

University of Southern Queensland
Faculty of Engineering & Surveying

**The accuracy of published co-ordinates on the
'Survey Mark Enquiry Service' (SMES) in
Victoria using GPS observations**

A Dissertation submitted by
Mr Scott Deas

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Courses ENG4111 and 4112 Research Project
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ABSTRACT

This project sets out to test the values attributed to survey marks within SMES and investigate their ability to meet the RTK GPS cadastral connection requirements of section 2.3.3 (i) of the Victorian practice directives 2007.

It also seeks to test the reliability of RTK GPS to measure these marks within the same cadastral connection requirements and to verify these measurements with independently derived static and rapid static observations.

This project found that a number of RTK observations introduced an element of uncertainty in their ability to produce reliable, accurate results. The use of static and rapid static measurements helped to confirm or dispel RTK data as well as validate SMES value accuracy. This project also found that the majority of SMES marks adequately reflect their published values to within 0.10 of a metre, in accordance with section 2.3.3 (i) of the Victorian practice directives 2007 accuracy requirements for RTK GPS.

The results of this project will help to clarify the accuracy limitations and reliability of RTK GPS when observing survey marks with 3rd order SMES values for the purpose of cadastral connections.

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**ENG4111 Research Project Part 1 & ENG4112 Research
Project Part 2**

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Dean
Faculty of Engineering and Surveying

CERTIFICATION

I certify that the ideas, designs and experimental work, results, analysis and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Scott Alexander DEAS

Student Number: 0050008209

A handwritten signature in black ink, appearing to read 'S. Deas', written over a horizontal line.

Signature

29th October 2009

Date

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CHAPTER 1

INTRODUCTION.

1.1 Project Topic

The accuracy of published co-ordinates on the ‘Survey Mark Enquiry Service’(SMES) in Victoria using GPS observations

1.2 Project Aim

The aim of this project is to test the quality of published SMES co-ordinates using a combination of RTK, fast static and static GPS observations on a series of 3rd order marks both in a rural and the suburban environment. From these results the difficulty of achieving the required cadastral connection accuracy of 0.10m, stated in 2.3.3 (i) of the Victorian Practice Directives January 2007 will be assessed (see appendix 7).

1.3 Background Information

Victorian law states that when a Licensed Surveyor lodges an abstract of field records with the Surveyor General or Titles office, that he or she must transform their bearing and coordinate datum onto the Map Grid of Australia 1994 (MGA94) (Surveyor General of Victoria, 2007). The principle reason for this is to update *Vicmap Property*, the states digital cadastre map base (Surveyor General of Victoria, 2007).

To perform a cadastral MGA connection a surveyor in the field must either traverse by total station to a minimum of 2 MGA marks, preferably 3, with the appropriate accuracy. The other option available is to connect to these marks via RTK GPS/GNSS

observations. Again, a minimum of 2 marks is required in order for the survey to be coordinated and rotated onto the MGA94 datum.

With the continued integration of GPS/GNSS receivers into the survey industry, the Surveyor General of Victoria has stipulated the requirements for various GNSS observation techniques within the 2007 Practice directives. Guidelines for Networked Real Time Kinematic (NRTK) GPS observations within the MELBpos network of Continually Operating Reference Stations (CORS) is outlined in section 2.3.3(i). This section states that only one known 3rd order MGA94 ground mark is required for verification of the MELBpos derived MGA solution, providing it varies by no more than 0.10m from the published value (Surveyor General of Victoria, 2007).

It has been stated that it is inevitable that differences in the order of 2-3cm would be found between GNSS observations and published SMES values (Ross, 2006). This level of variation however is far less than the 0.10m allowable differences between GNSS observations and SMES values in the Practice Directives.

With this in mind, this project sets out to test a small sample of the Victorian Survey Control Network of 3rd order survey marks and examine whether or not they are capable of achieving the desired accuracy. It will also test NRTK GPS observations and assess if they are accurate enough to measure SMES marks within the 0.10m tolerance.

1.4 Research Questions

- Are the coordinates attributed to survey marks within SMES sufficiently accurate to meet the RTK GPS cadastral connection requirements of section 2.3.3 (i) of the Victorian Practice Directives January 2007?
- Is an RTK GPS MGA connection sufficiently reliable to meet the accuracy requirements of section 2.3.3 (i) of the Victorian Practice Directives January 2007.
- Can independently derived static and rapid static observations aid in verifying the accuracy of RTK measurements and SMES coordinates?

CHAPTER 2

LITERATURE REVIEW.

2.1 Introduction.

This section will set out the background of technical information relevant to this projects aims and objectives. It will also explore the analysis and conclusions of other studies conducted which are of a similar nature to the work of this project. And lastly this section will compare and contrast those studies in an effort to understand the fundamental differences and similarities of what this project aim to achieve.

2.2 The Survey Mark Enquiry Service (SMES).

2.2.1 What is SMES?

The Survey Mark Enquiry Service (SMES) provides online survey mark information to the Victorian survey community. It allows coordinate and height values of known survey marks to be accessed online, as well as providing survey mark sketch images, a base map interface, online digital lodgement of survey information and reservation of permanent mark numbers, among many other features (Land Channel, 2008).

SMES provides a critical link to Victoria's Geodetic Infrastructure, which ties the known position and height values to nationally defined datum's (Office of Surveyor General, 2004). The maintenance of this network is essential for construction, asset management, mapping, GIS and the referencing of property boundaries, all to their relevant accuracies (Office of Surveyor General, 2004).

2.2.2 The Problem with SMES

The Victorian Geodetic Infrastructure or Survey Control Network (SCN) is estimated to have some 165,000 marks of varying degrees of accuracy (ICSM Geodesy Group, 2008). It is also estimated that only 100,000 of these marks have an accuracy suitable for survey use, 30% of which will have been deemed lost or destroyed (ICSM Geodesy Group, 2008). An argument could also be made that a large percentage of these remaining marks may no longer adequately reflect the values attributed to them due to some kind of physical disturbance. The dramatically reduced number of useable marks might well be attributed to the June 1997 paper *Victoria's Geodetic Infrastructure, Status and Future direction*, which resulted in a distinct shift in the Department of Sustainability and Environments (DSE) direction for the ground mark network. The paper made the assumption that GPSnet base stations, a network of Continuously Operating Reference Stations (CORS), would provide Victoria with most of its positioning needs. This led to the DSE reducing “. . . its ground mark maintenance program to satisfy only a core element of ground marks” (Office of Surveyor General, 2004, p4). A second report in March 1998 supported the 1997 paper and suggested a withdrawal from ground mark dependence and a movement towards the use of GPSnet (Office of Surveyor General, 2004). This change in direction for Victoria's Geodetic Infrastructure has meant that there will be a gradual increase in the use of GPSnet, and an ongoing reduction in the use of SMES ground marks (Office of Surveyor General, 2004)

2.2.3 The Importance of SMES

The main users of survey mark networks, such as that located on SMES, are surveyors (ICSM Geodesy Group, 2008). Despite the survey industrys growing reliance on GNSS, it cannot entirely replace the survey mark network on the ground, as it simply cannot satisfy all geodetic and spatial requirements (ICSM Geodesy Group, 2008). In Victoria, there is a requirement for cadastral surveys to be connected to MGA94 in order to update the Victorian digital cadastral map base, Vicmap Property (Surveyor General of Victoria, 2007). In order to do this, observations to two known third order marks for traditional methods and one known third order mark for GNSS observations is required (Office of Surveyor General, 2007). Survey monuments provide verification on GNSS network positions, redundancy of the network solution and quality assurance (ICSM Geodesy Group, 2008). This means that NRTK MELBpos derived MGA solutions must still be verified by observing to a 3rd order ground mark and shows why a robust, accurate network of SMES marks is still required.

Not all Victorian surveyors have the financial means to access GNSS equipment and NRTK services such as MELBpos. For many small survey firms, such an investment may well be impractical for the volume and scope of their work. These surveyors rely on Total stations to conduct their surveys in the more traditional survey methods. Ensuring accurate SMES marks are available in the vicinity of their surveys is important for connection to the MGA94 datum for non-GNSS users (ICSM Geodesy Group, 2008).

Sustaining an accurate local vertical datum is still dependant on the maintenance of 3rd order survey marks, due to the inability of GNSS to provide the required accuracy for orthometric heights (ICSM Geodesy Group, 2008). The uncertainty in GNSS heights due to satellite constellation, antenna heights, geoid-ellipsoid separation and variation between the geoid and mean sea level, make traditional level and staff methods of height determination more successful (ICSM Geodesy Group, 2008). The vertical component of the SMES network of marks is not the primary focus of this project, however the above points do highlight the need for continued ground mark maintenance.

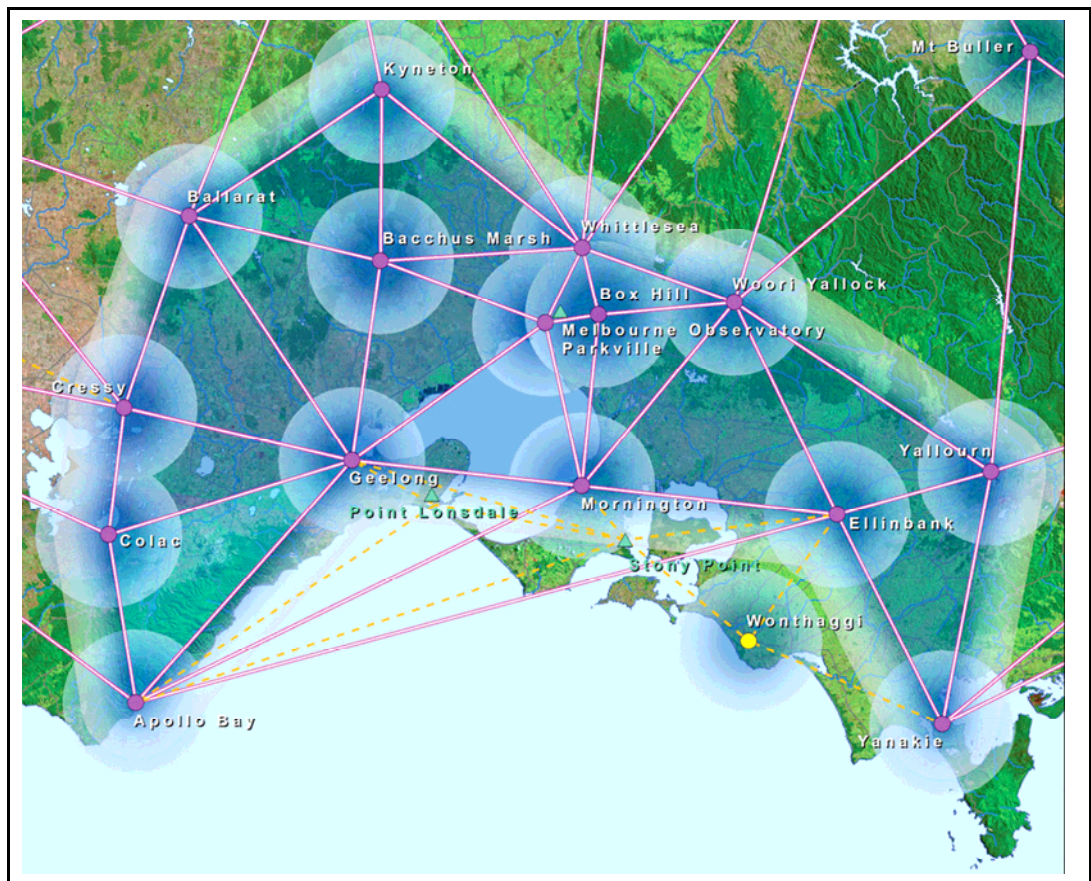
2.3 The Global Positioning System (GPS)

2.3.1 MELBpos

Coming online in January 2006, MELBpos is a strategically placed network of CORS located in and around the Melbourne Metropolitan area (see Figure 2.1), which enables highly accurate RTK positioning without the need for a base station. The system works by having GNSS data streamed from GPSnet (VICpos & MELBpos) CORS sites around Victoria, then collecting and processing it at a central server (Asmussen, 2007). This central server computes a network correction for GPS receivers in the MELBpos region and communicates these corrections to roving receivers over the internet (Zang, et al, 2006). The central server also generates a Virtual Reference Station (VRS) within its CORS network at a position near the rover (Retscher, 2002). This VRS provides improved positioning accuracy to the rover over longer distances without ever having physically existed (Retscher, 2002). Hale and Ramm (2005) state that a network such as MELBpos is supposedly capable of producing horizontal accuracy in the vicinity of 2cm.

The Surveyor General of Victoria's practice directives from January 2007 specify observation requirements for GPS/GNSS NRTK observations for cadastral connections. Despite the ability to generate MGA94 coordinates from a MELBpos networked solution, the requirements ask for verification to at least one known 3rd order mark (Surveyor General of Victoria, 2007).

Figure 2.1. – The NRTK MELBpos network as of January 2009. (DSE, 2009)



2.3.2 Real Time Kinematic (RTK)

RTK GPS is the streaming of real time data to a receiver unit, which enables instant access to three-dimensional coordinates at a point of observation. A reference station or a network of reference stations such as MELBpos, transfer phase corrections via a data link such as radio or internet, to one or more roving receivers, which then apply these corrections to its measurements (RMIT, 2003). Accuracies at the centimetre level are a possibility given the correct measurement techniques, environmental (e.g. multipath) and atmospheric conditions are present. A study conducted in August 2006 in Frisco, Texas in the United States, showed comparatively good agreement between RTK GPS observed coordinates and that of published state Grid (like SMES) values (Rolbiecki, Lyle, 2006). This study will be discussed later, but it provides valuable supporting evidence of the accuracies possible when using RTK, in a manner such as this project aspires to do.

2.3.3 Rapid Static

The Rapid Static technique involves the post processing of observed GPS data between a fixed reference station receiver and any number of roving receivers for a period of 1 to 20 minutes (Anderson, Mikhail, 1998). Occupation time is substantially reduced from that of static GPS thanks to more efficient ambiguity resolution from the use of dual code and carrier-phase data (Anderson, Mikhail, 1998). The Rapid Static technique is capable of achieving accuracies towards the centimetre level (RMIT, 2003).

Occupation time and accuracy depend greatly on Reference / Receiver separation distance, the number and orientation of satellites available and whether single or dual frequency receivers are used (Anderson, Mikhail, 1998). Anderson and Mikhail (1998) suggest keeping baseline lengths between receivers to within 25km for maximum efficiency. However RMIT's *Surveying using GNSS* (2003), suggests Reference / Receiver distance should not exceed 5km in order to achieve reliable Rapid Static data. They state that baselines longer than 5km result in extended Ambiguity Resolution (AR) time, therefore increasing the required observation time (RMIT, 2003). As Rapid Static's main advantage over the classic static technique is its reduced observation time, keeping the Reference / Receiver distance within 5km will help to utilise the main benefit of this method.

This project will utilise Rapid Static observations as a check between the observed RTK data and the published SMES values. They will provide confirmation on the validity of either value should a discrepancy between the two arise.

2.3.4 Classic Static

Providing the greatest accuracy for GPS surveying, classic static surveying involves the use of 2 or more GPS receivers, simultaneously receiving a least 4 satellite signals over an extended period of time (Anderson, Mikhail, 1998).

Occupation time is critical during static observations so that integer ambiguities can be resolved through the changing of satellite orientation (RMIT, 2003). The occupation time is dependant on a number of factors such as baseline length, satellite numbers and orientation, atmospheric and multipath conditions (RMIT, 2003). Over baselines of less than 10km, observation times of around 30 minutes should be sufficient for a dual frequency receiver (RMIT, 2003). A further 10 minutes of observations may extend the surveys distance a further 10km, dependant upon satellite availability and multipath conditions (RMIT, 2003).

This projects static baselines between marks fell within 10km, however the baselines to the Australian Regional GPS Network (ARGN) mark near the Melbourne CBD were just under 40km away. Observation times in this instance required careful consideration. Table 3.8 from the TxDOT survey manual recommended a 1 hour observation time for baselines ranging from 10 to 40km when undertaking static surveying techniques (TxDOT, 2008).

2.4 Other Studies

2.4.1 Case Study 1

The first case study is an investigation of a hybrid state coordinate system in Frisco, Texas in the United States. Rolbiecki and Lyle, aimed to create a hybrid State Plane Coordinate System (SPCS) “. . . so a surveyor can set up a local coordinate system on the entire Frisco survey control network and work in surface distances” (Rolbiecki and Lyle, 2006) . To do this, Rolbiecki and Lyle, observed 19 city survey marks by RTK GPS whilst connected to the Texas RTK Cooperative Network, which like MELBpos, creates a Virtual Reference Station (VRS) near the receiver, eliminating the need for a base station set-up. (Rolbiecki and Lyle, 2006)

Although their project focused primarily on the agreement of their localised data with a Hybrid Frisco State coordinate system, they did analyse the initial agreement between the published coordinates of the survey marks and their initial RTK observations. Their analysis is essentially the equivalent of what this project aims to achieve and their use of RTK GPS with VRS for data capture also draws comparison.

However consideration must be given to the fact that Rolbiecki and Lyle’s project and this one will have been conducted using different coordinate datum’s and ellipsoids from vastly dissimilar areas half a world away.

2.4.2 Case Study 2

Satalich and Ricketson (1996) investigated the repeatability of RTK GPS with multiple observations of 10 different stations over three days using their own site posted base station. The test site was already occupied with marks previously positioned using static observations. This allowed comparisons to be made with the RTK data on WGS84 coordinates. Their results found that the RTK data was generally within 0.025m horizontally of the static values and the vertical component fell within 0.030m when averaged over the three days (Satalich, Ricketson, 1996). Although this study shows relatively good horizontal agreement with the static values, the RTK baseline distances never exceed 500m and the authors concede that further testing would be required for distances in the range of 1 to 10km (Satalich, Ricketson, 1996). This point contrasts one of the main differences with this project, as the network of SMES marks to be tested, will most likely exceed Satalich and Ricketson's maximum tested range of 500m.

No comparisons between the observations and the National Geodetic Survey (NGS), for which half the marks had published first order values, were made by the authors. The static survey completed less than a year earlier was regarded as the benchmark for RTK data comparison. SMES will be the benchmark in this projects comparisons, with the rapid static observations providing supporting evidence. This projects basic fundamentals of testing RTK repeatability and accuracy has similar goals to that of Satalich and Ricketson's study, and their work will no doubt prove to be a useful reference.

2.4.3 Case Study 3

Hale et al (2005) studied the VICpos service in Victoria when using a variety of GPS receiver types operating under various observation conditions. VICpos provides differential GPS correction data in real time for GPS users across the state of Victoria, through a strategically placed network of 19 CORS operating under the GPSnet umbrella.

The most relevant part of Hales study was the comparison of corrected GPS observations to survey marks with published SMES co-ordinates under varying conditions. The four alternate scenarios were, Totally Clear Conditions (TCC), TCC in the vicinity of high voltage power lines, TCC averaged from three observations, and TCC with access to 4 to 5 satellites. The best results were acquired from TCC averaged from three observations, and then TCC. The other two scenarios offered unacceptable results.

This test, though not extensive, did display how GPS data can easily be corrupted by the surrounding environment and highlights the need to carefully select sites and observation windows.

This case study also helps to highlight the accuracy advantage of averaged coordinates from multiple observations as this scenario fielded the most accurate results of the other conditions. This project will also produce averaged coordinates from 3 independent rounds of RTK GPS observations to marks with known values. Despite Hales use of averaged coordinates being limited to one mark in totally clear conditions, it does draw attention to it being the most favourable method of observation.

