University of Southern Queensland

Faculty of Engineering and Surveying

Global Navigation Satellite Systems for Geodetic Network Surveys

A dissertation submitted by

Mr Liam Patrick CURRAN
Registered Surveying Associate

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ABSTRACT

GPS has brought a revolution to the surveying profession and GNSS continues to refine the satellite navigation technology. An abundance of research is available on the effectiveness of GNSS on the RTK style of surveying. However very little research has been conducted on the more precise static techniques.

The aim of this research is to analyse and quantify the precision, accuracy and timesaving gained by using several GNSS constellations over solely using the United States of Americas Department of Defence GPS.

A Fast Static geodetic network survey was designed and carried out under the guidelines set out by the ICSM (Intergovernmental Advisory Committee on Surveying and Mapping) in the SP1 (Standards and Practices for Control Surveys) document as the main part of the testing for this research.

Testing has revealed that unfiltered GNSS data improves the precision of the baselines over unfiltered GPS data and also makes considerable precision gains towards the level of filtered data. GNSS filtered data also showed improvement of the baseline precisions of GPS filtered data. By accepting the same level of precisions achievable with GPS only, testing also indicated that a GNSS user could reduce observation session lengths and still achieve the same precisions.

With GNSS hardware and software, users have the ability to observe more satellites simultaneously. The ability to track more satellites increases the amount of data recorded in every static session and improve its precision and reliability. Furthermore, the enhanced precision of GNSS over GPS improves the productivity of the user and can reduce the person-hours required for a static mission.

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Liam Patrick Curran

Student Number: 0011222154

Signature

Date

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NOMENCLATURE AND ACRONYMS

AHD: Australian Height Datum 1971

AHD D: Australian Height Datum Derived

Baseline: A three dimensional vector that is generated by simultaneous GNSS observations and then reduced to the vector of the marks in which it occupies.

CDMA: Code Division Multiple Accesses – the format of the broadcast empherides used by Compass, GPS and Galileo.

Class: is a function of the precision of a survey network, reflecting the precision of observations as well as suitability of network design, survey methods, instruments and reduction techniques used in that survey. Preferably, the CLASS is verified by an analysis of the minimally constrained least squares adjustment of the network (ICSM 2007).

CORS: Continuously Operating Reference Station

NRW: The State of Queensland's Department of Natural Resources and Water.

DoD: The United States of Americas Department of Defence

Epoch: A specified interval of time in which the GNSS receiver takes a measurement.

Empherides: The orbital positions of GNSS satellites that are broadcast by the satellites and used by GNSS equipment. Precise empherides can be obtained to increase the accuracy of the observations.

EU: European Union

FDMA: Frequency Division Multiple Access – the format of the broadcast empherides of GLONASS.

FOC: Full Operation Capacity

Fully Constrained: A least squares adjustment where the network is constrained by at least two horizontal control points and at least 3 vertical control points on a local geodetic datum usually with a geoiod.

GDA94: Geodetic Datum of Australia 1994

GDOP: Geometric Dilution of Precision

GLONASS: GLObal NAvigation Satellite System – the GNSS controlled by the Russian Federation.

GNSS: Global Navigation Satellite System – an all-encompassing term that includes all operational and future satellite navigation systems.

GPS: Global Positioning System – the GNSS controlled by the United States of Americas Department of Defence.

ICSM: Intergovernmental Advisory Committee on Surveying and Mapping

Independent Baselines: The maximum amount of independent base lines that can be generated in a session is one less than the amount of receivers used in the session.

Local Uncertainty: the average measure, in metres at the 95% confidence level, of the relative uncertainty of the coordinates, or height, of a point(s), with respect to the survey connections to adjacent points in the defined frame (ICSM 2007).

MGA94: Map Grid of Australia 1994

Order: is a function of the precision of a survey network, reflecting the precision of observations as well as suitability of network design, survey methods, instruments and reduction techniques used in that survey. Preferably, the CLASS is verified by an analysis of the minimally constrained least squares adjustment of the network (ICSM 2007).

PDOP: Position Dilution of Precision

PM: Permanent Mark – a survey mark placed in such a method that give it more stability than regular survey marks and is likely not to be disturbed in the foreseeable future.

Positional Uncertainty: The uncertainty of the coordinates or height of a point, in metres, at the 95% confidence level, with respect to the defined reference frame (ICSM 2007).

ppm: Parts Per Million

PPK: Post Processed Kinematic

PZ-90: Parametry Zemli 1990 (translated: Parameters of the Earth 1990) – the geodetic datum used by GLONASS

RINEX: Receiver Independent EXchange

RMS: Root Mean Squared

RTK: Real Time Kinematic

SCDB: Survey Control Database

SA: Selective Availability – a feature of GPS satellites that when enabled, causes significant random errors to autonomous users except the USA DoD and its military allies.

SP1: Standards and Practices for Control Surveys – the document produced by the ICSM to control the quality of surveying and mapping in Australia.

TBC: Trimble Business Centre

Trivial Baseline: Baseline(s) in a session that generate false redundancy in a network and therefore cause the network adjustment statistics to be unrealistically more favourable.

WGS-84: World Geodetic System 1984 – the geodetic datum used by GPS.

Zero Constrained: (or minimally constrained) a least squares adjustment the network is constrained by nothing but its own observations.

CHAPTER 1 – INTRODUCTION

1.1 Background

Traditionally, geodetic surveys were performed by land surveyors through repetitive terrestrial observations and Electronic Distance Measurements (EDM). This process was lengthy, tedious, and labour intensive. The discovery of errors meant that entire sets of observations from one or more survey stations would be observed again. The processing of the data was usually done manually or at least through manual data entry into computer programs. Data collectors would later be introduced and remove transcription errors of raw measurements from the process by integrating the collection and reduction of measurements by computers. Furthermore, the recent advent of auto-lock on servo and robotic total stations means that surveyors no longer are required to point to the prism targets over relatively short lines (≤-600 m).

In 1984, surveying became the first commercial profession to enter into the satellite navigation market with the popularisation of Global Positioning System (GPS) (Fossum et al, 1995). Surveyors also pioneered several technological enhancements to improve the overall accuracy of their techniques (Fossum et al, 1995). These enhancement techniques discovered and utilised by surveyors were able to achieve a level of accuracy beyond the original intent of what was meant to be a closed military system regardless of Selective Availability (SA). Until recent times, GPS has been the only constellation used for surveying in Australia. As recently as 2005, the Russian Federations (RF) GLObal NAvigation Satellite System (GLONASS) has been found to be broadcasting empherides up to eight times less accurate than GPS (Gibbons 2006). However, with the recent modernisation and rebuilding of the constellation and ground infrastructure, GLONASS and its M series satellites have received renewed confidence domestically and internationally.

Despite the first commercial GNSS receiver being available in 1996 from Ashtech (now Magellan) (Gakstatter 1996), mainstream adoption (in Australia at least) has only occurred with the recent releases of multi-system antennas and receivers from the more traditional surveying manufacturers (Leica, Sokkia, Topcon and Trimble).

While much research has been conducted to analyse the benefits of multi-system GNSS receivers for Real Time Kinematic (RTK) surveys along with its application to networks of Continuously Operating Reference Stations (CORS), research has not been completed on the application of GNSS receivers to static surveys, particularly geodetic survey networks in Australia.

1.2 Research Aim

The aim of this project is to analyse and quantify the precision, accuracy and timesaving gained by using several GNSS constellations over solely using the USAs DoD GPS.

1.3 Benefits

Despite a lack of cost-to-benefit ratio calculations, this research could provide a decision making aid for businesses considering purchasing or upgrading to the latest GNSS technology.

If the following hypotheses of this research prove to be correct, significant timesaving will be able to be achieved by using GNSS equipment over the GPS equipment.

1.3.1 Hypothesises

- There may be enough extra quality data from additional satellites in order to not require filtering the noisy data out of the solution (or be as meticulous when filtering).

- When the data is filtered, as it would be for static surveying, the quality of the solution may improve further with the additional data from the GLONASS satellites and the soon to be operational Compass and Galileo satellites.
- Having extra satellite data will introduce additional processing time into the office work, but the amount of time may be negligible but should be measured for completeness of this research.
- By having more satellites in every station occupation, the length of time required for each session will be reduced.

1.4 Justification

Currently all of the standards and best practices developed for use in Australia are based on the utilisation of GPS solely at full operation capacity (FOC). The GPS constellation is running beyond its full operation FOC of 24 satellites, currently providing positional transmissions from 32 satellites (US Coast Guard 2008). In South East Queensland, this translates to a range of five to ten GPS satellites visible at any one time (Mylne 2007). Despite having reached and fallen from its FOC status, the GLONASS constellation currently has 12 satellites operating (Russian Space Agency 2008) and should be able to provide augmentation for what is already a powerful positioning utility. With nearly twice the number of global navigation satellites broadcasting positions than when the standards and practices were formulated, it is a good time to review the old methodology in the new GNSS era.

Much of the surveying profession in Australia is embracing GNSS technology for the revolution that RTK has brought to the profession. By specification, static surveying has roughly twice the relative accuracy of kinematic surveying (Trimble Navigation Limited 2007b). While geodetic surveying has been virtually ignored by most private practices due to the planning required and lengthy occupation times for its use, the possible improvements of accuracy and reductions of occupation time that may be gained through the acquisition of additional satellites could sway the industry into the purchase/upgrade and increase their utilisation of alternate GNSS methodology.

1.5 Limitations of Research

The two operational GNSS constellations, GPS and GLONASS, for the past several years have been undergoing modernisation efforts (Gibbons 2006). Despite constant delays and questionability of feasibility, the European Union (EU) and China continue to work on their own constellations – Galileo and Compass respectively – to compliment the current navigation systems (Gibbons 2008). Due to the uncertainty of the launch dates and the unavailability of equipment to observe their test signals of both the forthcoming constellations are outside the scope of this research. Any analogies regarding future research upon the deployment of these constellations will be discussed in the final chapter.

1.6 Summary

While GPS has already brought revolution to the surveying profession, GNSS continues to refine the technology. The benefits of RTK GNSS are well recognised within the surveying profession, however the information available on GNSS in geodetic surveying lacks the same comprehensive coverage. With GPS currently operating with eight more satellites than its FOC and GLONASS working at about half FOC, nearly twice as many satellites are available for tracking than the original intent of GPS. This research aims to highlight the benefits of GNSS to geodetic surveying.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

This chapter will present a review of literature to identify the current research on the operational GNSS constellations and how they affect GNSS baseline observations. This will establish common procedures currently employed in surveying practices and possible testing regimes that may be utilised for this research. The literature review will also identify the gaps in current research to justify the need for this research.

The compatibility and interoperability of the operational GNSS constellations, the current standards and best practices, possible surveying styles to be used for the testing, post processing and possible testing ambiguities will all be reviewed in this chapter. The methodology used for GPS geodetic network surveys will also be reviewed and its relevance to GNSS surveys will be analysed to aid in the selection of the testing methodology to be used for this research.

Most importantly, the appropriate GNSS observation survey style (i.e. Static, PPK and RTK) for testing will be selected in this chapter. The requirements for surveyors in Queensland, standards, best practices and the identification of past testing ambiguities will be featured throughout this chapter.

2.2 Compatibility and Interoperability

Despite these constellations being built for essentially the same purpose, navigation, both have stemmed from independent research and remain under the control of distinct governing bodies. At a technical level, due to the original independent nature of the projects, GPS and GLONASS have different signal access schemes and until recent years, not even professional users (surveyors) had access to a reliable mainstream commercially available receiver that could utilise both of these systems.

2.2.1 Hardware

The problem with the mainstream manufacturing of GNSS hardware is the difference in signal access schemes used by the various constellations. GPS uses Code Division Multiple Access (CDMA), GLONASS uses Frequency Division Multiple Access (FDMA), and consequently the systems are not signal interoperable (Gibbons 2006). Previously, two different chips were required in order to utilise both constellations, usually at a high cost. The demodularisation and miniaturisation of recent equipment has lead to the only GPS being used by most receivers (because of the previously mentioned GLONASS data quality issues and the relative obscurity of dedicated GLONASS receivers outside the Russian Federation.

To resolve this problem, manufacturers have devised custom antennas, receivers, and chips. This has allowed survey receivers to continue to produce lightweight single component solutions suitable for use in both kinematic and static surveys with the added advantage of tracking GLONASS satellites. It seems, however, that their efforts may soon be futile, with the recent announcement from the Russian Federation for GLONASS to commit its K series to broadcasting empherides in the CDMA access scheme (Gibbons 2008). With many of the manufacturers having made these custom chips for simultaneous CDMA and FDMA observations, the newer K series GLONASS satellites using CDMA will no longer require the FDMA hardware. Many manufacturers may decide to remove FDMA compatibility from their hardware in order to make and sell their receivers at a lower price point.

One of the main advantages of GNSS hardware is that it can acquire more GPS satellites than GPS hardware can acquire. While it can be argued that the newer GPS hardware can track just as many GPS satellites as GNSS hardware, the newer GPS hardware is essentially identical to GNSS hardware. The software, the receivers' firmware in particular, limits the hardware abilities and causes it only to be able to track GPS.

2.2.2 Geodetic Datums and Transformations

GPS and GLONASS both operate on different geodetic datums. GPS uses the World Geodetic System of 1984 (WGS-84) and GLONASS uses Parametry Zemli (Translation: Parameters of the Earth) 1990 (PZ-90). For both systems to be observed simultaneously, the transformation parameters between WGS-84 and PZ-90 need to be defined. Geodetic datum transformations can range between three parameters and seven parameters with grid distortions. To complicate issues further there are two different PZ-90 datums, the original PZ-90 (KGS) and the one broadcast PZ-90 (GLONASS)(Zinoviev2005).

While the datum transformation used in a particular receiver may never be exposed because of its proprietary nature, it is important to be aware that incorrect or inaccurate parameters of transformation may cause results to diverge with time (rather than converge). This makes the manufacturers transformation parameters selection imperative for GNSS receivers to be functional. With WGS-84 being a dynamic datum, it may be necessary for these parameters to be updated frequently in the receiver.

Many of the surveying manufacturers are currently phasing out their GPS equipment and phasing in GNSS equipment to replace it. This trend is sure to be followed by their primary consumers – surveyors. While GNSS is not a new concept to surveyors, many may not be aware of the divergence of different datums used by the various GNSSs – a problem that could be exacerbated by the possible introduction of two more datums by Galileo and Compass. The answers to the problem would be to ensure all equipment has the latest firmware with all of the current corrections. As a preventive measure if such an issue were to arise, the surveying software may require an expiration date to reduce the risk of improper use of the equipment. Above all, surveyors need to be educated of this possible risk when using this equipment over long-term periods.

2.3 Queensland Requirements for Control Surveys

2.3.1 Department of Natural Resources and Water Requirements

The Department of Natural Resources and Water (NRW) is the governing body responsible for maintaining Land Surveying standards in Queensland. Since all testing is to be completed in Queensland, Toowoomba in particular, the survey will adhere to all of the applicable Acts and Regulations as in force. The standards for control surveys in Queensland as outlined by NRW are as follows:

> ‘Control surveys are required to comply with the Standards and Recommended Practices for Control Surveys as published by ICSM [specifically SP1].
> Details of new permanent mark must be provided to NRW using the approved permanent mark sketch form’

Therefore, apart from requiring the surveyor to comply with the standards and best practices as outlined in the publication of the Intergovernmental Advisory Committee on Surveying and Mapping (ICSM), the surveyor is only required to submit the Form 6 to NRW with the details of the new Permanent Mark(s) (PM) that have been installed.

2.3.2 ICSM Requirements

The ICSM is the body responsible for the coordination of standards of surveying and mapping between the Australian States and Territories and New Zealand. The document referred to by NRW is the *Standards and Practices* *for Control Surveys – Special Publication 1(SP1).* The guidelines provided in the document indicate best practices for surveying and aid professionals in achieving quality results. Geodetic positioning through satellite navigation has been perceived as one of the best tools for positioning without line of sight, this still does not escape the fact that measurements with GNSS are not legally traceable in Australia unless they have been validated with an appropriate Electronic Distance Measurement (EDM) instrument or existing coordinated marks are intergraded into the survey. Despite using GNSS equipment, most of the terrestrial surveying principles still apply. This includes standard practices like:

- Closure
- Redundant observations
- Connection to existing known marks
- Marking Practices
- Survey lodgement

The most important step of performing a GNSS survey is indentifying the correct method used to achieve the required accuracy. The level of precision is determined by the class of the survey and in turn will help determine the GNSS method employed. Due consideration should be given to the quality of the marks to ensure stability and longevity.

The methods described by the ICSM for GPS surveying are: Classic Static, Fast Static (or Quick Static or Rapid Static), Post Processed Kinematic (PPK) (or Stop and Go) and Real Time Kinematic (RTK). Methods of survey not cited by the ICSM such as “RTK & Infill” and “RTK & Logging” employ combinations of the aforementioned techniques (RTK & PPK and RTK & Fast Static respectively) (Trimble Navigation Limited 2008). Since the survey is to be a control network survey, it would be pointless to implement any of these combination techniques since using two techniques concurrently cannot produce redundancies.

Classic Static, as the name suggests, is the original method of collection of GNSS data. Classic Static is known for its collection of copious amounts of data through long occupation time and is the benchmark of precision and accuracy for GNSS surveying. Long observation times take advantage of significant changes in satellite geometry, which is beneficial to ambiguity resolution and increasing the quality of the overall result (University of Southern Queensland 2008). The epoch recording rate of this technique ranges from 15-30 seconds. The abovementioned qualities of Classic Static make it the only technique able to achieve the 3A and 2A classes of survey. The main problem with the technique is the session length it requires (30 mins plus 20 mins per km of baseline length). The long session times required for Classic Static combined with the exclusivity of 3A and 2A Class surveys, the technique is unnecessarily time-consuming and inefficient for surveys with baselines shorter than 10 kilometres.

The Fast Static technique shares many similarities with the Classic Static method. The main advantage of this method is that the occupation time is reduced to between 5 and 20 minutes and still produces results comparative to Classic Static. For this reason, Fast Static is the most common method of static surveying utilised by surveyors. The shorter session times bring increased recording intervals that range from 5 to 15 seconds per epoch. The length of observation sessions is determined by number of satellites in the solution and the Geometric Dilution of Precision (GDOP). Fast Static has the added advantage over Classic Static of access to pseudo range observations for low noise, low multipath error and high dynamic responsiveness (Trimble Navigation 2007). The shorter occupation times consequently do not have the change in satellite geometry that Classic Static benefits from and should not be used for baselines greater than 10 kilometres (Trimble Navigation Limited 2004).

The kinematic methods of survey – RTK and PPK – are characterised by their short occupation times and sparse amount of data (University of Southern Queensland 2006 and 2008). These techniques often are radial in nature and pertain to zero or minimal redundancy. The highest Class of survey achievable with these techniques without caveats is B. Without the need for dynamic or real-time data in network control surveys both RTK and PPK will be omitted from use in this research.

The ICSM also provides some general guidelines that apply to GNSS surveying, regardless of the method selected. These are:

- Observations should not been taken while the GDOP is above or equal to 8.0.
- Elevation Mask no less than 15° to avoid the gravitational effects of the earth's curvature on the satellite signal. (This correlates to Trimble Navigations recommendation in 1992).
- Direct reoccupation in adjacent sessions should have an antenna height change of at least 0.1m unless on a pillar.
- Multipath is the main cause for high magnitude of Root Mean Squared (RMS) or the Standard Deviation. Avoid highly reflective environments, where this is not possible, increase the occupation times.

The monumentation for highest classes of survey (3A or 2A) should be deep concrete pillars or solid rock (University of Southern Queensland 2008). The survey will utilise existing PMs and without invasive ground disturbance, the marks cannot be verified of their stability. Therefore, the marks should be assumed unsuitable for 3A and 2A classes of surveys. Nevertheless, for statistical purposes, 3A and 2A results could be computed.

Considering all of the above recommendations by the ICSM, the likely location of where the survey is to be conducted (Toowoomba) and that it is the most utilised static surveying method, the testing should be conducted using the Fast Static survey style.

2.3.3 Manufacturers Recommendations – Trimble Navigation

The ICSM (2004) states that in the event of inconsistency of information between their guidelines and the manufacturers guidelines, the manufacturers recommendations will prevail. The USQ surveying laboratory only possesses Trimble GNSS equipment and therefore will be the documentation referred to for this part of the research.

The elevation masks defaults recommended by Trimble Navigation (2008) are 10° for static surveys. As previously mentioned in section 2.2.2, the elevation mask recommended by the ICSM is 15°. This concurs with recommendations made by Trimble Navigation in 1992 and is likely to be the source of this mask given it is citied in SP1. Since newer antennas and receivers will be employed for this research, the most recent recommendations by Trimble Navigation will be used. Although this difference is relatively significant, using 10° elevation masks for the receiver settings and later manually filtering to 15° (if necessary) in the post processing of the data is a viable solution to the elimination of this problem.

Where the ICSM refers to GDOP masks, Trimble Navigation (2008) only gives reference to Positional Dilution of Precision (PDOP) masks – an element of GDOP. The default mask of 6.0 is considerably lower than the 8.0 GDOP mask recommended by the ICSM. In most circumstances, this PDOP mask will arise faster than the GDOP mask.

The ICSM recommends that the logging interval for Fast Static survey style have a frequency of 5-15 seconds. Trimble Navigation agrees with this recommendation, with a factory default recording epoch of 5 seconds – the highest frequency recommended by the ICSM.

