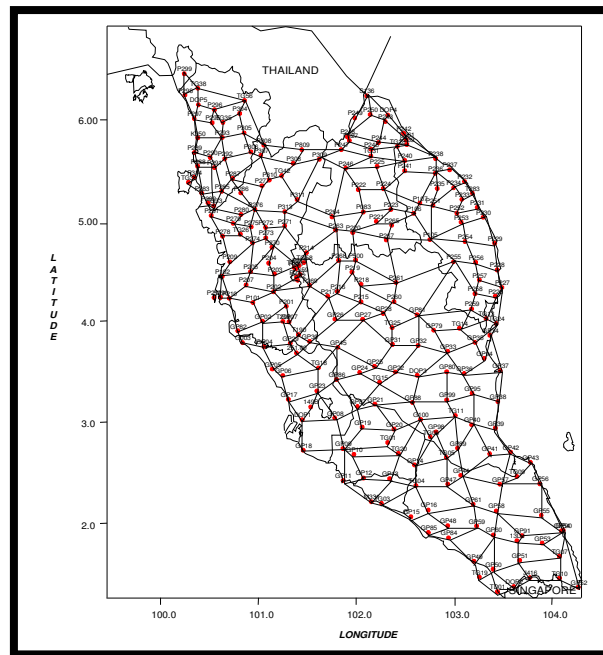


Figure 2 : GPS Network of Peninsular Malaysia and East Malaysia

1.3 GEODYSSSEA Project

GPS observations at Kuala Trengganu, Peninsular Malaysia and Tawau, Sabah were made from 28 Nov 1994 to 3 Dec 1994 continuously with **Trimble 4000SSE** GPS receivers together with members from other Asian and Asean countries. During the 1994 campaign, 2 additional stations namely Kertau and Timbalai were observed simultaneously for the same duration. In the 1996 campaign, 5 additional stations were observed. The acquired data was processed and the stations were connected to ITRF94.

The results show that the final coordinates have a comparatively high relative accuracy of up to $1-3 \times 10^{-8}$ and an absolute accuracy of better than ± 3 cm in the ITRF global reference frame as stated in Becker et al, April 1997. The most important finding in this project is the confirmation of the existence of the Sundaland block whose motion behavior is different from the Eurasian plate. **Figure 3** shows the velocities obtained from the results of (Simons, 2000) and the velocities are in the same direction for the regions in the Sundaland block.

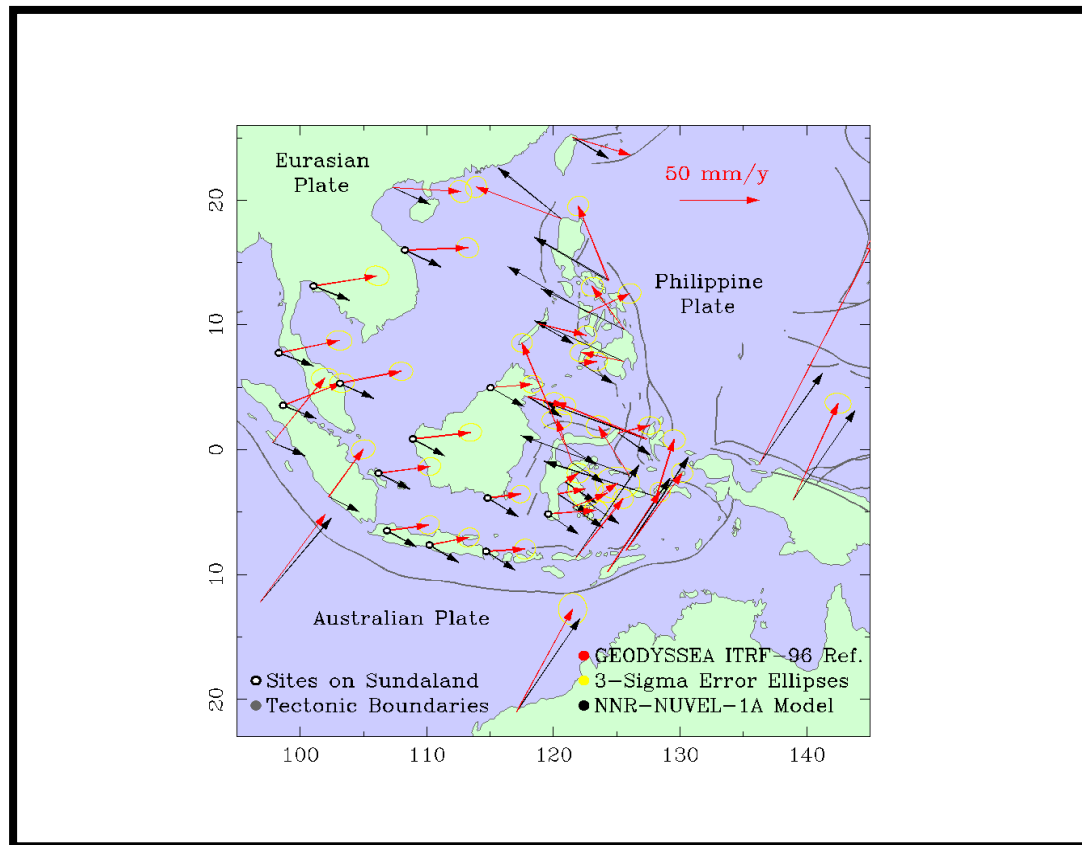


Figure 3 : Computed Velocity (from Simons, 2000)

At present fifteen (15) MASS stations (**Figure 4**) operated continuously for 24 hours a day and eight of the stations are situated in Peninsular Malaysia. With the growing capabilities of GPS as a high precision positioning system for surveying and mapping there is a necessity for the MASS stations to be defined on the precise reference system such as International Terrestrial Reference System (ITRS) that managed the International Terrestrial Reference Frame (ITRF). For this study, data from the 8 permanent GPS stations in Peninsular Malaysia were used.