CHAPTER 3

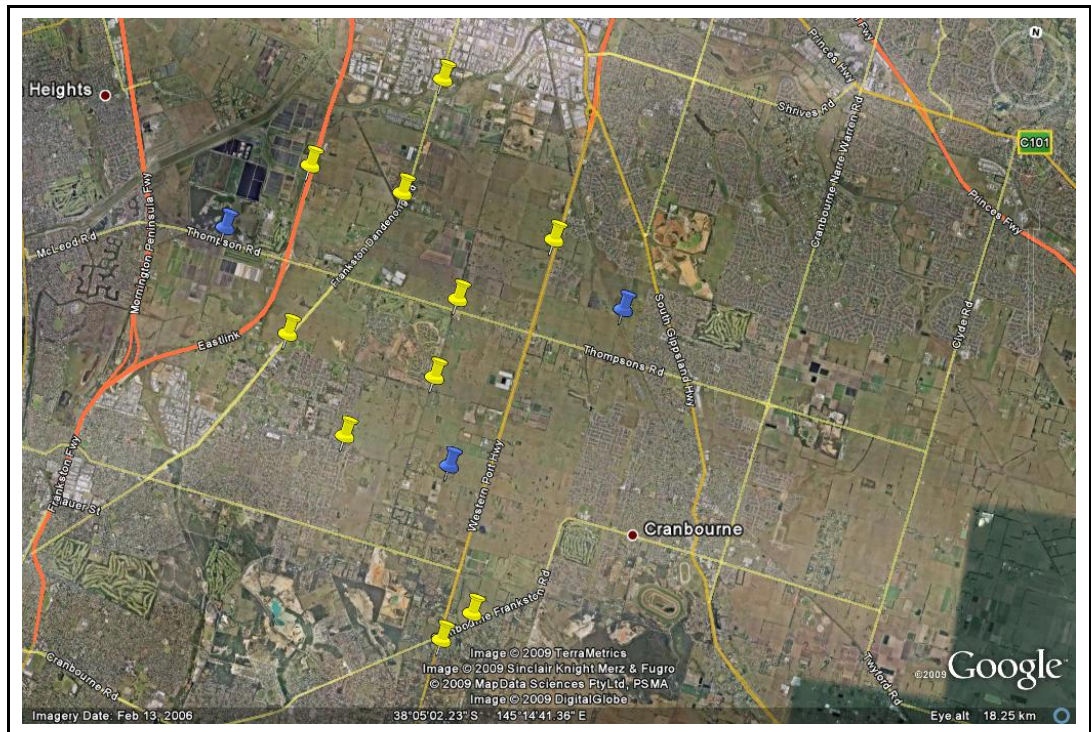
METHODOLOGY

3.1 Methodology

3.1.1 Area Selection

Both a rural and a residential environment were selected for the test sites and these areas were selected primarily for their availability of useful, 3rd order ground marks. The importance of a good spread of suitable marks was imperative to the aim of the study, which seeks to evaluate the quality of published SMES co-ordinates.

Figure 3.1 - Rural Site Marks – Suburb of Cranbourne



The rural site selected was near the suburb of Cranbourne, approximately 35km South East of Melbourne. The 13 marks selected were spread over a large area spanning over 11 km in length and 8 km in width. The area consists mainly of open grazing paddocks and is bounded by residential and commercial development on almost every side. (see figure 3.1)

This site was selected mainly because of the likelihood of future residential or commercial development within it, where there will be a need for 3rd order survey marks.

3.1.2 Mark Selection

Only 3rd order marks with co-ordinates stated to the millimetre were chosen for observation, as stated in the aim and objectives. By only selecting 3rd order marks, it is relevant to the Surveyor Generals GNSS requirements as well as maintaining a level of consistency and accuracy, reducing the risk of clouding the results.

It was necessary to pick and eliminate marks based on their surroundings in relation to trees and structures. The majority of 3rd order marks in the selected areas would have been placed without any consideration for the basic needs of GPS observation, which greatly reduced the number of suitable marks.

It eventually became necessary to reduce the number of marks observed in both the residential and rural environments to 13 each. This was mainly due to the inadequate surroundings of a number of marks or simply that they had been destroyed.

The marks that were selected generally had a clear view of the sky, free from overhanging trees and power poles. Signs, wire fencing and metal house roofs were unavoidable in a number of situations which in turn introduced the likelihood of multipath and contributed to an obstructed satellite view in the sky. These conditions would be no different to any other sample group of marks in any other environment and are therefore circumstances that had to be endured.

3.1.3 Static Component

In order to provide co-ordinates independent of SMES values and achieve the greatest accuracy, static observations were carried out on 3 separate marks in both the rural and residential environments. From these marks, the reference stations for the rapid static observations would be placed and therefore required a high degree of accuracy.

The coordinates for the selected static marks were derived from the Australian Regional GPS Network (ARGN) mark located at the Melbourne Observatory just south of the Melbourne CBD.

The ARGN network of highly accurate marks provides the geodetic framework for the spatial data infrastructure in Australia (Geoscience Australia, 2008). The Melbourne observatory site (MOBS) continually logs geodetic quality data all year round. The data from each ARGN site is freely available online from the Geoscience Australia site. (Geoscience Australia, 2008)

It was critical to achieve the right amount of occupation time during the static observations so that the integer ambiguities could be resolved through the changing of satellite orientation. The occupation time is dependent on a number of factors such as baseline length, satellite numbers and orientation, atmospheric and multipath conditions (RMIT, 2003).

As the static observations were to be conducted at the best observation times of the day and the marks selected were relatively free of any adverse multipath conditions, the baseline lengths were the critical element for consideration.

The baseline lengths between all of the static marks did not exceed ten kilometres, however all the baselines to the MOBS site in the city were nearly 40 km away. Research into satisfactory observation times resulted in a minimum duration of 1 hour being adopted for all static marks (TxDOT, 2008).

The Classic Static component was carried out using two Leica 1200 dual frequency GPS receivers, mounted on tribrachs and tripods. Observations were carried out using WGS84 coordinates, due to its fundamental relationship with all raw GPS observations (Geoscience Australia, 2008)

The recording rate was set at 30 second intervals to coincide with the ARGN MOBS recording rate and the elevation mask set at fifteen degrees, as recommended by the Standards and Practices for control surveys handbook (SP1) (ICSM, 2007).

The classic static stations were occupied in a 'Leap Frog' style ensuring each station was connected by at least two baselines within a triangular shape. For example, once receiver 'A' was finished simultaneously observing data with receiver 'B', it leaped to the next station, where it again began logging simultaneously with receiver 'B' which had remained in its original position. Once this occupation was finished, receiver 'B' leaped to another station, while receiver 'A' remained at its second station for further simultaneous observations with 'B'.

3.1.4 Rapid Static Component

The Rapid Static component was carried out using two Leica 1200 dual frequency GPS receivers, mounted on tribrachs and tripods. Observations were carried out using WGS84 coordinates.

Each mark was occupied for a minimum of ten minutes. Where trees or other obstructions reduced the sky view or multipath was of concern, a maximum of twenty minutes was used. If the position quality was too poor, observation of the mark was delayed until such time it had improved. These intervals were in accordance with the Survey Practice Handbook version 1.7, in order to minimise the effects of multipath.

The recording rate was set at five seconds and the elevation mask set at fifteen degrees, as recommended in SP1.

Occupation time and accuracy depended greatly on Reference / Receiver separation distance. As stated in section 2.3.3, it is recommended that Reference / Receiver distance not exceed 5km for maximum efficiency. Reference / Receiver distance was only really an issue in the rural environment where less than half of the marks were separated by a distance of 6 to 7kms from their base station. Generally these marks were given extra observation time to account for the excess distance.

The Rapid Static observations began with the reference receiver located at BASE A. Whilst the reference receiver continually logged data, the roving receiver conducted ten to twenty minute observations of the surrounding permanent marks.

To provide redundancy on the initial observations, a second round of Rapid Static measurements was carried out with the reference receiver located at BASE B. Again all 12 marks were occupied for a period of ten to twenty minutes, whilst the reference receiver continually logged data. The two independent observations of each mark provided an averaged solution for their coordinates.

Finally a third round of observations was carried out, this time with the reference receiver at BASE C. This provided increased redundancy on the results and would contribute to a tighter averaged solution in the coordinates. Despite BASE's A, B and C already having high quality static coordinates, taking Rapid Static observations of them also would help to measure the accuracy of this process.

The Rapid Static observations in this project will be primarily used as a check between the observed RTK data and the published SMES values. They will provide confirmation on the validity of either value should a discrepancy between the two arise.

3.1.5 RTK Component

The Real Time Kinematic (RTK) component was carried out using the Leica 1200 dual frequency GPS receiver back pack and pole. The receiver was operating under the MELBpos network and coordinates were observed on the MGA94 Zone 55 datum.

The occupation time was set at 60 seconds in order to average out verticality errors and enable any multipath to be minimised (RMIT, 2003). As stated in the Survey Practice Handbook version 1.7, where multipath is a concern, the station occupation times should be increased to average out the effects of multipath as satellite geometry changes.

The Recording Rate was set at one second and the elevation mask at fifteen degrees, as recommended by SP1.

In order to provide measurement redundancy 3 occupations of each mark were carried out with a minimum interval between observations of twenty minutes. SP1 ver 1.7, recommends a minimum interval of 45 minutes, however the Victorian Practice Directives January 2007 page 7, state that a minimum interval of twenty minutes should be applied. The second and third occupations of the point will be preceded by a new receiver initialisation as recommended by Surveyor General of Victoria Practice Directives 2007, Section 2.3.1.

3.1.6 Error Identification and Minimisation

All equipment, including tripods, tribrachs and poles were tested, calibrated and adjusted where required to ensure all inaccuracies were minimised and the best possible results achieved.

Sky plots of satellite availability were downloaded via the Leica Geo-office program in order to approximate the highest quality observation times of the day. This ensured the best satellite availability during observation times and helped to ensure the highest quality data was captured.

Due to a shortage of useable marks, the presence of propagation dependent errors such as multipath were difficult to avoid in a number of situations. Where multipath may have had an effect on measurement quality, observation times were generally increased to average out the affects.

A Zero Baseline Test was performed simultaneously on both receivers to verify measurement precision, ensure correct receiver operation and to validate the data processing software (RMIT, 2003). This was done by connecting both receivers up to one antenna via an antenna splitter, supplied by CRKennedy, Victoria. The resulting baseline length should equal zero for 2 receivers operating in perfect unison, however any sub-millimetre residuals will represent a vector of receiver errors (RMIT, 2003).

Due to a lack of material on conducting 'Zero Baseline Tests', it was decided that replicating the same field conditions as this project would be the best course of action. Therefore, two different tests were conducted on the receivers. One test set to a static configuration for the period of one hour and another set to a rapid static configuration for a ten minute duration (See section 4.1.1)

No Zero Baseline Test was carried out under RTK conditions, as only one receiver was used for this method and the results achieved from the static and rapid static tests showed the receivers were working adequately.

3.1.7 Data Reduction

The RTK processing began with the importation of Leica GSI files into GeoOffice (LGO) Version 7.

Any unacceptable residuals from the three independent observations showed up in the field. This enabled extra observations to be taken of a particular mark until there were at least three measurements falling within the averaging limits. During processing, poor measurements were interrogated and the offending observation removed from the averaging solution.

Once the data was deemed sound, it was ready for comparison with the SMES and rapid static values. The differences in the RTK and rapid static MGA94 coordinates were evaluated in order to validate the observed data.

The static and rapid static post processing of baselines was carried out in LGO using the default static job settings provided..

The static jobs required the importation of the ARGV MOBS data via the LGO Internet download option. This provided 24 hours of Geodetic Quality data for use as control for the raw GPS observations.

It was important to ensure consistent naming of stations to enable the averaging of point observations during processing. Cross checking of station signal heights in LGO with height records documented in the field, was also a necessary quality control measure.

The processing of the baselines was done in a manner consistent with how they were observed in the field. The baselines were processed and the points stored once ambiguity resolution was achieved.

A minimally constrained adjustment was undertaken, followed by a fully constrained adjustment, both of which passed the relevant quality tests after making the necessary baseline manipulations (see appendices 2 to 5).

CHAPTER 4

DISCUSSION RESULTS

4.1 QUALITY CONTROL

4.1.1 Zero Baseline Test

Table 4.1 - Static – Zero Baseline Test Results

MARK	E / N	RECEIVER 1	RECEIVER 2	RESIDUALS
LANGWARRIN	E	340662.8820	340662.8820	0.0000
PM 141	N	5775439.3670	5775439.3671	-0.0001

As discussed in the methodology, the residuals shown in table 4.1 are the results of one hour of data logging from two receivers joined to one antenna. The results show sub millimetre differences in position between the two receivers, which provides a good indication that the units are working in satisfactory unison.

Table 4.2 - Rapid Static – Zero Baseline Test Results

MARK	E / N	RECEIVER 1	RECEIVER 2	RESIDUALS
LANGWARRIN	E	340662.8820	340662.8820	0.0000
PM 141	N	5775439.3670	5775439.3669	0.0001

The rapid static zero baseline test provided the results displayed in table 4.2 from ten minutes of continuous data logging between the receivers. A similar result to the static testing was achieved with a one tenth of a millimetre difference in the northing. This test showed good unison between the receivers whilst operating under rapid static conditions.

As explained in section 3.1.6, no RTK testing was conducted. This was due to only one receiver being required for RTK observations and the static and rapid static testing provided adequate proof the GPS receivers were working properly.

4.2 RTK COMPONENT

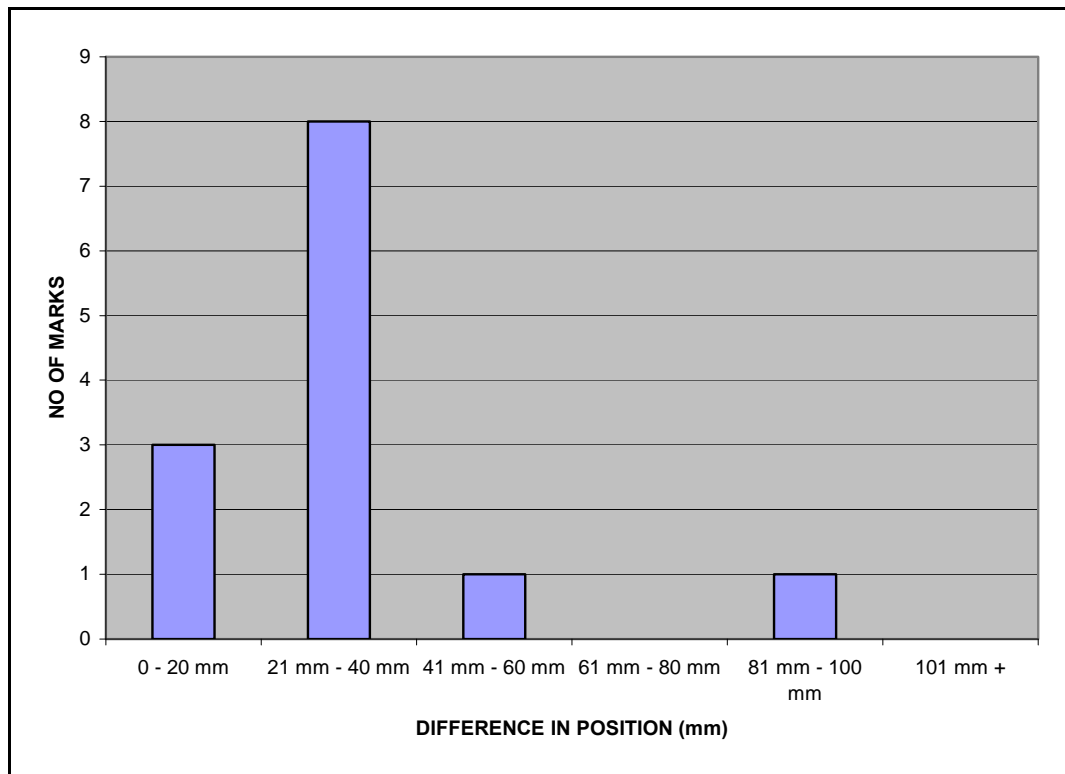
4.2.1. RTK / SMES Difference In Position - Residential Marks

Table 4.3 - RTK / SMES – Difference in Position Table – Residential Marks

MARK	Δ Easting	Δ Northing	Diff in Position
LANGWARRIN PM 99	-0.013	0.005	0.014
FRANKSTON PM 119 (Base B)	0.011	-0.042	0.043
LANGWARRIN PM 141 (Base C)	-0.038	0.011	0.040
LANGWARRIN PM 157	-0.031	0.005	0.031
FRANKSTON PM 277	-0.015	-0.029	0.033
FRANKSTON PM 367	-0.026	-0.015	0.030
FRANKSTON PM 475	-0.020	-0.004	0.020
FRANKSTON PM 552 (Base A)	-0.029	-0.020	0.035
FRANKSTON PM 651	-0.025	0.008	0.026
FRANKSTON PM 653	-0.008	-0.006	0.010
FRANKSTON PM 660	-0.095	-0.022	0.097
FRANKSTON PM 726	-0.023	-0.025	0.033
FRANKSTON PM 898	-0.020	0.005	0.021
		Average	0.033

The data shown in Table 4.3 shows the differences between the published SMES values and the RTK observations within the residential site. Generally the residuals fall within the limits of what you would hope to achieve from such observations, with the average difference in position being 0.033m. PM 660 appears to be the only real outlier of the sample group with a difference in position of 0.097m.

Figure 4.1 - RTK / SMES – Difference in Position Graph – Residential Marks



As figure 4.1 shows, PM 660 is the only member of the sample group, which shows an undesirable level of accuracy. Despite the 2007 practice directives allowing for 0.10m difference in position, PM 660 would be close enough to the limit (0.097m) to be regarded as unacceptable.

Only PM 119 falls within the 0.041m to 0.060m range, which although still acceptable under the practice directive requirements, is entering the undesirable level of accuracy area. As its value only just falls within this bracket (0.043m) it could quite fairly be regarded as acceptable.

The remaining RTK observations however show relatively good agreement with their corresponding SMES values, with eleven of the thirteen observed marks falling within 0.04m of their published value.

Figure 4.2 - RTK / SMES – Difference in Position Plot – Residential Marks

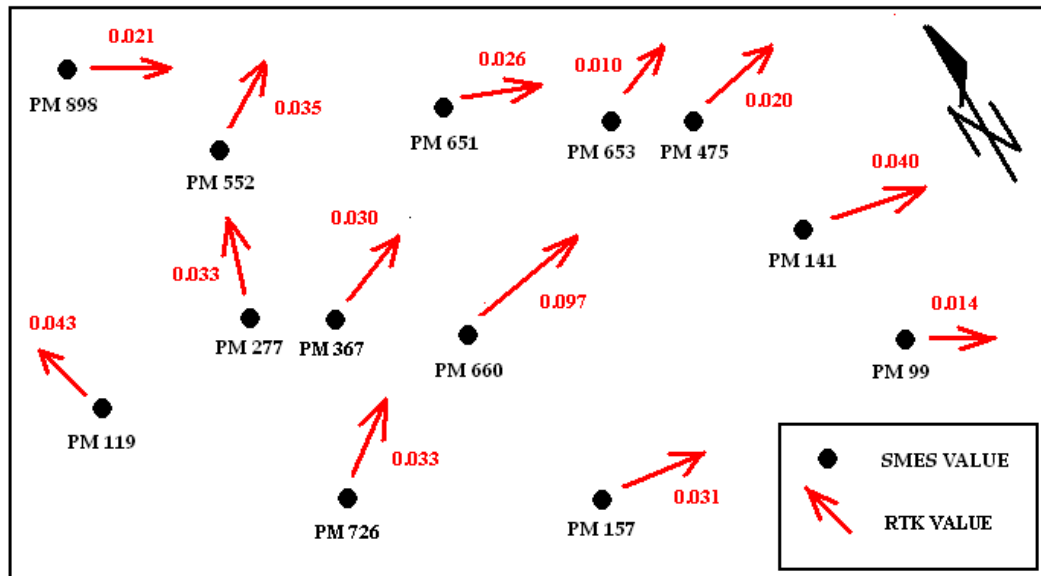


Figure 4.2 shows a plot of the residential RTK vector directions and distances from their published SMES values. The plot represents the data displayed in table 4.3 and shows how the majority of observations have reasonable good agreement with their stated positions. The obvious exception is PM 660.