For the Fast Static technique, the ICSM states that the length of observation times should be based on the number of satellites and their geometry as recommended by the manufacturer. This is so that enough data is collected in order to resolve ambiguities. Trimble Navigation recommends the following observation times for dual frequency receivers:

- 20 mins for four satellites
- 15 mins for five satellites
- 8 mins for six or more satellites

With the added advantage of GLONASS satellite tracking, based on personal experience with RTK GNSS, there should be no periods during the local daytime without at least eight satellites and each occupation should have 10 or more satellites being tracked. However, in the case that more than two receivers are used in a post processed survey, it is possible that one of the receivers may be logging data in a less than optimal conditions (i.e. high multipath). When this is the case, it is not abnormal to plan for all of the receivers to start logging data simultaneously and continue to log the data for an entire 20 minutes. This will also ensure that enough data has been logged when using multiple “roving” receivers.

2.4 GNSS Post Processing

The major difference between RTK and other GNSS techniques is that the baselines are not being generated on-the-fly by using radio equipment to broadcast corrections from a base station. Instead, the data is collected in the receiver or on an external data collector and stored processing after the data is observed.

Once all of the data has been collected and transferred to a computer, it then needs to be processed by a software package capable of reading raw GNSS data. The data then needs to be viewed and edited so the survey metadata can be validated and dependent baselines can be removed. The baselines are then processed, noisy data is removed and poor performing satellites (i.e. noisy for the entire session) can be removed from the solutions. The baselines are then reprocessed – many iterations of this reprocessing may occur. Finally, the baseline data is constrained in a network adjustment by known coordinates on a known projection to produce the final data for the survey. Examples of this type of software are: Leica Geo Office, StarPlus StarNet and Trimble Business Centre (TBC).

2.4.1 Baseline Processing

The baseline processor is an essential feature for static surveying. Geodetic grade antennas and receivers are required to observe GNSS phase data (along with the code data) in order to produce survey accurate baselines. Combining and processing carrier phase data collected from two stations simultaneously, generates a baseline between two points (USQ 2008). This is then further reduced with antenna height to produce the baseline vector between the surveyed marks. According to the University of Southern Queensland (2008), baseline vector processing software performs the following steps:

1. Computes a best-fit value for point positions from code pseudoranges.
2. Creates undifferenced phase data from receiver carrier phase readings and satellite orbit data. Time tags may also be corrected.
3. Creates undifferenced phase data and computes their correlations.
4. Computes the estimates of baseline vectors using triple-differencing processing. This method is insensitive to cycle slips and provides least accurate results.
5. Computes double-difference solution solving for vector and (real) values of phase ambiguities.
6. Estimates integer value of phase ambiguities computed in step 5, and decides whether to continue with the fixed ambiguities.
7. Computes fixed bias solution based upon best ambiguity estimates computed in step 6.

8. Computes several other fixed bias solutions using integer values differing slightly (i.e. by 1) from selected values.
9. Computes ratio of statistical fit between chosen fixed solution and the next best solution. This ratio should be at least 1.5 to 3 indicating that the chosen solution is at least 1.5 to 3 times better than the next most likely solution.

2.4.2 Network Adjustment

Once baseline processing is complete, trivial baselines (see Nomenclature and Acronyms section) need to be removed/disabled before running a network adjustment. While the ICSM (2007) states that trivial baselines may be included in an adjustment, the redundancy number used must be reduced before the calculation of the variance factor. The software package used may not allow the degrees of freedom to be altered and therefore the trivial baselines need to be removed. This is to prevent the statistical information from having a favourable bias to report the measurements are more precise than they truly are. Most post processing software packages also come with a network adjustment module that uses least squares as the adjustment method. In Australia, to produce the statistical information recommended by the ICSM (2007), they are required to be able to perform two types of adjustments in order to submit the required metadata regarding the survey. (Both of which are further described in the Nomenclature and Acronyms section):

- Zero (or minimally) Constrained
- Fully Constrained

The zero constrained adjustment is used to compute the Positional Uncertainty and the Class of the survey – the quality of the survey. A fully constrained adjustment determines the Local Uncertainty and the Order – the quality of how survey fits to the connected coordinated marks.

2.4.3 Data Filtering

For purpose of this project, filtering will refer to the process of eliminating noisy data from post processed solutions. This process is usually still an empirical one that is performed in conjunction with proprietary software. At this time, no published research could be found on formulas or algorithms that will determine how to filter the raw data other than by empirical methods. Typically, empirical methods will remove sections of noisy data or turn off satellites individually in each occupation based on the following criteria:

- A section of the satellite data frequently loses lock throughout some or all of the session (USQ 2008).
- The satellite is close to the elevation mask and slips in and out of cycle lock (USQ 2008).

2.5 Testing Options

Despite extensive searching to find literature on testing methodology, very little has been found on accredited calibration/testing of GNSS equipment. The lack of such accredited facilities in Australia can be rationalised by the country only recently recognising GNSS as a legal traceability form of measurement under the National Measurement Regulations 1999 (Cwlth) through amendments. Legal traceability can be achieved by combining carrier phase measurements and the Australian Fiducial Network and its legally accepted positions. Since this survey has no requirement for legal traceability, it will not be pursued. Idealistically, antennas and receivers would have the calibration ranges maintained by NRW similar to that of EDM instruments, but this is currently not the case.

2.5.1 Calibration Range

In Western Australia, a joint venture between the Curtin University of Technology, Western Australian Department of Land Administration and Main

Roads Western Australia have attempted to create such a facility (Featherstone et al 2001). Due to geographic location of the facility relative to Toowoomba, using this range is cost prohibitive.

Tanoi has also investigated the establishment for such a facility at USQ in 2005. While the results seem positive for the testing, the facility lacks accreditation. All of the stations used in the facility reside in the within the extent of the USQ Toowoomba campus. Fast static has a recommended maximum range of 10 km (ICSM 2007) and since all of the distances between the testing stations falls considerably short of this, this facility will not be used.

2.5.2 Typical Static Survey

An alternate method of testing could be to observe PMs with "known" high order coordinated marks that are registered in the NRW SCDB. However, with the dwindling number of surveyors in Queensland (Commonwealth of Australia 2008a), NRW has also been experiencing depleted human resources and therefore the maintenance level of SCDB is questionable. With this method of testing, time constraints may prohibit further investigation of in case of disagreement of survey marks coordinates (whether error is in the SCDB or by movement/disturbance. The design and observation of a network with a higher than normal redundancy, should make the quality of the survey exceed the quality of the mark coordinates. With a very high quality survey, the marks coordinates could be used as a gross check.

2.6 Testing Ambiguities

The control of the testing process is very important to produce results that minimise uncontrollable variables. As previously mentioned, the GPS and GLONASS constellations are completely independent of each other. With the continuous rotation of the earth and orbits of 44 satellites (US Coast Guard 2008 and Russian

Space Agency 2008), the satellite availability and geometry is constantly changing. With so many variables, the likelihood of the exact configuration of satellites being repeated is remote. As discovered by Mylne in 2007, the testing ambiguities are not resolved by taking observations over equal observation periods because of the aforementioned satellite variables. Many of the same analogies can be applied to the use of different antenna/receiver combinations and different positions of the antennas. In order to remove all of these ambiguities, the GNSS versus GPS testing needs to occur simultaneously, at the same place and with the same antenna/receiver combination.

With the flexibility of post-processed static surveying, all of these testing issues can be resolved. As mentioned in section 2.4, GNSS post-processing software has the ability to freely toggle the use of specific satellites for each occupation in a solution. By producing a GNSS solution, then disabling the GLONASS satellites from the solution, a GPS-only solution can be formed. This removes the need for doubling up of equipment and trying to synchronise the start and finish times for two receivers at the same location. The observations will not only be able to be performed by the same make and model of antenna/receiver. It will in be the exact the same unit used for all observations in the occupations. Allowing the testing to be completed at the same time, place and with identical antennas and receivers.

2.7 Conclusions

Through extensive research and development from the instrument manufacturers, all compatibility and interoperability issues can be resolved without direct input of the user segment. Any future changes and possible issues with datums and signal access schemes could theoretically be resolved with firmware upgrades and minor (if at all) hardware upgrades).

The current edition of SP1 version 1.7 was released in September 2007 but has not changed dramatically from version 1.6 that was released in November in 2004 and for this reason can still be considered somewhat dated, with the recent advances in GNSS positioning technology. This can be observed by the document still referring only to the GPS constellation. However, the document does provide valid frameworks in which to perform GNSS surveys based on the GPS techniques outlined. Ultimately, the use of the same methodology of GPS surveys to perform GNSS surveys will determine if increased productivity and accuracy is achievable with the newer equipment. By providing a framework for manufacturers recommendations to predicate ICSM requirements, the document effectively becomes dynamic with the technological releases.

All of the standards and practices that are set out by the ICSM for GPS surveying have remained relatively unchanged since their inclusion in the document. These standards are based on GPS as the sole constellation being used, and running at a maximum of 24 satellites (FOC). However, with GPS running at 32 satellites and 12 extra satellites available for observation from the GLONASS constellation giving a total of 44 satellites, there is nearly the equivalent of two FOC constellations easily observable by anyone in the user segment with the right equipment.

Although currently an empirical process, combinations of receivers and processing softwares could employ predetermined and/or user defined formulas or algorithms to provide less user input for the their post processing systems based of the known performances of various receiver models. This could effectively reduce the overall time for survey missions and the bottom end costs of conducting missions.

CHAPTER 3 – TESTING METHODOLOGY

3.1 Introduction

The literature reviewed in Chapter 2 has indentified the fast static survey style as the method for testing in this research. Also analysed was the possible problems with GNSS compatibility, past testing methods and the removal of possible testing ambiguities to ensure the validity of this research.

This chapter will provide a detailed outline of the methods used to test hypothesises outlined in Chapter 1 based on the methods identified in Chapter 2. This will ensure that by using similar equipment and software or accessing the raw data that has been collected by this survey that the replication of the results produced by this research is possible.

For testing in Queensland, the standard practices used should not be different from those recommended by the ICSM and any major alterations would void the validity of the testing and its application to real world scenarios in Australia. To try to maintain the connection of this research to reality, the method used will essentially be identical to a typical static survey performed by any private practice and not anything requiring special testing facilities.

3.2 Testing Location Criteria

Since the survey conducted will be a static network (as opposed a kinematic radial), there will be six stations plus one Continuously Operating Reference Station (CORS). A CORS has been setup for several years now on top of Z-Block at the University of Southern Queensland – Toowoomba Campus. Only last year was this CORS updated to a GNSS CORS (Trimble Net R5). The current CORS setup is to log GNSS raw data at one second epochs whilst broadcasting RTK corrections for the use of students and other users in the broadcast area.

The six other stations have been determined by following criteria:

- At least four are to have First Order Horizontal Coordinates
- At least five are to have at least Fourth Order Vertical Levels
- The remaining two may or may not have any Horizontal or Vertical Information
- All are to be existing Permanent Marks in the NRW Survey Control Database (SCDB).
- All sites should be moderate to zero multipath for GNSS observations (where possible).
- Regular spacing (where possible) through the city centre of the Toowoomba and the surrounding suburbs with an area of about 10 square kilometres.
- Easily accessible by a two wheel drive vehicles.
- Easy to locate – a prominent feature.

3.3 Reconnaissance

One of the most important elements of geodetic surveying is planning. Formulating a mission plan will ensure that others have a much better understanding of what you are trying to achieve and how this objective is intended to be reached. In most cases (including this one) the surveyors whom are participating in the static survey will have had nothing to do with the project until the date of the survey.

Based on the criteria set out in section 3.2, a Toowoomba SCDB search was done in FileMaker Pro 9 Advanced database application. This was to filter PMs that had 1st order horizontal coordinates and a minimum of 4th order elevation, which reduced the database down to 31 suitable marks. This query revealed that Toowoomba has zero first or second order vertical marks. The coordinates of these marks were then entered into Google Earth so they could be inspected by aerial photography/satellite imagery for suitability and overall geometry.

A list of 12 suitable marks was then compiled and their coordinates were uploaded into a Trimble Geo XT (mapping grade GPS seen in figure 3.1) for field inspection. The field inspection eliminated those difficult to find (including one trig station on top of a water tower at Picnic Point) and provided an opportunity to analyse the multipath potential of each location. Subsequently, the list was reduced to five PMs and an extra mark was selected nearby the centriod with “No Order” and “No Class” to increase the total number of PMs to six. A summary of the selected marks is in the table below and their mapped positions can be seen in Appendix Band full Form 6 Permanent Mark details in are Appendix C.

Figure 3.1 - Trimble Geo XT – Mapping Grade GPS

(Source: http://www.trimble.com/geoxt.shtml)

Permanent Marks (Pos)	Horizontal Order	Vertical Order
PM 12514 (Cen)	No Order	No Order
PM 40424 (S)	1st Order	4th Order
PM 40435 (SW)	1st Order	4th Order
PM 40827 (NE)	1st Order	4th Order
PM 40828 (N)	1st Order	4th Order
PM 59005 (NW)	1st Order	4th Order

Table 3.1 - Selected Permanent Marks Order Details.

3.4 Equipment for Field Survey

The following equipment is available for utilisation in this research and will be used in the field survey:

- 1 x Trimble Net R5 Reference Station
- 1 x Trimble Zephyr Geodetic 2
- 3 x Trimble R8 GNSS Receivers
- 3 x TSC2 Data Collectors (running Trimble Survey Controller v12.22)
- 1 x Computer (Acting as data collector for the Net R5)
- 3 x Tripods
- 3 x Tribrachs
- 3 x Tribrach Adapters and Short Poles
- 3 x Offset Tapes
- 3 x Motor Vehicles
- 3 x Mobile Phones
- Batteries

3.4.1 Trimble GNSS Antennas and Receivers

Trimble antennas and receivers have been chosen for this study since the university currently only owns this brand of GNSS equipment (An SPS880 and a Net R5). To reduce complications and to follow the recommendation to have all receivers and antennas of the same make and model (USQ 2006), all three roving receivers will be Trimble R8 GNSSs. The SPS880 that was originally intended to be utilised but was not used for the survey since it had difficulty acquiring GLONASS satellites on the scheduled date of the mission. The GNSS equipment used for the survey is in figure 3.2.

Figure 3.2 - Trimble R8 GNSS and Net R5 with Zephyr Geodetic 2

(Source: Trimble Navigation Limited 2007a and 2007b)

All of the abovementioned receivers have the following common task specific features (Trimble Navigation Limited 2006 and 2007a and b):

- R-Track technology
- Claimed Fast Static accuracies:
    - Horizontal±5mm + 0.5ppm RMS
    - Vertical ±5mm + 1ppm RMS
- 72 channel tracking
- Custom GNSS chips
- High precision multiple correlator for GNSS pseudo range measurements

- Unfiltered, unsmoothed pseudo range measurements data for low noise, low multipath error, low time domain correlation and high dynamic response.
- Low elevation tracking technology

3.5 Mission Plan

With the testing sites and the equipment all identified, the next step in the process is to formulate the mission plan. While forming a mission plan is not essential all static surveying, like surveys may only use a “base and rover” setup where only one baseline is measured per session. This survey, however, will use three roving receivers to measure two independent baselines per session and it will be necessary to plan the mission. To avoid two field parties arriving at the same mark for the same session, and to optimise the field time (normally the most expensive component) required for the entire survey and for many other logistical and geometrical reasons, the mission is planned.

Based on the testing sites, no baselines in the final solution will be longer than 10 kilometres as per the recommendation of the ICSM (2007) for fast static surveys. The quality of the survey to is aimed to produce Class A results since this is the highest level achievable by the Fast Static survey method. The ICSM recommends that surveys of high order be used mainly for scientific purposes. By choosing the highest class of survey possible for the fast static style, the results should be more revealing and any analogies between the GNSS and the GPS datasets should be more obvious and less prone to be caused by low quality of survey.

Initially, the CORS data will be ignored, but will be added in later once most of the processing of the main mission data is carried out. This is somewhat similar to the way RINEX data files can be accessed/purchased from Geoscience Australia’s (2008b) AusPos and the Department of Natural Resources and Waters (2008) SunPOZ to supplement GNSS static surveys. This additional data will be used to provide one extra independent baseline to each station in different sessions (adding more than one baseline per session from the CORS data would produce trivial baselines). Although this step is not necessary, the data logged will be used more like a back up, in case of problems on station occupations and sessions. This data may also be used to replace a PM for the entire survey if it is found to be problematic.

With six stations, the requirement of three independent occupations for 20% of the stations and 100% of the stations to be occupied twice (ICSM 2007), it is mathematically possible to achieve this requisite in five sessions with three receivers. However, since things do not always run smoothly, an additional session will be added to ensure that extra sessions are not necessary on days after the scheduled mission date. Six sessions with three roving receivers will allow all of the stations to be independently occupied three times. If all things go to plan, and following the addition of CORS data, there should be a much higher than required amount of baselines and occupations to compute a tight 3-dimensional least squares network and additional baselines from the CORS data.

Now that all the information regarding the number of receivers and number of session was compiled, a baseline plan was then drafted (Appendix D). The plan aimed to minimise driving time while attempting to avoid having the same mark occupied consecutively in adjacent sessions.

The surveyors assisting with the survey were driven to all of the PMs before the survey. The session plan/guide in Table 3.2 – using on the baseline plan – was generated to aid the surveyors on the day. The surveyors were all given a copy of this table, a map of Toowoomba (with the baseline plan marked on it) and a brief procedures guide on how the survey should be conducted before the date of the survey.

Session Guides

Operator/Receiver	Session					
	1	**2**	**3**	**4**	**5**	**6**
Liam/R8 GNSS Base	40828	59005	40828	40827	40828	40827
Will/R8 GNSS Rover	40827	12514	40424	12514	40424	40424
Jeff/R8 GNSS MinSurv	59005	40435	12514	59005	40435	40435

Station	Session					
	1	**2**	**3**	**4**	**5**	**6**
40828	Liam		Liam		Liam	
40827	Will			Liam		Liam
59005	Jeff	Liam		Jeff		
12514		Will	Jeff	Will		
40435		Jeff			Jeff	Jeff
40424			Will		Will	Will

Total Occupations

Session	Permanent Mark Number					
	40828	**40827**	**59005**	**12514**	**40435**	**40424**
1	1	1	1			
2			1	1	1	
3	1			1		1
4		1	1	1		
5	1				1	1
6		1			1	1
Total	**3**	**3**	**3**	**3**	**3**	**3**

Table 3.2 - Session Plan

3.6 Field Survey

The date of the survey was the Sunday the 7th of September 2008. The assisting surveyors were given the allocated GNSS equipment along with the necessary ancillary equipment. They were then given a briefing on the operation of the equipment and procedures to perform the fast static survey.

A final check was then performed on the equipment to ensure it all was operating correctly for the survey. The two R8 GNSS receivers were both found to be operating correctly, however the SPS880 was found to be unable to acquire GLONASS signals in all survey styles (Fast Static and RTK). It was also determined that university's TSC2 was not running a recent enough version of Trimble Survey Controller (others were running v12.22) to be able to log GLONASS observations when in static mode. These issues with the SPS880 were critical, and therefore it was excluded from the survey and subsequently this research. Fortunately, I was able to contact a colleague in Toowoomba who had access to a R8 GNSS receiver and TSC2 also running Trimble Survey Controller 12.22, making all three roving receiver configurations identical. After successfully configuring and checking the new equipment, the survey was able to commence.

Each session in the survey followed the procedure as outlined below:

1. Drive to the PM allocated for the session (An example of two of the PMs sites in Figure 3.3 and 3.4).
2. Setup the R8 GNSS over the survey mark.
3. Measure the height of the antenna to the centre of bumper three times and enter the mean/median height into the controller.
4. The two assisting surveyors contacted me and once all field parties were ready, a "commence session" message was returned and the data logging was initiated. This was to ensure a complete overlap of data.
5. The session was ended after 20 minutes of data was recorded.
6. Move to the next PM in the next session or back to the university for the final session.

Figure 3.3 - R8 GNSS at PM 40435 in Session 2 – Worst Site for Sky Visibility.

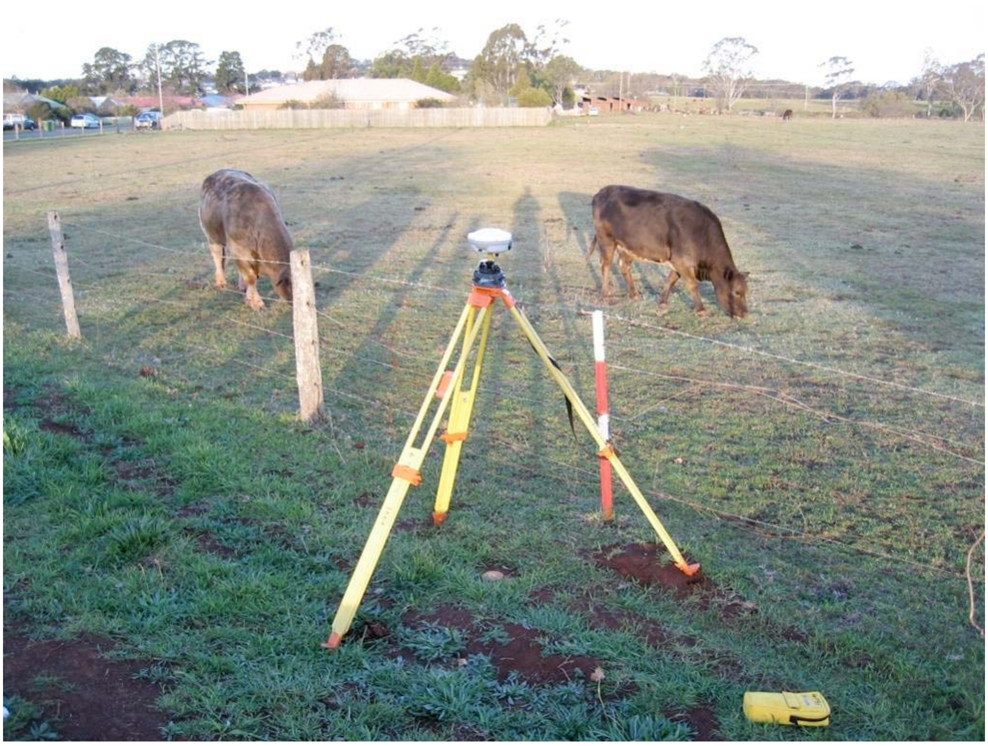

Figure 3.4 - R8 GNSS at PM 40424 in Session 6 – Best Site for Sky Visibility.