With the availability of various precise IGS station coordinates, IGS precise orbits and Earth orientation parameters from IERS, the objective to realize a new precise global reference frame in ITRF2000 for Peninsular Malaysia can be achieved.

The Bernese GPS processing software version 4.2 was used in the processing of fifteen (15) Mass stations together with eleven (11) IGS stations (**Figure 5**). The software is capable of computing the GPS baseline by using double differencing as well as un-differenced data for precise point positioning. This new version of Bernese has new features such as the capability of using of ocean tide correction, estimated troposphere and introducing Neill mapping function in the software. Prior to Version 4.0 the used of ocean tide loading is not possible.

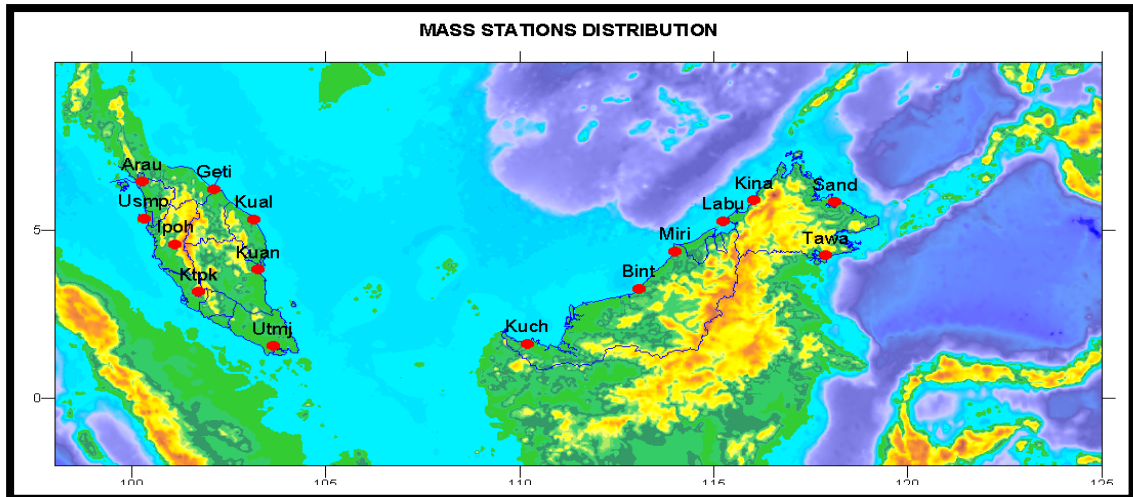


Figure 4 : Distribution of the MASS Stsations

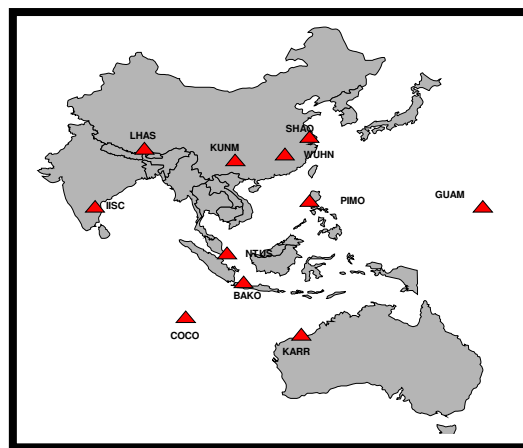


Figure 5 : IGS stations distribution

2.2 Final Combined Solution

The final combined solution for 1999 – 2000 consists of 105 weekly solutions and 26 stations (11 IGS stations and 15 Mass stations). Two strategies have been tried in order to have optimum results as well as to check any outliers in the final adjustment. The two strategies are as follow:

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

Free Network Adjustment

The general principle of free network adjustment with the introduction of Helmert Transformation is to adjust the daily normal equation freely and later transform using eleven (11) IGS stations. With the introduction of reference velocity for the fixed stations, the final coordinates for all stations were transform to the middle of the observation epoch, and in this case the coordinates were transform to 1 January 2000. The RMS of residuals for individual stations are shown in **Table 3**.

From **Table 3**, it shows that Mass station UTMJ has a slightly bigger RMS value in the north 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 10 mm in the horizontal component and 5 to 15 mm in the height component. Comparison for IGS stations have been made and it is found that the RMS for individual component is 5.2 mm, 8.3 mm and 3.9 mm for the north, east and height component respectively.

Station	North (m)	East (m)	Up (m)
Arau	5.40	6.20	9.50
Geti	6.30	6.90	8.90
Kual	7.40	6.50	6.00
Utmj	10.20	6.70	15.00
Ktpk	5.80	6.10	7.20
Ipoh	5.00	6.50	6.20
Usmg	6.80	7.40	6.70
Kuan	5.20	6.60	7.20

Table 3 : RMS of residuals for individual stations

It can be concluded that the accuracy for Mass stations with respect to the ITRF2000 reference frame with free network strategy is 5 to 8 mm in the horizontal component and 4mm height.