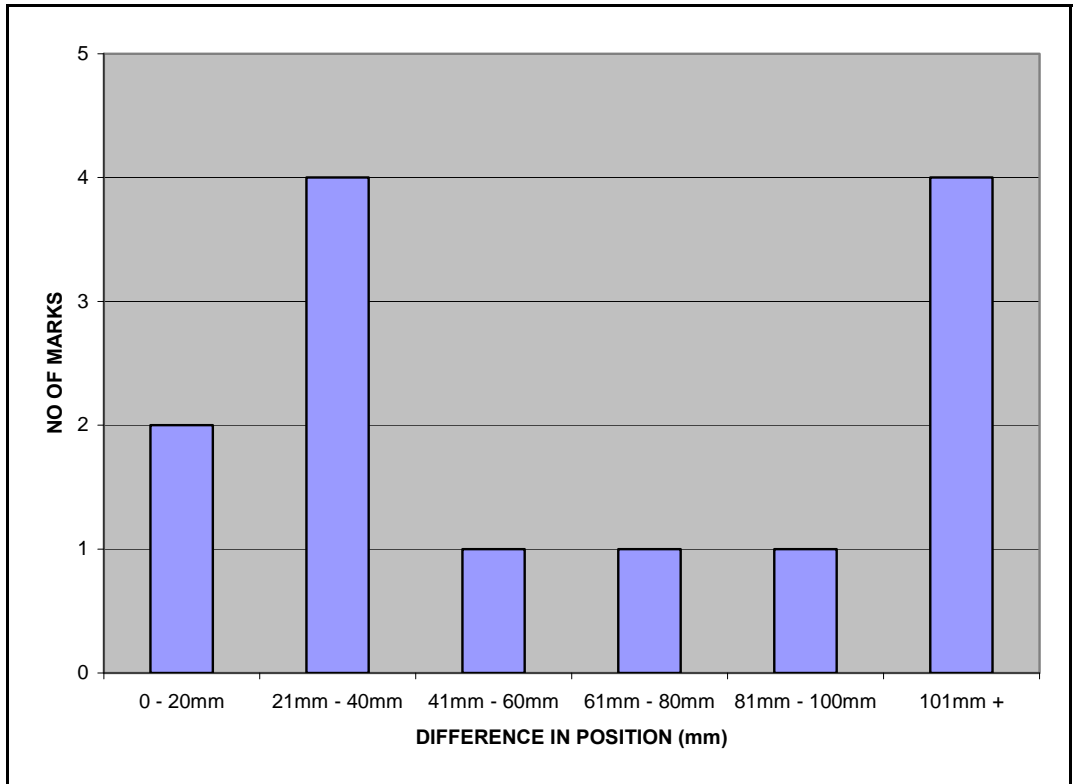
4.2.2 RTK / SMES Difference In Position - Rural Marks

Table 4.4 - RTK / SMES – Difference in Position Table – Rural Marks

MARK	Δ Easting	Δ Northing	Diff in Position
EUMEMMERRING PM 31	0.057	0.102	0.117
LYNDHURST PM 31	-0.001	0.049	0.049
LANGWARRIN PM 55	0.012	-0.020	0.023
LANGWARRIN PM 130	0.024	-0.012	0.027
LYNDHURST PM 236	-0.018	0.000	0.018
LYNDHURST PM 238 (Base A)	0.093	0.130	0.160
LYNDHURST PM 241	0.043	0.075	0.086
EUMEMMERRING PM 257	-0.017	-0.013	0.022
LYNDHURST PM254	0.085	0.068	0.109
LYNDHURST PM 283 (Base B)	0.008	0.029	0.031
LYNDHURST PM 288 (Base C)	0.019	0.002	0.020
LYNDHURST PM 396	0.041	0.113	0.120
MMB 5875	0.028	0.073	0.078
		Average	0.066

Table 4.4 shows the results from the RTK observations within the rural area. The delta eastings and northings of the rural area appear larger than what was achieved in the residential zone. As a result the differences in position vary quite a bit from their published SMES values. The average difference in position for the rural environment is double (0.066m) the residential zone value (0.033m).

Figure 4.3 - RTK / SMES – Difference in Position Graph – Rural Marks



As figure 4.3 shows, the rural marks are far less agreeable with their corresponding SMES values than the residential group was. Only 6 marks fall within 0.04m of their SMES value compared to eleven in the residential group. A further three marks can be found within the undesirable accuracy range of 0.041m to 0.100m compared to two in the residential. And a group of four marks exceed 0.101m, ranging in difference from 0.109m to 0.160m. These last four marks exceed the 0.10m allowable difference under the 2007 practice directives and could not be considered in any MGA94 connection solution.

Figure 4.4 - RTK / SMES – Difference in Position Plot – Rural Marks

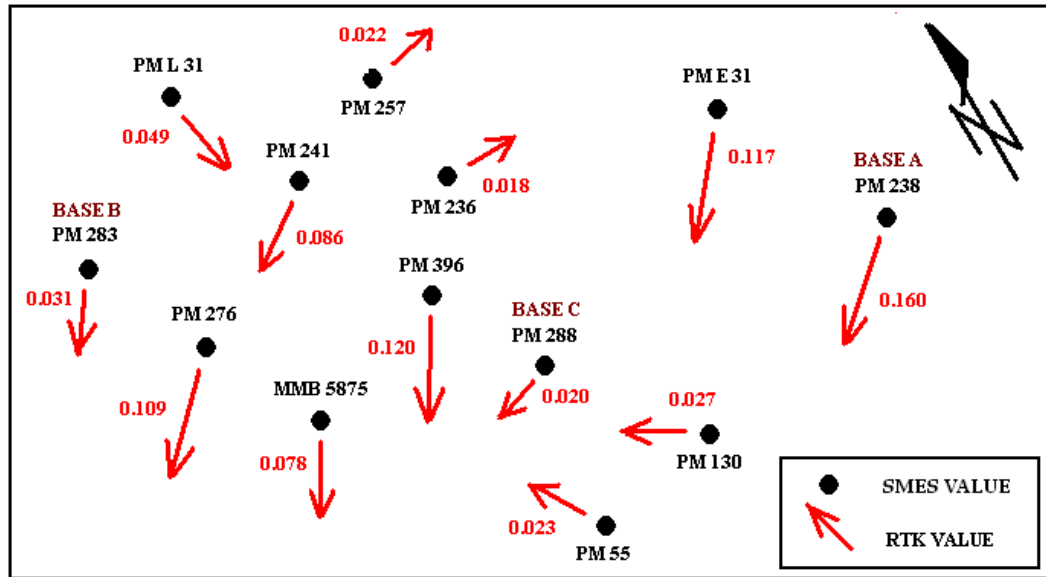


Figure 4.4 shows a plot of the RTK observations against their matching SMES value in the rural environment. The vector directions and distances appear much more erratic than the residential mark plot in figure 4.2. The plot of the RTK observations implies that many of the marks are positioned drastically different to what their published values suggest. It will be necessary to verify the RTK measurements with the rapid static observations in order to confirm the validity of these observed positions.

4.2.3 - RTK - Further Analysis

Table 4.5 - RTK / SMES – Occupation Analysis – Residential Marks

MARK	RTK / SMES - DIFFERENCE IN POSITION		
	1 OCCUPATION	2 OCCUPATIONS	3 OCCUPATIONS
LANGWARRIN PM 99	0.013	0.015	0.014
FRANKSTON PM 119 (Base B)	0.044	0.045	0.043
LANGWARRIN PM 141 (Base C)	0.044	0.041	0.040
LANGWARRIN PM 157	0.032	0.033	0.031
FRANKSTON PM 277	0.050	0.037	0.033
FRANKSTON PM 367	0.043	0.033	0.030
FRANKSTON PM 475	0.028	0.026	0.020
FRANKSTON PM 552 (Base A)	0.044	0.034	0.035
FRANKSTON PM 651	0.010	0.027	0.026
FRANKSTON PM 653	0.010	0.014	0.010
FRANKSTON PM 660	0.097	0.097	0.097
FRANKSTON PM 726	0.030	0.033	0.033
FRANKSTON PM 898	0.021	0.024	0.021
MEAN	0.036	0.035	0.033

Table 4.5 shows the RTK difference in position in the residential environment after one, two and three occupations of each point. In most instances the residuals do not differ significantly and the mean values of each round show a reduction in the position difference from the first round of observations (0.036m) through to the third (0.033m).

A number of the first round observations appear to have a position closer to the SMES value than that of their corresponding third round measurement. This however does not necessarily mean that the observations are decreasing in accuracy, but possibly that their true position is being realised through the observation of multiple rounds. This process of multiple rounds provides redundancy on the final results and guards against erroneous single measurements. This point is highlighted in table 4.6, where it can be seen that the first round observation of PM 277 (0.050m) has some difference from its second (0.037m) and third (0.033m) round observations. Although not a severe variation in position, the final location of the point would have been 0.017m further from its SMES value had only one round of observations been conducted.

Table 4.6 - RTK / SMES – Occupation Analysis – Rural Marks

MARK	RTK / SMES - DIFFERENCE IN POSITION		
	1 OCCUPATION	2 OCCUPATIONS	3 OCCUPATIONS
EUMEMMERRING PM 31	0.105	0.117	0.117
LYNDHURST PM 31	0.048	0.054	0.049
LANGWARRIN PM 55	0.015	0.020	0.023
LANGWARRIN PM 130	0.024	0.028	0.027
LYNDHURST PM 236	0.036	0.027	0.018
LYNDHURST PM 238 (Base A)	0.156	0.161	0.160
LYNDHURST PM 241	0.081	0.085	0.086
EUMEMMERRING PM 257	0.013	0.021	0.022
LYNDHURST PM254	0.104	0.109	0.109
LYNDHURST PM 283 (Base B)	0.033	0.033	0.031
LYNDHURST PM 288 (Base C)	0.018	0.018	0.020
LYNDHURST PM 396	0.116	0.124	0.120
MMB 5875	0.083	0.079	0.078
MEAN	0.064	0.067	0.066

Table 4.6 shows the RTK difference in position within the rural site after one, two and three occupations of each point. In almost all instances the first round of observations produce a position closer to the SMES value than that of the following rounds. Similar to the residential results, this does not necessarily mean the initial observation is a better realisation of the marks position, as it needs to be verified by a second measurement. The actual position of the mark may in fact be physically further away than this initial observation, which can then be realised by conducting further rounds of measurements.

However it must be said that the opposite is also a possibility. The second and third rounds of observations may in deed be degrading the quality of the final position of the marks. This may be due to a decline in observation conditions during these periods as a result of reduced satellite numbers or poor satellite orientation. Despite this possibility, the variations between rounds are relatively minor and would therefore carry little significance.

With all this in mind, the benefits of conducting multiple rounds of RTK observations can be seen through the results presented in tables 4.5 and 4.6. The results lend support to the RTK data capturing process and provide confidence when making conclusions on the data.

4.3 Static Component

4.3.1 Static - Residential Marks

Table 4.7 - Static – Residential Marks Results Table

MARK	SMES / STATIC RESULTS			RTK / STATIC Diff in Position
	Δ Easting	Δ Northing	Diff in Position	
FRANKSTON PM 552 (Base A)	-0.025	-0.016	0.030	0.005
FRANKSTON PM 119 (Base B)	0.012	-0.055	0.056	0.013
LANGWARRIN PM 141 (Base C)	-0.040	-0.007	0.040	0.018

Table 4.7 shows the static GPS results for the rapid static base stations in the residential environment. There appears to be some noticeable deviation between the SMES values and observed static values of the marks. The RTK observations of the marks tend to have a similar difference in position to the static measurements, indicating some possible movement from their stated SMES position.

Figure 4.5 - Static / SMES / RTK – Residential Marks Plot

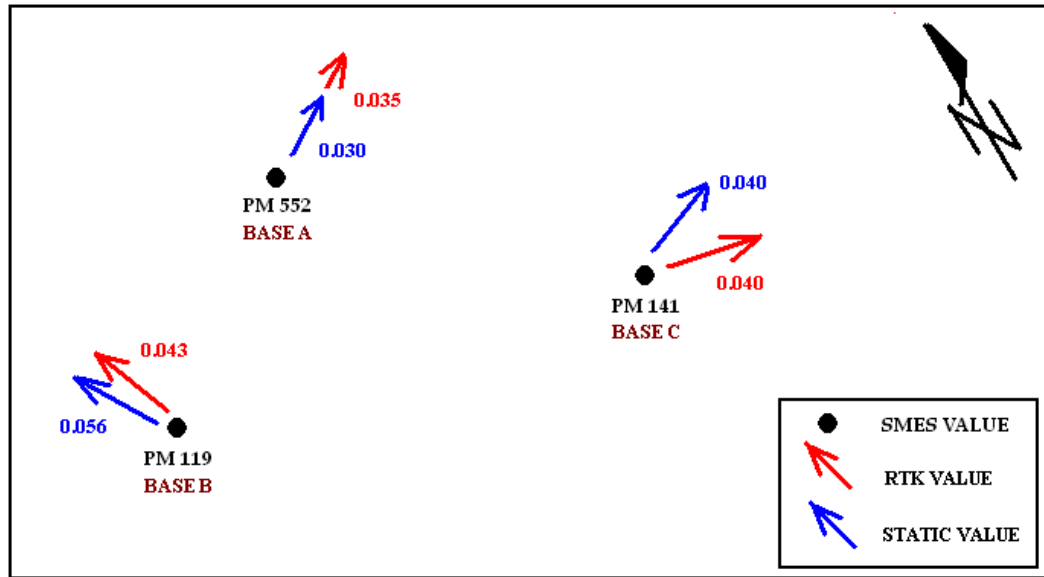


Figure 4.5 shows the vector directions of the static and RTK observations from their stated SMES value in the residential environment. As the table 4.7 indicated, the static and RTK values are showing relatively good agreement with each other in relation to their position from the SMES value. This is an indication that the SMES values of these marks may not completely represent their actual position.

4.3.2 Static – Rural Marks

Table 4.8 - Static – Rural Marks Results Table

MARK	SMES / STATIC RESULTS			RTK / STATIC Diff in Position
	Δ Easting	Δ Northing	Diff in Position	
LYNDHURST PM 238 (BASE A)	0.046	-0.021	0.050	0.159
LYNDHURST PM 283 (BASE B)	-0.020	-0.030	0.036	0.066
LYNDHURST PM 288 (BASE C)	0.027	-0.004	0.028	0.010

Table 4.8 shows the static GPS results for the rapid static base stations in the rural environment. Again, there are some noticeable differences between the SMES values and observed static values of the marks. However the RTK differences for base's A and B seem to be quite erratic in relation to the given SMES and static positions. They appear to agree with neither value and have introduced some uncertainty as to the true position of the marks. Base C shows relatively good agreement with both its SMES and RTK value giving a reasonably good indication of its position.

Figure 4.6 - Static / SMES / RTK – Rural Marks Plot

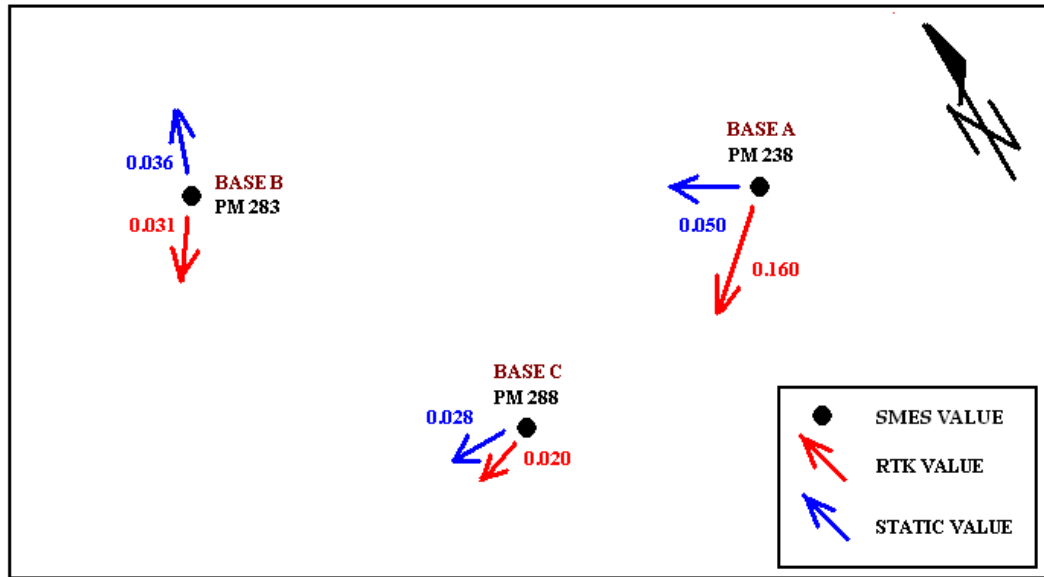


Figure 4.6 shows the vector directions of the static and RTK observations from their stated SMES value in the rural environment. The static and RTK vector directions and distances of base's A and B show no consistency with their stated SMES values. The reasons behind the erratic nature of the directions and distances is difficult to comprehend. Base A is positioned quite close to a railway line with overhanging wires and occasionally passing trains, which may present some adverse measurement conditions for RTK observation. Base B on the other hand is relatively free of any influencing sources of multipath with an uninterrupted 360-degree view of the sky.

4.4 Rapid Static Component

4.4.1 Rapid Static - Residential Marks

Table 4.9 - Rapid Static / SMES Difference in Position Results Table – Residential Marks

MARK	SMES / Rapid Static DIFF IN POS	SMES / RTK DIFF IN POS	RTK / Rapid Static DIFF IN POS
LANGWARRIN PM 99	0.010	0.014	0.014
FRANKSTON PM 119 (Base B)	0.056	0.043	0.013
LANGWARRIN PM 141 (Base C)	0.040	0.040	0.018
LANGWARRIN PM 157	0.031	0.031	0.011
FRANKSTON PM 277	0.040	0.033	0.008
FRANKSTON PM 367	0.038	0.030	0.012
FRANKSTON PM 475	0.037	0.020	0.021
FRANKSTON PM 552 (Base A)	0.030	0.035	0.005
FRANKSTON PM 651	0.022	0.026	0.023
FRANKSTON PM 653	0.016	0.010	0.007
FRANKSTON PM 660	0.099	0.097	0.019
FRANKSTON PM 726	0.044	0.033	0.012
FRANKSTON PM 898	0.018	0.021	0.011
AVERAGE	0.037	0.033	0.013

Table 4.9 shows the difference in position between SMES / rapid static observations and RTK / rapid static observations within the residential environment. It also presents the RTK / SMES difference in position to enable comparison with the rapid static / SMES difference. As the table shows, there appears to be reasonably consistent differences between all the marks in relation to the SMES / rapid static and the SMES / RTK differences.

It is worth noting that with a number of marks the RTK position is as far away from its rapid static position as it is from its SMES value. These observations however have relatively small residuals between SMES, rapid static and RTK positions and would be considered only minor.

The general agreement between the RTK and rapid static measurements is also displayed in the average differences in position residuals. There is only a 0.004m difference between the SMES / rapid static (0.037m) and the SMES / RTK (0.033m) averages. This is supported by the 0.013m average differences between the rapid static and RTK measured positions of the mark.

Analysis of the data in table 4.9 provides positive, independent verification on the accuracy of the RTK measurements.

Figure 4.7 - Rapid Static / SMES – Difference in Position Graph – Residential Marks

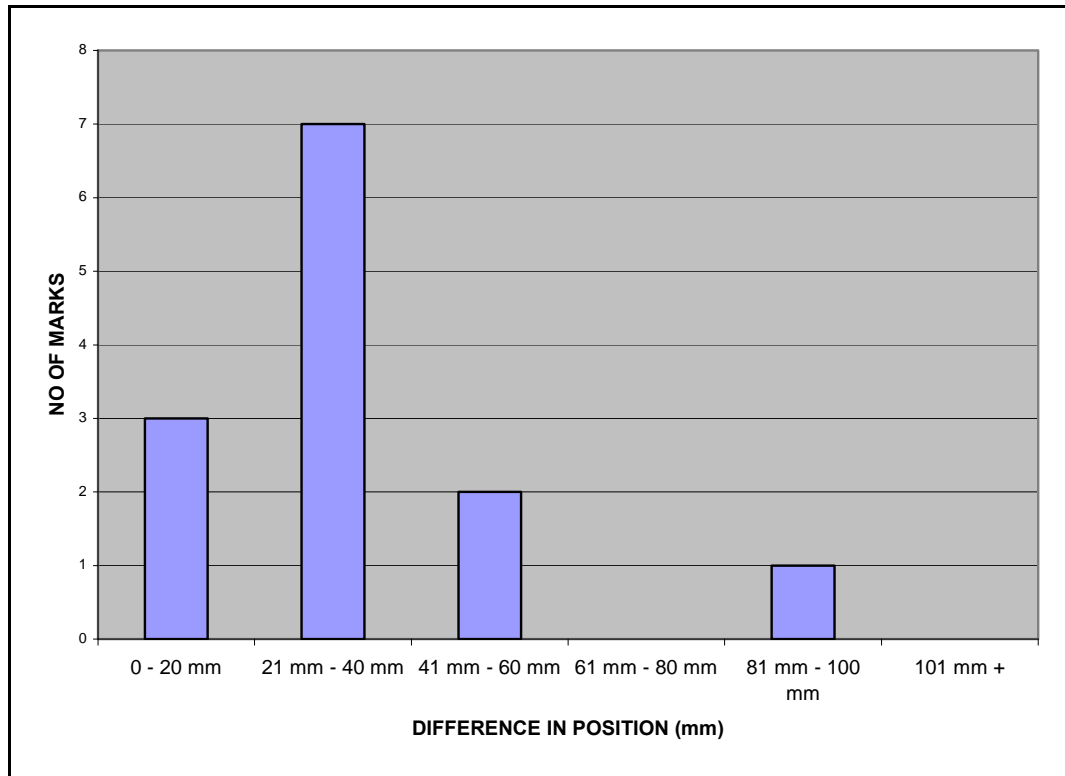


Figure 4.7 shows the grouping of residential rapid static observations relative to their difference in position from their corresponding SMES value. This graph draws close comparison with the residential RTK / SMES graph in figure 4.1. The notable differences between the two graphs is the rapid static observations have seven observations falling within the 0.021m to 0.040m range of their SMES value and two within the 0.041m to 0.060m range. In comparison the RTK has eight within the 0.021m to 0.040m range and one between 0.041m and 0.060m.