Despite the initial delays of starting the survey, the entire static mission was completed successfully in a single day. Immediately after the field survey concluded, the data from all the survey controllers/data recovered was transferred to a PC and several backups were made of that data. No post processing was carried out on the day of the survey.

3.7 Post Processing

This section is particularly important since many of the steps have been added to the regular procedures to allow for the GNSS and GPS comparisons. For this project, Trimble Business Centre Advanced (TBC) has seen selected as the software for post processing, since it can process GNSS baselines, perform least squares network adjustments and has advanced reporting functionality. In addition, since all of the GNSS hardware was of Trimble make, Trimble software should present the least compatibility issues.

3.7.1 Zero Constrained Adjustments

All of the data from the field survey was compiled and imported into TBC. Once this process was complete, the occupation spreadsheet (seen in Figure 3.5) was then cross-referenced with the field notes (Appendix E) to verify the antenna heights and the antenna reference point (i.e. the point on the antenna to which the height was measured to from the top of the survey mark – in this case the centre of bumper). At this stage, it was also noted that no occupation was shorter than 20 minutes – as per the mission plan.

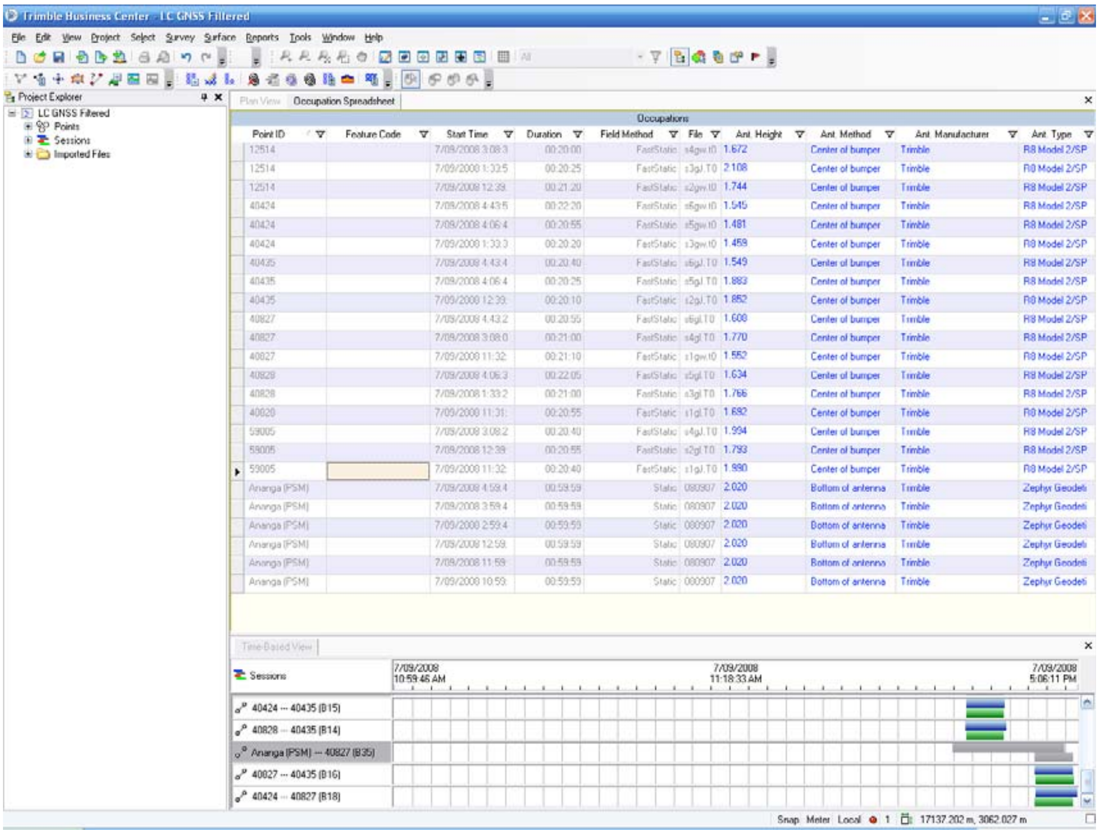

Figure 3.5 - Occupation Spreadsheet

The USQ CORS data was then accessed from the web interface at http://www.usq.edu.au/engineer/surveying/gpsbase/local/liam.htm downloaded and imported into the TBC and all trivial baselines were removed (from the roving and CORS data). The CORS data was temporally disabled so that rover data could be analysed first.

All of the remaining baselines were selected, the baseline processing was executed and the baseline precisions generated. Without any baselines being "flagged" for being classed as low precision or "failed" for extremely poor precision, the network adjustment module was then run. Since none of the PMs coordinates were used to constrain the network, this was a zero constrained adjustment. The resulting network of observations appears in Figure 3.6. The "Baseline Processing Report" (see appendix F) and the "Network Adjustment Report" (see Appendix G) were then generated and this first adjustment would now be known as "GNSS Raw".

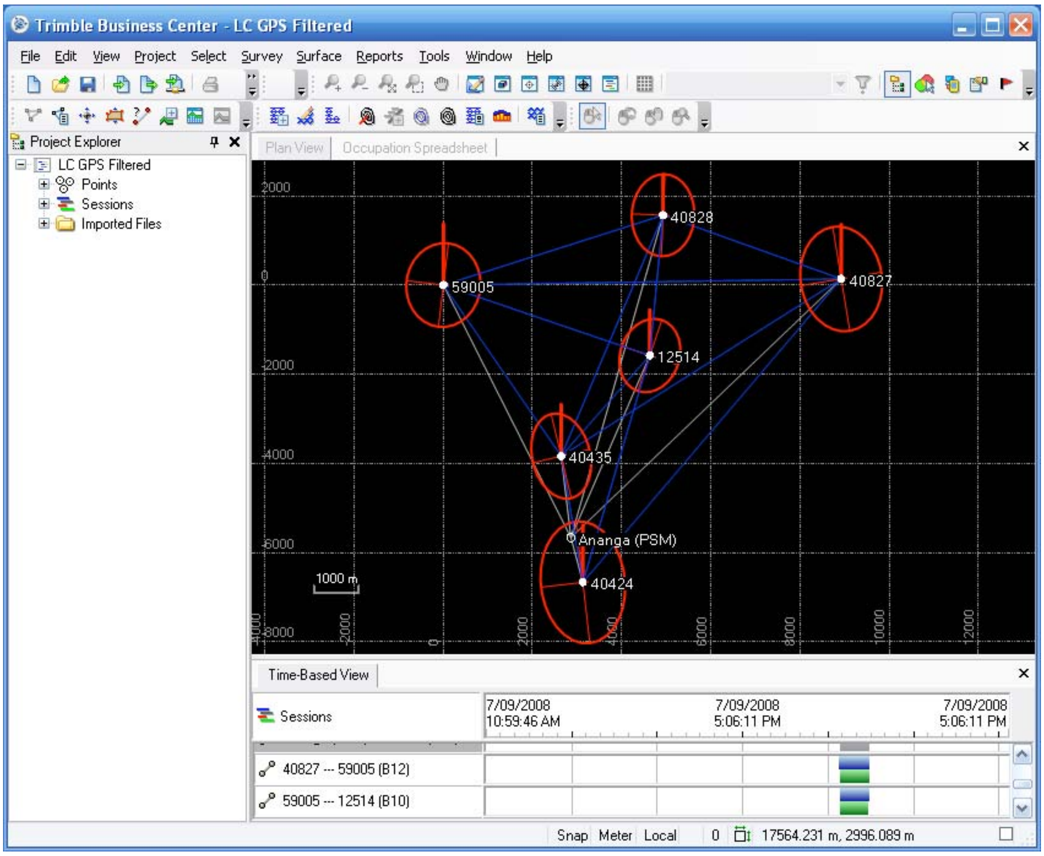

Figure 3.6 - Baselines Processed and Network Adjusted

The session editor in TBC is designed to allow the user to view the quality of the data. The tick marks (refer to figure 3.7 particularly the R14 satellite) indicate the receiver starting to observe a new cycle. Many tick marks on a single line indicate that the signal from that satellite may no be travelling directly to the antenna (multipath) or may be moving above and below the elevation mask throughout the session. For this part of the research, the session editor will be used to disable GLONASS (indicated by “R” in figure 3.7) satellites in every session, leaving only the GPS satellites (indicated by “G”). The baselines are then reprocessed, network adjusted and the reports generated. The project was saved and the data will be known as “GPS Raw”.

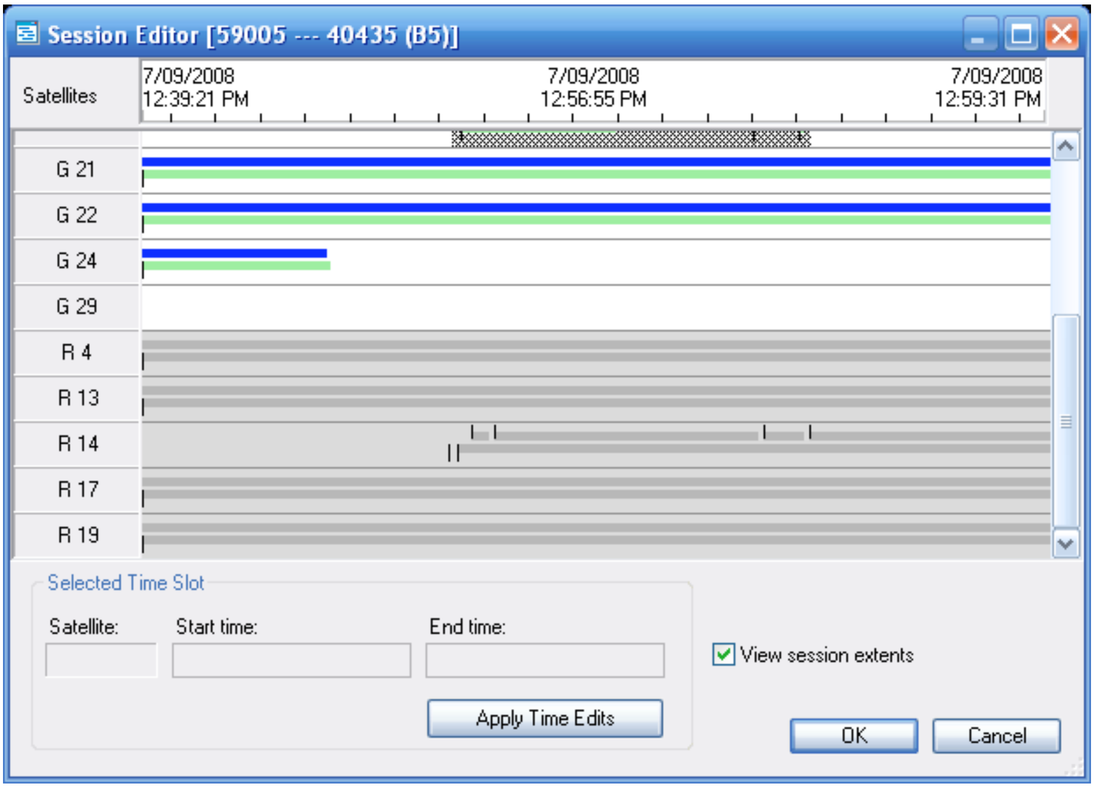

Figure 3.7 - Session Editor: GLONASS Satellites Disabled

The original GNSS raw file reopened again and the session editor was used this time as it was intended – to remove the noisy data. As seen in Figure 3.8, small sections of data are disabled. Each baseline is viewed individually, to visually search for the aforementioned cycle slips. Once this process was complete, the baselines were again reprocessed; network adjusted and was saved as "GNSS Filtered". GPS and GLONASS were filtered separately and the time taken to filter to GLONASS satellites was measured in order to quantify the extra time required for office processing additional satellite data of GNSS surveying.

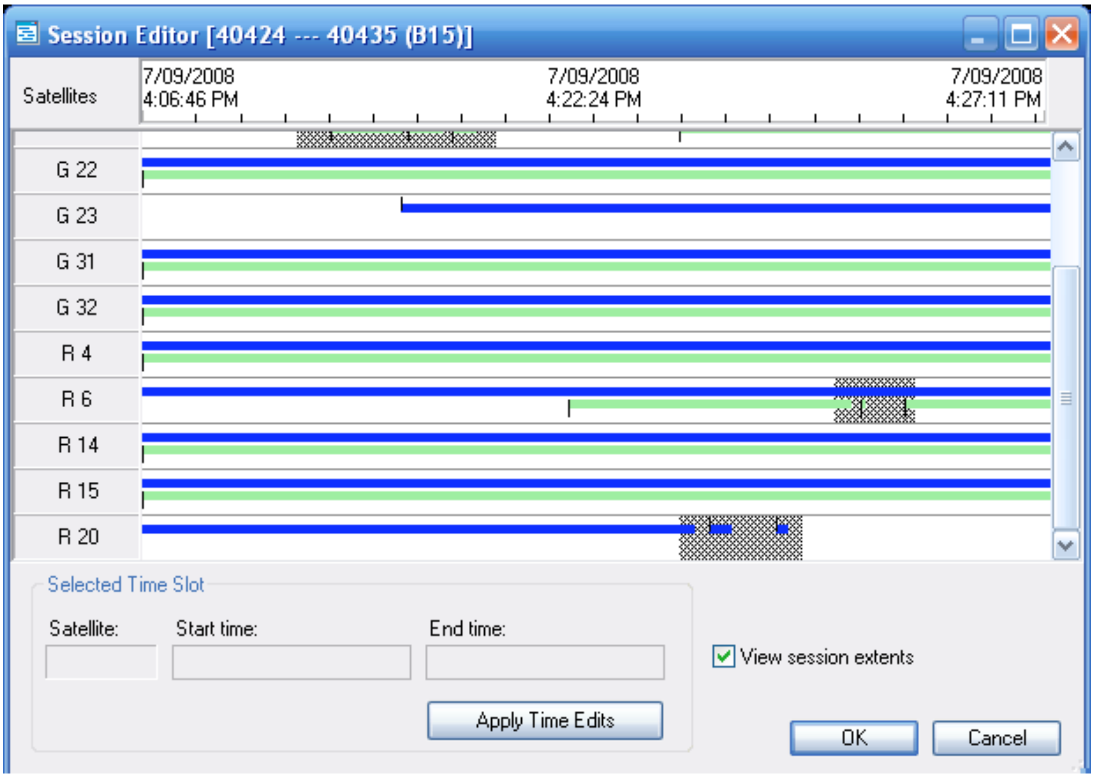

Figure 3.8 - Session Editor: Filtering

The final set of results produced by a zero constrained adjustment was the "GPS Filtered" dataset. Similarly to how the GPS Raw results were produced, using the "GNSS Filtered" dataset and disabling the GLONASS satellites in the session editor the GPS Filtered results were produced after baseline processing and network adjustment.

3.7.2 CORS Data

At this point, the CORS data from USQ was been planned to be included into the adjustment for additional redundancy and extra results. However, once the data was enabled and trivial baselines removed and the independent baselines processed, several errors presented and were unable to be rectified (i.e. failing at step 6 in section 2.4.1). Normally, these data conflicts would have been resolved but due to time constraints and all of the other data functioning correctly, the CORS data was excluded from the network.

Despite using only Trimble GNSS hardware and software for the survey, the data formats from the R8 GNSS receivers and the data from the Net R5 was different. The R8 GNSS output *.T01 files for its GNSS data and the Net R5 produced RINEX files. If time were available to debug this issue, the first effort to resolve this issue would be to attempt to convert all the files to the same format (i.e. all RINEX or *.T01) and reprocess the baselines. Next, may be to ensure all baselines are added and processed from the outset (and not disable initially as in this methodology).

3.7.3 Fully Constrained Adjustment

To verify the quality of both the Permanent Marks SCDB and the data collected by the Survey, MGA94 coordinates and AHD elevations of the known marks along with Ausgeoid98 was used to perform a fully constrained adjustment and compute the Local Uncertainties. The details of these marks can be seen in Appendix C. Since QA cannot be performed on the survey through terrestrial observations or EDM measurements due to a lack of line of sight between the marks, using known marks for the majority of the stations will allow QA to be completed through the comparison between the computed and the known coordinates via a fully constrained adjustment.

Initially, all of the PMs with known coordinates (all except PM 12514) were used to constrain the observations; this resulted in an unacceptable scalar being applied to the network adjustment error ellipses. The network adjustment module flagged PM 59005 for exceeding both horizontal and vertical precision tolerances. Consequently, it was removed from the fully constrained (horizontal and vertical) adjustment and the network was readjusted. The network without PM 59005 produced much better results than the original fully constrained adjustment but still could be statistically improved by removing one more horizontal constraint.

By individually toggling each remaining horizontal constraint and noting the network adjustment results, it was determined that statistically the best fit was produced by removing the horizontal constraint on PM 40435. Fortunately, this did not cause more geometric distortion than the removal of PM 59005 from the constraints. Finally, constraining both the horizontal and vertical by PM 59005 was tested with the new adjustment, which produced similar errors to when it was included the first time. PM 59005 was then removed from the adjustment. Figure 3.9 shows the final fully constrained network adjustment and its constraint configuration.

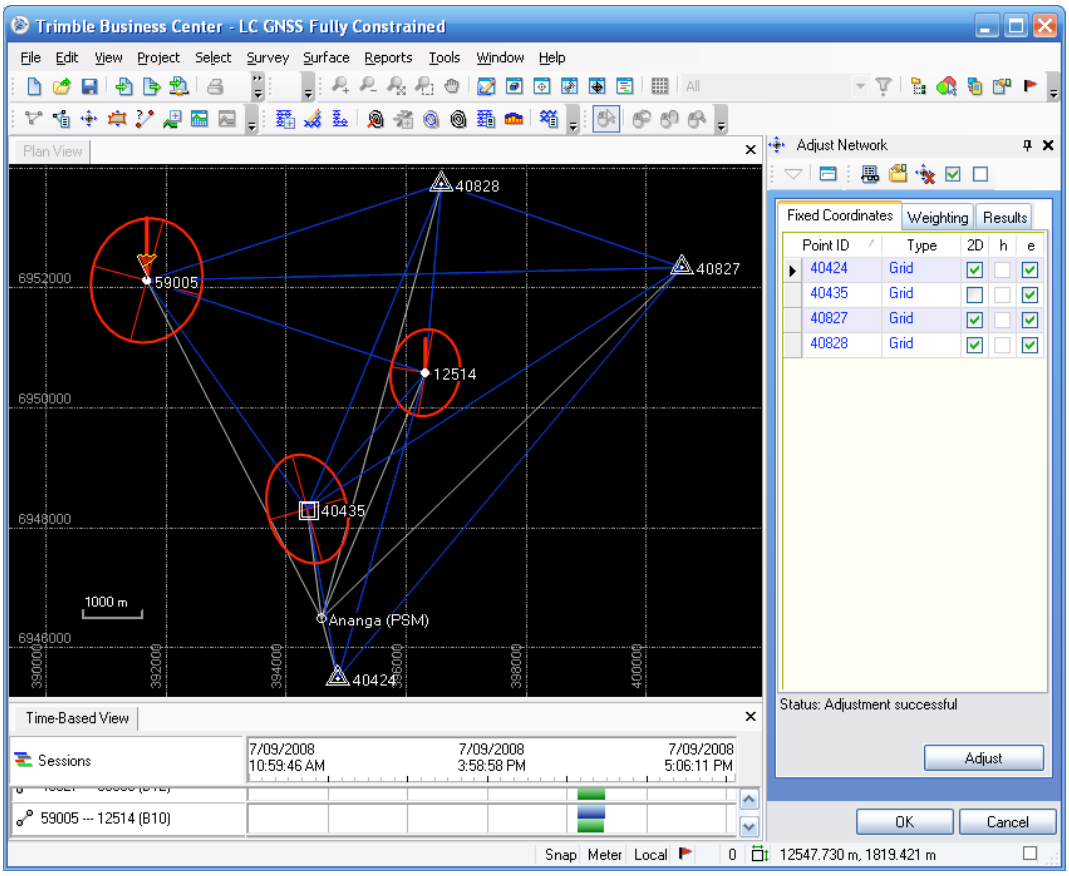

Figure 3.9 - GNSS Filtered: Fully Constrained

3.7.4 Decreasing the Length of Sessions

It was originally intended to make the precision comparisons of the filtered data with the network adjustment results. However, with the results of the GNSS and GPS filtered results being identical, the baseline processing report was the next point of comparisons. The difference between the baseline horizontal and vertical precisions averaged an improvement of about 0.001 metres for GNSS over GPS-only observations. The raw data was not included in this process, since in reality, unfiltered data would never be used for the final positions computed in a post processed geodetic survey.

To test the extent of time that GNSS session lengths can be reduced to achieve the same precisions as GPS-only surveying, 30 seconds of data was disabled from every session in the GNSS Filtered and the baselines were reprocessed. After checking the results, an extra 30 seconds was removed if the precision remained the same. This process was repeated until the results in the baseline processing report were similar to those in the GPS filtered results. Given the relatively small differences in baseline precisions, it was only necessary to repeat this process four times (two minutes) to produce these similar precisions. An example of a session reduced by two minutes can be seen in Figure 3.10. The editing of the selected time slot in the aforementioned figure allows the session lengths to be edited precisely.