Heavily Constrained Adjustment

Station	North (m)	East (m)	Up (m)
Arau	3.10	14.60	11.40
Geti	3.30	14.80	12.0
Kual	3.00	13.80	8.7
Utmj	3.60	12.80	15.70
Ktpk	3.10	11.50	9.6
Ipoh	2.90	12.30	8.10
Usmg	3.00	12.30	11.1
Kuan	3.00	12.30	9.90

Table 4 : RMS of Residuals for Individual Stations

RMS of coordinates repeatability is shown in **Table 4** and the accuracy of station coordinates is between 3 to 15 mm in horizontal component and 8 to 16 mm for the height. The coordinates of heavily constrained adjustment will be adopted as the final coordinates (Epoch 02.01.2000).

The existing GPS Network of 238 points (**Figure 2**) for Peninsular Malaysia has been computed in the ITRF-2000 coordinates using the 7 MASS stations as fixed.

3.0 HEIGHT SYSTEM

3.1 Introduction

Bench Mark values are one of the products of the Department of Survey and Mapping Malaysia (DSMM) to support various activities in the field of geodetic, mapping, engineering surveys and other scientific studies. In Peninsular Malaysia, a leveling network was started in 1912 using the Land Survey Datum 1912 (LSD1912). Since then, it has been used as a base for the secondary leveling.

However, it was soon realized that the network suffers some shortcomings. Not only that the measurement was not uniform, the network adjustment carried out was not homogeneous either. In addition to this, with the technological advances in the field of surveying, there now exists a demand for an accurate height control among users.

This has prompted the DSMM to seriously study the existing height control. In early 1980s, in an effort to redefine a new National Geodetic Vertical Datum (NGVD) for Peninsular Malaysia, the DSMM has successfully implemented three projects. These projects were the Tidal Observation Project, the Precise Levelling Project and Gravity Survey project with the following objectives.

Tidal Observation project : To determine the MSL and tide studies

Precise Levelling Project : Connecting the tide gauges with precise leveling

Gravity Survey Project : Orthometric Corrections for heights

3.2 Tidal Observation Project

The establishment of the Tidal Observation Network (TON) in Malaysia commenced in 1983. This project was initialized and carried out by DSMM under supervision and assistance given by the Japan Maritime Safety Agency. By the end of 1995, altogether twenty-one (21) stations (**Figure 6**) were established and in operation, in which twelve (12) located around the Peninsular and the rest in Sarawak and Sabah. The stations were evenly distributed along the coast and the locations selected to show typical characteristics of tides of the adjacent sea. The stations were constructed on a rigid shore or where a stable structure extends into the sea.

The Geodesy Section is responsible for the monitoring of the tide gauge stations which involves regular maintenance of the gauges as well as the collection, processing, analysis and distribution of observed tidal data. The observed tidal data and other related values are published annually in two reports released by the DSMM, namely *The Tidal Observation Record* and *The Tidal Prediction Table*.

DSMM was also involved in the ASEAN-Australia Tides and Tidal Phenomena Project (AATTP) which was implemented in 1985 for the purpose of improving regional cooperation in marine science. The project aimed to obtain simultaneous observations of sea level time series in the ASEAN region and to centralize all modern sea level data into a certified database. The tidal stations at Lumut and

Cendering were included in the network of Global Sea Level Observing System (GLOSS) coordinated by the Intergovernmental Oceanographic Commission (IOC).

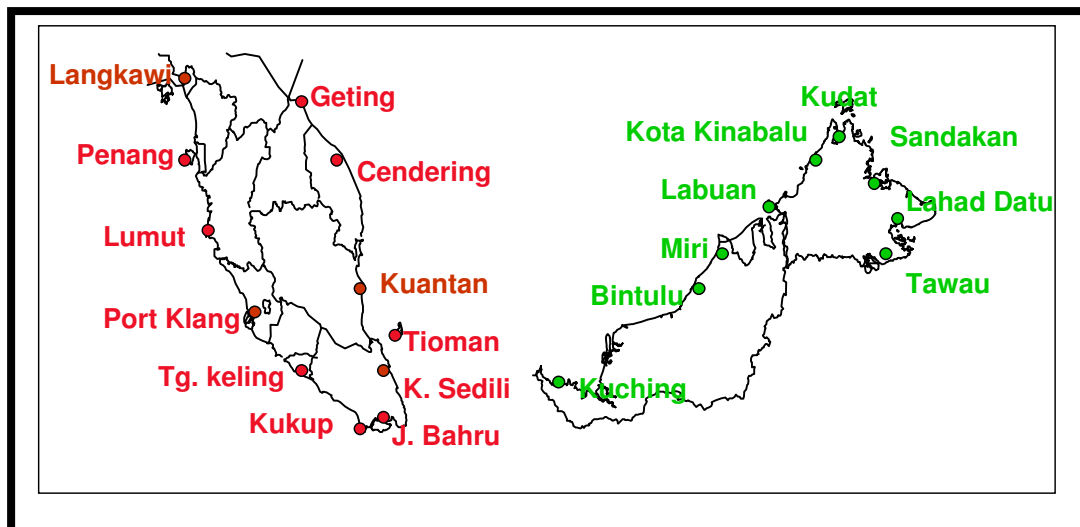


Figure 6 : The Location of Tidal Stations in Malaysia



Figure 7 : Tidal Station in Kukup

3.3 Precise Levelling Project

In 1983, DSMM began to redetermine the precise MSL value in conjunction with the establishment of the new Precise Levelling Network for Peninsular Malaysia. This was carried out by the setting-up of a Tidal Observation Network that consists of 12 tidal stations. Subsequently, Port Kelang was selected for the adoption as a

reference level for the NGVD origin, based upon a 10-year tidal observations (1984-93). In 1994, a monument to signify the establishment of the NGVD was built within the DSMM compound in Kuala Lumpur. Here, the Port Kelang Datum was extended to the new monument via precise levelling and gravity survey.