This is further evidence that the majority of marks in the residential zone have reasonably good agreement with their published SMES values and that all but one are able to satisfy the 0.10m requirement of section 2.3.3 (i) of the 2007 practice directives. PM 660 (0.099m) is the only mark, which would more than likely fail due to its close proximity to the threshold. The data in figure 4.7 also helps to verify the accuracy of the RTK observations.

Figure 4.8 - Rapid Static / SMES / RTK - Residential Marks Plot

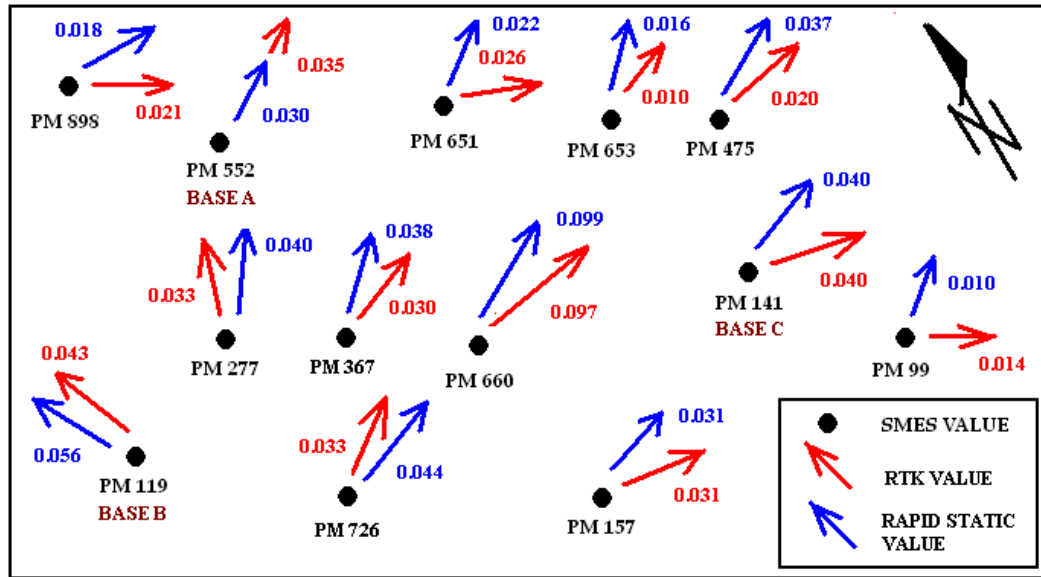


Figure 4.8 shows the vector directions of the residential rapid static and RTK observations from their stated SMES positions. Once again the relatively good agreement between the residential RTK and rapid static observations can be seen. Vector directions and distances show relative consistency with one another and where they do not the residuals are quite small.

The residuals between the rapid static observations and their SMES values are also relatively good on the whole. Residuals within 0.04m could be regarded as having reasonably good agreement.

4.4.2 Rapid Static - Rural Marks

Table 4.10 - Rapid Static / SMES Difference in Position Results Table – Rural Marks

MARK	SMES / Rapid Static DIFF IN POS	SMES / RTK DIFF IN POS	RTK / Rapid Static DIFF IN POS
EUMEMMERRING PM 31	0.016	0.117	0.123
LYNDHURST PM 31	0.030	0.049	0.074
LANGWARRIN PM 55	0.032	0.023	0.010
LANGWARRIN PM 130	0.027	0.027	0.003
LYNDHURST PM 236	0.010	0.018	0.016
LYNDHURST PM 238 (Base A)	0.050	0.160	0.159
LYNDHURST PM 241	0.021	0.086	0.087
EUMEMMERRING PM 257	0.025	0.022	0.004
LYNDHURST PM 254	0.055	0.109	0.085
LYNDHURST PM 283 (Base B)	0.036	0.031	0.066
LYNDHURST PM 288 (Base C)	0.028	0.020	0.010
LYNDHURST PM 396	0.002	0.120	0.119
MMB 5875	0.031	0.078	0.107
AVERAGE	0.028	0.066	0.066

Table 4.10 shows the difference in position between SMES / rapid static observations and RTK / rapid static observations within the rural environment. It also presents the SMES / RTK difference in position to enable comparison with the SMES / rapid static difference.

This table shows reasonably good agreement between the rapid static measurements and their associated SMES values. They have an average difference of 0.028m between them and only the observations at PM 238 (0.050m) and PM 254 (0.055m), show any real signs of disagreement.

The rapid static observations do not show good agreement with the RTK measurements. Only five of the possible thirteen RTK values share any agreement with the rapid static observations. The remaining RTK measurements range from 0.074m to 0.159m difference with their corresponding rapid static measurement. These differences are consistent however with the variations seen between the RTK / SMES observations, which may suggest multiple erroneous RTK measurements have occurred.

Figure 4.9 - Rapid Static / SMES – Difference in Position Graph – Rural Marks

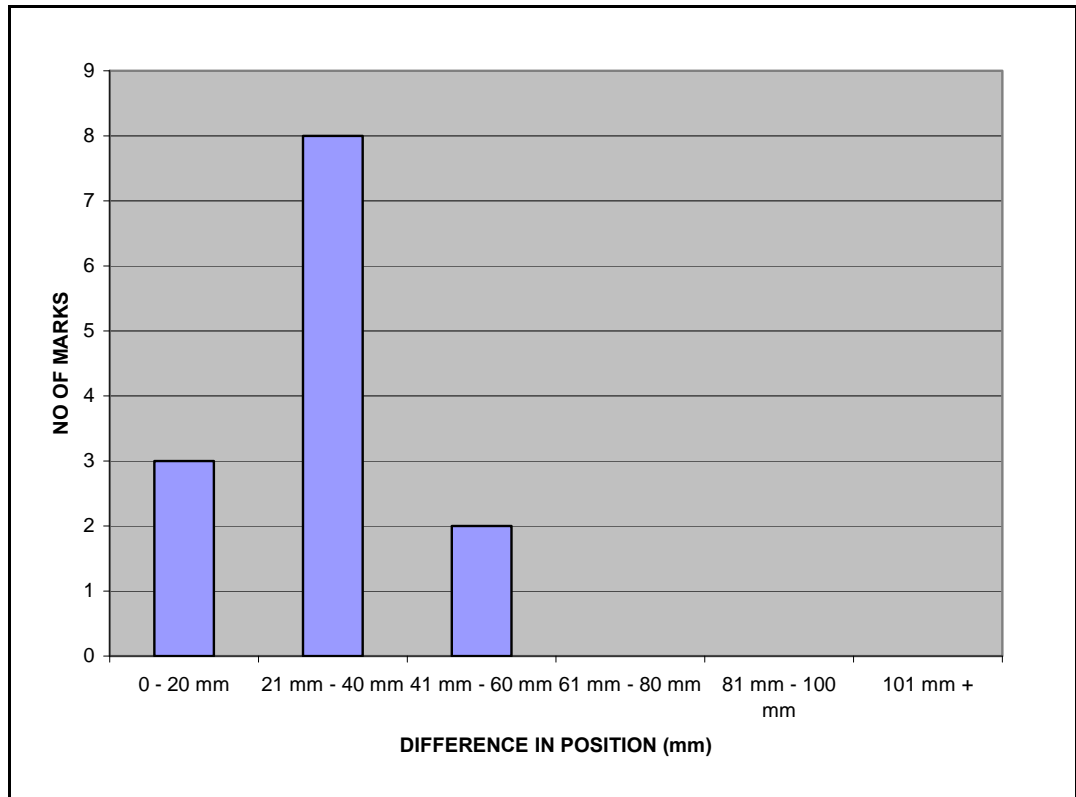


Figure 4.9 shows the graphed difference in position values of the rapid static observations from their corresponding SMES values. This graph further highlights the relatively good agreement the rapid static observations share with their SMES values. Eleven of the thirteen observations fall on or within 0.040m of their SMES value and the remaining two measurements in the 0.041m to 0.060m range still adequately satisfy the 0.10m practice directive requirement.

The data displayed in this chart shows obvious differences to the rural RTK / SMES graph in figure 4.3 in which 4 marks exceeded the 0.10m threshold. A further three observations ranged anywhere within 0.041mm to 0.100m of their SMES marks and only six fell beneath the 0.040m level. This RTK data on its own suggested the majority of marks had significant positional differences with their stated SMES values within the rural environment.

The rapid static data displayed in figure 4.9 would suggest that the SMES values of the majority of rural marks would reasonably represent their actual physical position on the ground. It suggests that all marks in the sample group would adequately satisfy the 2007 Victorian practice directive requirements of being within 0.10m from their stated SMES value.

Figure 4.10 - Rapid Static / SMES / RTK - Rural Marks Plot

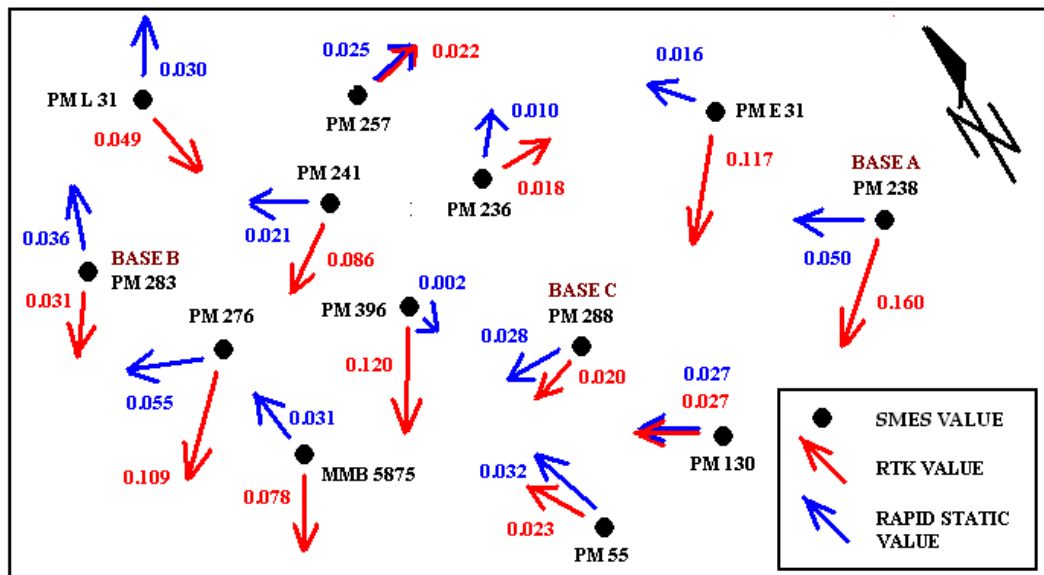


Figure 4.10 plots the rural SMES, rapid static and RTK data from table 4.11 showing vector directions and distances. This plot shows the erratic relationship SMES and rapid static values share with the RTK observations in the rural area. In isolation, the rapid static and SMES data appear in general agreement with one another. However the RTK vectors show little consistency with the rapid static data, varying dramatically in direction and distance from their stated SMES values.

CHAPTER 5

CONCLUSIONS

5.1 Summary

The Zero Baseline tests carried out on the two Leica 1200 GPS receivers used in this project produced satisfactory results. The tests were carried out under static and rapid static conditions in order to replicate field conditions and provide some documented quality control on the equipment.

The residential RTK observations produced quite favourable results when compared to their corresponding SMES values. Eleven of the thirteen observations fell within 0.040m of their stated values with one in the 0.041m to 0.060m range. The final mark exceeded its value by 0.097m, which could be considered close enough to the threshold to be regarded as unsatisfactory. The remaining marks met the requirements of section 2.3.3 (i) of the Victorian Practice Directives January 2007 to be within 0.100m of their stated SMES values.

Around half of the rural RTK observations provided poor agreement with their associated SMES values. Only six marks from the sample group of thirteen produced results within 0.040m of their stated position. A further three marks ranged somewhere between 0.049m and 0.086m, and a total of four marks exceeded the 0.10m threshold required by the practice directives. These marks ranged from 0.109m to 0.160m difference from their published SMES position.

Analysis of RTK measurements at the first, second and third rounds of observations showed consistent results in the residential environment. On some occasions, residuals in the first round of observations were closer to the SMES value than that of the second and third sequence. This did not necessarily symbolize a loss of accuracy, but perhaps represented a tightening of position through the averaging of multiple observations. This was possibly reflected in the average difference in position values, which showed the third round (0.033m) had a smaller residual than the first (0.036m).

The same analysis was conducted for the rural RTK observations, which produced higher SMES / RTK difference in position residuals, yet maintained consistency of measurement over each of the three rounds. There appeared to be more instances of lower first round residuals with the rural data and the average difference in position residual was higher for the third round (0.066m) than it was for the first (0.064m).

The residential static observations produced difference in position residuals ranging from 0.030m to 0.056m from their stated SMES values. These differences compared favourably with the RTK residuals of the same points, indicating some possible minor discrepancies with the stated position of the marks.

The rural static observations provided a somewhat different scenario. They produced SMES / static difference in position residuals ranging from 0.028m to 0.050m, however the RTK / static differences showed almost no relationship to one another. Only Base C showed a good correlation between the SMES, RTK and static values. Base's A and B only provided uncertainty as to the true position of the marks.

The residential rapid static observations generally provided good verification of the RTK measurements of the same marks. Consistent differences between the two sets of observations and their SMES values were found and they plotted relatively close to one another in position. Three marks fell within 0.020m of their SMES value, seven within the 0.021m to 0.040m range, two within 0.041m to 0.060m and one mark just below the 0.10m threshold at 0.099m.

The rural rapid static observations showed relatively good agreement with their published SMES values, however compared badly with around half of the RTK measurements. Three marks fell within 0.020m of their SMES value, eight within the 0.021m to 0.040m range and two within 0.041m to 0.060m. No marks failed to be within the 0.10m practice directive requirement. This was in stark contrast to the rural RTK measurements, which had four marks fail and had several others within reach.

5.2 Conclusions

RTK observations provided contrasting results in the residential and rural environments. The residential RTK observations showed twelve of the thirteen marks fell within 0.060m of their stated SMES value. The rural RTK observations revealed seven of the thirteen marks fell within 0.060m of their SMES values, two in the 0.061m to 0.100m range and four beyond 0.101m.

The residential rapid static measurements validated the accuracy of the RTK positions producing similar results. The rural rapid static observations however contrasted heavily with the RTK data and showed relatively good agreement with their corresponding SMES values.

Despite the good agreement with the rapid static observations in the residential environment, the rural RTK values introduced an element of uncertainty with the RTK reliability. The fact that four marks failed the required practice directive accuracy using RTK GPS and yet agreed favourably when observed with rapid static, introduces some doubt about the RTK accuracy and reliability.

The use of static and rapid static to confirm the validity of RTK measurements and test the accuracy of SMES values was shown to be a valuable exercise. In the residential environment, the static and rapid static data aided in verifying the accuracy of the RTK measurements. In the rural environment it exposed erroneous RTK observations and confirmed the position of some marks was consistent with their stated SMES location.

Analysis of SMES value accuracy showed that in the residential environment, twelve of the thirteen marks adequately fell within 0.10m of its published SMES value. In the rural environment all thirteen marks fell within 0.060m of their SMES values. These figures suggest that the majority of SMES marks reflect their published values adequately enough to within 0.10m, in accordance with section 2.3.3 (i) of the Victorian practice directives 2007 accuracy requirements for RTK GPS.

5.3 Recommendations

Further Investigation into the accuracy and reliability of RTK GPS is needed in order to determine and better understand the source and reasons for erroneous observations.

A more extensive static survey of 3rd order survey marks may yield a greater indication of the accuracy of their associated SMES values.

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APPENDICES

Appendix A
Project Specification

ENG4111 / 4112 RESEARCH PROJECT
PROJECT SPECIFICATION

FOR **Scott Alexander DEAS**

TOPIC ***INVESTIGATING THE ACCURACY OF PUBLISHED CO-ORDINATES ON THE 'SURVEY MARK ENQUIRY SERVICE' (SMES) IN VICTORIA USING GPS OBSERVATIONS.***

SUPERVISOR Mr Glenn CAMPBELL

PROJECT AIM To test the quality of published SMES co-ordinates using a combination of RTK and fast static GPS observations to evaluate the difficulty of achieving the required cadastral connection accuracy.

PROGRAMME (Issue A, 23rd March 2009)

- 1.) Review existing literature related to the accuracy of SMES co-ordinates and GPS (RTK & Static) observations.
- 2.) Select 15 to 20 existing marks with the desired degree of accuracy in each of the Rural and Residential study areas.
- 3.) Identify and design a measurement protocol in order to reduce any inaccuracies in results.
- 4.) Perform RTK and Fast Static GPS observations on chosen marks in the selected study areas.
- 5.) Analyse and compare the two sets of observed co-ordinates with the SMES values of the selected marks.
- 6.) Assess what implications arise from the results with regard to cadastral connections.
- 7.) Submit an academic dissertation on the research.

As Time Permits

- 8.) Allocate new values to rogue SMES marks based on adjusted observed values.

AGREED _____(Student)_____ (Supervisor)

Date / / 2009

Date / / 2009

Examiner / Co-ordinator: _____

Appendix B

Residential - Static Post Processing Reports

Results - Baseline

MOBS - BASEB

Project Information

Project name: FINAL_STAT_RES_2
 Date created: 08/20/2009 17:51:00
 Time zone: 10h 00'
 Manager: SCOTT DEAS
 Coordinate system name: MGA55
 Application software: LEICA Geo Office 7.0
 Processing kernel: PSI-Pro 2.0
 Processed: 10/20/2009 21:47:28

Point Information

Receiver type / S/N:	Reference: MOBS GRX1200GGPRO / 356538 ASH701945C_M NONE / CR20020709	Rover: BASEB GX1230 / 452367
Antenna type / S/N:		AX1202 Tripod / -
Antenna height:	1.5000 m	1.3630 m
Initial coordinates:		
Latitude:	37° 49' 45.89870" S	38° 09' 00.56383" S
Longitude:	144° 58' 31.20698" E	145° 07' 34.15264" E
Ellip. Hgt:	40.8020 m	26.8184 m

Processing Parameters

Parameters	Selected	Used	Comment
Cut-off angle:	15°	15°	
Ephemeris type (GPS):	Broadcast	Broadcast	
Ephemeris type (GLONASS):	Broadcast	Broadcast	
Solution type:	Automatic	Phase: all fix	
GNSS type:	Automatic	GPS	
Frequency:	Automatic	Automatic	
Fix ambiguities up to:	80 km	80 km	
Min. duration for float solution (static):	5' 00"	5' 00"	
Sampling rate:	Use all	30	
Tropospheric model:	Hopfield	Hopfield	
Ionospheric model:	Automatic	Computed	
Use stochastic modelling:	Yes	Yes	
Min. distance:	8 km	8 km	
Ionospheric activity:	Automatic	Automatic	

Satellite Selection

Manually disabled GPS satellites (PRNs): None
 Manually disabled GLONASS satellites (Slot Id): None

Final Coordinates

	Reference:MOBS	Rover:BASEB	
Coordinates:			
Latitude:	37° 49' 45.89870" S	38° 09' 00.56374" S	
Longitude:	144° 58' 31.20698" E	145° 07' 34.15248" E	
Ellip. Hgt:	40.8020 m	26.8012 m	
Solution type:	Phase: all fix		
GNSS type:	GPS		
Frequency:	IonoFree (L3)		
Ambiguity:	Yes		
Quality:	Sd. Lat: 0.0009 m	Sd. Lon: 0.0006 m	Sd. Hgt: 0.0026 m
	Posn. Qlty: 0.0011 m	Sd. Slope: 0.0009 m	

Processing Errors and Warnings

Error Orbit:	Missing orbits for satellite G17.
Error Orbit:	Missing orbits for satellite G23.
Error Orbit:	Missing orbits for satellite G27.
Error Orbit:	Missing orbits for satellite G30.