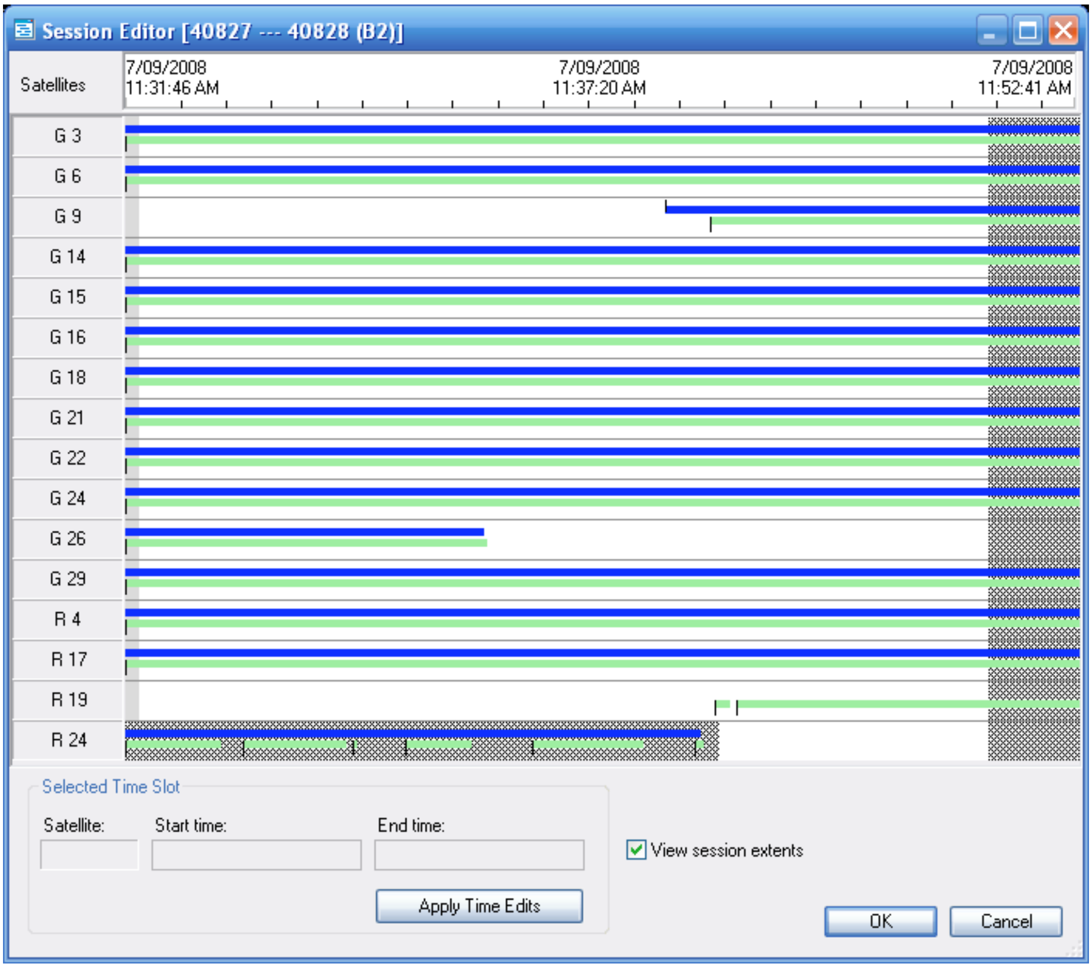

Figure 3.10 - Removing Exactly 2 Minutes of Session Data

3.8 Conclusion

From the planning of the mission through to the post processing, all of the above procedures use the same methods that would be used to conduct static GPS network surveys in practice. Apart from the GNSS (rather than GPS) receivers used and the numerous extra stages of data processing required to produce the extra results necessary for this research, the above testing procedure conforms to the standards and best practices as recommended in SP1 by the ICSM and should be valid for use in Queensland and all of Australia.

The hardware and software used for the above testing are no different to the setups that may be found in private practices (since they were borrowed from private practices) that have recently (in the last two years) purchased GNSS surveying equipment.

The full set of the results and reports generated from this chapter can be found in appendices F and G. The results required for analysis in Chapter 5, will be extracted from the aforementioned appendices and compiled in Chapter 4.

CHAPTER 4 – RESULTS

4.1 Introduction

All the procedures outlined in Chapter 3 have produced the required survey and statistical data through the report generation facilities of Trimble Business Centre. With all of the results complied, the data now needs to be presented graphically so any analogies in the data can be more easily identified.

The chapter will present a summary of the results generated in by Chapter 3 and found in Appendices G and F. This summary of data will be the information required to test the hypotheses outlined in section 1.3.1 and the information that surveyors would use from the survey.

This chapter will extract the information in the Baseline Processing Reports and Network Adjustment Reports from the aforementioned appendices. The data was extracted from the reports and the information, and then imported into Microsoft Excel for statistical analysis. The excel data was then imported into Apple's Numbers to produce the graphs.

4.2 Zero Constrained Adjustments

The data in the graphs of this section is based on the calculated horizontal Positional Uncertainty as specified by the following equations (ICSM 2007):

$$C = \frac{b}{a}$$

$$K = q_0 + q_1 C + q_2 C^2 + q_3 C^3$$

$$Radius = aK$$

Where:

a = semi-major axis of the standard (1σ) error ellipse

b = semi-minor axis of the standard (1σ) error ellipse

$q_0 = 1.960790$

$q_1 = 0.004071$

$q_2 = 0.114276$

$q_3 = 0.371625$

And for vertical:

1.96 x (elevation error at 1σ)

Trimble Business Centre defaults to reporting the errors required at the 95% confidence level. Therefore, all of the data in the reports will need to be scaled back to the one-sigma level (i.e. scaled by the inverse of 1.96).

The class of the survey is determined by the technique used, the amount of occupations of each station and an empirically derived formula. With fast static as the method used and all the required amount of independent occupations exceeded, the highest achievable class of the survey is A (ICSM 2007). However, the Class that is achieved by indication of the statistical data will be assigned.

$$r = c(d + 0.2)$$

Where “d” is the distance to any station.

And “c” is an empirically derived number that assigns the class. The “c” values for some of the classes of survey follow:

Horizontal:	Vertical:
3A = 2	3A = 2
2A = 8	2A = 6
A = 18	A = 15

4.2.1 GNSS Raw v GPS Raw

The raw data GNSS raw and GPS raw that were produced in section 3.7.1 has been used to compute the positional uncertainties for every PM and the average has been computed are below in figures 4.1 and 4.2.

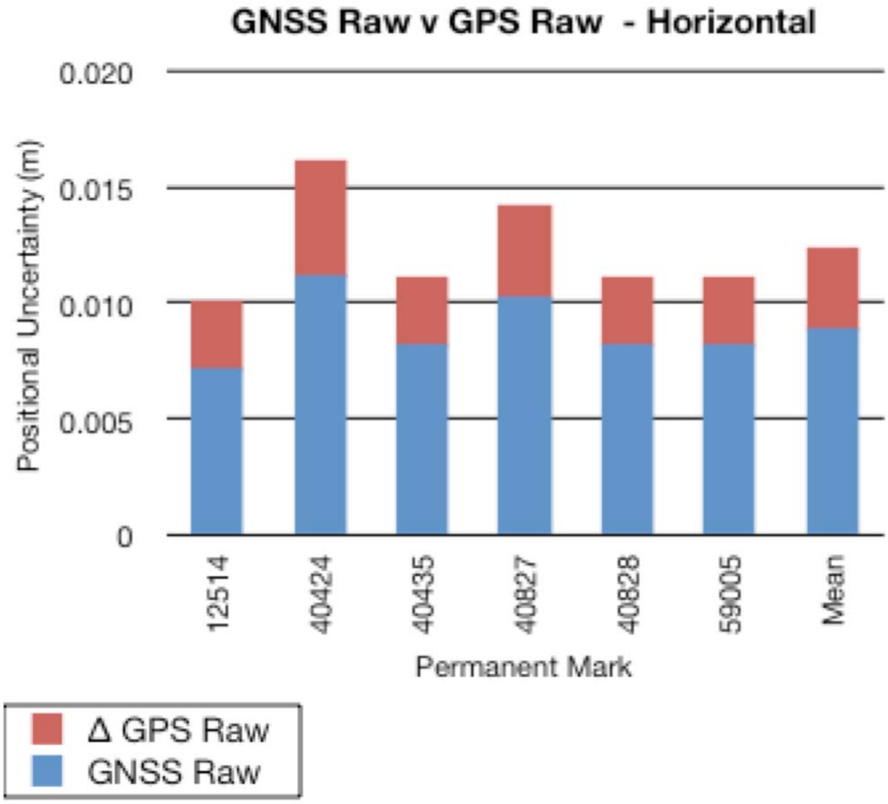

Figure 4.1 - Horizontal Positional Uncertainty - GNSS Raw v GPS Raw

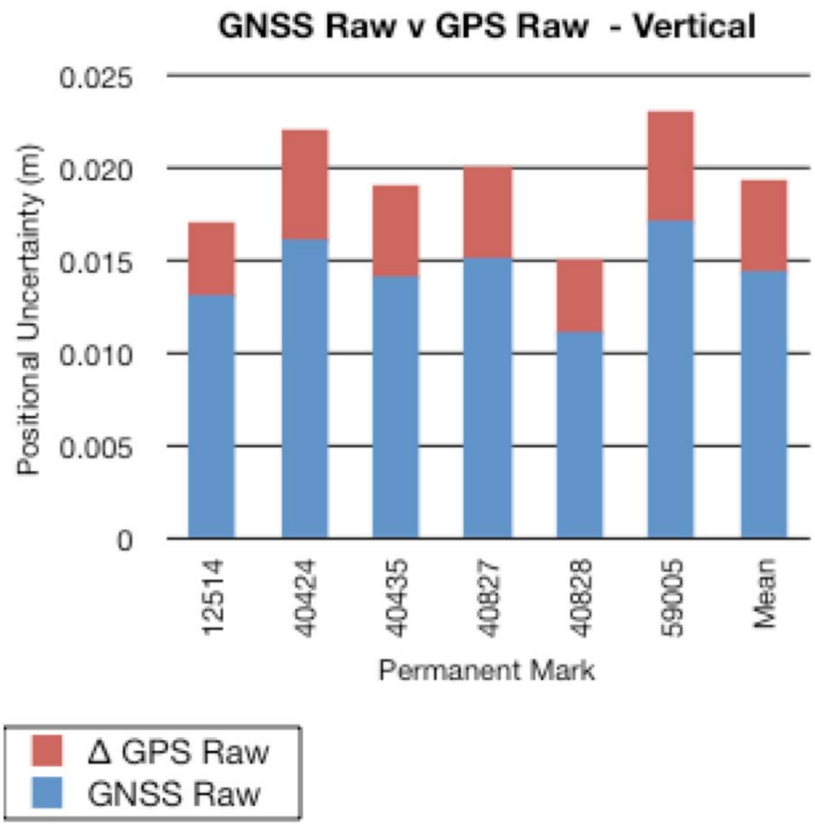

Figure 4.2 - Vertical Positional Uncertainty - GNSS Raw v GPS Raw

	Raw GNSS Class		Raw GPS Class	
PM	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**
12514	2A	2A	2A	2A
40424	2A	2A	2A	A
40435	2A	2A	2A	A
40827	2A	2A	2A	A
40828	2A	2A	2A	2A
59005	2A	2A	2A	A

Table 4.1 - Classes allocated to Raw Data

4.2.2 GNSS Raw v GNSS and GPS Filtered

The GNSS and the GPS filtered network adjustment results produced identical semi-major and semi-minor axes of their error ellipses. It was originally intended to only compare GNSS raw against GPS filtered positional uncertainty but since the two filtered results were the same, both will be compared. These results are in figures 4.3 and 4.4. The classes achieved for the filtered results are in section 4.5.

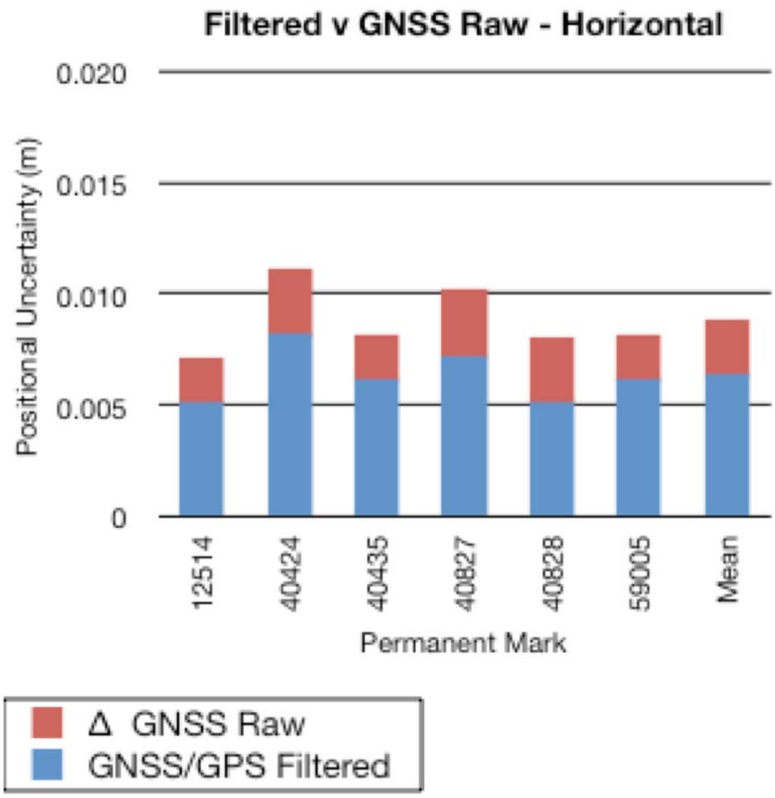

Figure 4.3 - Horizontal Positional Uncertainty - Filtered GNSS/GPS v GNSS Raw

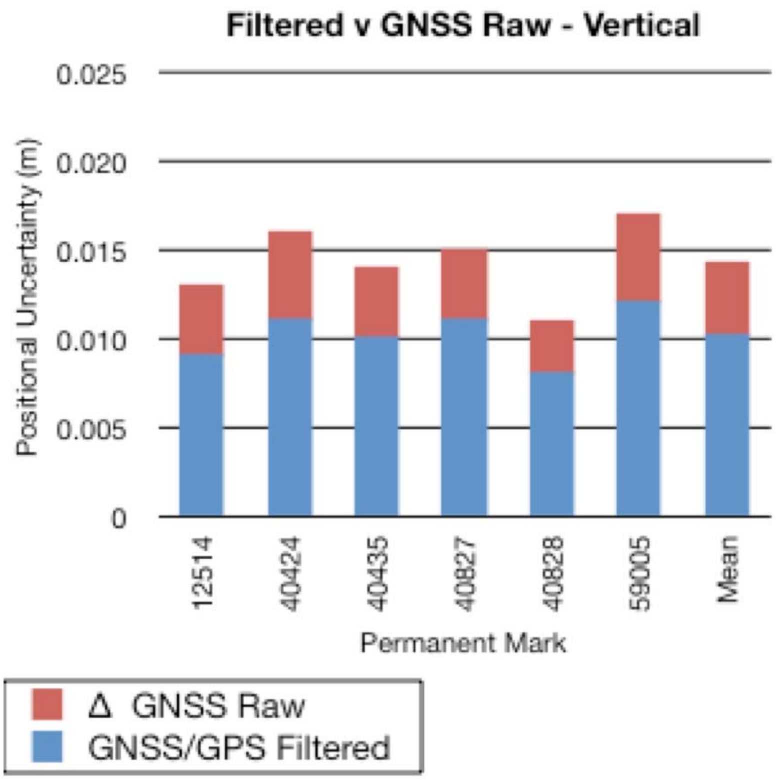

Figure 4.4 - Vertical Positional Uncertainty - Filtered GNSS/GPS v GNSS Raw

4.2.3 Filtered

Given that the positional uncertainties for both GNSS and GPS Filtered results (horizontal and vertical) were identical, the network adjustment results were unable to differentiate between the two datasets. However, the baseline precisions did show improvement with the GNSS over GPS. The 95% confidence intervals produced by the baseline processing reports were used to produce the graphs in figures 4.5 and 4.6. The baselines not listed below are the trivial baselines and therefore excluded from the processing.

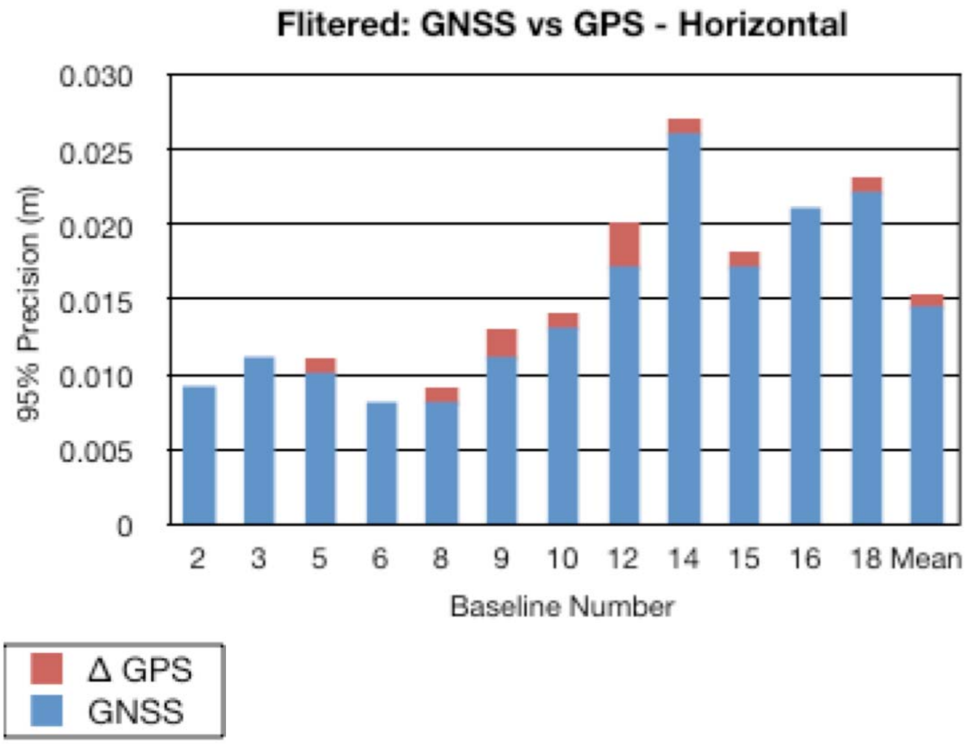

Figure 4.5 - Horizontal Baseline Precision

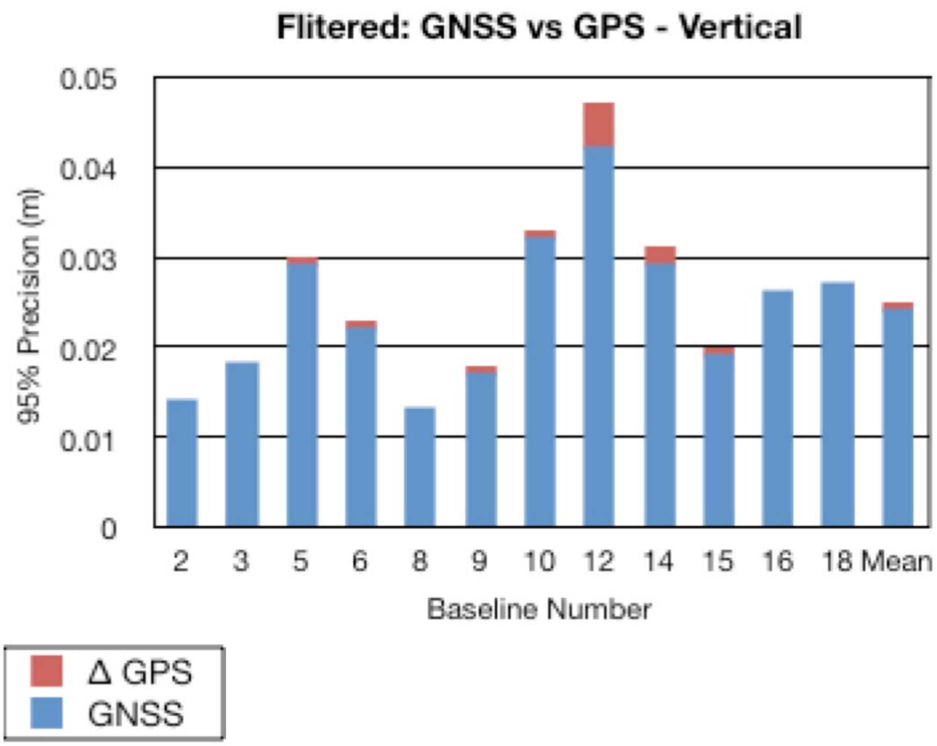

Figure 4.6 - Vertical Baseline Precision

4.3 Productivity

For this section it was intended to remove one minute of data in every session, however, with the difference between the GNSS and GPS filtered data being smaller than expected, this required shortening the session lengths by 30 second at a time in order to gain more accurate results. The results remained unchanged until the two-minute mark was reached. To verify that the precisions reached were close to those reached with the GPS filtered data the differences between the baseline precisions were averaged. The average was 0.000m (for both horizontal and vertical) indicating that the precisions, while slightly different, were similar when all of the baselines were taken into account.

By decreasing the lengths of the session by 30 seconds at a time, 30 seconds becomes the margin of error of the results. Inclusive of the error margin, with an average of 21 minutes per session and average maximum of two minutes for session length to be reduced, figure 4.7 was produced.