3.3.1 Present Levelling Network

The Precise Levelling Network project was conducted in 1984. The project consists of establishing a first-order levelling survey along main roads and newly completed highways. It consists of 2089 precise levelling bench marks over a distance of 1946 km as shown in **MAP 8**. Apart from this, second class levelling is also carried out to densify the network. A total of 824 bench marks have been planted using this technique, covering a distance of 1158 km. The whole network has precisions ranging from 3 to 12 mm per km which correspond to first and second class requirements. It incorporates corrections for rod scale, temperature, level collimation and refraction.

3.3.2 Levelling Techniques

Motorised Levelling

Precision levelling is extremely tedious and time consuming. Since 1988, DSMM has embarked on a project in collaboration with SwedSurvey called Motorised Levelling.

Two specifically modified vehicles are used, each for the level instrument and rod transport. Both instrument (Carl Zeiss Jenna Ni 002A) and rods are set-up and operated from within the respective vehicles.



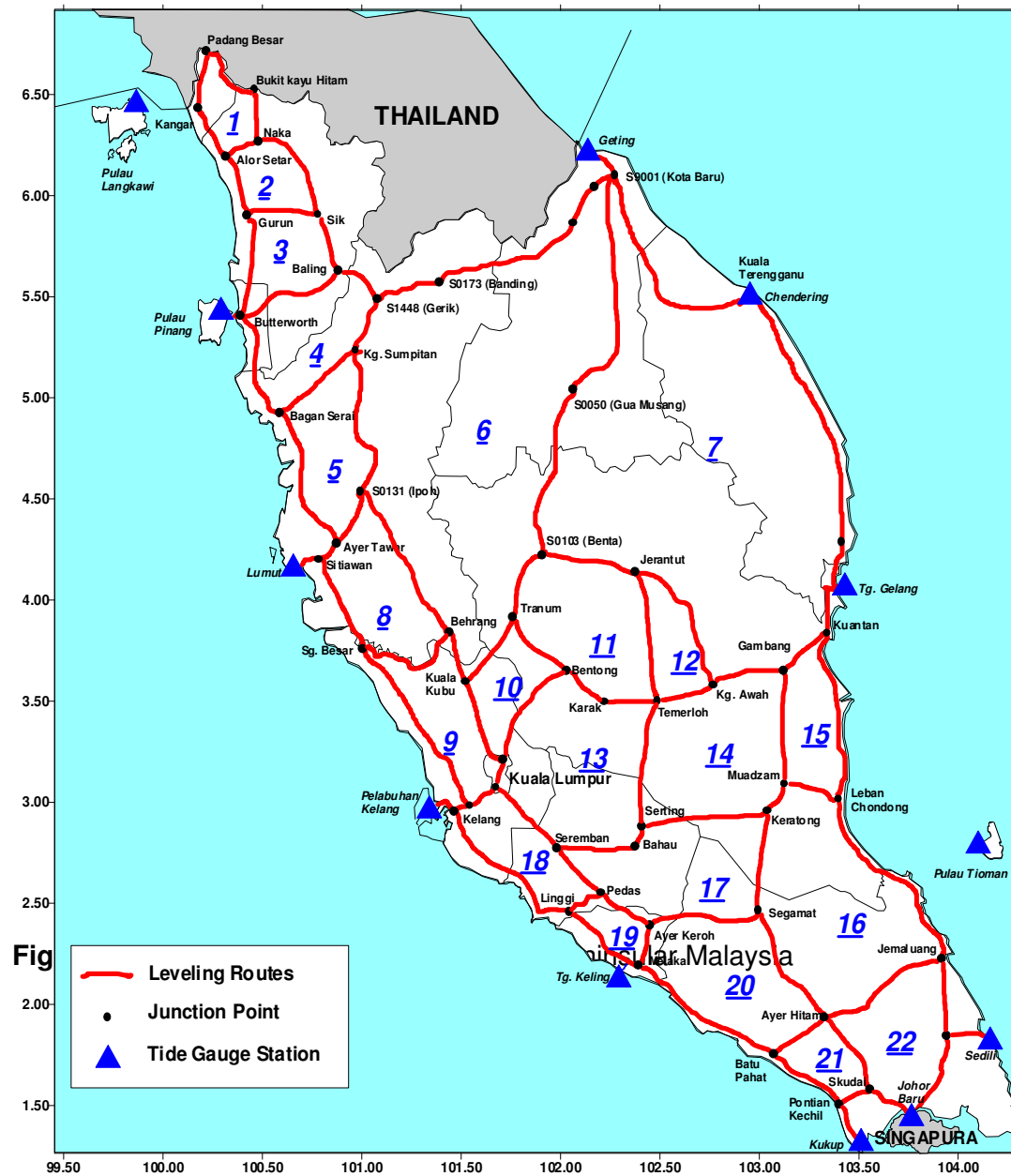
Figure 8 : Motorized Levelling



Figure 9 : Digital Levelling

Digital Automatic Levelling

The basic instruments used are the level and a graduated invar rod. All readings and bookings are made automatically. Software used for processing is DELTA..Network adjustment software used for the difference in heights adjustment is Geolab network Adjustment Software.