Network Adjustment

www.MOVE3.com

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Created: 10/28/2009 18:45:38

Project Information

Project name: FINAL_STAT_RES_2
 Date created: 08/20/2009 17:51:00
 Time zone: 10h 00'
 Manager: SCOTT DEAS
 Coordinate system name: MGA55
 Application software: LEICA Geo Office 7.0
 Processing kernel: MOVE3 4.0.1

General Information

Adjustment

Type: Minimally constrained
 Dimension: 3D
 Coordinate system: WGS 1984
 Height mode: Ellipsoidal

Number of iterations: 1
 Maximum coord correction in last iteration: 0.0000 m  (tolerance is met)

Stations

Number of (partly) known stations: 1
 Number of unknown stations: 3
 Total: 4

Observations

GPS coordinate differences: 15 (5 baselines) (including 1 baseline as free observation)
 Known coordinates: 3
 Total: 18 (including 3 free observations)

Unknowns

Coordinates: 12
 Total: 12

Degrees of freedom: 6

Testing

Alfa (multi dimensional): 0.2222
 Alfa 0 (one dimensional): 5.0 %
 Beta: 80.0 %
 Sigma a-priori (GPS): 10.0

Critical value W-test: 1.96

Critical value T-test (2-dimensional):	2.42	
Critical value T-test (3-dimensional):	1.89	
Critical value F-test:	1.37	
F-test:	1.06	✓ (accepted)

Results based on a-posteriori variance factor

Adjustment Results

Coordinates

Station		Coordinate	Corr	Sd	
BASEA	Easting	336975.4864 m	0.0002 m	0.0051 m	
	Northing	5777360.3391 m	0.0014 m	0.0071 m	
	Height	17.5582 m	0.0058 m	0.0185 m	
BASEB	Easting	335810.2997 m	-0.0005 m	0.0045 m	
	Northing	5775865.7210 m	0.0007 m	0.0061 m	
	Height	26.8121 m	-0.0007 m	0.0155 m	
BASEC	Easting	340662.9218 m	0.0000 m	0.0043 m	
	Northing	5775439.3739 m	0.0000 m	0.0059 m	
	Height	81.5184 m	0.0000 m	0.0136 m	
MOBS	Easting	321819.5998 m	0.0000 m	-	fixed
	Northing	5811180.0425 m	0.0000 m	-	fixed
	Height	40.8020 m	0.0000 m	-	fixed

Observations and Residuals

	Station	Target	Adj obs	Resid	Resid (ENH)	Sd
DX	MOBS	BASEC	7843.2562 m	0.0000 m	0.0000 m	0.0096 m
DY			-27553.7257 m	0.0000 m	0.0000 m	0.0075 m
DZ			-28494.3645 m	0.0000 m	0.0000 m	0.0095 m
DX	MOBS	BASEB	10380.9597 m	-0.0045 m	0.0024 m	0.0106 m
DY			-23418.6526 m	0.0002 m	-0.0020 m	0.0093 m
DZ			-28049.3634 m	-0.0055 m	0.0064 m	0.0099 m
DX	MOBS	BASEB	10380.9597 m	0.0075 m	-0.0015 m	0.0106 m
DY			-23418.6526 m	-0.0035 m	0.0007 m	0.0093 m
DZ			-28049.3634 m	0.0072 m	-0.0108 m	0.0099 m
DX	MOBS	BASEA	8958.2862 m	0.0159 m	-0.0088 m	0.0129 m
DY			-23884.0126 m	-0.0005 m	-0.0001 m	0.0102 m
DZ			-26886.7803 m	0.0103 m	-0.0168 m	0.0122 m
DX	MOBS	BASEA	8958.2862 m	-0.0128 m	0.0113 m	0.0129 m
DY			-23884.0126 m	-0.0048 m	-0.0029 m	0.0102 m
DZ			-26886.7803 m	-0.0097 m	0.0120 m	0.0122 m



External Reliability

Station		Ext Rel [m]		Station	Target
BASEA	Latitude	0.0184	DZ	MOBS	BASEA
	Longitude	-0.0163	DY	MOBS	BASEA
	Height	-0.0178	DZ	MOBS	BASEA
BASEB	Latitude	0.0155	DZ	MOBS	BASEB
	Longitude	-0.0127	DY	MOBS	BASEB
	Height	-0.0150	DZ	MOBS	BASEB
BASEC	Latitude	None			
	Longitude	None			
	Height	None			

MOBS	Latitude	0.0000	DZ	MOBS	BASEC
	Longitude	0.0000	DY	MOBS	BASEC
	Height	0.0000	DZ	MOBS	BASEC

Testing and Estimated Errors

Observation Tests

	Station	Target	MDB	Red	BNR	W-Test	T-Test
DX	MOBS	BASEC					
DY							
DZ							
DX	MOBS	BASEB	0.0308 m	43	3.1	-0.43	0.21
DY			0.0308 m	43	2.8	-0.50	
DZ			0.0388 m	45	3.0	-0.36	
DX	MOBS	BASEB	0.0308 m	56	2.5	0.43	0.21
DY			0.0308 m	56	2.9	0.50	
DZ			0.0388 m	54	2.8	0.36	
DX	MOBS	BASEA	0.0421 m	50	2.8	1.84	1.79
DY			0.0327 m	25	3.7	2.05	
DZ			0.0460 m	54	2.9	0.89	
DX	MOBS	BASEA	0.0421 m	49	2.8	-1.84	1.79
DY			0.0327 m	74	2.3	-2.05	
DZ			0.0460 m	45	2.8	-0.89	

Redundancy:

W-Test:

Appendix C

Rural - Static Post Processing Reports

Network Adjustment

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Created: 10/28/2009 19:02:25

Project Information

Project name: FINAL_STAT_RURAL_2
 Date created: 08/20/2009 17:46:10
 Time zone: 10h 00'
 Manager: SCOTT DEAS
 Coordinate system name: MGA55
 Application software: LEICA Geo Office 7.0
 Processing kernel: MOVE3 4.0.1

General Information

Adjustment

Type: Minimally constrained
 Dimension: 3D
 Coordinate system: WGS 1984
 Height mode: Ellipsoidal

Number of iterations: 1
 Maximum coord correction in last iteration: 0.0000 m  (tolerance is met)

Stations

Number of (partly) known stations: 1
 Number of unknown stations: 3
 Total: 4

Observations

GPS coordinate differences: 15 (5 baselines) (including 1 baseline as free observation)
 Known coordinates: 3
 Total: 18 (including 3 free observations)

Unknowns

Coordinates: 12
 Total: 12

Degrees of freedom: 6

Testing

Alfa (multi dimensional): 0.2222
 Alfa 0 (one dimensional): 5.0 %
 Beta: 80.0 %
 Sigma a-priori (GPS): 10.0

Critical value W-test: 1.96

Critical value T-test (2-dimensional):	2.42	
Critical value T-test (3-dimensional):	1.89	
Critical value F-test:	1.37	
F-test:	0.68	✓ (accepted)

Results based on a-posteriori variance factor

Adjustment Results

Coordinates

Station		Coordinate	Corr	Sd	
BASEA	Easting	347306.8444 m	-0.0003 m	0.0026 m	
	Northing	5784596.7803 m	-0.0003 m	0.0040 m	
	Height	28.0234 m	-0.0024 m	0.0092 m	
BASEB	Easting	339199.8176 m	0.0000 m	0.0023 m	
	Northing	5784939.9422 m	0.0000 m	0.0032 m	
	Height	8.5157 m	0.0000 m	0.0073 m	
BASEC	Easting	344338.1667 m	0.0002 m	0.0033 m	
	Northing	5780959.1549 m	-0.0018 m	0.0046 m	
	Height	34.9210 m	0.0011 m	0.0097 m	
MOBS	Easting	321819.5998 m	0.0000 m	-	fixed
	Northing	5811180.0425 m	0.0000 m	-	fixed
	Height	40.8020 m	0.0000 m	-	fixed

Observations and Residuals

	Station	Target	Adj obs	Resid	Resid (ENH)	Sd
DX	MOBS	BASEB	3791.5434 m	0.0000 m	0.0000 m	0.0053 m
DY			-23180.5325 m	0.0000 m	0.0000 m	0.0042 m
DZ			-20952.3155 m	0.0000 m	0.0000 m	0.0049 m
DX	MOBS	BASEC	2952.7489 m	-0.0056 m	0.0009 m	0.0066 m
DY			-28760.5115 m	0.0028 m	-0.0027 m	0.0060 m
DZ			-24180.0516 m	-0.0083 m	0.0100 m	0.0068 m
DX	MOBS	BASEC	2952.7489 m	0.0056 m	-0.0009 m	0.0066 m
DY			-28760.5115 m	-0.0027 m	0.0069 m	0.0060 m
DZ			-24180.0516 m	0.0134 m	-0.0131 m	0.0068 m
DX	MOBS	BASEA	-589.4332 m	-0.0042 m	0.0025 m	0.0063 m
DY			-29999.4974 m	-0.0001 m	-0.0019 m	0.0050 m
DZ			-21357.2482 m	-0.0051 m	0.0058 m	0.0065 m
DX	MOBS	BASEA	-589.4332 m	0.0022 m	-0.0039 m	0.0063 m
DY			-29999.4974 m	0.0032 m	0.0048 m	0.0050 m
DZ			-21357.2482 m	0.0061 m	-0.0038 m	0.0065 m

External Reliability

Station		Ext Rel [m]		Station	Target
BASEA	Latitude	0.0155	DZ	MOBS	BASEA
	Longitude	-0.0099	DY	MOBS	BASEA
	Height	-0.0107	DZ	MOBS	BASEA
BASEB	Latitude	None			
	Longitude	None			
	Height	None			
BASEC	Latitude	0.0138	DZ	MOBS	BASEC
	Longitude	-0.0089	DX	MOBS	BASEC
	Height	-0.0120	DZ	MOBS	BASEC

MOBS	Latitude	0.0000	DX	MOBS	BASEB
	Longitude	0.0000	DY	MOBS	BASEB
	Height	0.0000	DY	MOBS	BASEB

Testing and Estimated Errors

Observation Tests

	Station	Target	MDB	Red	BNR	W-Test	T-Test
DX	MOBS	BASEB					
DY							
DZ							
DX	MOBS	BASEC	0.0253 m	62	2.2	-0.67	1.16
DY			0.0197 m	46	3.1	-1.01	
DZ			0.0291 m	37	3.7	-1.66	
DX	MOBS	BASEC	0.0253 m	37	3.6	0.67	1.16
DY			0.0197 m	53	2.8	1.01	
DZ			0.0291 m	62	2.2	1.66	
DX	MOBS	BASEA	0.0218 m	50	3.3	-0.87	0.84
DY			0.0183 m	21	4.1	-1.36	
DZ			0.0288 m	34	4.0	-1.03	
DX	MOBS	BASEA	0.0218 m	49	2.5	0.87	0.84
DY			0.0183 m	78	2.1	1.36	
DZ			0.0288 m	65	2.0	1.03	

Redundancy:

W-Test:

Appendix D

Residential - Rapid Static Post Processing Reports

Network Adjustment

www.MOVE3.com

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Created: 10/28/2009 18:50:54

Project Information

Project name: FINAL_RS_RES_4
 Date created: 08/19/2009 22:31:07
 Time zone: 10h 00'
 Manager: SCOTT DEAS
 Coordinate system name: MGA55
 Application software: LEICA Geo Office 7.0
 Processing kernel: MOVE3 4.0.1

General Information

Adjustment

Type: Constrained
 Dimension: 3D
 Coordinate system: WGS 1984
 Height mode: Ellipsoidal

Number of iterations: 1
 Maximum coord correction in last iteration: 0.0000 m  (tolerance is met)

Stations

Number of (partly) known stations: 3
 Number of unknown stations: 10
 Total: 13

Observations

GPS coordinate differences: 81 (27 baselines) (including 2 baselines as free observations)
 Known coordinates: 9
 Total: 90 (including 6 free observations)

Unknowns

Coordinates: 39
 Total: 39

Degrees of freedom: 51

Testing

Alfa (multi dimensional): 0.5549
 Alfa 0 (one dimensional): 5.0 %
 Beta: 80.0 %
 Sigma a-priori (GPS): 10.0

Critical value W-test: 1.96

Critical value T-test (2-dimensional):	2.42	
Critical value T-test (3-dimensional):	1.89	
Critical value F-test:	0.96	
F-test:	0.71	✓ (accepted)

Results based on a-posteriori variance factor

Adjustment Results

Coordinates

Station	Coordinate	Corr	Sd		
BASEA	Easting	336975.4864 m	0.0000 m	0.0002 m	fixed
	Northing	5777360.3391 m	0.0000 m	0.0003 m	fixed
	Height	17.5582 m	0.0000 m	0.0005 m	fixed
BASEB	Easting	335810.2997 m	0.0000 m	0.0002 m	fixed
	Northing	5775865.7210 m	0.0000 m	0.0003 m	fixed
	Height	26.8120 m	0.0000 m	0.0005 m	fixed
BASEC	Easting	340662.9218 m	0.0000 m	0.0002 m	fixed
	Northing	5775439.3739 m	0.0000 m	0.0003 m	fixed
	Height	81.5184 m	0.0000 m	0.0005 m	fixed
PM157	Easting	339602.0607 m	0.0053 m	0.0018 m	
	Northing	5774549.6957 m	0.0007 m	0.0023 m	
	Height	98.9762 m	0.0041 m	0.0064 m	
PM277	Easting	337681.8212 m	0.0039 m	0.0013 m	
	Northing	5776053.1353 m	-0.0017 m	0.0015 m	
	Height	46.5088 m	0.0059 m	0.0037 m	
PM367	Easting	337776.7147 m	0.0035 m	0.0013 m	
	Northing	5775996.5016 m	-0.0019 m	0.0016 m	
	Height	49.5073 m	0.0048 m	0.0035 m	
PM475	Easting	339675.1390 m	0.0053 m	0.0013 m	
	Northing	5777009.2967 m	-0.0014 m	0.0016 m	
	Height	64.0400 m	0.0034 m	0.0046 m	
PM651	Easting	339052.3109 m	0.0040 m	0.0013 m	
	Northing	5777189.1655 m	-0.0006 m	0.0017 m	
	Height	52.4491 m	0.0045 m	0.0040 m	
PM653	Easting	339577.7094 m	0.0046 m	0.0011 m	
	Northing	5777019.4625 m	-0.0004 m	0.0015 m	
	Height	62.5649 m	0.0050 m	0.0034 m	
PM660	Easting	338499.6022 m	0.0055 m	0.0056 m	
	Northing	5775624.5610 m	0.0010 m	0.0062 m	
	Height	62.9469 m	0.0071 m	0.0104 m	
PM726	Easting	337910.7957 m	0.0066 m	0.0020 m	
	Northing	5774792.9804 m	-0.0008 m	0.0027 m	
	Height	81.5770 m	0.0078 m	0.0066 m	
PM898	Easting	336614.7813 m	0.0043 m	0.0014 m	
	Northing	5777977.3170 m	-0.0041 m	0.0019 m	
	Height	14.0778 m	0.0041 m	0.0042 m	
PM99	Easting	341435.1058 m	0.0000 m	0.0035 m	
	Northing	5775187.1493 m	0.0000 m	0.0043 m	
	Height	85.3977 m	0.0000 m	0.0092 m	

Observations and Residuals

	Station	Target	Adj obs	Resid	Resid (ENH)	Sd
DX	BASEC	BASEA	1115.0196 m	0.0140 m	-0.0065 m	0.0025 m

DY			3669.7096 m	-0.0019 m	-0.0035 m	0.0018 m
DZ			1607.5724 m	0.0055 m	-0.0132 m	0.0020 m
DX	BASEB	BASEA	-1422.6816 m	-0.0009 m	-0.0008 m	0.0023 m
DY			-465.3611 m	0.0016 m	-0.0001 m	0.0017 m
DZ			1162.5793 m	-0.0014 m	0.0022 m	0.0019 m
DX	BASEA	PM99	-1419.9440 m	0.0000 m	0.0000 m	0.0058 m
DY			-4392.1168 m	0.0000 m	0.0000 m	0.0053 m
DZ			-1820.1760 m	0.0000 m	0.0000 m	0.0073 m
DX	BASEA	PM898	-114.9154 m	0.0028 m	-0.0018 m	0.0034 m
DY			504.5088 m	0.0002 m	0.0019 m	0.0026 m
DZ			493.0836 m	0.0041 m	-0.0043 m	0.0028 m
DX	BASEA	PM653	-1312.8301 m	0.0001 m	0.0013 m	0.0029 m
DY			-2248.1343 m	-0.0016 m	0.0015 m	0.0022 m
DZ			-336.5865 m	0.0027 m	-0.0025 m	0.0028 m
DX	BASEA	PM651	-1099.4247 m	-0.0045 m	-0.0019 m	0.0031 m
DY			-1760.7012 m	0.0055 m	0.0011 m	0.0024 m
DZ			-188.7116 m	-0.0040 m	0.0079 m	0.0030 m
DX	BASEA	PM475	-1363.1822 m	0.0016 m	-0.0035 m	0.0036 m
DY			-2331.5359 m	0.0032 m	0.0017 m	0.0024 m
DZ			-347.0044 m	0.0018 m	-0.0007 m	0.0034 m
DX	BASEA	PM367	236.3881 m	0.0003 m	0.0009 m	0.0030 m
DY			-1107.6592 m	-0.0012 m	-0.0003 m	0.0023 m
DZ			-1104.8255 m	0.0003 m	-0.0009 m	0.0025 m
DX	BASEA	PM277	262.2335 m	0.0007 m	0.0046 m	0.0032 m
DY			-1011.4135 m	-0.0061 m	-0.0092 m	0.0025 m
DZ			-1056.9505 m	-0.0085 m	0.0020 m	0.0024 m
DX	BASEA	PM157	-69.9238 m	0.0103 m	-0.0179 m	0.0047 m
DY			-3083.2246 m	0.0147 m	-0.0159 m	0.0037 m
DZ			-2301.4400 m	-0.0201 m	0.0123 m	0.0044 m
DX	BASEC	PM898	1000.1042 m	-0.0080 m	0.0007 m	0.0036 m
DY			4174.2183 m	0.0048 m	0.0017 m	0.0026 m
DZ			2100.6560 m	-0.0052 m	0.0105 m	0.0028 m
DX	BASEC	PM726	1879.2872 m	-0.0072 m	-0.0012 m	0.0046 m
DY			2060.3807 m	0.0064 m	0.0042 m	0.0035 m
DZ			-465.4448 m	-0.0021 m	0.0088 m	0.0051 m
DX	BASEC	PM653	-197.8105 m	-0.0018 m	0.0014 m	0.0028 m
DY			1421.5753 m	-0.0005 m	-0.0014 m	0.0020 m
DZ			1270.9858 m	-0.0027 m	0.0026 m	0.0029 m
DX	BASEC	PM651	15.5949 m	0.0024 m	0.0015 m	0.0031 m
DY			1909.0084 m	-0.0035 m	0.0011 m	0.0023 m
DZ			1418.8608 m	0.0045 m	-0.0059 m	0.0031 m
DX	BASEC	PM475	-248.1626 m	0.0039 m	0.0003 m	0.0035 m
DY			1338.1736 m	-0.0031 m	0.0007 m	0.0022 m
DZ			1260.5680 m	0.0048 m	-0.0069 m	0.0035 m
DX	BASEC	PM367	1351.4077 m	0.0033 m	-0.0008 m	0.0031 m
DY			2562.0504 m	-0.0013 m	-0.0034 m	0.0023 m
DZ			502.7469 m	-0.0017 m	-0.0017 m	0.0027 m
DX	BASEC	PM277	1377.2531 m	-0.0052 m	-0.0065 m	0.0034 m
DY			2658.2961 m	0.0116 m	0.0033 m	0.0025 m
DZ			550.6219 m	-0.0043 m	0.0112 m	0.0025 m
DX	BASEC	PM157	1045.0958 m	-0.0076 m	0.0057 m	0.0047 m
DY			586.4849 m	-0.0016 m	-0.0072 m	0.0036 m
DZ			-693.8676 m	-0.0134 m	0.0125 m	0.0045 m
DX	BASEB	PM898	-1537.5970 m	-0.0010 m	0.0047 m	0.0036 m
DY			39.1477 m	-0.0050 m	-0.0014 m	0.0027 m
DZ			1655.6630 m	-0.0002 m	-0.0014 m	0.0030 m
DX	BASEB	PM726	-658.4140 m	0.0053 m	0.0010 m	0.0044 m