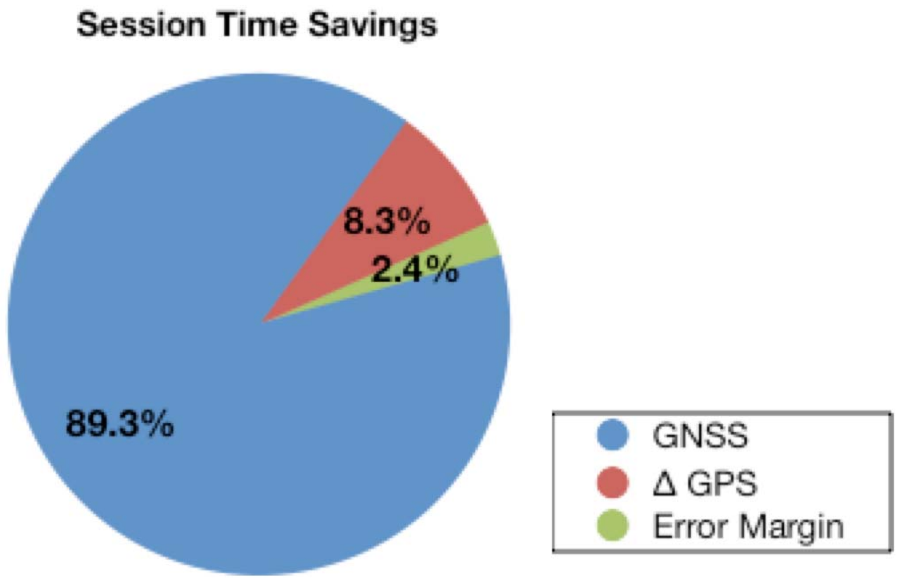

Figure 4.7 - Session Time Savings

The extra processing time required in the office averaged only 10 seconds per baseline. As originally hypothesised, this extra post processing time is negligible and easily out weighed by the time saved in the fieldwork.

4.4 Fully Constrained Adjustment

The fully constrained adjustment was used as a form of quality assurance for this research, through connections to known high order PMs. The computation of local uncertainty and order are quantifies the fit of the observations to the local control network.

4.4.1 Local Uncertainty

Local uncertainty is calculated by the same formulae as positional uncertainty however; the error ellipse components are derived from a fully constrained adjustment (rather than a zero constrained adjustment). The results of the fully constrained adjustment preformed in section 3.7.3 can be seen in table 4.1. The constraints used in the adjustment are indicated by "Fixed" in the table.

	Local Uncertainty	
PM	**Horizontal**	**Vertical**
12514	0.009	0.015
40424	Fixed	Fixed
40435	0.011	Fixed
40827	Fixed	Fixed
40828	Fixed	Fixed
59005	0.013	0.027

Table 4.2 - Local Uncertainty (GNSS Filtered)

4.4.2 Order of Survey

Order is a function of class, the quality of the fit to the local marks and the quality of the marks coordinates. As with local uncertainty, is the result of a fully constrained adjustment with one caveat, no mark can have an order above the order of the mark in which it was derived.

	Order	
PM	**Horizontal**	**Vertical**
12514	1^{st}	4^{th}
40424	1^{st}	4^{th}
40435	1^{st}	4^{th}
40827	1^{st}	4^{th}
40828	1^{st}	4^{th}
59005	1^{st}	4^{th}

Table 4.3 - Order Assigned to PMs (GNSS Filtered)

4.5 NRW Form 6 Information

The information required for NRW form sixes if survey was to be lodged is complied on the following page in tables 4.4 and 4.5.

Horizontal

PM	Datum	Latitude	Longitude	Easting	Northing
12514	GDA94	S27°33'52.55197"	E151°56'58.95191"	396317.287	6950588.058
40424	GDA94	S27°36'37.83052"	E151°56'04.22078"	394860.174	6945489.266
40435	GDA94	S27°35'05.85884"	E151°55'46.48617"	394349.533	6948315.233
40827	GDA94	S27°32'56.66936"	E151°59'35.40740"	400593.839	6952343.303
40828	GDA94	S27°32'10.37535"	E151°57'09.72110"	396586.030	6953734.721
59005	GDA94	S27°33'01.25973"	E151°54'10.16304"	391674.508	6952126.284
				MGA94:	Zone 56

Vertical

PM	Datum	Height
12514	AHD D	593.542
40424	AHD	683.293
40435	AHD	682.050
40827	AHD	614.622
40828	AHD	608.797
59005	AHD D	615.137

Table 4.4 - Survey Coordinate Information

	Local Uncertainty		Positional Uncertainty	
PM	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**
12514	0.009	0.015	0.005	0.009
40424	Fixed	Fixed	0.008	0.011
40435	0.011	Fixed	0.006	0.010
40827	Fixed	Fixed	0.007	0.011
40828	Fixed	Fixed	0.005	0.008
59005	0.013	0.027	0.006	0.012

	Order		Class	
PM	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**
12514	1st	4th	3A	2A
40424	1st	4th	2A	2A
40435	1st	4th	3A	2A
40827	1st	4th	2A	2A
40828	1st	4th	3A	2A
59005	1st	4th	3A	2A

Table 4.5 - Survey Metadata

4.6 Conclusion

The results are all now collected form the survey and the results are generally as expected based on prior experience with static surveying. The zero constrained adjustment (4.2) and the productivity (4.3) sections are the most important for the comparisons of data in this research. Sections 4.4 and 4.5 are mainly concerned with the fully constrained results and are more relevant to the quality assurance of the information and completeness of the survey. Section 4.5 in particular, is mainly concerned with the information that surveyors would use from the survey in their practices. The figures and tables presented in this chapter will be analysed in the following chapter.

CHAPTER 5 – DATA ANALYSIS

5.1 Introduction

With all the data extracted from the baseline processing reports and the network adjustment reports required to address the aims of the research complied in Chapter 4,this chapter will analyse the data.

Chapter 5 will critically analyse the results generated in Chapter 4. This analysis will investigate the improvements in precision and productivity that GNSS has made over GPS. The magnitude of these gains will be analysed in order to determine their relationship to real word benefits to the end users – surveyors.

This chapter will use the graphs and tables presented in Chapter 4 to analyse the data as to whether they it proves or disproves the hypotheses set out in Chapter 1. For an additional visual aid, all of the positional uncertainty graphs have been complied into two graphs for this chapter in figures 5.1 and 5.2.

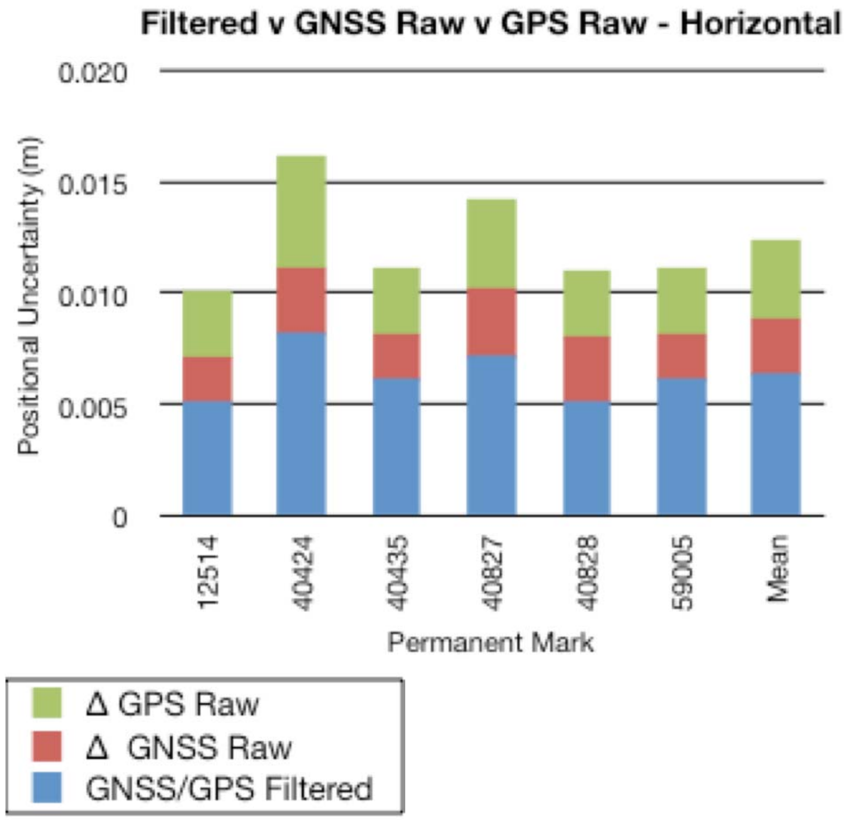

Figure 5.1 - Combined Horizontal Positional Uncertainties

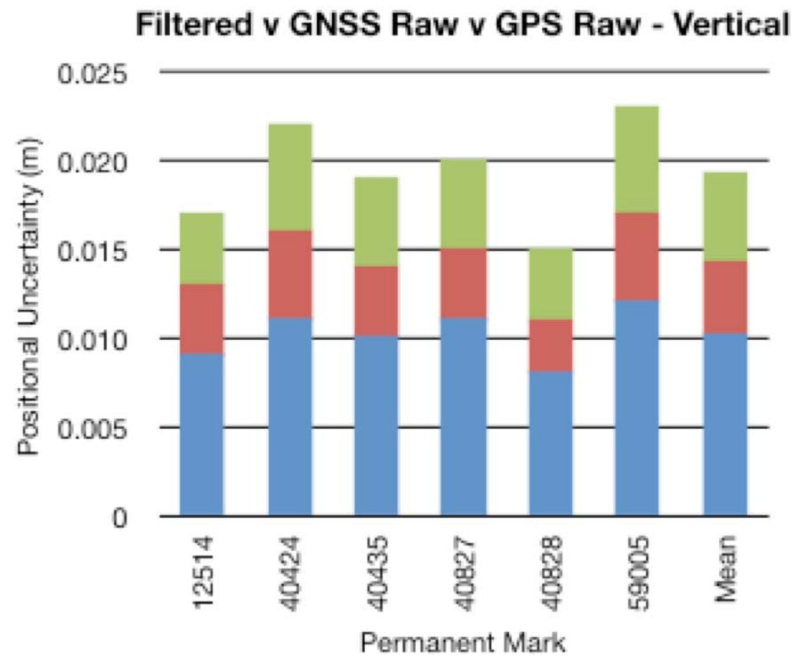

Figure 5.2 - Combined Vertical Positional Uncertainties

5.2 Raw - GNSS v GPS

At any one time, the GNSS data had three to five extra GLONASS satellites from which to observe extra raw data. In any occupation, this translated to recording 25 to 35 percent more data. GNSS raw data shows an improved positional uncertainty over GPS raw data by an average of 33% in horizontal results and an average of 26% for the vertical.

It would appear that the site with the optimal sky visibility has gained the most from the additional data (refer to figure 51 and 5.2, PM 40424 has the best sky visibility). Given that much other research has proven that RTK GNSS is more reliable than RTK GPS in areas of high multipath, this result was unexpected. It can be rationalised that the best sites for GNSS surveying will improve the most since minimal noisy data is being observed with extra quality data. While sites that are less than optimal for GNSS surveying may benefit from observing extra clean data, extra noisy data is also observed. However, despite having observed extra noisy data, the consistent improvement in precision of GNSS over GPS suggests that the extra clean data outweighs the noisy data.

5.3 GNSS Raw v Filtered

As mentioned in section 4.2.2, the GNSS and GPS filtered results were identical. By having identical results, the comparisons will be made to both the filtered results against the GNSS raw results. While it can be seen in figures 5.1 and 5.2 that GNSS raw data have had significant gains over GPS raw data, GNSS raw data has still not made it to the quality level of filtered data.

When compared to the filtered data, GNSS raw data remains 33 percent worse than filtered data for horizontal, and 28 percent worse for the vertical positional uncertainty. Considerable gains have been made with GNSS raw data over GPS raw towards the precision of filtered data. Until more satellites come online, there is no substitute for the filtering process that is part of post processing.

5.4 Filtered - GNSS v GPS

The hypothesis reflects that the GNSS filtered was expected to make some gains over GPS filtered. The direct comparison between the filtered GNSS and GPS baseline reports suggest that GNSS was in some cases equal to, but in most cases better than the GPS baseline precision.

While there were precision gains made in the baseline processing reports, the network adjustment reports suggest that the gains made do not add to the overall result of the zero constrained adjustment. Further testing may be required to prove or disprove this hypothesis; therefore the testing in this research regarding the improvement of precision of GNSS filtered results over GPS filtered results is inconclusive.

5.5 Productivity

The productivity gained with the fieldwork, is the main quantifiable timesaving result this research has found. As seen in figure 4.7, a range 8.3-11.7 percent of the time spent occupying each station can be eliminated from each session of a survey. For three field parties and six sessions like this survey, this translates to about a 32 to 44 minutes timesaving for this survey. Broken down, this is 1.7 to 2.5 minutes per person per session. While this mission is relatively small, this timesaving scaled up to a larger mission could definitely prove to reduce the cost of person-hours and equipment hire significantly. A large scale mission for example: if a survey required 100 marks at Class A, every mark would be required to be occupied twice and 20 percent would be required to be occupied three times. A two party crew could save six to nine field hours for the mission.

Unconsidered though, was one element of mission planning that seems no longer to be required with GNSS. A former part of GPS mission planning to maximise the fieldwork efficiency, was to plan the sessions so that each occupation had optimal observation windows. The aim of this extra planning was to be in transit when the number of visible satellites was low and for the sessions to commence when the constellation configuration had a high amount (six or more) of satellites. However, with GNSS, no session in the entire survey had less than 10 visible satellites. Therefore, by having more observable satellites, this formerly necessary planning element can be removed from the process and added to the productivity gains of using GNSS over GPS.

5.6 Fully Constrained Adjustment

PM 59005 was excluded from the adjustment due to coordinates of the mark disagreeing with the other marks and the network observations. On reinspection of the photography taken in conjunction with the reconnaissance, PM 59005 was found to be residing in black soil (see diagram 5.3), which in Toowoomba is empirically known for its unstable properties when it is exposed to varying moisture levels. Normally, since the main survey mark of the western area was removed from the fully constrained adjustment another PM with similar order coordinates would be observed and included in the adjustment. This would have removed an eastern bias from the resulting network coordinates. Furthermore, PM 12514 had no order for either its horizontal or vertical position. Since it was the main PM benefiting from the survey and was geometrically inside the boundary formed by the all of the constraining marks the final solution was acceptable but not optimal.

The statistics indicate that the class of the survey achieved was in fact a level closer to 3A and 2A, despite the ICSM suggesting that only Class A should be achieved with fast static. This was a clear indicator that the quality of the survey exceeds the quality of the coordinates marks connected to in the adjustment, especially since only 4^{th} Order vertical elevations were available (i.e. the class of the survey to produce this order of mark is only Class D). Therefore, the results of the fully constrained adjustment can only be considered as a gross check, and cannot prove or disprove any errors were in the static network.

5.7 Conclusion

The additional satellite data gained from using GNSS hardware and software has shown that a very precise positioning GPS still can be further refined to improve its performance. The precision gains of GNSS raw data show why RTK GNSS has improved reliability, but mostly demonstrate that by adding more quality data into the solutions outweighs the noisy data. This can only be enhanced when GLONASS has more satellites in orbit and Galileo and Compass come online.

GNSS raw data has also gained significant headway on data that has gone through the filtration process. This further reinforces that extra satellites improve precision in static surveys. GNSS filtered data has made some improvement over GPS however further testing is required to confirm whether an improvement can be made to the end result.

CHAPTER 6 – CONCLUSION

6.1 Introduction

Chapter 5 has critically analysed the results in Chapter 4 and shown that GNSS outperforms GPS in fast static surveying. Furthermore, by outperforming GPS, GNSS has proven that productivity can be increased if the user is willing to accept the same precisions that GPS would have achieved.

This chapter will discuss the implications of this research to the surveying profession and identify gaps in the testing that were not initially considered. Following will be an outlook on future research that could be conducted to further enhance the knowledge base available to surveyors on GNSS static surveys.

By further analysing the information presented in Chapter 5, this chapter will present the benefits of GNSS to surveyors and post processed surveying.

6.2 Implications of Research

A GPS constellation of 32 satellites had reduced the need for planning observation windows for statics surveys. The 44 available GNSS satellites have eliminated nearly all-possible need for observation windows to be part of the planning process.

Surveyors are now having a positive dilemma because of this research. The choice they now have is whether to work more productively or to perform measurements more precisely. While most surveyors will appreciate the ability to perform more precise measurements without any additional effort, businesses and their clients will both welcome increased efficiency and a reduction in the cost of person-hours.

Also proven in this research, is the fast static survey styles ability to achieve classes of survey above Class A. The ICSM may have unwritten reasons for not permitting fast static surveys to be labelled above Class A. The two static modes of GNSS surveying (Classic and Fast Static) cannot be differentiated through receiver specifications and if this research can achieve 2A and above results, then these reasons should be made available to surveyors.

Despite SP1 progressing from v1.6 to v1.7 throughout the progress of this research, SP1 still fails to acknowledge the existence of GNSS. This research and all of the research on RTK GNSS have proven that GNSS outperforms GPS. The ICSM should update SP1 and any other relevant documents in line with other regulating authorities like NRW. NRW's progress can be viewed in the latest update of the Cadastral Survey Requirements, where the meridian of a survey may now be: "MGA (Zone 56) vide GNSS" instead of "vide GPS" as per the old requirement.

6.3 Research Gaps

Very little information could be found as part of the literature review on the effect of GNSS on static surveying. This research has filled the gaps in research for the effects of GNSS on post processed static surveying by identifying that more simultaneously recorded satellite data improves precision and productivity.

Time saved from less planning has not been quantified in this research. Such testing could have been performed as part of this testing; however it was not considered from the outset of the research and time constraints have prevented it from becoming a late addition. This information could also be accessed from a surveyor with more experience in static surveying and the required information could be derived empirically.

The ICSM (2004 and 2007) has suggested that Class A is the highest achievable class with fast static surveying. Since this is the case, research could be conducted with the same survey data as to the minimum time that can be spent in each occupation to achieve this class. This could produce the absolute optimisation of field time spent to produce Class A surveys. The method used could be identical to that used in section 3.7.4 for reducing the length of sessions.

Furthermore, regular (i.e. non geodetic) surveys could benefit from similar optimisation techniques and could test the observation times recommended by Trimble Navigation. The minimum session lengths (as in section 2.3.3) that are based on recommendations for dual frequency GPS receivers and remain unchanged and applied to multi-constellation GNSS receivers.

Toowoomba has a severe lack of 1st and 2nd Order PMs on AHD. This has prevented the quality assurance of the data being carried out as intended. To rectify this problem, the quality of the marks coordinates could be upgraded and the fully constrained adjustment rerun with the new coordinates. Alternatively, the whole process could be repeated on a calibration facility as outlined in section 2.5.1. Hopefully, NRW will provide such a facility in the near future.

6.4 Future Research

Static surveying robustness allows it to gain more accurate positions than kinematic surveying in all conditions. The worst site for testing in this research had approximately 60-precent sky visibility. The testing in this research indicates that static GNSS is capable of improving the precisions of measurement in moderate to high multipath environments. Further testing should be conducted to test the limits of GNSS static surveying in high multipath environments. This could also investigate static surveying effectiveness for multipath mitigation when compared to kinematic surveying.

Much of the same research conducted could be applied to the testing of the classic static technique. Through its citation and correlation, it would seem that the ICSM recommendations for this technique are based on Trimble Navigations recommendations in 1991. Since there are now an extra 20 satellites available for tracking (Russian Space Agency 2008; United States Coast Guard 2008) the technique may also be able to achieve the same results with shortened occupation times.

Throughout this research several GNSS satellites have been launched. On the 27th of April, the EU launched and second of its test vehicles (Gibbons 2008). Also, Just 18 days after testing (25 September 2008), the Russian Federation successfully launched three more GLONASS satellites into orbit and will be operational within 45 days of launch (Gibbons 2008). Three more GLONASS satellites are due to be launched on the 25th of December 2008. With all of these constant additions to GNSS infrastructure, the same testing could be repeated and even more satellites would be acquired. As previously mentioned, the GNSS status at the time of testing had approximately the equivalent of two constellations running at FOC. Milestones to repeat such testing could be when GLONASS, Galileo and Compass all reach their FOC. With approximately two and a half times the amount of satellites, testing should concentrate on the baseline precisions in high multipath environments.

Upon completing a static survey in a base and rover type setup for work during this research, a compelling reason for use of the dual style (i.e. RTK and Logging) methods when real time data is not needed. After observing several baselines and returning to the base to move it to a different station, it was found that a bird had perched on the base. The survey continued, but after some post processing, it was found that the baseline measured in the session prior to the discovery of the bird was extremely noisy as a result and therefore could not be used in the adjustment. Had RTK and Logging been used, the radio link would have enabled a “High RMS” or “Poor PDOP” warning to be displayed during the session. The problem could have been investigated while the rover was still logging and the session length could have been extended to combat the baseline failing. Surveyors could benefit from more research being available on the dual style methods.

6.5 Close

The aim of this research was to analyse and quantify the precision, accuracy and timesaving gained by using several GNSS constellations over solely using the United States of Americas Department of Defence GPS.

Fast static survey testing has revealed that unfiltered GNSS data improves the precision of the baselines over unfiltered GPS data and also makes considerable precision gains towards the level of filtered data. GNSS filtered data also showed improvement of the baseline precisions of GPS filtered data. By accepting the same level of precisions achievable with GPS only, testing also indicated that a GNSS user could reduce observation session lengths and still achieve the same precisions.

With GNSS hardware and software, users have the ability to observe more satellites simultaneously. The ability to track more satellites increases the amount of data recorded in every static session and improve its precision and reliability. Furthermore, the enhanced precision of GNSS over GPS improves the productivity of the user and can reduce the person-hours required for a static mission.

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Appendix A – Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: Liam Patrick CURRAN

TOPIC: AN ANALYSIS OF MODERN GEODETIC GRADE GLOBAL NAVIGATION SATELLITE SYSTEMS EQUIPMENT FOR POST PROCESSED SURVEYS.