4.0 Gravity Survey Project

4.1 First Order Gravity Survey

The first order gravity survey was first carried out in 1988 and completed in April 1992 with a total of 180 points in Peninsular Malaysia. The distribution is between 30-50 km along the Precise levelling Network with a misclosure of 30 μ gals. This network is known as the Peninsular Malaysia Gravity Standard Network 1989 (PMGSN'89). PMGSN'89 consists of standard benchmarks and other stations and is based on International Gravity Standard Network 1971 (IGSN71).

4.2 Second Order Gravity Survey

The second order gravity survey was implemented in order to densify the points between the first order points. These points were positioned between the gravity stations from the first order points at interval of 5 km for low elevation and 1 km for elevation higher than 100 m above Mean Sea Level. The rejection criterion for misclosure is 50 μ gals. To date, there are 1242 second order gravity points and these surveys were conducted for the purpose of applying orthometric corrections to the levelling network.

4.3 Third Order Gravity Survey

The third order gravity survey was started in 1994 by DSMM with the objective of establishing gravity points in gridded form at a density of 5-10 square kilometer per station. The accuracy of the misclosure is maintained at 100 μ gals.

To date, a total of 1410 third order gravity survey points has been obtained by DSMM. The Geological Survey Department Malaysia (GSDM) has also contributed another 3895 gravity points in grid form at a density of 25 square kilometer per station with an accuracy of 100 μ gals. The gravity data obtained from UTM consisted of 2921 stations, of which 1969 points are common with the data included in the DSMM and GSDM data set.

4.4 Gravity Database

DSMM has formed a bank gravity database, which consists of collected data from various bodies and agents in the country that had conducted gravity surveys independently for various purposes. Among those agencies that had contributed to this database are DSMM, Geological Survey Department Malaysia (GSDM) and Universiti Teknologi Malaysia (UTM). DSMM had also obtained sea-borne gravity data from Bureau Gravimetricque Internationale (BGI) and satellite altimetry data from Geosat/ERM/GM and ERS-1/GM. In Peninsular Malaysia, the gravity database is made up of 14,942 terrestrial and sea-borne data (original, there are 9,648 terrestrial

and 7263 sea-borne data, totaling to 16,911 but minus 1969 duplicate points on land). 27,122 gravity values derived from satellite altimetry are then added, increasing the data to a total of 44,033 gravity points. Figure 11 shows the distribution of these data.

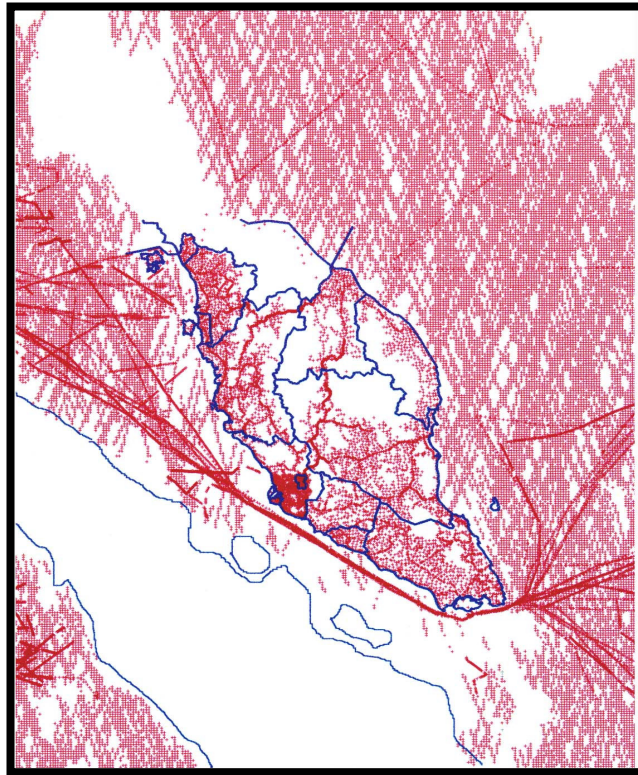


Figure 11 : Gravity Data In Peninsular Malaysia

5.0 Research Activities at UTM

5.1 Geodetic and GPS Study Group

The Geodetic and GPS Study Group at UTM has been working with the industry in various projects and has accumulated substantial expertise in training programmes, GPS applications and software development capabilities. The existing GPS Laboratory has been equipped with the latest GPS related instruments available in the market such as the following:

- GPS geodetic receivers (6 units of the Trimble 4800 series with Geomatics software)
- GPS vehicle positioning and navigation system (5 units Trimble PRO XR/Beacon GPS receiver with ASPEN software)
- Continuous Operating GPS System (CORS) (2 units Trimble 4700 CORS GPS receiver TRS software)
- GPS hydrographic positioning system (1 set of Trimble DSM212 GPS receiver with HYDRO pro software)
- High precision GPS processing software (Micro-Cosm and Bernese Softwares)