DY			-2074.6900 m	-0.0049 m	-0.0025 m	0.0034 m
DZ			-910.4379 m	0.0025 m	-0.0071 m	0.0050 m
DX	BASEB	PM660	-1407.8947 m	0.0000 m	0.0000 m	0.0087 m
DY			-2290.4439 m	0.0000 m	0.0000 m	0.0068 m
DZ			-254.3294 m	0.0000 m	0.0000 m	0.0075 m
DX	BASEB	PM653	-2735.5117 m	0.0014 m	-0.0020 m	0.0027 m
DY			-2713.4954 m	0.0015 m	-0.0006 m	0.0019 m
DZ			825.9928 m	-0.0005 m	0.0001 m	0.0027 m
DX	BASEB	PM651	-2522.1063 m	-0.0027 m	0.0010 m	0.0031 m
DY			-2226.0623 m	0.0006 m	-0.0027 m	0.0022 m
DZ			973.8678 m	-0.0054 m	0.0053 m	0.0032 m
DX	BASEB	PM475	-2785.8638 m	-0.0179 m	0.0069 m	0.0037 m
DY			-2796.8970 m	0.0041 m	0.0020 m	0.0023 m
DZ			815.5750 m	-0.0108 m	0.0200 m	0.0033 m
DX	BASEB	PM367	-1186.2936 m	-0.0025 m	0.0001 m	0.0030 m
DY			-1573.0202 m	0.0015 m	0.0017 m	0.0021 m
DZ			57.7538 m	-0.0001 m	0.0023 m	0.0023 m
DX	BASEB	PM277	-1160.4482 m	0.0013 m	0.0001 m	0.0033 m
DY			-1476.7745 m	-0.0010 m	0.0003 m	0.0022 m
DZ			105.6289 m	0.0016 m	-0.0023 m	0.0021 m
DX	BASEB	PM157	-1492.6055 m	0.0002 m	-0.0001 m	0.0044 m
DY			-3548.5857 m	0.0001 m	0.0014 m	0.0035 m
DZ			-1138.8607 m	0.0019 m	-0.0013 m	0.0043 m

External Reliability

Station		Ext Rel [m]		Station	Target
BASEA	Latitude	0.8493	Latitude	BASEB	-
	Longitude	0.6865	Longitude	BASEB	-
	Height	142.7531	DX	BASEB	PM660
BASEB	Latitude	0.8493	Latitude	BASEB	-
	Longitude	0.6865	Longitude	BASEB	-
	Height	142.7510	DX	BASEB	PM660
BASEC	Latitude	0.8493	Latitude	BASEB	-
	Longitude	0.6865	Longitude	BASEB	-
	Height	142.7513	DX	BASEB	PM660
PM157	Latitude	0.8493	Latitude	BASEB	-
	Longitude	0.6865	Longitude	BASEB	-
	Height	142.7515	DX	BASEB	PM660
PM277	Latitude	0.8493	Latitude	BASEB	-
	Longitude	0.6865	Longitude	BASEB	-
	Height	142.7516	DX	BASEB	PM660
PM367	Latitude	0.8493	Latitude	BASEB	-
	Longitude	0.6865	Longitude	BASEB	-
	Height	142.7517	DX	BASEB	PM660
PM475	Latitude	0.8493	Latitude	BASEB	-
	Longitude	0.6865	Longitude	BASEB	-
	Height	142.7517	DX	BASEB	PM660
PM651	Latitude	0.8493	Latitude	BASEB	-
	Longitude	0.6865	Longitude	BASEB	-
	Height	142.7519	DX	BASEB	PM660
PM653	Latitude	0.8493	Latitude	BASEB	-
	Longitude	0.6865	Longitude	BASEB	-
	Height	142.7515	DX	BASEB	PM660
PM660	Latitude	None			
	Longitude	None			
	Height	None			





PM726	Latitude	0.8493	Latitude	BASEB	-
	Longitude	0.6865	Longitude	BASEB	-
	Height	142.7512	DX	BASEB	PM660
PM898	Latitude	0.8493	Latitude	BASEB	-
	Longitude	0.6865	Longitude	BASEB	-
	Height	142.7521	DX	BASEB	PM660
PM99	Latitude	None			
	Longitude	None			
	Height	None			


Testing and Estimated Errors

Coordinate Tests

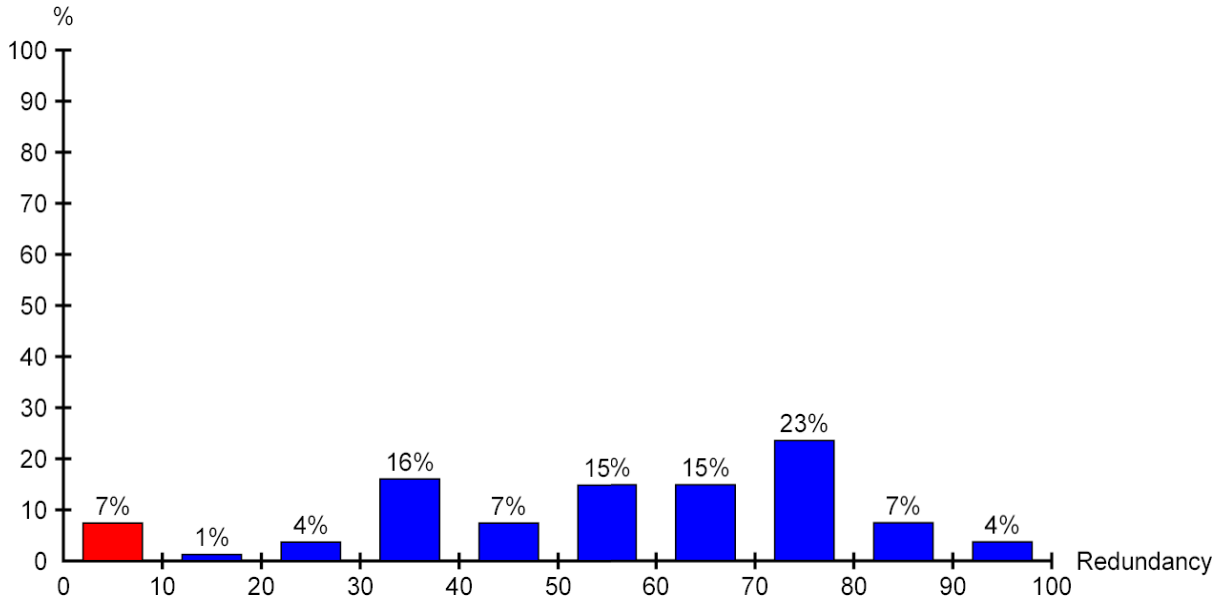
Station		MDB	BNR	W-Test	T-Test
BASEA	Latitude	1.8107 m	1.7	0.00	0.00
	Longitude	1.4427 m	1.8	-0.01	
	Height	4.5620 m	1.4	-0.01	
BASEB	Latitude	1.5916 m	3.0	0.01	0.00
	Longitude	1.3000 m	3.0	0.00	
	Height	3.6459 m	3.2	0.00	
BASEC	Latitude	1.9611 m	1.4	-0.01	0.00
	Longitude	1.6537 m	1.4	0.01	
	Height	4.2357 m	1.6	0.00	

Observation Tests

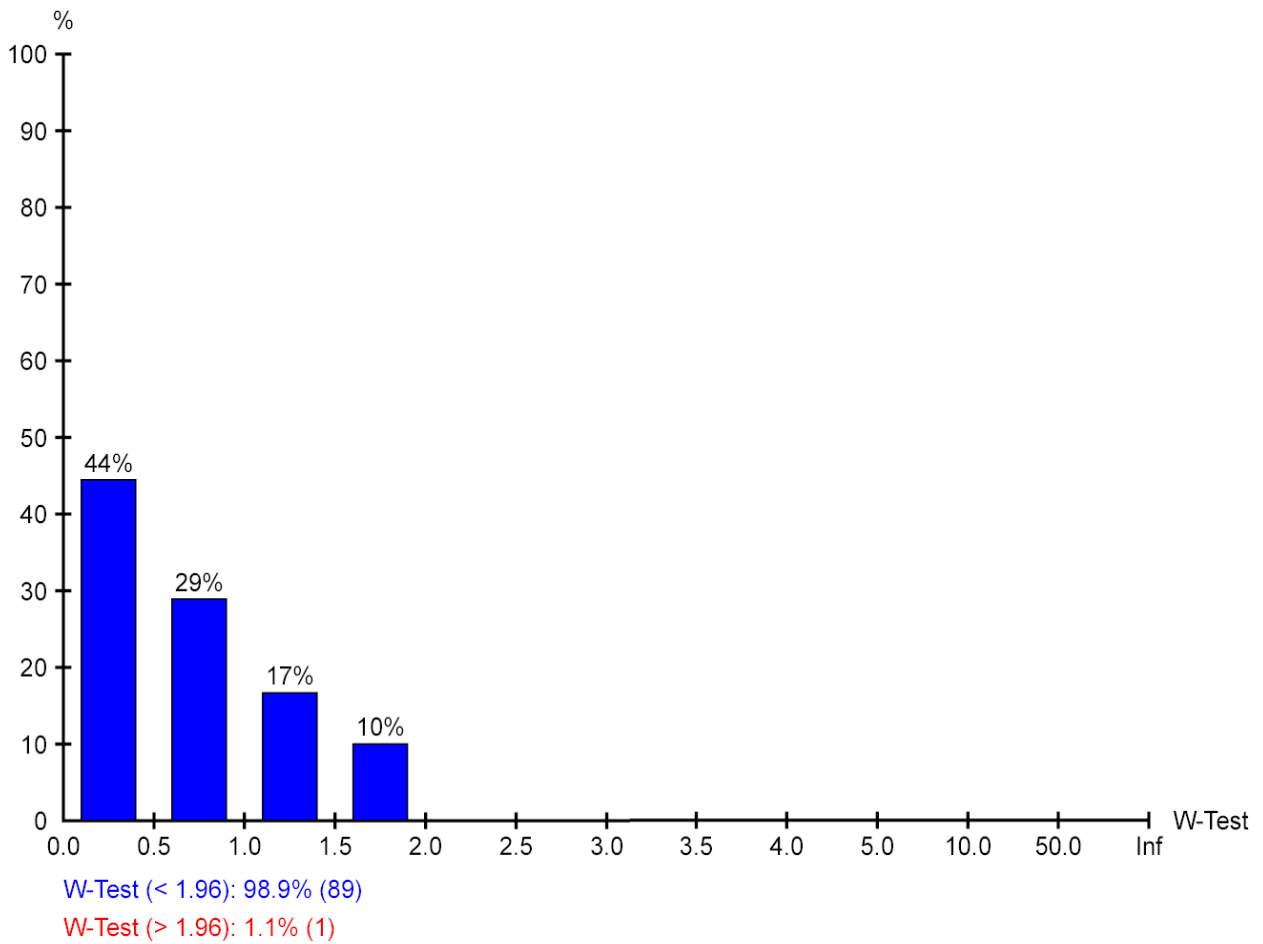
	Station	Target	MDB	Red	BNR	W-Test	T-Test
DX	BASEC	BASEA	0.0151 m	96	1.1	1.76	2.01 
DY			0.0082 m	74	1.7	1.69	
DZ			0.0089 m	61	2.1	0.88	
DX	BASEB	BASEA	0.0098 m	71	1.6	0.22	0.17
DY			0.0076 m	76	1.7	0.38	
DZ			0.0084 m	59	2.1	-0.38	
DX	BASEA	PM99					
DY							
DZ							
DX	BASEA	PM898	0.0124 m	33	3.4	1.04	1.19
DY			0.0102 m	64	2.6	1.11	
DZ			0.0126 m	60	2.2	1.05	
DX	BASEA	PM653	0.0103 m	62	2.3	-0.94	0.46
DY			0.0084 m	69	2.3	-0.51	
DZ			0.0112 m	56	2.4	0.88	
DX	BASEA	PM651	0.0111 m	54	2.6	0.36	0.96
DY			0.0094 m	69	2.7	1.22	
DZ			0.0127 m	37	3.2	-0.29	
DX	BASEA	PM475	0.0120 m	52	2.3	1.10	1.14
DY			0.0100 m	77	2.0	1.76	
DZ			0.0133 m	70	1.9	0.53	
DX	BASEA	PM367	0.0111 m	38	3.7	-0.50	0.13
DY			0.0100 m	68	2.7	-0.59	
DZ			0.0121 m	70	2.3	0.18	
DX	BASEA	PM277	0.0115 m	38	3.3	0.10	2.27 
DY			0.0110 m	79	2.3	-1.50	
DZ			0.0135 m	84	1.8	-2.00 	
DX	BASEA	PM157	0.0302 m	83	1.4	1.75	1.89 
DY			0.0150 m	85	1.7	1.44	

DZ			0.0217 m	76	1.8	0.15	
DX	BASEC	PM898	0.0138 m	75	2.2	-0.31	1.03
DY			0.0099 m	46	2.9	0.32	
DZ			0.0118 m	38	3.5	-0.72	
DX	BASEC	PM726	0.0162 m	59	2.1	-0.80	1.34
DY			0.0142 m	55	2.3	1.15	
DZ			0.0215 m	73	1.9	0.95	
DX	BASEC	PM653	0.0101 m	47	2.7	-0.49	0.38
DY			0.0082 m	50	2.5	-0.90	
DZ			0.0126 m	76	2.1	-0.52	
DX	BASEC	PM651	0.0119 m	61	2.2	-0.55	0.82
DY			0.0095 m	58	2.2	-0.94	
DZ			0.0131 m	60	2.2	0.79	
DX	BASEC	PM475	0.0112 m	30	3.6	-0.11	0.65
DY			0.0086 m	39	3.4	-0.87	
DZ			0.0128 m	77	2.6	0.21	
DX	BASEC	PM367	0.0132 m	64	1.9	1.05	0.60
DY			0.0108 m	70	1.8	-0.25	
DZ			0.0127 m	72	1.8	-1.07	
DX	BASEC	PM277	0.0147 m	65	1.8	0.27	1.55
DY			0.0132 m	89	1.5	1.88	
DZ			0.0108 m	59	2.1	0.37	
DX	BASEC	PM157	0.0175 m	73	1.8	-0.64	1.57
DY			0.0141 m	65	1.8	-1.78	
DZ			0.0214 m	86	1.5	-1.41	
DX	BASEB	PM898	0.0157 m	75	1.5	-0.97	0.96
DY			0.0120 m	71	1.6	-1.69	
DZ			0.0158 m	82	1.4	-0.35	
DX	BASEB	PM726	0.0162 m	29	4.6	0.80	1.34
DY			0.0142 m	38	4.1	-1.15	
DZ			0.0215 m	23	4.7	-0.95	
DX	BASEB	PM660					
DY							
DZ							
DX	BASEB	PM653	0.0098 m	49	2.8	1.38	0.86
DY			0.0078 m	47	2.8	1.35	
DZ			0.0109 m	51	2.7	-0.41	
DX	BASEB	PM651	0.0112 m	55	2.5	0.16	0.17
DY			0.0094 m	47	2.5	-0.29	
DZ			0.0164 m	91	2.3	-0.60	
DX	BASEB	PM475	0.0153 m	95	2.0	-1.25	2.15 
DY			0.0097 m	56	2.1	-0.72	
DZ			0.0121 m	39	2.9	-0.68	
DX	BASEB	PM367	0.0132 m	73	1.8	-0.44	0.44
DY			0.0092 m	40	3.2	0.76	
DZ			0.0107 m	34	3.7	0.74	
DX	BASEB	PM277	0.0128 m	76	2.5	-0.35	0.51
DY			0.0095 m	18	4.9	-0.05	
DZ			0.0096 m	23	4.9	1.09	
DX	BASEB	PM157	0.0162 m	32	4.5	-0.35	0.33
DY			0.0117 m	39	3.7	0.36	
DZ			0.0168 m	31	4.2	0.99	

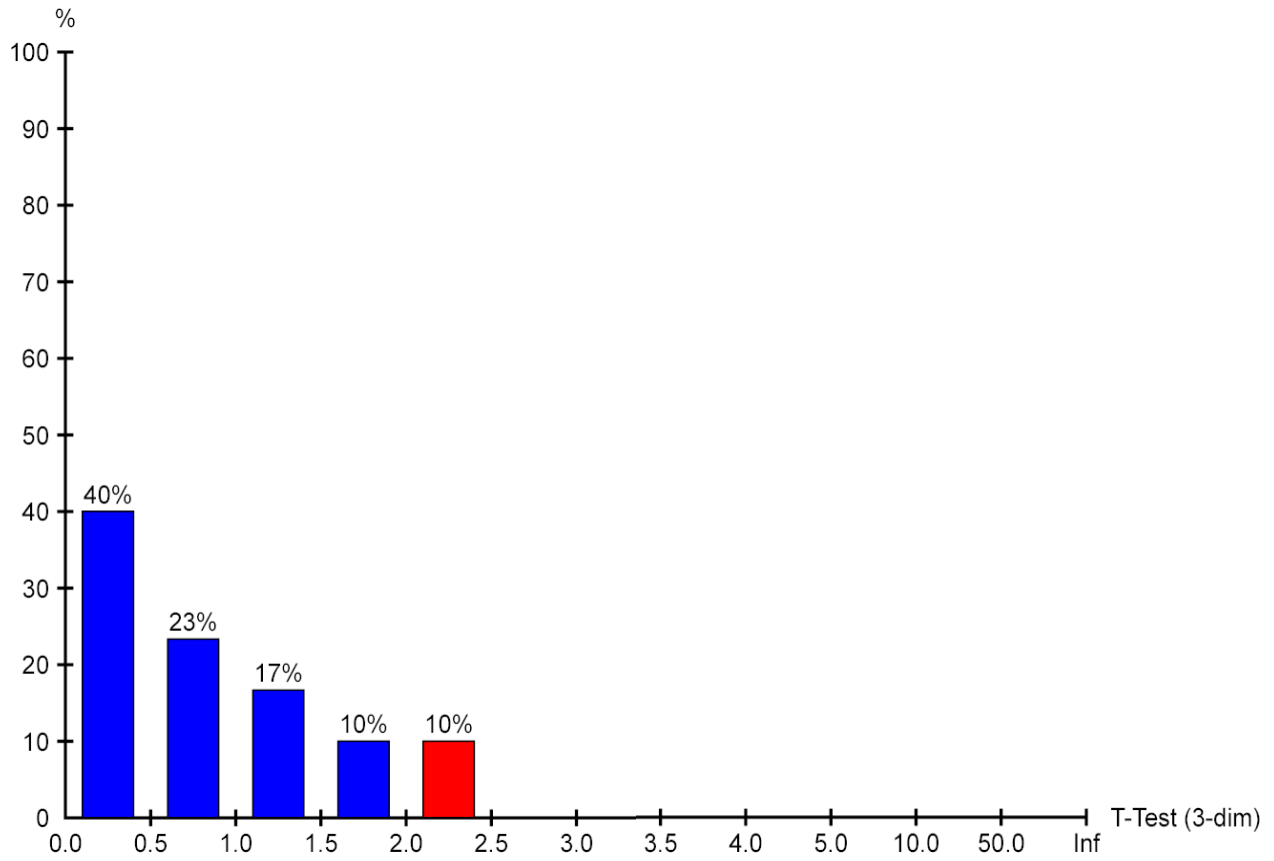
Redundancy:



W-Test:



T-Test (3-dimensional):



T-Test (3-dim) (< 1.89): 86.7% (26)

T-Test (3-dim) (> 1.89): 13.3% (4)

Appendix E

Rural - Rapid Static Post Processing Reports

- when it has to be **right**

Network Adjustment

www.MOVE3.com

(c) 1993-2008 Grontmij

Licensed to Leica Geosystems AG

Created: 10/28/2009 19:04:15

Project Information

Project name: FINAL_RS_RURAL_4
 Date created: 08/20/2009 17:34:06
 Time zone: 10h 00'
 Manager: SCOTT DEAS
 Coordinate system name: MGA55
 Application software: LEICA Geo Office 7.0
 Processing kernel: MOVE3 4.0.1

General Information

Adjustment

Type: Constrained
 Dimension: 3D
 Coordinate system: WGS 1984
 Height mode: Ellipsoidal

Number of iterations: 1
 Maximum coord correction in last iteration: 0.0000 m  (tolerance is met)

Stations

Number of (partly) known stations: 3
 Number of unknown stations: 10
 Total: 13

Observations

GPS coordinate differences: 78 (26 baselines)
 Known coordinates: 9
 Total: 87

Unknowns

Coordinates: 39
 Total: 39

Degrees of freedom: 48

Testing

Alfa (multi dimensional): 0.5474
 Alfa 0 (one dimensional): 5.0 %
 Beta: 80.0 %
 Sigma a-priori (GPS): 10.0