SUPERVISORS: Peter Gibbings
Glenn Campbell

PROJECT AIM: The aim of this project is to analyse and quantify the precision, accuracy and timesaving gained by using several Global Navigation Satellite Systems (GNSS) over solely using the Global Positioning System (GPS) in Fast Static Surveys.

PROGRAMME: (**Issue A, date 23/03/08**)

1. Research international GNSS inter-compatibility and infrastructure expansion efforts, survey network design, requirements for control surveys in Queensland and GNSS data filtering.
2. Conduct a fast static GNSS network survey as required by the Department of Natural Resources and Water (NRW) for Control Surveys.
3. Post-process the GNSS observation data in a suitable software package.
4. Calculate local uncertainty for GNSS and GPS observations using:
   a. Unfiltered data.
   b. Filtered data.
5. Measure time taken to filter extra data in GNSS dataset.
6. Calculate the observation period required to reach the GPS local uncertainties using GNSS data.
7. Submit an academic dissertation on the research.

As time permits:

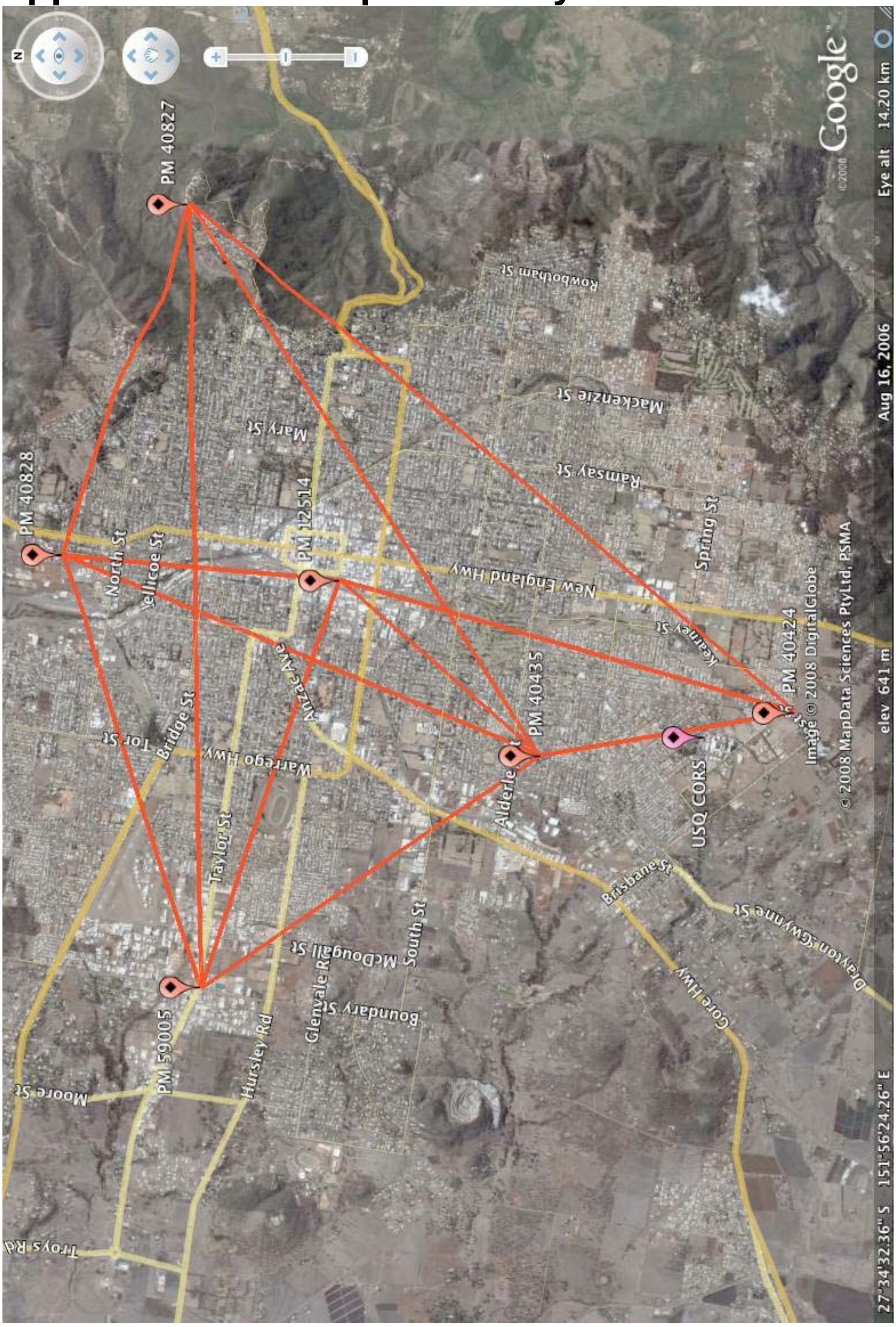
8. Calculate positional uncertainty for the datasets in 4a and 4b and submit survey to NRW.

AGREED (student)
(supervisor)______________________________ ______________________________

Date: / / 2008 Date: / / 2008

Co-examiner: ______________________________

Appendix B – Map of Survey



(Source: Google Earth)

Appendix C – Permanent Mark Form 6s

Survey Search Detail Report
Details of Registered PSM: **12514**
Located in: **TOOWOOMBA**

CONICS

Administrative

Alternate Names	TCC448, ,		
Locality Description	WATER/HERRIES ST	Parish	DRAYTON
Local Authority	TOOWOOMBA	Town	TOOWOOMBA
Additional Comments:			

Mark Details

Mark Type	STAND		Mark Condition	GOOD	
Installed By	AB YEATES		Installed Date	1/06/1959	
Last Visited	28/08/2006				
Connection(S)	RC191632	SP177893	IS165193	RP903981	IS95558

Horizontal

Datum	GDA94	Order	NO ORDER
Latitude	27 33 52.5268	Longitude	151 56 59.0076
Easting	396318.807	Northing	6950588.845
Zone	56	Class	NO CLASS
Adjustment Name	GDA - TRANSFORMED QLD_0900 GRID	Fixed By	SCALED

Vertical

Height	593.546	VDatum	AHD D
VOrder	NO ORDER	VClass	NO CLASS
VFixed By	SPIRIT LEVELLING	Origin	10022
Geoid/Ellipsoid Separation (N)	0.000		
Model			

Designed and Created by Richard Gray-Spence for the CONICS Companies - 2007

Survey Search Detail Report
Details of Registered PSM: **40424**
Located in:**TOOWOOMBA**

CONICS

Administrative

Alternate Names	TW 217, WEST/NELSON,		
Locality Description	WEST & NELSON ST	**Parish**	DRAYTON
Local Authority	TOOWOOMBA	**Town**	TOOWOOMBA
Additional Comments:			

Mark Details

Mark Type	STAND		**Mark Condition**	GOOD
Installed By	DMS		**Installed Date**	1/01/1975
Last Visited	7/07/2006			
Connection(S)	SP189204	SP176411	SP176361	SP164751 SP164719

Horizontal

Datum	GDA94	**Order**	1st ORDER
Latitude	27 36 37.8305	**Longitude**	151 56 4.2208
Easting	394860.174	**Northing**	6945489.266
Zone	56	**Class**	CLASS A
Adjustment Name	GDA - QLD SUPPLEMENTARY AREA 2 AND 3	**Fixed By**	GPS

Vertical

Height	683.293	**VDatum**	AHD
VOrder	4th ORDER	**VClass**	Class D
VFixed By	SPIRIT LEVELLING	**Origin**	
Geoid/Ellipsoid Separation (N)	14.489		
Model	AUSGEOID98		

Designed and Created by Richard Gray-Spence for the CONICS Companies - 2007

Survey Search Detail Report
Details of Registered PSM: **40435**
Located in: **TOOWOOMBA**

CONICS

Administrative

Alternate Names	SMITHFIELD, TW 218,		
Locality Description	PANDA/CHEVIOT	Parish	DRAYTON
Local Authority	TOOWOOMBA	Town	TOOWOOMBA
Additional Comments:	***60% GPS able due to some trees***		

Mark Details

Mark Type	STAND	Mark Condition	GOOD
Installed By	DMS	Installed Date	1/01/1975
Last Visited	7/07/2006		
Connection(S)			

Horizontal

Datum	GDA94	Order	1st ORDER
Latitude	27 35 5.8591	Longitude	151 55 46.4861
Easting	394349.532	Northing	6948315.224
Zone	56	Class	CLASS A
Adjustment Name	GDA - TOOWOOMBA INTERNAL CONTROL	Fixed By	TRIG

Vertical

Height	682.050	VDatum	AHD
VOrder	4th ORDER	VClass	Class D
VFixed By		Origin	
Geoid/Ellipsoid Separation (N)	0.000		
Model			

Designed and Created by Richard Gray-Spence for the CONICS Companies - 2007

Survey Search Detail Report
Details of Registered PSM: **40827**
Located in: **TOOWOOMBA**

CONICS

Administrative

Alternate Names	KATOOMBA, PR HENRY DRIVE, `E 13		
Locality Description	PRINCE HENRY DRIVE	**Parish**	DRAYTON
Local Authority	TOOWOOMBA	**Town**	TOOWOOMBA
Additional Comments:	***looks like mark been hit by slaser***		

Mark Details

Mark Type	STAND		**Mark Condition**	DAMAGED	
Installed By	DMS		**Installed Date**	1/01/1975	
Last Visited	7/07/2006				
Connection(S)	IS189447	SP184805	SP173298	SP170103	IS165188

Horizontal

Datum	GDA94	**Order**	1st ORDER
Latitude	27 32 56.6694	**Longitude**	151 59 35.4074
Easting	400593.839	**Northing**	6952343.303
Zone	56	**Class**	CLASS A
Adjustment Name	GDA - QLD1R1	**Fixed By**	GPS

Vertical

Height	614.622	**VDatum**	AHD
VOrder	4th ORDER	**VClass**	Class D
VFixed By	TRIG	**Origin**	
Geoid/Ellipsoid Separation (N)	14.331		
Model	AUSGEOID98		

Designed and Created by Richard Gray-Spence for the CONICS Companies - 2007

Survey Search Detail Report
Details of Registered PSM: **40828**
Located in: **TOOWOOMBA**

CONICS

Administrative

Alternate Names	TW 216, ,		
Locality Description	MOLE & PEACE ST	**Parish**	DRAYTON
Local Authority	TOOWOOMBA	**Town**	TOOWOOMBA
Additional Comments:			

Mark Details

Mark Type	STAND		**Mark Condition**	GOOD	
Installed By	DMS		**Installed Date**	1/01/1975	
Last Visited	10/02/2004				
Connection(S)	SP170106	CPS9242-22	AG3936		

Horizontal

Datum	GDA94	**Order**	1st ORDER
Latitude	27 32 10.3754	**Longitude**	151 57 9.7211
Easting	396586.03	**Northing**	6953734.721
Zone	56	**Class**	CLASS A
Adjustment Name	GDA - TOOWOOMBA INTERNAL CONTROL	**Fixed By**	TRIG

Vertical

Height	608.797	**VDatum**	AHD
VOrder	4th ORDER	**VClass**	Class D
VFixed By		**Origin**	
Geoid/Ellipsoid Separation (N)	0.000		
Model			

Designed and Created by Richard Gray-Spence for the CONICS Companies - 2007

Survey Search Detail Report
Details of Registered PSM: **59005**
Located in:**TOOWOOMBA**

CONICS

Administrative

Alternate Names	TAYLOR/BOUNDARY, TCC 2634,		
Locality Description	TAYLOR/BOUNDARY	**Parish**	DRAYTON
Local Authority	TOOWOOMBA	**Town**	TOOWOOMBA
Additional Comments:			

Mark Details

Mark Type	STAND		**Mark Condition**	GOOD	
Installed By	TOOWOOMBA CC		**Installed Date**	26/08/1986	
Last Visited	28/09/2007				
Connection(S)	SP209400	SP203001	SP199169	RC195596	SP195614

Horizontal

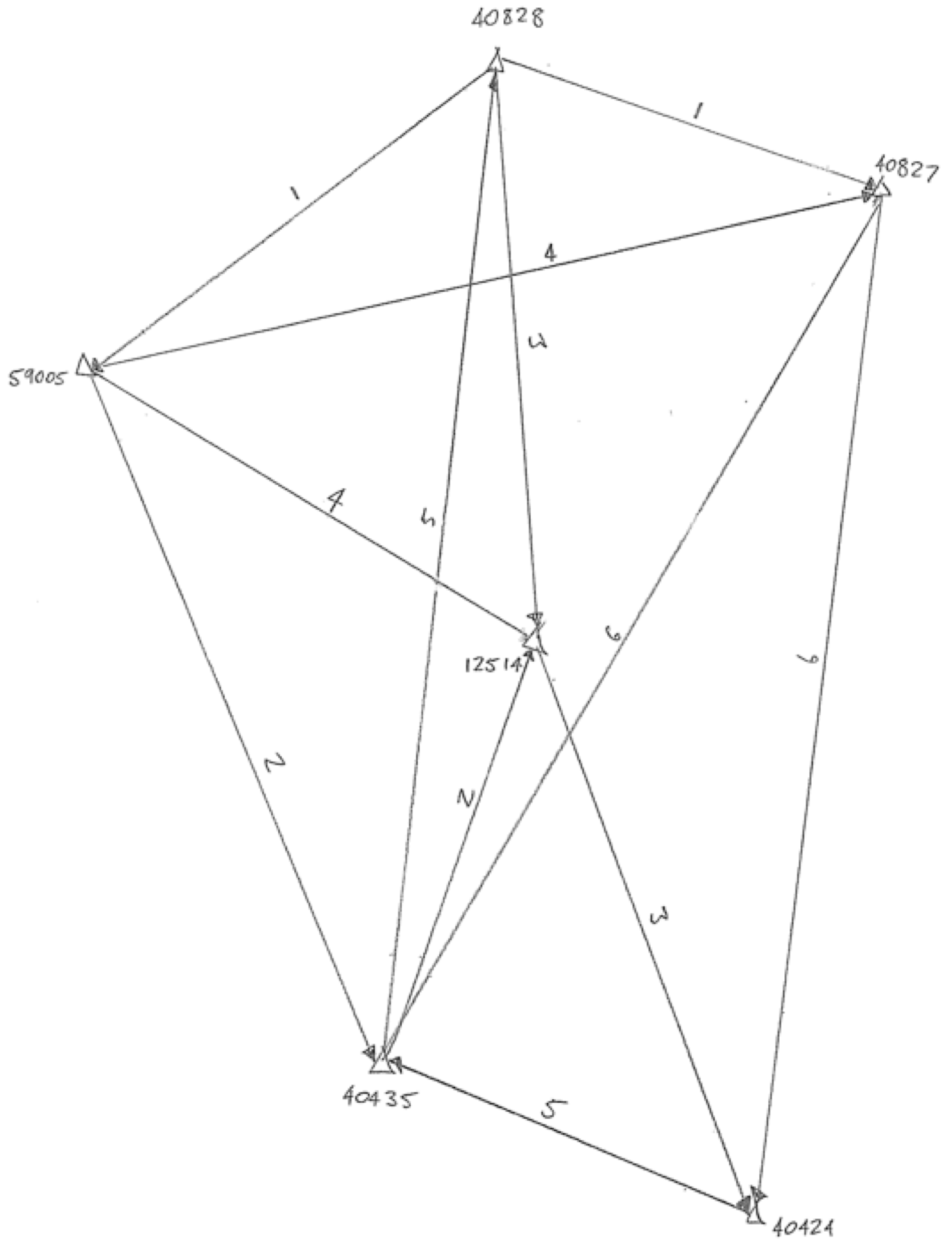
Datum	GDA94	**Order**	1st ORDER
Latitude	27 33 1.2597	**Longitude**	151 54 10.1623
Easting	391674.487	**Northing**	6952126.284
Zone	56	**Class**	CLASS A
Adjustment Name	GDA - JONDARYAN SHIRE COUNCIL CONTROL	**Fixed By**	GPS

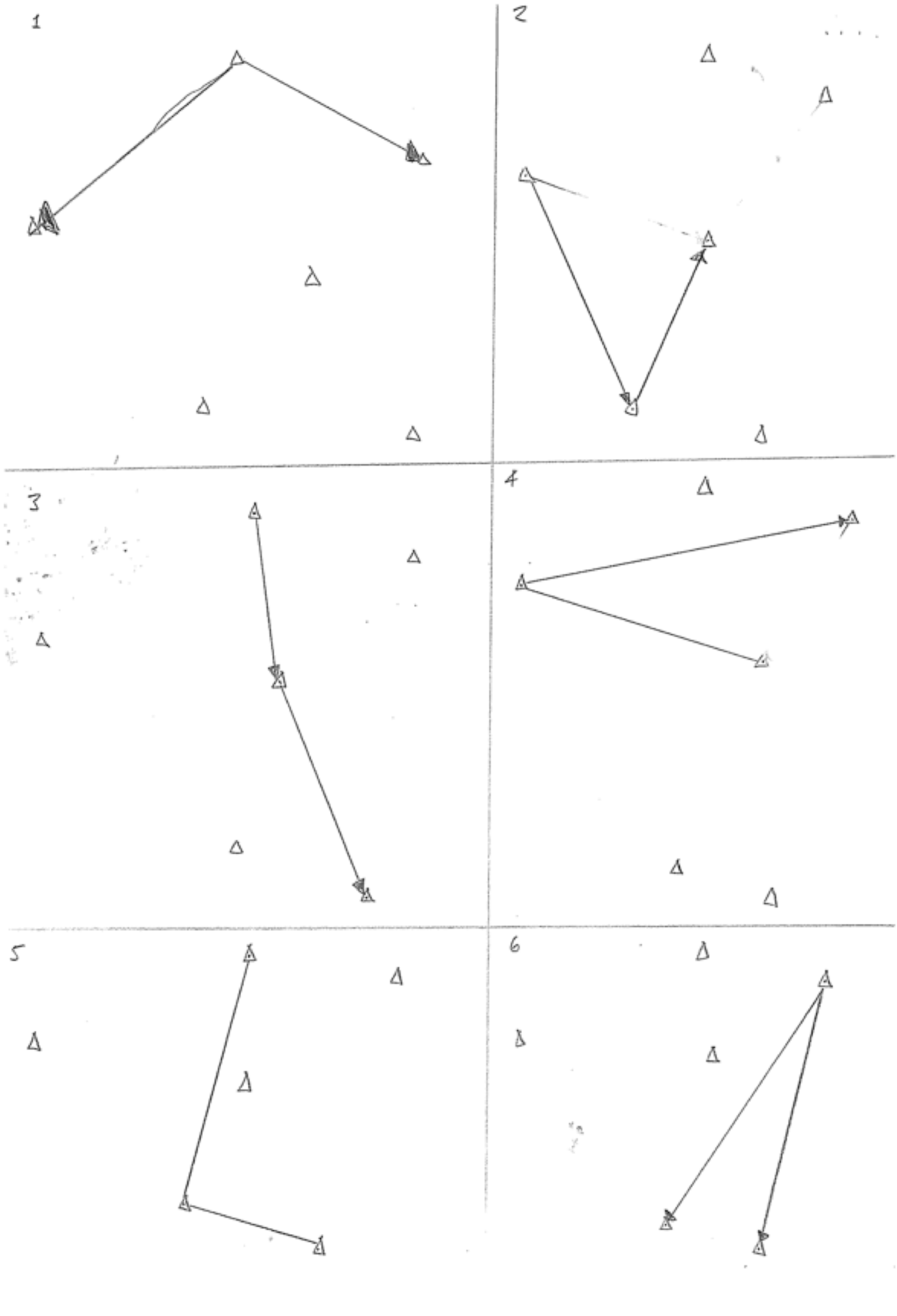
Vertical

Height	615.218	**VDatum**	AHD D
VOrder	4th ORDER	**VClass**	Class D
VFixed By		**Origin**	10854
Geoid/Ellipsoid Separation (N)	0.000		
Model			

Designed and Created by Richard Gray-Spence for the CONICS Companies - 2007

Appendix D – Mission Plan Baseline Configuration




1
2
3
4
5
6

Appendix E – Survey Field Notes

CONICS

Static Survey Log Sheet SHEET #...1...

JOB...LC R8Base... JOB No...

Date... Weather...
Field Staff...Liam Curran...
Equipment (Rover, antenna)...Conics R8 Base S/N,s...
(Rover, antenna)... S/N,s...

BASE STATION

BASE AT ...40828... TIME: START... STOP...
FILE NAME... ANT HT:...(m)...(ft)
DESCRIPTION... SV #... PDOP...

ROVER FILES

1
STATION NAME ...40828... TIME: START...11.31... STOP...11.52
FILE NAME...519L... ANT HT:...1.693 / 1.693 / (1.692)...(m)...(ft)
DESCRIPTION...AM... SV #... PDOP...1.3

2
STATION NAME ...59005... TIME: START...12.40... STOP...
FILE NAME...529L... ANT HT:...1.794 / 1.793 / 1.792...(m)...(ft)
DESCRIPTION... SV #... PDOP...1.7

3
STATION NAME ...40828... TIME: START...13.34... STOP...
FILE NAME... ANT HT:...1.766 / 1.766 / 1.765...(m)...(ft)
DESCRIPTION... SV #... PDOP...2.2

4
STATION NAME ...40827... TIME: START...3.08... STOP...
FILE NAME... ANT HT:...1.769 / 1.770 / 1.771...(m)...(ft)
DESCRIPTION... SV #... PDOP...2.6

Static Survey Log Sheet SHEET #...2...

JOB...LC R8 Base............ JOB No..................

STATION NAME ...40828.........TIME: START....✓....STOP..........
5 FILE NAME................................ ANT HT:..1.634 ✓ 1.635 1.634...(m)................(ft)
DESCRIPTION...................................... SV #.................PDOP.....