5.2 Towards the Implementation of Coordinated Cadastral System

Malaysian Cadastral System is based on the dimensions of each parcel and its location with respect to adjacent parcels. Realizing the needs of modern GIS and the efficiency of GPS as a positioning tool, there is a move by various countries to convert similar dimensional systems into “coordinate based cadastre”. A collaborative study between the Universiti Teknologi Malaysia (UTM) and the Department of Survey and Mapping, Malaysia (DSMM), on the implementation of Coordinated Cadastral System (CCS) has been carried out. The studies are taken in two stages where the first focuses on two major issues: i) the application of GPS technique for control network densification to support the implementation of CCS; and ii) the adjustment of large cadastral network. In the second stage the study focuses on the following issues: i) the definition and realization of a geocentric datum for Malaysia; ii) methodology for the development of digital coordinated cadastral database; iii) techniques for integrating the digital cadastral and mapping data; and iv) institutional issues on the implementation of CCS.

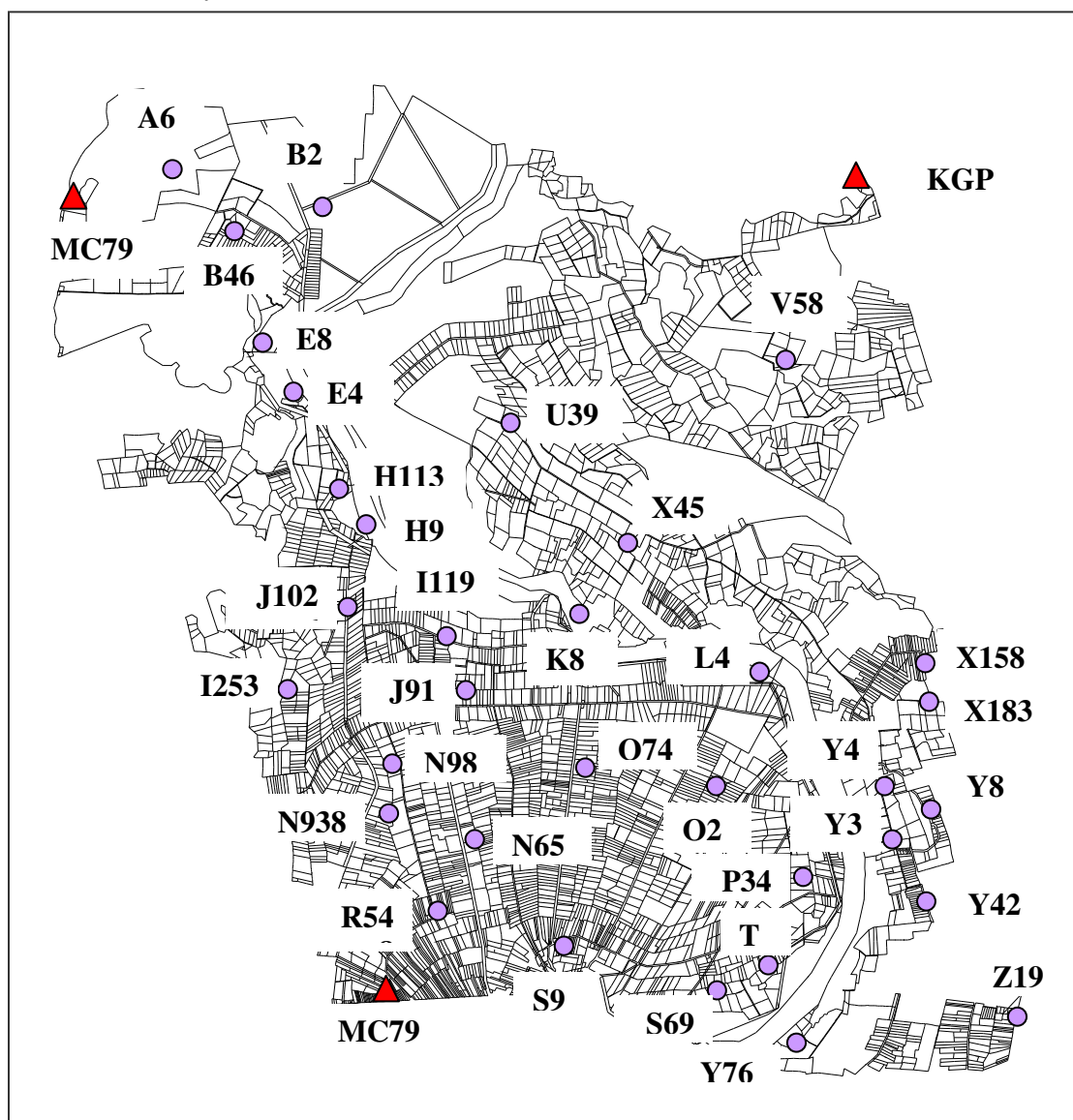


Figure 12 : Distribution of the selected boundary marks (circles) and the base stations (triangles) used in the GPS campaign

A unified coordinate system with referenced to the universally adopted datum is required to accommodate the future requirements in cadastral and mapping integrated purposes. In view to this fact and with the mission of being a modern geographic data provider, the DSMM determines to introduce a nation-wide cadastral field reform by implementing CCS project. The existing Cassini coordinate system which has been used in cadastre for years is being proposed to be replaced with RSO coordinate system. Cassini system based on several State origins is found to be no longer suitable for future CCS needs where a homogenous coordinate system is preferable. An investigation on adjustments of large cadastral network using different coordinate systems in Peninsular Malaysia being carried out to determine the most suitable approach leading to the establishment of homogenous coordinate system in the country.