Critical value W-test: 1.96

Critical value T-test (2-dimensional):	2.42	
Critical value T-test (3-dimensional):	1.89	
Critical value F-test:	0.96	
F-test:	0.72	✓ (accepted)

Results based on a-posteriori variance factor

Adjustment Results

Coordinates

Station	Coordinate	Corr	Sd		
BASEA	Easting	347306.8444 m	0.0000 m	0.0001 m	fixed
	Northing	5784596.7803 m	0.0000 m	0.0002 m	fixed
	Height	28.0234 m	0.0000 m	0.0002 m	fixed
BASEB	Easting	339199.8176 m	0.0000 m	0.0001 m	fixed
	Northing	5784939.9422 m	0.0000 m	0.0002 m	fixed
	Height	8.5157 m	0.0000 m	0.0002 m	fixed
BASEC	Easting	344338.1667 m	0.0000 m	0.0001 m	fixed
	Northing	5780959.1549 m	0.0000 m	0.0002 m	fixed
	Height	34.9210 m	0.0000 m	0.0002 m	fixed
EPM31	Easting	345725.8807 m	0.0000 m	0.0013 m	
	Northing	5785749.6380 m	0.0000 m	0.0018 m	
	Height	34.0555 m	0.0000 m	0.0043 m	
LPM31	Easting	340648.2368 m	0.0000 m	0.0016 m	
	Northing	5786442.1921 m	0.0000 m	0.0021 m	
	Height	10.5671 m	0.0000 m	0.0056 m	
MMB5875	Easting	342163.7642 m	0.0000 m	0.0020 m	
	Northing	5781251.1760 m	0.0000 m	0.0025 m	
	Height	48.0336 m	0.0000 m	0.0057 m	
PM130	Easting	345252.1069 m	0.0000 m	0.0015 m	
	Northing	5778136.7787 m	0.0000 m	0.0017 m	
	Height	63.9910 m	0.0000 m	0.0039 m	
PM236	Easting	343989.8147 m	0.0000 m	0.0012 m	
	Northing	5784283.6040 m	0.0000 m	0.0015 m	
	Height	22.0024 m	0.0000 m	0.0036 m	
PM241	Easting	342575.7219 m	0.0000 m	0.0018 m	
	Northing	5786180.3464 m	0.0000 m	0.0019 m	
	Height	14.2582 m	0.0000 m	0.0040 m	
PM257	Easting	343007.5672 m	0.0000 m	0.0012 m	
	Northing	5788553.4970 m	0.0000 m	0.0017 m	
	Height	17.4337 m	0.0000 m	0.0035 m	
PM276	Easting	340719.6823 m	0.0000 m	0.0014 m	
	Northing	5783093.9678 m	0.0000 m	0.0016 m	
	Height	14.9403 m	0.0000 m	0.0035 m	
PM396	Easting	343757.6711 m	0.0000 m	0.0012 m	
	Northing	5782692.0455 m	0.0000 m	0.0015 m	
	Height	25.8698 m	0.0000 m	0.0033 m	
PM55	Easting	344727.1055 m	0.0000 m	0.0028 m	
	Northing	5777556.5315 m	0.0000 m	0.0029 m	
	Height	69.8194 m	0.0000 m	0.0066 m	

Observations and Residuals

	Station	Target	Adj obs	Resid	Resid (ENH)	Sd
DX	BASEC	BASEA	-3542.1914 m	-0.0038 m	0.0020 m	0.0019 m

DY			-1238.9727 m	0.0002 m	0.0031 m	0.0014 m
DZ			2822.7893 m	0.0014 m	0.0017 m	0.0015 m
DX	BASEB	BASEC	-838.7992 m	0.0037 m	-0.0002 m	0.0019 m
DY			-5579.9878 m	-0.0024 m	0.0019 m	0.0014 m
DZ			-3227.7332 m	0.0058 m	-0.0071 m	0.0018 m
DX	BASEA	BASEC	3542.1914 m	-0.0047 m	0.0010 m	0.0019 m
DY			1238.9727 m	0.0021 m	0.0014 m	0.0014 m
DZ			-2822.7893 m	-0.0022 m	0.0054 m	0.0015 m
DX	BASEA	BASEB	4380.9906 m	0.0033 m	0.0010 m	0.0020 m
DY			6818.9605 m	-0.0036 m	-0.0001 m	0.0015 m
DZ			404.9439 m	0.0036 m	-0.0059 m	0.0018 m
DX	BASEC	PM55	1521.7824 m	0.0063 m	-0.0047 m	0.0058 m
DY			-1450.9077 m	0.0013 m	-0.0028 m	0.0035 m
DZ			-2704.0681 m	0.0000 m	-0.0035 m	0.0039 m
DX	BASEC	PM276	937.0833 m	0.0041 m	-0.0004 m	0.0030 m
DY			3704.5312 m	-0.0024 m	0.0006 m	0.0023 m
DZ			1747.3111 m	0.0045 m	-0.0065 m	0.0027 m
DX	BASEC	PM257	-3171.7202 m	0.0034 m	-0.0007 m	0.0029 m
DY			3645.4788 m	-0.0015 m	-0.0025 m	0.0022 m
DZ			6008.9727 m	-0.0004 m	-0.0026 m	0.0028 m
DX	BASEC	PM241	-1700.3372 m	-0.0092 m	-0.0005 m	0.0039 m
DY			3204.6726 m	0.0070 m	-0.0050 m	0.0025 m
DZ			4148.8088 m	-0.0154 m	0.0185 m	0.0028 m
DX	BASEC	PM236	-1517.0569 m	-0.0021 m	0.0007 m	0.0030 m
DY			1400.0983 m	0.0007 m	0.0018 m	0.0020 m
DZ			2629.4670 m	0.0006 m	0.0013 m	0.0022 m
DX	BASEC	PM130	930.6276 m	0.0066 m	-0.0013 m	0.0037 m
DY			-1693.0551 m	-0.0031 m	-0.0023 m	0.0022 m
DZ			-2251.9763 m	0.0027 m	-0.0073 m	0.0021 m
DX	BASEC	MMB5875	1059.5889 m	0.0067 m	-0.0004 m	0.0043 m
DY			1904.4495 m	-0.0042 m	-0.0015 m	0.0032 m
DZ			254.6298 m	0.0043 m	-0.0089 m	0.0040 m
DX	BASEC	EPM31	-3256.5062 m	-0.0142 m	-0.0021 m	0.0033 m
DY			460.4272 m	0.0124 m	0.0046 m	0.0026 m
DZ			3750.0781 m	-0.0088 m	0.0202 m	0.0033 m
DX	BASEB	PM55	682.9832 m	-0.0005 m	0.0033 m	0.0058 m
DY			-7030.8955 m	-0.0037 m	0.0022 m	0.0036 m
DZ			-5931.8013 m	0.0042 m	-0.0040 m	0.0042 m
DX	BASEB	PM396	-1404.5679 m	0.0035 m	-0.0001 m	0.0026 m
DY			-4520.7994 m	-0.0023 m	0.0005 m	0.0021 m
DZ			-1849.8005 m	0.0039 m	-0.0057 m	0.0023 m
DX	BASEB	PM276	98.2840 m	-0.0007 m	0.0005 m	0.0028 m
DY			-1875.4566 m	0.0000 m	-0.0021 m	0.0021 m
DZ			-1480.4221 m	-0.0031 m	0.0024 m	0.0024 m
DX	BASEB	PM241	-2539.1364 m	0.0007 m	0.0002 m	0.0036 m
DY			-2375.3151 m	-0.0007 m	0.0004 m	0.0023 m
DZ			921.0756 m	0.0012 m	-0.0015 m	0.0023 m
DX	BASEB	PM236	-2355.8561 m	0.0086 m	-0.0024 m	0.0033 m
DY			-4179.8895 m	-0.0031 m	-0.0040 m	0.0021 m
DZ			-598.2662 m	0.0018 m	-0.0080 m	0.0023 m
DX	BASEB	PM130	91.8284 m	-0.0167 m	-0.0001 m	0.0038 m
DY			-7273.0429 m	0.0118 m	0.0050 m	0.0023 m
DZ			-5479.7095 m	-0.0097 m	0.0221 m	0.0025 m
DX	BASEB	MMB5875	220.7897 m	-0.0091 m	0.0014 m	0.0044 m
DY			-3675.5383 m	0.0046 m	0.0021 m	0.0032 m
DZ			-2973.1034 m	-0.0053 m	0.0112 m	0.0040 m
DX	BASEB	LPM31	-1591.0523 m	-0.0072 m	0.0013 m	0.0045 m

DY			-693.3472 m	0.0034 m	0.0029 m	0.0031 m
DZ			1158.9900 m	-0.0024 m	0.0077 m	0.0031 m
DX	BASEA	PM396	2976.4227 m	-0.0042 m	0.0002 m	0.0027 m
DY			2298.1611 m	0.0027 m	-0.0005 m	0.0021 m
DZ			-1444.8566 m	-0.0046 m	0.0067 m	0.0024 m
DX	BASEA	PM276	4479.2747 m	0.0023 m	-0.0008 m	0.0029 m
DY			4943.5039 m	-0.0006 m	0.0048 m	0.0023 m
DZ			-1075.4782 m	0.0079 m	-0.0066 m	0.0027 m
DX	BASEA	PM257	370.4712 m	-0.0011 m	0.0002 m	0.0025 m
DY			4884.4516 m	0.0005 m	0.0014 m	0.0020 m
DZ			3186.1834 m	0.0008 m	0.0004 m	0.0026 m
DX	BASEA	PM130	4472.8190 m	-0.0005 m	0.0001 m	0.0036 m
DY			-454.0824 m	0.0002 m	0.0000 m	0.0021 m
DZ			-5074.7656 m	-0.0004 m	0.0007 m	0.0020 m
DX	BASEA	LPM31	2789.9384 m	0.0069 m	-0.0004 m	0.0045 m
DY			6125.6133 m	-0.0044 m	-0.0031 m	0.0032 m
DZ			1563.9339 m	0.0024 m	-0.0079 m	0.0033 m
DX	BASEA	EPM31	285.6852 m	0.0046 m	-0.0001 m	0.0030 m
DY			1699.4000 m	-0.0031 m	-0.0004 m	0.0023 m
DZ			927.2888 m	0.0039 m	-0.0068 m	0.0031 m

External Reliability

Station		Ext Rel [m]		Station	Target
BASEA	Latitude	0.5194	Latitude	BASEA	-
	Longitude	0.4651	Longitude	BASEC	-
	Height	1.1393	Height	BASEA	-
BASEB	Latitude	0.5193	Latitude	BASEA	-
	Longitude	0.4651	Longitude	BASEC	-
	Height	1.1393	Height	BASEA	-
BASEC	Latitude	0.5193	Latitude	BASEA	-
	Longitude	0.4651	Longitude	BASEC	-
	Height	1.1393	Height	BASEA	-
EPM31	Latitude	0.5194	Latitude	BASEA	-
	Longitude	0.4651	Longitude	BASEC	-
	Height	1.1393	Height	BASEA	-
LPM31	Latitude	0.5193	Latitude	BASEA	-
	Longitude	0.4651	Longitude	BASEC	-
	Height	1.1393	Height	BASEA	-
MMB5875	Latitude	0.5193	Latitude	BASEA	-
	Longitude	0.4651	Longitude	BASEC	-
	Height	1.1393	Height	BASEA	-
PM130	Latitude	0.5193	Latitude	BASEA	-
	Longitude	0.4651	Longitude	BASEC	-
	Height	1.1393	Height	BASEA	-
PM236	Latitude	0.5193	Latitude	BASEA	-
	Longitude	0.4651	Longitude	BASEC	-
	Height	1.1393	Height	BASEA	-
PM241	Latitude	0.5193	Latitude	BASEA	-
	Longitude	0.4651	Longitude	BASEC	-
	Height	1.1393	Height	BASEA	-
PM257	Latitude	0.5193	Latitude	BASEA	-
	Longitude	0.4651	Longitude	BASEC	-
	Height	1.1393	Height	BASEA	-
PM276	Latitude	0.5193	Latitude	BASEA	-
	Longitude	0.4651	Longitude	BASEC	-
	Height	1.1393	Height	BASEA	-

PM396	Latitude	0.5193	Latitude	BASEA	-
	Longitude	0.4651	Longitude	BASEC	-
	Height	1.1393	Height	BASEA	-
PM55	Latitude	0.5193	Latitude	BASEA	-
	Longitude	0.4651	Longitude	BASEC	-
	Height	1.1393	Height	BASEA	-





Testing and Estimated Errors

Coordinate Tests

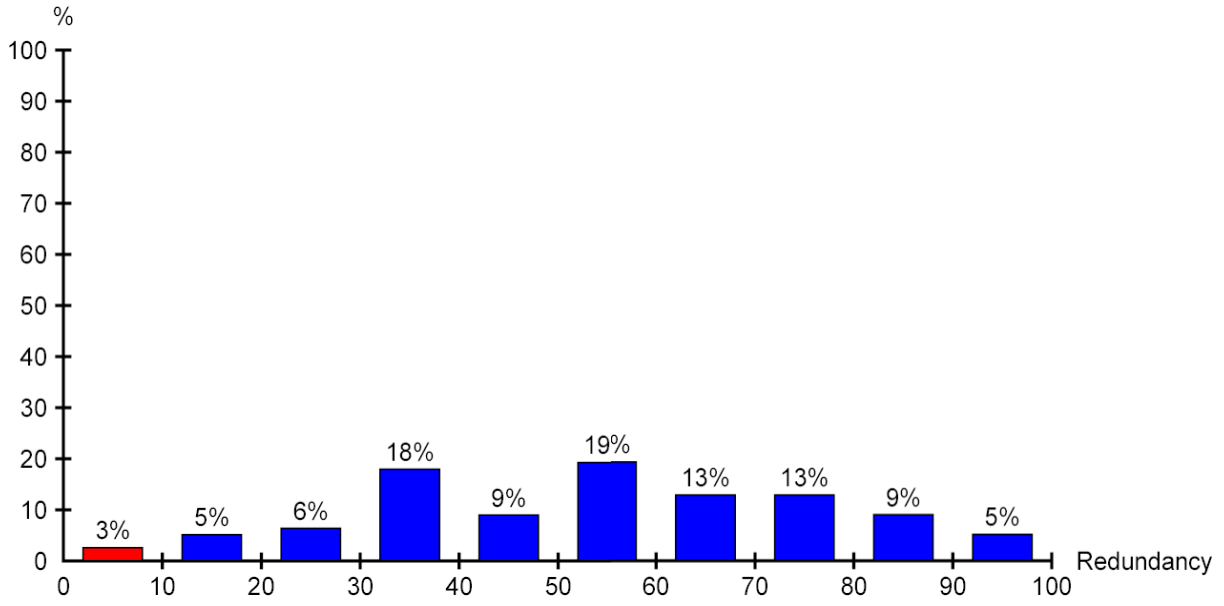
Station		MDB	BNR	W-Test	T-Test
BASEA	Latitude	1.2390 m	2.4	0.00	0.00
	Longitude	1.0326 m	2.4	0.01	
	Height	2.6838 m	2.4	-0.02	
BASEB	Latitude	1.6493 m	1.2	0.00	0.00
	Longitude	1.5814 m	1.0	0.01	
	Height	3.6778 m	1.2	0.01	
BASEC	Latitude	1.2401 m	2.4	0.00	0.00
	Longitude	1.0265 m	2.5	-0.02	
	Height	2.6862 m	2.4	0.02	

Observation Tests

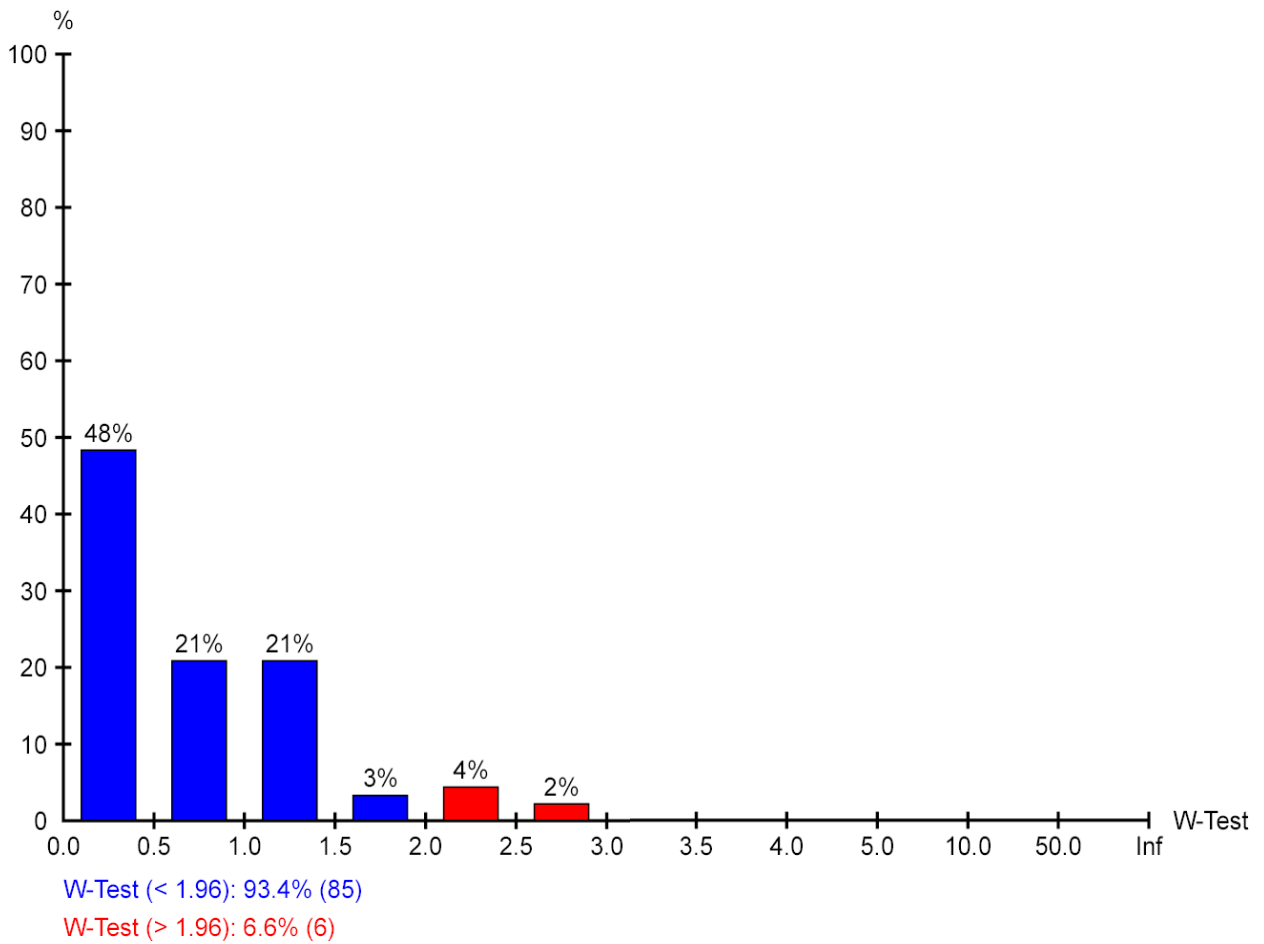
	Station	Target	MDB	Red	BNR	W-Test	T-Test
DX	BASEC	BASEA	0.0089 m	81	1.4	-1.63	0.93
DY			0.0082 m	90	1.2	-0.99	
DZ			0.0106 m	89	1.0	1.05	
DX	BASEB	BASEC	0.0073 m	55	2.3	0.07	1.08
DY			0.0058 m	59	2.1	-0.34	
DZ			0.0089 m	84	1.8	1.04	
DX	BASEA	BASEC	0.0097 m	81	1.3	-0.91	0.84
DY			0.0067 m	72	1.7	0.18	
DZ			0.0068 m	57	2.3	-0.36	
DX	BASEA	BASEB	0.0070 m	61	2.3	-0.43	0.80
DY			0.0063 m	77	2.1	-0.80	
DZ			0.0084 m	70	1.8	0.86	
DX	BASEC	PM55	0.0244 m	63	2.4	1.41	0.81
DY			0.0157 m	37	3.6	1.11	
DZ			0.0256 m	2	7.5	-0.60	
DX	BASEC	PM276	0.0130 m	71	1.7	0.32	0.28
DY			0.0113 m	78	1.5	0.01	
DZ			0.0149 m	81	1.4	0.44	
DX	BASEC	PM257	0.0106 m	68	2.3	0.99	0.53
DY			0.0084 m	55	2.5	0.00	
DZ			0.0125 m	62	2.4	-0.97	
DX	BASEC	PM241	0.0179 m	68	2.0	0.21	1.29
DY			0.0111 m	67	2.0	0.04	
DZ			0.0172 m	90	1.3	-1.47	
DX	BASEC	PM236	0.0130 m	17	4.9	-1.61	1.22
DY			0.0079 m	33	4.1	0.01	
DZ			0.0094 m	43	3.3	1.09	
DX	BASEC	PM130	0.0160 m	65	1.9	0.83	0.89
DY			0.0090 m	63	2.1	-0.35	
DZ			0.0089 m	55	2.4	0.21	
DX	BASEC	MMB5875	0.0168 m	35	3.6	1.14	1.20
DY			0.0130 m	48	3.3	-0.26	