STATION NAME ...40827.........TIME: START...........STOP..........
6 FILE NAME................................ ANT HT:..1.608 1.609 1.608 ✓...(m)................(ft)
DESCRIPTION...................................... SV #.................PDOP.....

STATION NAME ....TIME: START...........STOP..........
FILE NAME................................ ANT HT:..............(m)................(ft)
DESCRIPTION...................................... SV #.................PDOP.....

STATION NAME ....TIME: START...........STOP..........
FILE NAME................................ ANT HT:..............(m)................(ft)
DESCRIPTION...................................... SV #.................PDOP.....

STATION NAME ....TIME: START...........STOP..........
FILE NAME................................ ANT HT:..............(m)................(ft)
DESCRIPTION...................................... SV #.................PDOP.....

STATION NAME ....TIME: START...........STOP..........
FILE NAME................................ ANT HT:..............(m)................(ft)
DESCRIPTION...................................... SV #.................PDOP.....

STATION NAME ....TIME: START...........STOP..........
FILE NAME................................ ANT HT:..............(m)................(ft)
DESCRIPTION...................................... SV #.................PDOP.....

STATION NAME ....TIME: START...........STOP..........
FILE NAME................................ ANT HT:..............(m)................(ft)
DESCRIPTION...................................... SV #.................PDOP.....

CONICS

Static Survey Log Sheet

SHEET #...1.....

JOB...LC R8 Min Surv........ JOB No..................

Date..7/9/07.. Weather....Cold, Partly Cloudy..............
Field Staff.......Jeff Pickford...
Equipment (Rover, antenna)..TSC2.............. S/N,s.....................
(Rover, antenna)...R8.............................. S/N,s..4749142127..

BASE STATION

BASE AT ...59005..........................TIME: START..11:32........ STOP..11:52...
FILE NAME....S1a9J.................... ANT HT:..1.991 (.990) (.990)...(m)...............(ft)
DESCRIPTION..Cnr. Taylor & Boundary... SV #.................PDOP.....

ROVER FILES

STATION NAME ..40435...............TIME: START..12:39...STOP..12:59
FILE NAME....S2g9J.................... ANT HT:..1.852 (853) (852)....(m)................(ft)
DESCRIPTION..Near Koala St intersection SV #.................PDOP.....

STATION NAME ..12514....................TIME: START..1:34...STOP..1:54..
FILE NAME......S3gJ................... ANT HT:..2.108 (.107) (.108).....(m)................(ft)
DESCRIPTION..Near Milne bay............... SV #.................PDOP.....

STATION NAME ..59005..........................TIME: START..3:09.....STOP..3:29
FILE NAME...S4gJ..................... ANT HT:..1.992 (.994) 1.995....(m)................(ft)
DESCRIPTION..Cnr. Taylor st & Boundary SV #.................PDOP..2.6

STATION NAME ..40435.................TIME: START..4:06...STOP..4:37
FILE NAME....S5gJ........................ ANT HT:..1.884 (1.883) (1.883)...(m)................(ft)
DESCRIPTION... SV #.................PDOP.....

Static Survey Log Sheet SHEET #..2....

JOB.. JOB No..................

STATION NAME ..40435.................TIME: START..4:43...STOP..5:04..
FILE NAME....S6G5..................... ANT HT:..1.550 (.549) (.549)...(m)..................(ft)
DESCRIPTION... SV #...................PDOP..1.7

STATION NAME ....TIME: START............STOP..........
FILE NAME..................................... ANT HT:...............(m)..................(ft)
DESCRIPTION... SV #...................PDOP.....

STATION NAME ....TIME: START............STOP..........
FILE NAME..................................... ANT HT:...............(m)..................(ft)
DESCRIPTION... SV #...................PDOP.....

STATION NAME ....TIME: START............STOP..........
FILE NAME..................................... ANT HT:...............(m)..................(ft)
DESCRIPTION... SV #...................PDOP.....

STATION NAME ....TIME: START............STOP..........
FILE NAME..................................... ANT HT:...............(m)..................(ft)
DESCRIPTION... SV #...................PDOP.....

STATION NAME ....TIME: START............STOP..........
FILE NAME..................................... ANT HT:...............(m)..................(ft)
DESCRIPTION... SV #...................PDOP.....

STATION NAME ....TIME: START............STOP..........
FILE NAME..................................... ANT HT:...............(m)..................(ft)
DESCRIPTION... SV #...................PDOP.....

STATION NAME ....TIME: START............STOP..........
FILE NAME..................................... ANT HT:...............(m)..................(ft)
DESCRIPTION... SV #...................PDOP.....

Static Survey Log Sheet SHEET #...1...

JOB...LC R8 Rover........ JOB No..................

Date.............. Weather...Partly cloudy.........................
Field Staff....Will Dorahy..
Equipment (Rover, antenna).......................... S/N,s.......................
(Rover, antenna).. S/N,s.......................

~~**BASE STATION**~~

BASE AT ....TIME: START.................. STOP..........
FILE NAME.................................... ANT HT:...............(m)...............(ft)
DESCRIPTION.. SV #..................PDOP.....

ROVER FILES

STATION NAME ..40827.............TIME: START..11.31..STOP.11.52
FILE NAME.................................... ANT HT:...............(m)...............(ft)
DESCRIPTION..Prince Henry Hts.......... SV #..................PDOP.1.5

STATION NAME ....12514..............TIME: START.12.39..STOP...1.00
FILE NAME.................................... ANT HT:...1.744.(m)...............(ft)
DESCRIPTION..int. Water st................... SV #..................PDOP.1.8

STATION NAME .....40424..........TIME: START...1.33..STOP.1.54
FILE NAME.................................... ANT HT:...1.459..(m)...............(ft)
DESCRIPTION..West St........................ SV #..................PDOP.1.5

STATION NAME ...12514...............TIME: START.3.08...STOP.3.28
FILE NAME.................................... ANT HT:...1.672...(m)...............(ft)
DESCRIPTION...int. Water st................. SV #..................PDOP.2.5

Static Survey Log Sheet SHEET #...2...

JOB.. JOB No..................

STATION NAME ...40424.............TIME: START............STOP..........
FILE NAME.................................... ANT HT:..1.481...(m)................(ft)
DESCRIPTION.. SV #..................PDOP.....

STATION NAME ...40424.............TIME: START............STOP..........
FILE NAME.................................... ANT HT:..1.545...(m)................(ft)
DESCRIPTION.. SV #..................PDOP.....

STATION NAME ....TIME: START............STOP..........
FILE NAME.................................... ANT HT:..............(m)................(ft)
DESCRIPTION.. SV #..................PDOP.....

STATION NAME ....TIME: START............STOP..........
FILE NAME.................................... ANT HT:..............(m)................(ft)
DESCRIPTION.. SV #..................PDOP.....

STATION NAME ....TIME: START............STOP..........
FILE NAME.................................... ANT HT:..............(m)................(ft)
DESCRIPTION.. SV #..................PDOP.....

STATION NAME ....TIME: START............STOP..........
FILE NAME.................................... ANT HT:..............(m)................(ft)
DESCRIPTION.. SV #..................PDOP.....

STATION NAME ....TIME: START............STOP..........
FILE NAME.................................... ANT HT:..............(m)................(ft)
DESCRIPTION.. SV #..................PDOP.....

STATION NAME ....TIME: START............STOP..........
FILE NAME.................................... ANT HT:..............(m)................(ft)
DESCRIPTION.. SV #..................PDOP.....

Appendix F – Baseline Processing Reports

F1 - GNSS Raw

Project information		**Coordinate System**	
Name:	C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GNSS Raw.vce	Name:	Default
Size:	264 KB	Datum:	WGS 1984
Modified:	14/10/2008 9:37:49 AM	Zone:	Default
Reference number:		Geoid:	
Description:		Vertical datum:	

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	DHeight (Meter)
40424 --- 40435 (B15)	40435	40424	Fixed	0.017	0.019	170°15'12"	2872.492	1.136
59005 --- 40435 (B5)	40435	59005	Fixed	0.010	0.029	325°25'47"	4657.374	-66.817
12514 --- 40435 (B6)	40435	12514	Fixed	0.008	0.022	41°22'50"	3007.094	-88.478
40828 --- 40435 (B14)	40435	40828	Fixed	0.026	0.029	22°55'12"	5864.391	-73.162
40827 --- 40435 (B16)	40435	40827	Fixed	0.020	0.023	57°40'12"	7432.794	-67.453
40828 --- 12514 (B8)	40828	12514	Fixed	0.008	0.013	185°21'57"	3158.970	-15.333
40827 --- 40828 (B2)	40827	40828	Fixed	0.009	0.013	289°36'41"	4243.625	-5.728
40828 --- 59005 (B3)	40828	59005	Fixed	0.011	0.017	252°21'06"	5169.533	6.324
59005 --- 12514 (B10)	59005	12514	Fixed	0.013	0.032	108°50'18"	4892.236	-21.661
12514 --- 40424 (B9)	12514	40424	Fixed	0.011	0.017	196°26'06"	5304.313	89.619
40827 --- 59005 (B12)	40827	59005	Fixed	0.017	0.041	269°04'19"	8924.336	0.549
40424 --- 40827 (B18)	40424	40827	Fixed	0.022	0.026	40°24'25"	8938.461	-68.568

Acceptance Summary

Processed	Passed	Flag	Fail
12	12	0	0

Date: 15/10/2008 9:35:36 AM	Project: C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GNSS Raw.vce	Trimble Business Center

F2 - GPS Raw

Project information		Coordinate System	
Name:	C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GPS Raw.vce	Name:	Default
Size:	290 KB	Datum:	WGS 1984
Modified:	14/10/2008 10:20:07 AM	Zone:	Default
Reference number:		Geoid:	
Description:		Vertical datum:	

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	DHeight (Meter)
40424 --- 40435 (B15)	40435	40424	Fixed	0.018	0.020	170°15'12"	2872.493	1.139
59005 --- 40435 (B5)	40435	59005	Fixed	0.011	0.030	325°25'48"	4657.376	-66.821
12514 --- 40435 (B6)	40435	12514	Fixed	0.008	0.023	41°22'50"	3007.094	-88.477
40828 --- 40435 (B14)	40435	40828	Fixed	0.027	0.031	22°55'12"	5864.390	-73.158
40827 --- 40435 (B16)	40435	40827	Fixed	0.021	0.026	57°40'13"	7432.788	-67.443
40828 --- 12514 (B8)	40828	12514	Fixed	0.009	0.013	185°21'57"	3158.969	-15.333
40827 --- 40828 (B2)	40827	40828	Fixed	0.009	0.014	289°36'41"	4243.625	-5.728
40828 --- 59005 (B3)	40828	59005	Fixed	0.011	0.018	252°21'06"	5169.533	6.326
59005 --- 12514 (B10)	59005	12514	Fixed	0.014	0.033	108°50'18"	4892.235	-21.660
12514 --- 40424 (B9)	12514	40424	Fixed	0.013	0.018	196°26'06"	5304.314	89.618
40827 --- 59005 (B12)	40827	59005	Fixed	0.019	0.043	269°04'20"	8924.319	0.480
40424 --- 40827 (B18)	40424	40827	Fixed	0.023	0.027	40°24'25"	8938.450	-68.568

Acceptance Summary

Processed	Passed	Flag	Fail
12	12	0	0

Date: 15/10/2008 9:32:28 AM	Project: C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GPS Raw.vce	Trimble Business Center

F3 - GNSS Filtered

Project information		**Coordinate System**	
Name:	C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GNSS Filtered.vce	Name:	Default
Size:	269 KB	Datum:	WGS 1984
Modified:	14/10/2008 9:40:02 AM	Zone:	Default
Reference number:		Geoid:	
Description:		Vertical datum:	

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	DHeight (Meter)
40424 --- 40435 (B15)	40435	40424	Fixed	0.017	0.019	170°15'12"	2872.491	1.135
59005 --- 40435 (B5)	40435	59005	Fixed	0.010	0.029	325°25'47"	4657.375	-66.817
12514 --- 40435 (B6)	40435	12514	Fixed	0.008	0.022	41°22'50"	3007.094	-88.477
40828 --- 40435 (B14)	40435	40828	Fixed	0.026	0.029	22°55'12"	5864.392	-73.164
40827 --- 40435 (B16)	40435	40827	Fixed	0.021	0.026	57°40'12"	7432.791	-67.442
40828 --- 12514 (B8)	40828	12514	Fixed	0.008	0.013	185°21'57"	3158.970	-15.333
40827 --- 40828 (B2)	40827	40828	Fixed	0.009	0.014	289°36'41"	4243.625	-5.728
40828 --- 59005 (B3)	40828	59005	Fixed	0.011	0.018	252°21'06"	5169.534	6.326
59005 --- 12514 (B10)	59005	12514	Fixed	0.013	0.032	108°50'18"	4892.236	-21.661
12514 --- 40424 (B9)	12514	40424	Fixed	0.011	0.017	196°26'06"	5304.314	89.619
40827 --- 59005 (B12)	40827	59005	Fixed	0.017	0.042	269°04'18"	8924.362	0.643
40424 --- 40827 (B18)	40424	40827	Fixed	0.022	0.027	40°24'25"	8938.455	-68.568

Acceptance Summary

Processed	Passed	Flag	Fail
12	12	0	0

Date: 15/10/2008 9:39:54 AM	Project: C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GNSS Filtered.vce	Trimble Business Center

F4 - GPS Filtered

Project information		**Coordinate System**	
Name:	C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GPS Filtered.vce	Name:	Default
Size:	290 KB	Datum:	WGS 1984
Modified:	14/10/2008 9:42:30 AM	Zone:	Default
Reference number:		Geoid:	
Description:		Vertical datum:	

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	DHeight (Meter)
40424 --- 40435 (B15)	40435	40424	Fixed	0.018	0.020	170°15'12"	2872.493	1.139
59005 --- 40435 (B5)	40435	59005	Fixed	0.011	0.030	325°25'48"	4657.376	-66.821
12514 --- 40435 (B6)	40435	12514	Fixed	0.008	0.023	41°22'50"	3007.094	-88.477
40828 --- 40435 (B14)	40435	40828	Fixed	0.027	0.031	22°55'12"	5864.390	-73.158
40827 --- 40435 (B16)	40435	40827	Fixed	0.021	0.026	57°40'13"	7432.789	-67.442
40828 --- 12514 (B8)	40828	12514	Fixed	0.009	0.013	185°21'57"	3158.970	-15.333
40827 --- 40828 (B2)	40827	40828	Fixed	0.009	0.014	289°36'41"	4243.625	-5.727
40828 --- 59005 (B3)	40828	59005	Fixed	0.011	0.018	252°21'06"	5169.534	6.325
59005 --- 12514 (B10)	59005	12514	Fixed	0.014	0.033	108°50'18"	4892.235	-21.660
12514 --- 40424 (B9)	12514	40424	Fixed	0.013	0.018	196°26'06"	5304.314	89.617
40827 --- 59005 (B12)	40827	59005	Fixed	0.020	0.047	269°04'18"	8924.359	0.634
40424 --- 40827 (B18)	40424	40827	Fixed	0.023	0.027	40°24'25"	8938.451	-68.568

Acceptance Summary

Processed	Passed	Flag	Fail
12	12	0	0

Date: 15/10/2008 9:37:24 AM	Project: C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GPS Filtered.vce	Trimble Business Center

F5 - GNSS Filtered less Two Minutes

Project information		**Coordinate System**	
Name:	C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GNSS Filtered Time.vce	Name:	Default
Size:	269 KB	Datum:	WGS 1984
Modified:	15/10/2008 12:08:15 PM	Zone:	Default
Reference number:		Geoid:	
Description:		Vertical datum:	

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	DHeight (Meter)
40827 --- 40828 (B2)	40827	40828	Fixed	0.010	0.014	289°36'41"	4243.626	-5.727
40828 --- 59005 (B3)	40828	59005	Fixed	0.012	0.019	252°21'06"	5169.533	6.324
59005 --- 40435 (B5)	40435	59005	Fixed	0.010	0.030	325°25'47"	4657.375	-66.817
12514 --- 40435 (B6)	40435	12514	Fixed	0.008	0.023	41°22'50"	3007.094	-88.480
40828 --- 12514 (B8)	40828	12514	Fixed	0.008	0.013	185°21'57"	3158.970	-15.332
12514 --- 40424 (B9)	12514	40424	Fixed	0.011	0.018	196°26'06"	5304.314	89.618
59005 --- 12514 (B10)	59005	12514	Fixed	0.013	0.033	108°50'18"	4892.237	-21.661
40827 --- 59005 (B12)	40827	59005	Fixed	0.018	0.044	269°04'18"	8924.365	0.654
40828 --- 40435 (B14)	40435	40828	Fixed	0.027	0.031	22°55'12"	5864.392	-73.164
40424 --- 40435 (B15)	40435	40424	Fixed	0.018	0.021	170°15'12"	2872.492	1.135
40827 --- 40435 (B16)	40435	40827	Fixed	0.022	0.026	57°40'12"	7432.791	-67.445
40424 --- 40827 (B18)	40424	40827	Fixed	0.023	0.028	40°24'25"	8938.453	-68.570

Acceptance Summary

Processed	Passed	Flag	Fail
12	12	0	0

Date: 15/10/2008 1:03:26 PM	Project: C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GNSS Filtered Time.vce	Trimble Business Center

Appendix G – Network Adjustment Reports

G1 - GNSS Raw

Project information		**Coordinate System**	
Name:	C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GNSS Raw.vce	Name:	Default
Size:	264 KB	Datum:	WGS 1984
Modified:	6/10/2008 3:32:46 PM	Zone:	Default
Reference number:		Geoid:	
Description:		Vertical datum:	

Network Adjustment Report

Adjustment Settings

Set-Up Errors

GNSS

Error in Height of Antenna: 0.001 m
Centering Error: 0.001 m

Covariance Display

Horizontal:

Propagated Linear Error [E]: U.S.
Constant Term [C]: 0.000 m
Scale on Linear Error [S]: 1.960

Three-Dimensional

Propagated Linear Error [E]: U.S.
Constant Term [C]: 0.000 m
Scale on Linear Error [S]: 1.960

Adjustment Statistics

Number of Iterations for Successful Adjustment: 2
Network Reference Factor: 1.00
Chi Square Test (95%): Passed
Precision Confidence Level: 95%
Degrees of Freedom: 21

Post Processed Vector Statistics

Reference Factor: 1.00
Redundancy Number: 21.00

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Fixed
12514	4632.136	0.005	-1578.569	0.005	?	?	
40424	3129.467	0.006	-6665.591	0.009	?	?	
40435	2643.789	0.005	-3834.464	0.006	?	?	
40827	8925.240	0.006	139.188	0.008	?	?	
40828	4928.819	0.005	1566.432	0.006	?	?	
59005	1.958	0.006	1.144	0.006	?	?	

Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Fixed
12514	S27°33'52.53675"	E151°56'59.03345"	633.537	0.013	
40424	S27°36'37.81538"	E151°56'04.30256"	723.158	0.016	
40435	S27°35'05.84382"	E151°55'46.56788"	722.027	0.014	
40827	S27°32'56.65410"	E151°59'35.48875"	654.592	0.015	
40828	S27°32'10.36016"	E151°57'09.80256"	648.870	0.011	
59005	S27°33'01.24455"	E151°54'10.24456"	655.195	0.017	

Error Ellipse Components

Point ID	Semi-major axis (Meter)	Semi-minor axis (Meter)	Azimuth
12514	0.007	0.006	13°
40424	0.011	0.008	169°
40435	0.008	0.006	163°
40827	0.010	0.008	165°
40828	0.008	0.006	178°
59005	0.008	0.007	4°

Observation ID		Observation	A-posteriori Error	Residual	Standardized Residual
40827 --> 59005 (V12)	**Az.**	269°04'19"	0.248 sec	-0.446 sec	-2.944
	ΔHt.	0.603 m	0.025 m	0.054 m	1.667
	Ellip Dist.	8924.347 m	0.009 m	0.011 m	1.015
40827 --> 40828 (V2)	**Az.**	289°36'41"	0.470 sec	0.487 sec	2.240
	ΔHt.	-5.722 m	0.019 m	0.006 m	0.920
	Ellip Dist.	4243.628 m	0.008 m	0.004 m	1.086
40828 --> 12514 (V8)	**Az.**	185°21'57"	0.446 sec	-0.047 sec	-0.237
	ΔHt.	-15.333 m	0.017 m	0.000 m	0.007
	Ellip Dist.	3158.963 m	0.009 m	-0.007 m	-1.895
59005 --> 12514 (V10)	**Az.**	108°50'19"	0.372 sec	0.314 sec	1.264
	ΔHt.	-21.658 m	0.023 m	0.003 m	0.139
	Ellip Dist.	4892.243 m	0.008 m	0.007 m	0.930
40435 --> 12514 (V6)	**Az.**	41°22'50"	0.529 sec	-0.007 sec	-0.029
	ΔHt.	-88.490 m	0.020 m	-0.012 m	-0.727
	Ellip Dist.	3007.089 m	0.007 m	-0.005 m	-1.257
40435 --> 40827 (V16)	**Az.**	57°40'12"	0.324 sec	0.012 sec	0.034
	ΔHt.	-67.435 m	0.022 m	0.018 m	1.066
	Ellip Dist.	7432.798 m	0.009 m	0.004 m	0.627
12514 --> 40424 (V9)	**Az.**	196°26'06"	0.333 sec	-0.141 sec	-0.959
	ΔHt.	89.621 m	0.021 m	0.002 m	0.231
	Ellip Dist.	5304.319 m	0.011 m	0.005 m	0.981
40424 --> 40827 (V18)	**Az.**	40°24'25"	0.294 sec	0.239 sec	0.831
	ΔHt.	-68.567 m	0.024 m	0.002 m	0.084
	Ellip Dist.	8938.452 m	0.011 m	-0.009 m	-0.976
40435 --> 59005 (V5)	**Az.**	325°25'48"	0.356 sec	0.189 sec	0.896
	ΔHt.	-66.832 m	0.024 m	-0.015 m	-0.686
	Ellip Dist.	4657.377 m	0.009 m	0.002 m	0.450
40435 --> 40424 (V15)	**Az.**	170°15'12"	0.567 sec	0.227 sec	0.794
	ΔHt.	1.132 m	0.021 m	-0.005 m	-0.354
	Ellip Dist.	2872.484 m	0.012 m	-0.008 m	-0.780
40435 --> 40828 (V14)	**Az.**	22°55'12"	0.296 sec	0.128 sec	0.296
	ΔHt.	-73.157 m	0.020 m	0.005 m	0.223
	Ellip Dist.	5864.386 m	0.009 m	-0.005 m	-0.383
40828 --> 59005 (V3)	**Az.**	252°21'06"	0.365 sec	-0.015 sec	-0.062
	ΔHt.	6.325 m	0.021 m	0.001 m	0.072
	Ellip Dist.	5169.534 m	0.008 m	0.001 m	0.222

Covariance Terms

From Point	To Point		Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)
12514	40424	**Az.**	196°26'06"	0.333 sec	1 : 494986	1 : 493365
		ΔHt.	89.621 m	0.021 m		
		ΔElev.	?	?		
		Ellip Dist.	5304.319 m	0.011 m		
12514	40435	**Az.**	221°22'17"	0.530 sec	1 : 403811	1 : 401671
		ΔHt.	88.490 m	0.020 m		
		ΔElev.	?	?		
		Ellip Dist.	3007.089 m	0.007 m		
40435	40424	**Az.**	170°15'12"	0.566 sec	1 : 238443	1 : 238387
		ΔHt.	1.132 m	0.021 m		
		ΔElev.	?	?		
		Ellip Dist.	2872.484 m	0.012 m		
40827	40424	**Az.**	220°22'48"	0.294 sec	1 : 790582	1 : 789989
		ΔHt.	68.567 m	0.024 m		
		ΔElev.	?	?		
		Ellip Dist.	8938.452 m	0.011 m		
40827	40435	**Az.**	237°38'27"	0.324 sec	1 : 846201	1 : 844847
		ΔHt.	67.435 m	0.022 m		
		ΔElev.	?	?		
		Ellip Dist.	7432.798 m	0.009 m		
40827	40828	**Az.**	289°36'41"	0.472 sec	1 : 505036	1 : 505414
		ΔHt.	-5.722 m	0.019 m		
		ΔElev.	?	?		
		Ellip Dist.	4243.628 m	0.008 m		
40828	12514	**Az.**	185°21'57"	0.445 sec	1 : 368797	1 : 368695
		ΔHt.	-15.333 m	0.017 m		
		ΔElev.	?	?		
		Ellip Dist.	3158.963 m	0.009 m		
40828	40435	**Az.**	202°54'34"	0.296 sec	1 : 629762	1 : 627485
		ΔHt.	73.157 m	0.020 m		
		ΔElev.	?	?		