A study regarding the development of National Digital Cadastral Database (NDCDB) in Malaysia has been carried out. This study concerns with the issues related to the development of procedure in establishing the NDCDB. This has been carried out with the objective of producing digital cadastral data given in the geocentric Rectified Skew Orthomorphic (RSO) coordinate system defined by GPS. This could be realized by first establishing the cadastral control infrastructure using GPS measurement by connecting to the newly established GPS network. A total of 250 cadastral markers with 2.5km spacing have been selected and observed using GPS in the test area of 40km x 40km. The resulting GPS derived coordinates for the markers are given in geocentric RSO forming the Cadastral Control Database (CCDB). The CCDB provides control for the conversion of the existing State DCDB to the NDCDB.

In the conversion process, automation in the data selection procedure has been developed to select specific window size for block adjustment and to extract attributes of features from corresponding CCDB and the existing State DCDB. Adjustment results show that the new set of coordinate for all the cadastral markers have been generated with sufficient accuracy needed for the NDCDB development in the country.

Another study has been carried out concerns with the issues related to integration of the digital cadastral data with topographic/mapping data which is to be addressed to facilitate geographic (spatial) information users requirements. The existing Computer Aided Mapping System (CAMS) database need to be converted to the common GPS derived coordinate system. This is being done following geo-referencing procedure using coordinate transformation technique after selecting sufficient control points from the CCDB. Experiment results over the test area indicate that the cadastral and topographic data could be integrated with sufficient accuracy for GIS applications.

5.3 Establishment of GPS Tide Gauge Monitoring Network

In order to monitor changes in absolute sea level, the vertical motion of the crust at the tide gauge location must be monitored in an accurate global terrestrial reference frame. The existing tide gauges around the Peninsular has been connected together forming a precise GPS network. During the week of June 2000, three days GPS observation campaign has been carried out on the existing ten (10) tidal stations. The network was connected to the existing seven (7) MASS stations and eight (8) global sites of the IGS stations in the region.

The computation has been carried out in stages using Bernese GPS Processing Software including precise orbit determination of the GPS satellites from the IGS/MASS data set and, estimation of positions of the tidal stations. The precision of the estimated ellipsoidal heights for the tide gauge benchmarks is found to be better than 5mm and their corresponding coordinates are given in the ITRF97 at epoch 2000.5. Station coordinates for this network could be improved by longer GPS observation campaign in future.