DZ			0.0167 m	41	3.4	-0.04		
DX	BASEC	EPM31	0.0119 m	63	2.0	-1.01	2.86	
DY			0.0113 m	81	1.7	0.80		
DZ			0.0162 m	73	1.6	-0.26		
DX	BASEB	PM55	0.0244 m	34	3.5	-1.41	0.81	
DY			0.0157 m	58	2.5	-1.11		
DZ			0.0256 m	96	2.1	0.60		
DX	BASEB	PM396	0.0101 m	38	3.5	0.48	1.58	
DY			0.0082 m	39	3.5	0.09		
DZ			0.0101 m	38	3.5	1.31		
DX	BASEB	PM276	0.0113 m	52	2.5	0.33	1.75	
DY			0.0092 m	51	2.7	-0.77		
DZ			0.0112 m	29	3.9	-2.18		
DX	BASEB	PM241	0.0179 m	27	4.5	-0.21	1.29	
DY			0.0111 m	25	4.7	-0.04		
DZ			0.0172 m	5	8.8	1.47		
DX	BASEB	PM236	0.0130 m	77	2.2	1.61	1.22	
DY			0.0079 m	53	2.7	-0.01		
DZ			0.0094 m	33	3.6	-1.09		
DX	BASEB	PM130	0.0191 m	77	1.4	-1.01	1.55	
DY			0.0143 m	89	1.0	0.70		
DZ			0.0184 m	93	0.9	0.12		
DX	BASEB	MMB5875	0.0168 m	59	2.5	-1.14	1.20	
DY			0.0130 m	47	2.7	0.26		
DZ			0.0167 m	53	2.6	0.04		
DX	BASEB	LPM31	0.0141 m	60	2.9	-1.15	0.99	
DY			0.0105 m	31	3.7	0.12		
DZ			0.0132 m	19	4.9	0.63		
DX	BASEA	PM396	0.0101 m	46	3.0	-0.48	1.58	
DY			0.0082 m	45	3.0	-0.09		
DZ			0.0101 m	45	3.1	-1.31		
DX	BASEA	PM276	0.0113 m	59	2.4	-0.60	1.48	
DY			0.0093 m	55	2.5	0.77		
DZ			0.0126 m	76	1.9	2.07		
DX	BASEA	PM257	0.0106 m	19	4.8	-0.99	0.53	
DY			0.0084 m	32	4.1	0.00		
DZ			0.0125 m	31	3.9	0.97		
DX	BASEA	PM130	0.0145 m	51	3.4	0.01	0.03	
DY			0.0084 m	31	4.2	-0.08		
DZ			0.0086 m	30	4.3	-0.26		
DX	BASEA	LPM31	0.0141 m	34	3.3	1.15	0.99	
DY			0.0105 m	59	2.7	-0.12		
DZ			0.0132 m	71	2.1	-0.63		
DX	BASEA	EPM31	0.0119 m	26	5.1	1.01	2.86	
DY			0.0113 m	13	6.1	-0.80		
DZ			0.0162 m	22	6.0	0.26		

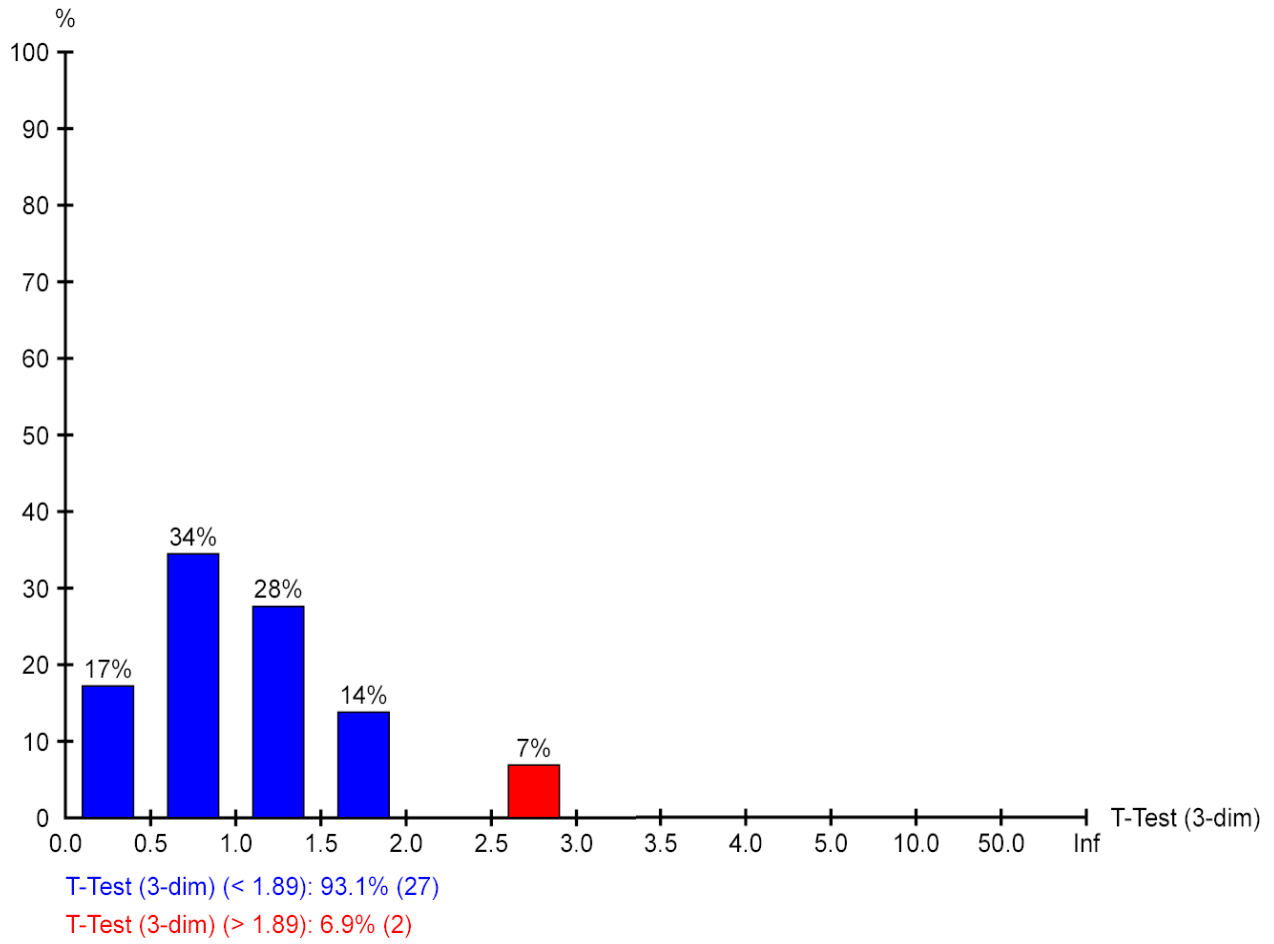
Redundancy:



W-Test:



T-Test (3-dimensional):



Appendix F

SMES values charts

Locate Survey Marks (SMES)

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Survey Mark Search Results and Reports

Selected Marks 1 - 10 of 13 (out of 91)

Coordinates: MGA94 - Easting/Northing

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	Number	Name	Status	Zone	MGA94 Easting	MGA94 Northing	AHD Height	HOrder	VOrder	PSF	HF	CSF
<input checked="" type="checkbox"/>	261901190	FRANKSTON PM 119	OK	55	335810.312	5775865.666	21.245	3	3	0.9999320	0.9999967	0.9999287
<input checked="" type="checkbox"/>	261902770	FRANKSTON PM 277 C262-11	OK	55	337681.799	5776053.102	40.845	3	3	0.9999245	0.9999936	0.9999181
<input checked="" type="checkbox"/>	261903670	FRANKSTON PM 367 C262-12	OK	55	337776.688	5775996.474	43.848	3	3	0.9999241	0.9999931	0.9999172
<input checked="" type="checkbox"/>	261904750	FRANKSTON PM 475 C261-38	OK	55	339675.110	5777009.273	58.311	3	3	0.9999166	0.9999909	0.9999074
<input checked="" type="checkbox"/>	261905520	FRANKSTON PM 552 C262-5	OK	55	336975.461	5777360.323	11.959	3	3	0.9999273	0.9999981	0.9999255
<input checked="" type="checkbox"/>	261906510	FRANKSTON PM 651 C261-41	OK	55	339052.294	5777189.152	46.726	3	3	0.9999190	0.9999927	0.9999117
<input checked="" type="checkbox"/>	261906530	FRANKSTON PM 653 C261-39	OK	55	339577.699	5777019.450	56.833	3	3	0.9999170	0.9999911	0.9999080
<input checked="" type="checkbox"/>	261906600	FRANKSTON PM 660 C262-16	OK	55	338499.512	5775624.520	57.351	3	3	0.9999212	0.9999910	0.9999122
<input checked="" type="checkbox"/>	261907260	FRANKSTON PM 726	OK	55	337910.762	5774792.952	75.910	2	3	0.9999236	0.9999881	0.9999117
<input checked="" type="checkbox"/>	261908980	FRANKSTON PM 898 C262-2	OK	55	336614.764	5777977.312	8.435	3	3	0.9999288	0.9999987	0.9999275

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Survey Mark Search Results and Reports

Selected Marks 11 - 13 of 13 (out of 91)

Coordinates: MGA94 - Easting/Northing

Data Source: Vicmap Control - SMES

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< 1 2

	Number	Name	Status	Zone	MGA94 Easting	MGA94 Northing	AHD Height	HOrder	VOrder	PSF	HF	CSF
<input checked="" type="checkbox"/>	297200990	LANGWARRIN PM 99	OK	55	341435.099	5775187.142	79.6	3	5	0.9999097	0.9999875	0.9998972
<input checked="" type="checkbox"/>	297201410	LANGWARRIN PM 141 SR75G67C LANGWARRIN PM 169	OK	55	340662.882	5775439.367	75.793	2	3	0.9999127	0.9999881	0.9999008
<input checked="" type="checkbox"/>	297201570	LANGWARRIN PM 157 C261-32	OK	55	339602.030	5774549.689	93.277	3	3	0.9999169	0.9999854	0.9999022

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Survey Mark Search Results and Reports

Selected Marks 1 - 10 of 13 (out of 288)

Coordinates: MGA94 - Easting/Northing

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1 2 >

	Number	Name	Status	Zone	MGA94 Easting	MGA94 Northing	AHD Height	HOrder	VOrder	PSF	HF	CSF
<input checked="" type="checkbox"/>	260300310	EUMEMMERRING PM 31	OK	55	345725.891	5785749.626		3		0.9998931		
<input checked="" type="checkbox"/>	260302570	EUMEMMERRING PM 257 MMB 5239	OK	55	343007.549	5788553.480	11.287	3	4	0.9999036	0.9999982	0.9999018
<input checked="" type="checkbox"/>	297200550	LANGWARRIN PM 55 SR82D17	OK	55	344727.119	5777556.502	63.809	3	3	0.9998969	0.9999900	0.9998869
<input checked="" type="checkbox"/>	297201300	LANGWARRIN PM 130 SR75G42	OK	55	345252.130	5778136.764	57.991	3	3	0.9998949	0.9999909	0.9998858
<input checked="" type="checkbox"/>	302500310	LYNDHURST PM 31 SR57A9 DVA 68/39	OK	55	340648.217	5786442.170	4.534	3	3	0.9999127	0.9999993	0.9999120
<input checked="" type="checkbox"/>	302502360	LYNDHURST PM 236 C102-3 SR75G39C	OK	55	343989.810	5784283.595	15.891	3	3	0.9998998	0.9999975	0.9998973
<input checked="" type="checkbox"/>	302502380	LYNDHURST PM 238 C131-9	OK	55	347306.890	5784596.759	21.866	3	3	0.9998872	0.9999966	0.9998837
<input checked="" type="checkbox"/>	302502410	LYNDHURST PM 241 1017-3	OK	55	342575.741	5786180.337	8.151	2	3	0.9999052	0.9999987	0.9999039
<input checked="" type="checkbox"/>	302502540	LYNDHURST PM 254 617-5 MMB 5751	OK	55	340719.736	5783093.957	8.947	3	3	0.9999125	0.9999986	0.9999111
<input checked="" type="checkbox"/>	302502830	LYNDHURST PM 283 MMB 5021	OK	55	339199.798	5784939.912	2.550	3	4	0.9999185	0.9999996	0.9999181

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Survey Mark Search Results and Reports

Selected Marks 11 - 13 of 13 (out of 288)

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Coordinates: MGA94 - Easting/Northing

Data Source: Vicmap Control - SMES

< 1 2

	Number	Name	Status	Zone	MGA94 Easting	MGA94 Northing	AHD Height	HOrder	VOrder	PSF	HF	CSF
<input checked="" type="checkbox"/>	302502880	LYNDHURST PM 288 SR75G60	OK	55	344338.194	5780959.151	28.894	3	3	0.9998984	0.9999955	0.9998939
<input checked="" type="checkbox"/>	302503960	LYNDHURST PM 396 SR75G38C	OK	55	343757.670	5782692.047	19.818	3	3	0.9999007	0.9999969	0.9998976
<input checked="" type="checkbox"/>	450058750	MMB 5875	OK	55	342163.768	5781251.145	42.055	3	4	0.9999068	0.9999934	0.9999002

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Appendix G

Section 2.3.3 (i) Surveyor General of Victoria 2007

Practice Directives



Surveyor-General of Victoria

Practice Directives

January 2007

2.3. MGA94 Datum derived by GNSS Observations

Under certain circumstances GNSS observations can be used to compute co-ordinate information for updating *Vicmap Property*. The requirement to connect to two known 3rd order or better ground marks may be replaced by a combination of GNSS observations and verification to at least one known 3rd order ground mark.

2.3.1 GNSS real-time observations

GNSS real-time observations must contain at least two independent occupations on a local control point to ensure that the solutions initialised (fixed) properly. The second occupation is to be separated by at least 20 minutes from the first occupation of the control point and the second determination of the position is to be determined from a new initialisation process. The horizontal component of the differences between the two determinations of the control point should not exceed 0.05 metres.

2.3.2 Verifying co-ordinates from GNSS observations

The MGA94 co-ordinates derived from GNSS observations are to be verified by a connection to at least one known 3rd order MGA94 ground mark. A variation in the horizontal component of the coordinate difference of up to 0.10 metres is acceptable. Where this variation exceeds 0.10 metres, the surveyor must connect to at least one other known 3rd order MGA94 ground mark to reconcile the difference.

2.3.3 Typical GNSS observation verification techniques

Typically the combination of GNSS observations and verification to at least one known 3rd order ground mark are as follows:-

- (i) Where a Networked Real-time Kinematic (NRTK) position coordinate solution (like MELBpos) is to be used, the surveyor shall determine MGA94 bearings and coordinates by performing two independent occupations of the GNSS rover instrument at a control point. Re-occupation is to be separated by a time period of not less than 20 minutes. The horizontal component of the differences between the two determinations of the control point position must not exceed 0.05 metres. The MGA94 coordinates derived from this process should be verified by connection to at least one known 3rd order MGA94 ground mark. A variation in the horizontal component of the coordinate difference of up to 0.10 metres is acceptable. Where this variation exceeds 0.10 metres, the surveyor must connect to at least one other known 3rd order MGA94 ground mark to reconcile the difference.
- (ii) Where position coordinates are computed using single GPSnet reference station by Real Time Kinematic (RTK) solutions (like VICpos) within 20 kilometres of the reference station, the surveyor is to determine MGA94 bearings and coordinates as described for NRTK above. RTK solutions are not valid for connection purposes if the distance from the reference station to the instrument exceeds 20 kilometres.
- (iii) Where a Real Time Kinematic (RTK) solution is performed using the surveyor's own base station and rover, the surveyor is to determine MGA94 bearings and coordinates from the best fit of a networked connection to at least two (preferably three or more) known 3rd order MGA94 ground marks. Where 3rd order MGA94 ground marks are not available, the survey may be placed on MGA94 bearing datum derived from the GNSS observation. In this case, MGA94 coordinates are not to be computed, but the report is to state that MGA94 bearing datum was derived from the GNSS equipment used.
- (iv) Where the survey is performed using post-processing kinematic data from a networked solution (like MELBpos) by creating a "virtual reference station", the surveyor shall determine MGA94 bearings and coordinates by performing two independent occupations at the control point with the GNSS rover instrument, as described for NRTK above. Solutions from a "virtual reference station" are not valid for connection purposes if the distance from the origin used to generate the virtual reference station to the rover exceeds 5 kilometres.
- (v) Where the survey is performed by post-processing static data from adjoining GPSnet reference stations, the surveyor is to determine MGA94 bearings and coordinates by connecting to at least two GPSnet reference stations and one known 3rd order MGA94

ground mark. The horizontal component of the vector computed from GNSS measurements between the GPSnet reference stations and the published co-ordinates should not exceed 0.05m.

- (vi) Where the survey is performed by post-processing static data independent of GPSnet reference stations, the surveyor is to determine MGA94 bearings and coordinates by connecting to at least three known 3rd order MGA94 ground marks.

Surveyors *MUST* ensure that they follow “best practice” GNSS observation techniques at all times and are advised to retain all raw data derived from the observations, eg. satellite phase and range data stored in RINEX.

These directions as provided relate to the connection of a survey to MGA94 and not to the actual performance of the cadastral survey.

Guidelines for the use of GNSS are provided by the ICSM in their Standards and Practices document ‘SP1’ which is available from its website, www.icsm.gov.au.

2.4. Re-establishment Surveys, Partial Surveys and Non-Survey Subdivisions

Connection of surveys to MGA94 is not required for surveys supporting: -

- a) non-survey subdivisions (see Appendix 4 - The Land Registry Non-Survey Guidelines) ;
- b) partial surveys that create one small lot from a significantly larger allotment (applicable primarily to a rural environment).; or
- c) Notices of Having Re-established a Parcel pursuant to Regulation 16 of the *Surveying (Cadastral Surveys) Regulations 2005*.

2.5. Recording Connection Information

2.5.1 Co-ordination of New PCMs/PMs that will not form part of the adjusted network

MGA94 co-ordinates for new PCMs/PMs should only be computed where the survey in which they are recorded is connected directly to two or more ground marks with MGA94 values of 3rd order standard or higher **OR** an appropriate combination of ground marks and GNSS observations as outlined above.

2.5.2 Co-ordination of Parcel Corners

The co-ordinates of parcel corners are to be computed in accordance with the parameters set out in this Practice Directive and quoted in the Report of a Licensed Surveyor to the nearest 0.01 metres.

2.5.3 Method of Presenting Co-ordinate Information

The co-ordinate information is to be presented in *Microsoft Word* format as an addendum within the Surveyors Report. Refer to Appendix 3 for the template of the Schedule of Co-ordinates. The template is available for download from www.land.vic.gov.au/surveying refer ‘Directives and Services’, ‘Surveyor-General Practice Directives’. This template is to be used as the standard format within Reports by the Licensed Surveyor lodged with Land Registry or the Surveyor-General.

Co-ordinate information must be presented in this manner and not on the Abstract of Field Records. All parcel corners for the land under survey are to be shown on the Schedule of Coordinates and are to be identified by corresponding numbers on the abstract of field records. All parcel corners must be numbered clockwise around the parcel, commencing with Point No.1 at the most northerly parcel corner. It is important to record the relevant plan number with each parcel corner entry within the Schedule as a safeguard against parcel corner coordinates becoming ‘separated’ within the map base storage table prior to entry into the map base.

2.5.4 Recording of the Map Projection, Zone and Co-ordinates

All survey plans and abstracts of field records related to MGA94 are to clearly display the map projection as MGA94 and relevant Zone (54 or 55) as notations on the north point. Other written documentation is to include similar notations within that document.