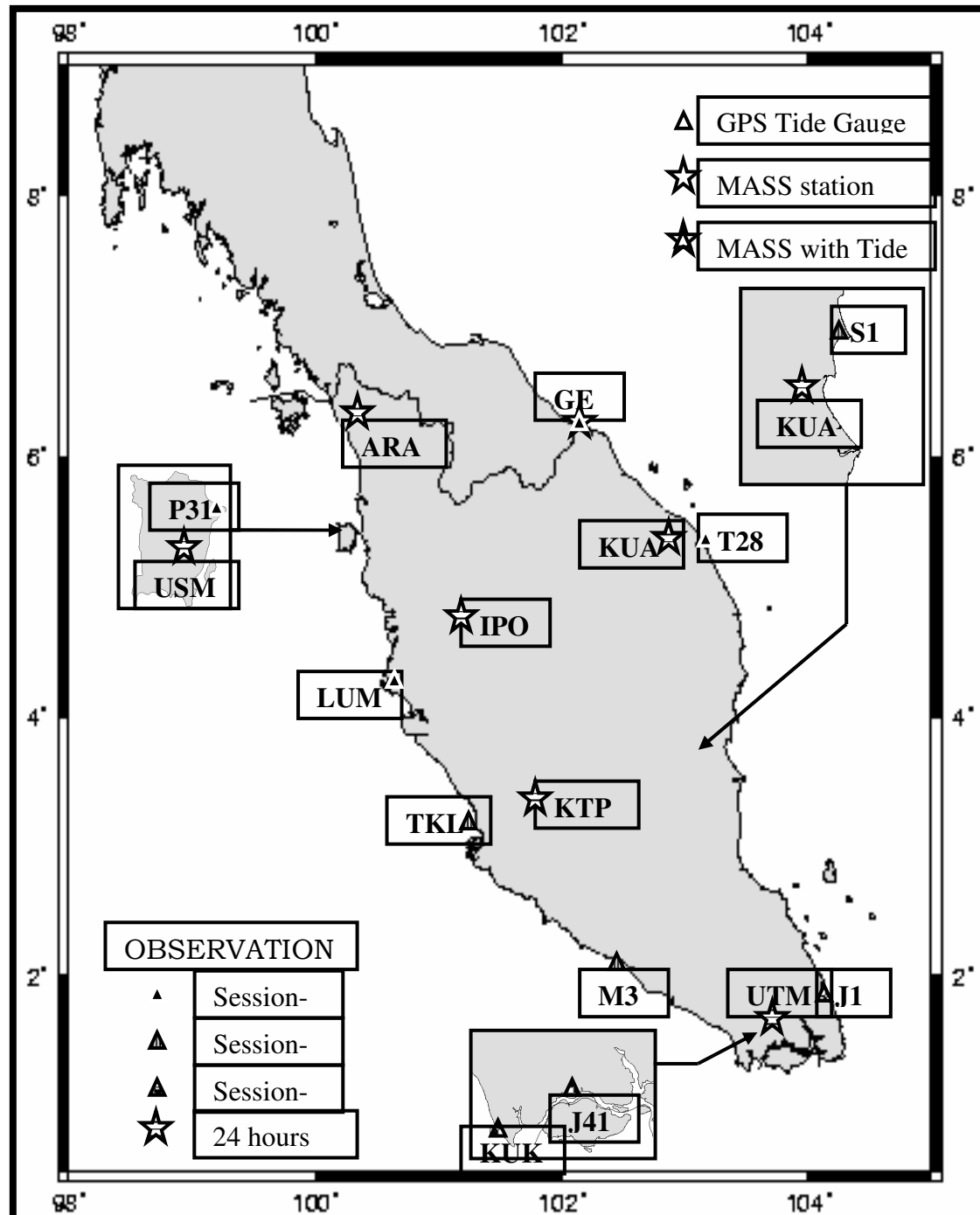


Figure 13 : Distribution of the tidal stations together with MASS stations

6.0 Future Activities

6.1 Malaysian Active GPS System (MASS)

MASS is the latest venture of DSMM in providing 24 hours GPS data for GPS users in Malaysia. The system consists of 15 permanent GPS tracking stations situated at strategic locations in the country as shown in **Figure 6**. **Figure 14** and **15** show the monument for the antenna and equipment of Arau station. Another two permanent GPS stations has been set-up in Segamat, Johor and Sibu, Sarawak and are in operation for better distribution and coverage for various applications. With the MASS network continuously in operation for next few years, better quality data can be acquired and analysis for the purpose of monitoring deformation or other scientific applications. More stations will be set-up in the near future for monitoring of the atmospheric delays.



Figure 14 : Choke Ring Antenna



Figure 15 : Equipments at MASS

6.2 Geodetic Positioning and Monitoring of Tide Gauge Station

Absolute sea-level height at the related tide gauges need to be determined in order to maintain the reliability of the sea level data. Connecting the existing tidal stations to a higher order network of permanent GPS tracking stations could practically do this. Through this, the tide gauge measurements could be directly referenced to the established global frame. The systematic errors due to various relative land motion could be evaluated by continuously comparing the height of the tide gauge station and the height of the permanent GPS station nearby.

Two permanent GPS stations had been set-up at the tide gauge stations of Tumpat, Kelantan (Figure 16) in Peninsular Malaysia and Bintulu, Sarawak in East Malaysia for the study. Periodal GPS campaigns will be made to connect the other tide gauges to the other permanent GPS stations. Through this study, absolute sea-level determination can be made and also to unify the height datums of Peninsular Malaysia and East Malaysia.



Figure 16 : MASS Station at Tide Gauge Station (Getting)

6.3 Airborne Gravity Survey Project

Under the 8th Malaysia Plan, DSMM will do the airborne gravity for the whole of Malaysia during 2002-2003. DSMM will engage a foreign consortium who are skillful and experienced in the field of airborne geoid mapping. For the gravity survey, a 5 km spacing flight lines, which follow the shape of the area in order to obtain long flight lines for good survey design will be made. They are supplemented by crosslines in order to assess the quality of the airborne gravity surveys. A stable local aircraft with autopilot will be used, with good flight dynamics (phugoid motion) at low airspeeds.

The LaCoste and Romberg gravimeters will be used to collect the basic airborne gravity data and to augment these data with a Honeywell H764G INS data from strapdown system. Airborne gravity data will be acquired at a flight speed of 150-250 km/hr with aircraft altitude of less than 4500 m, typically at 300-1000 m above topography, depending on weather conditions. Flight path are recovered and differentially corrected daily to ensure all lines flown are within the specification. The quality of individual flight data will be checked by field computations of single baselines (one rover to one static), combined with results from one gravimeter. Visual inspection/plotting will quickly identify problematic data and make the necessary background information for decisions to re-fly a line.

The results of the gravity processing, yield filtered free-air gravity anomalies at altitude. A preliminary geoid model (EGM96) is used to correct from gravity disturbances to proper anomalies, consistent with other surface gravity data. Quality control of the processed free-air gravity data aloft will be checked by profile plots, comparisons to expected topographic signals, free-air anomaly contour plots, and

upward continuation of surface data in regions with sufficient gravity data spacing (mainly areas of Peninsular Malaysia).

In the geoid determination, central methods of physical geodesy BVP problems such as collocation, Fourier methods, use of terrain data and harmonic downward continuation will be used. The final geoid model will be on a dense grid (1') and correspond to ITRF2000 (WGS84) GPS system

The final geoid will be compared to available GPS leveling data on benchmarks to assure a geoid datum consistent with Malaysian Mean Sea Level, and used to validate the computed geoid. The accuracy of the derived geoid product will be assessed in a separate least-squares collocation error study. From the terrain-reduced data empirical covariance functions will be estimated for the different regions (Peninsular Malaysia, Sarawak and Sabah), and use for formal error estimation.

Therefore, the end products of this project are

2 mGal accuracy of 5 km spacing for the airborne gravity survey
relative geoid accuracies of 5 cm and 1-2 ppm.

7.0 Conclusion

The current and future geodetic activities that has been conducted by DSMM and UTM could provide users of GPS and scientific community the opportunity to undertake various geodetic, mapping, surveying and mapping activities with better control of coordinates and meaningful geodetic information.

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