		Ellip Dist.	5864.386 m	0.009 m		
59005	12514	**Az.**	108°50'19"	0.373 sec	1 : 629644	1 : 627887
		ΔHt.	-21.658 m	0.023 m		
		ΔElev.	?	?		
		Ellip Dist.	4892.243 m	0.008 m		
59005	40435	**Az.**	145°26'32"	0.356 sec	1 : 514358	1 : 513202
		ΔHt.	66.832 m	0.024 m		
		ΔElev.	?	?		
		Ellip Dist.	4657.377 m	0.009 m		
59005	40827	**Az.**	89°06'49"	0.249 sec	1 : 959906	1 : 959860
		ΔHt.	-0.603 m	0.025 m		
		ΔElev.	?	?		
		Ellip Dist.	8924.347 m	0.009 m		
59005	40828	**Az.**	72°22'29"	0.366 sec	1 : 651880	1 : 651772
		ΔHt.	-6.325 m	0.021 m		
		ΔElev.	?	?		
		Ellip Dist.	5169.534 m	0.008 m		

Date: 14/10/2008 9:33:03 AM	Project: C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GNSS Raw.vce	Trimble Business Center

G2 - GPS Raw

Project information		**Coordinate System**	
Name:	C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GPS Raw.vce	Name:	Default
Size:	290 KB	Datum:	WGS 1984
Modified:	10/10/2008 3:01:59 PM	Zone:	Default
Reference number:		Geoid:	
Description:		Vertical datum:	

Network Adjustment Report

Adjustment Settings

Set-Up Errors

GNSS

Error in Height of Antenna: 0.001 m
Centering Error: 0.001 m

Covariance Display

Horizontal:

Propagated Linear Error [E]: U.S.
Constant Term [C]: 0.000 m
Scale on Linear Error [S]: 1.960

Three-Dimensional

Propagated Linear Error [E]: U.S.
Constant Term [C]: 0.000 m
Scale on Linear Error [S]: 1.960

Adjustment Statistics

Number of Iterations for Successful Adjustment: 2
Network Reference Factor: 1.00
Chi Square Test (95%): Passed
Precision Confidence Level: 95%
Degrees of Freedom: 21

Post Processed Vector Statistics

Reference Factor: 1.00
Redundancy Number: 21.00

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Fixed
12514	4632.124	0.006	-1578.580	0.008	?	?	
40424	3129.456	0.009	-6665.603	0.013	?	?	
40435	2643.776	0.006	-3834.476	0.009	?	?	
40827	8925.225	0.009	139.171	0.011	?	?	
40828	4928.805	0.007	1566.418	0.009	?	?	
59005	1.945	0.008	1.134	0.009	?	?	

Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Fixed
12514	S27°33'52.53711"	E151°56'59.03298"	633.596	0.017	
40424	S27°36'37.81576"	E151°56'04.30214"	723.216	0.022	
40435	S27°35'05.84421"	E151°55'46.56740"	722.083	0.019	
40827	S27°32'56.65466"	E151°59'35.48819"	654.655	0.020	
40828	S27°32'10.36061"	E151°57'09.80205"	648.929	0.015	
59005	S27°33'01.24489"	E151°54'10.24409"	655.249	0.023	

Error Ellipse Components

Point ID	Semi-major axis (Meter)	Semi-minor axis (Meter)	Azimuth
12514	0.010	0.008	19°
40424	0.016	0.011	173°
40435	0.011	0.008	167°
40827	0.014	0.011	171°
40828	0.011	0.008	3°
59005	0.011	0.010	8°

Adjusted GPS Observations

Observation ID		Observation	A-posteriori Error	Residual	Standardized Residual
40827 --> 59005 (V12)	**Az.**	269°04'19"	0.339 sec	-0.630 sec	-3.027
	ΔHt.	0.594 m	0.034 m	0.114 m	2.565
	Ellip Dist.	8924.345 m	0.013 m	0.026 m	1.601
40827 --> 40828 (V2)	**Az.**	289°36'41"	0.641 sec	0.669 sec	2.447
	ΔHt.	-5.726 m	0.025 m	0.001 m	0.161
	Ellip Dist.	4243.628 m	0.011 m	0.003 m	0.798
40828 --> 12514 (V8)	**Az.**	185°21'57"	0.623 sec	-0.068 sec	-0.235
	ΔHt.	-15.334 m	0.023 m	-0.001 m	-0.061
	Ellip Dist.	3158.960 m	0.012 m	-0.009 m	-1.594
59005 --> 12514 (V10)	**Az.**	108°50'19"	0.520 sec	0.338 sec	0.989
	ΔHt.	-21.653 m	0.031 m	0.007 m	0.210
	Ellip Dist.	4892.244 m	0.011 m	0.009 m	0.831
40435 --> 12514 (V6)	**Az.**	41°22'50"	0.723 sec	0.007 sec	0.021
	ΔHt.	-88.487 m	0.028 m	-0.010 m	-0.448
	Ellip Dist.	3007.090 m	0.011 m	-0.004 m	-0.849
12514 --> 40424 (V9)	**Az.**	196°26'06"	0.460 sec	-0.163 sec	-0.750
	ΔHt.	89.621 m	0.029 m	0.003 m	0.225
	Ellip Dist.	5304.319 m	0.016 m	0.005 m	0.634
40435 --> 59005 (V5)	**Az.**	325°25'48"	0.500 sec	0.196 sec	0.689
	ΔHt.	-66.834 m	0.034 m	-0.013 m	-0.432
	Ellip Dist.	4657.378 m	0.012 m	0.002 m	0.320
40435 --> 40424 (V15)	**Az.**	170°15'12"	0.781 sec	0.172 sec	0.470
	ΔHt.	1.134 m	0.029 m	-0.006 m	-0.316
	Ellip Dist.	2872.484 m	0.017 m	-0.009 m	-0.672
40435 --> 40827 (V16)	**Az.**	57°40'13"	0.439 sec	0.056 sec	0.118
	ΔHt.	-67.427 m	0.031 m	0.015 m	0.627
	Ellip Dist.	7432.794 m	0.013 m	0.005 m	0.478
40424 --> 40827 (V18)	**Az.**	40°24'25"	0.397 sec	0.205 sec	0.549
	ΔHt.	-68.561 m	0.033 m	0.007 m	0.279
	Ellip Dist.	8938.446 m	0.016 m	-0.005 m	-0.348
40828 --> 59005 (V3)	**Az.**	252°21'06"	0.496 sec	0.106 sec	0.317
	ΔHt.	6.320 m	0.028 m	-0.006 m	-0.403
	Ellip Dist.	5169.533 m	0.011 m	-0.001 m	-0.143
40435 --> 40828 (V14)	**Az.**	22°55'12"	0.399 sec	0.066 sec	0.110
	ΔHt.	-73.154 m	0.028 m	0.005 m	0.155
	Ellip Dist.	5864.384 m	0.013 m	-0.006 m	-0.310

Covariance Terms

From Point	To Point		Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)
12514	40424	**Az.**	196°26'06"	0.460 sec	1 : 340899	1 : 339748
		ΔHt.	89.621 m	0.029 m		
		ΔElev.	?	?		
		Ellip Dist.	5304.319 m	0.016 m		
12514	40435	**Az.**	221°22'17"	0.724 sec	1 : 284646	1 : 282433
		ΔHt.	88.487 m	0.028 m		
		ΔElev.	?	?		
		Ellip Dist.	3007.090 m	0.011 m		
40435	40424	**Az.**	170°15'12"	0.780 sec	1 : 169432	1 : 169391
		ΔHt.	1.134 m	0.029 m		
		ΔElev.	?	?		
		Ellip Dist.	2872.484 m	0.017 m		
40827	40424	**Az.**	220°22'48"	0.398 sec	1 : 542324	1 : 541874
		ΔHt.	68.561 m	0.033 m		
		ΔElev.	?	?		
		Ellip Dist.	8938.446 m	0.016 m		
40827	40435	**Az.**	237°38'27"	0.440 sec	1 : 589362	1 : 588506
		ΔHt.	67.427 m	0.031 m		
		ΔElev.	?	?		
		Ellip Dist.	7432.794 m	0.013 m		
40827	40828	**Az.**	289°36'41"	0.643 sec	1 : 378681	1 : 378962
		ΔHt.	-5.726 m	0.025 m		
		ΔElev.	?	?		
		Ellip Dist.	4243.628 m	0.011 m		
40828	12514	**Az.**	185°21'57"	0.622 sec	1 : 258599	1 : 258545
		ΔHt.	-15.334 m	0.023 m		
		ΔElev.	?	?		
		Ellip Dist.	3158.960 m	0.012 m		
40828	40435	**Az.**	202°54'34"	0.399 sec	1 : 442702	1 : 440957
		ΔHt.	73.154 m	0.028 m		
		ΔElev.	?	?		

		Ellip Dist.	5864.384 m	0.013 m		
59005	12514	**Az.**	108°50'19"	0.521 sec	1 : 452988	1 : 451949
		ΔHt.	-21.653 m	0.031 m		
		ΔElev.	?	?		
		Ellip Dist.	4892.244 m	0.011 m		
59005	40435	**Az.**	145°26'32"	0.500 sec	1 : 373841	1 : 372277
		ΔHt.	66.834 m	0.034 m		
		ΔElev.	?	?		
		Ellip Dist.	4657.378 m	0.012 m		
59005	40827	**Az.**	89°06'49"	0.340 sec	1 : 691326	1 : 691297
		ΔHt.	-0.594 m	0.034 m		
		ΔElev.	?	?		
		Ellip Dist.	8924.345 m	0.013 m		
59005	40828	**Az.**	72°22'29"	0.498 sec	1 : 472291	1 : 472236
		ΔHt.	-6.320 m	0.028 m		
		ΔElev.	?	?		
		Ellip Dist.	5169.533 m	0.011 m		

Date: 14/10/2008 9:43:46 AM	Project: C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GPS Raw.vce	Trimble Business Center

G3 - GNSS Filtered

Project information		**Coordinate System**	
Name:	C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GNSS Filtered.vce	Name:	Default
Size:	269 KB	Datum:	WGS 1984
Modified:	14/10/2008 9:29:00 AM	Zone:	Default
Reference number:		Geoid:	
Description:		Vertical datum:	

Network Adjustment Report

Adjustment Settings

Set-Up Errors

GNSS

Error in Height of Antenna:	0.001 m
Centering Error:	0.001 m

Covariance Display

Horizontal:

Propagated Linear Error [E]:	U.S.
Constant Term [C]:	0.000 m
Scale on Linear Error [S]:	1.960

Three-Dimensional

Propagated Linear Error [E]:	U.S.
Constant Term [C]:	0.000 m
Scale on Linear Error [S]:	1.960

Adjustment Statistics

Number of Iterations for Successful Adjustment:	2
Network Reference Factor:	1.00
Chi Square Test (95%):	Passed
Precision Confidence Level:	95%
Degrees of Freedom:	21

Post Processed Vector Statistics

Reference Factor:	1.00
Redundancy Number:	21.00
A Priori Scalar:	1.17

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Fixed
12514	4632.158	0.003	-1578.539	0.004	?	?	
40424	3129.489	0.004	-6665.558	0.006	?	?	
40435	2643.810	0.003	-3834.433	0.004	?	?	
40827	8925.260	0.004	139.228	0.006	?	?	
40828	4928.840	0.003	1566.464	0.004	?	?	
59005	1.978	0.004	1.170	0.004	?	?	

Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Fixed
12514	S27°33'52.53576"	E151°56'59.03423"	633.458	0.009	
40424	S27°36'37.81431"	E151°56'04.30336"	723.076	0.011	
40435	S27°35'05.84281"	E151°55'46.56866"	721.946	0.010	
40827	S27°32'56.65280"	E151°59'35.48948"	654.513	0.011	
40828	S27°32'10.35912"	E151°57'09.80332"	648.790	0.008	
59005	S27°33'01.24371"	E151°54'10.24531"	655.121	0.012	

Error Ellipse Components

Point ID	Semi-major axis (Meter)	Semi-minor axis (Meter)	Azimuth
12514	0.005	0.004	13°
40424	0.008	0.006	170°
40435	0.006	0.004	163°
40827	0.007	0.005	168°
40828	0.005	0.004	179°
59005	0.006	0.005	5°

Adjusted GPS Observations

Observation ID		Observation	A-posteriori Error	Residual	Standardized Residual
40828 --> 12514 (V8)	**Az.**	185°21'57"	0.311 sec	-0.104 sec	-0.755
	ΔHt.	-15.333 m	0.012 m	0.000 m	-0.033
	Ellip Dist.	3158.964 m	0.006 m	-0.006 m	-2.221
40435 --> 40827 (V16)	**Az.**	57°40'12"	0.227 sec	-0.236 sec	-0.947
	ΔHt.	-67.433 m	0.016 m	0.010 m	0.732
	Ellip Dist.	7432.802 m	0.006 m	0.011 m	2.041
40827 --> 59005 (V12)	**Az.**	269°04'19"	0.175 sec	0.101 sec	0.937
	ΔHt.	0.608 m	0.018 m	-0.035 m	-1.508
	Ellip Dist.	8924.347 m	0.007 m	-0.015 m	-1.974
40435 --> 12514 (V6)	**Az.**	41°22'50"	0.370 sec	0.004 sec	0.023
	ΔHt.	-88.488 m	0.014 m	-0.011 m	-0.982
	Ellip Dist.	3007.089 m	0.005 m	-0.005 m	-1.918
40828 --> 59005 (V3)	**Az.**	252°21'06"	0.255 sec	-0.254 sec	-1.434
	ΔHt.	6.331 m	0.015 m	0.005 m	0.674
	Ellip Dist.	5169.536 m	0.006 m	0.003 m	0.826
12514 --> 40424 (V9)	**Az.**	196°26'06"	0.233 sec	-0.131 sec	-1.292
	ΔHt.	89.619 m	0.015 m	0.000 m	-0.064
	Ellip Dist.	5304.316 m	0.007 m	0.003 m	0.759
40435 --> 40424 (V15)	**Az.**	170°15'12"	0.397 sec	0.158 sec	0.798
	ΔHt.	1.131 m	0.015 m	-0.004 m	-0.491
	Ellip Dist.	2872.482 m	0.008 m	-0.009 m	-1.285
59005 --> 12514 (V10)	**Az.**	108°50'18"	0.261 sec	0.115 sec	0.670
	ΔHt.	-21.664 m	0.016 m	-0.002 m	-0.138
	Ellip Dist.	4892.243 m	0.005 m	0.006 m	1.201
40827 --> 40828 (V2)	**Az.**	289°36'41"	0.334 sec	0.136 sec	0.900
	ΔHt.	-5.723 m	0.013 m	0.005 m	1.056
	Ellip Dist.	4243.625 m	0.006 m	0.000 m	-0.093
40435 --> 40828 (V14)	**Az.**	22°55'12"	0.207 sec	0.119 sec	0.395
	ΔHt.	-73.155 m	0.014 m	0.009 m	0.579
	Ellip Dist.	5864.387 m	0.007 m	-0.005 m	-0.551
40435 --> 59005 (V5)	**Az.**	325°25'47"	0.250 sec	0.022 sec	0.153
	ΔHt.	-66.824 m	0.017 m	-0.007 m	-0.509
	Ellip Dist.	4657.373 m	0.006 m	-0.002 m	-0.436
40424 --> 40827 (V18)	**Az.**	40°24'25"	0.205 sec	0.070 sec	0.350
	ΔHt.	-68.563 m	0.017 m	0.005 m	0.385
	Ellip Dist.	8938.457 m	0.008 m	0.002 m	0.282

Covariance Terms

From Point	To Point		Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)
12514	40424	**Az.**	196°26'06"	0.232 sec	1 : 705279	1 : 702783
		ΔHt.	89.619 m	0.015 m		
		ΔElev.	?	?		
		Ellip Dist.	5304.316 m	0.008 m		
12514	40435	**Az.**	221°22'17"	0.370 sec	1 : 576496	1 : 573034
		ΔHt.	88.488 m	0.014 m		
		ΔElev.	?	?		
		Ellip Dist.	3007.089 m	0.005 m		
40435	40424	**Az.**	170°15'12"	0.397 sec	1 : 339748	1 : 339666
		ΔHt.	1.131 m	0.015 m		
		ΔElev.	?	?		
		Ellip Dist.	2872.482 m	0.008 m		
40827	40424	**Az.**	220°22'48"	0.206 sec	1 : 1098300	1 : 1097653
		ΔHt.	68.563 m	0.017 m		
		ΔElev.	?	?		
		Ellip Dist.	8938.457 m	0.008 m		
40827	40435	**Az.**	237°38'26"	0.227 sec	1 : 1170174	1 : 1168827
		ΔHt.	67.433 m	0.016 m		
		ΔElev.	?	?		
		Ellip Dist.	7432.802 m	0.006 m		
40827	40828	**Az.**	289°36'41"	0.335 sec	1 : 721540	1 : 722097
		ΔHt.	-5.723 m	0.013 m		
		ΔElev.	?	?		
		Ellip Dist.	4243.625 m	0.006 m		
40828	12514	**Az.**	185°21'57"	0.311 sec	1 : 524781	1 : 524694
		ΔHt.	-15.333 m	0.012 m		
		ΔElev.	?	?		
		Ellip Dist.	3158.964 m	0.006 m		
40828	40435	**Az.**	202°54'34"	0.207 sec	1 : 893863	1 : 890402
		ΔHt.	73.155 m	0.014 m		
		ΔElev.	?	?		

		Ellip Dist.	5864.387 m	0.007 m		
59005	12514	**Az.**	108°50'18"	0.261 sec	1 : 902039	1 : 899428
		ΔHt.	-21.664 m	0.016 m		
		ΔElev.	?	?		
		Ellip Dist.	4892.243 m	0.005 m		
59005	40435	**Az.**	145°26'32"	0.250 sec	1 : 736364	1 : 734441
		ΔHt.	66.824 m	0.017 m		
		ΔElev.	?	?		
		Ellip Dist.	4657.373 m	0.006 m		
59005	40827	**Az.**	89°06'49"	0.176 sec	1 : 1360115	1 : 1360048
		ΔHt.	-0.608 m	0.018 m		
		ΔElev.	?	?		
		Ellip Dist.	8924.347 m	0.007 m		
59005	40828	**Az.**	72°22'29"	0.256 sec	1 : 924692	1 : 924500
		ΔHt.	-6.331 m	0.015 m		
		ΔElev.	?	?		
		Ellip Dist.	5169.536 m	0.006 m		

Date: 14/10/2008 9:38:14 AM	Project: C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GNSS Filtered.vce	Trimble Business Center

G4 - GPS Filtered

Project information		Coordinate System	
Name:	C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GPS Filtered.vce	Name:	Default
Size:	290 KB	Datum:	WGS 1984
Modified:	10/10/2008 3:12:08 PM	Zone:	Default
Reference number:		Geoid:	
Description:		Vertical datum:	

Network Adjustment Report

Adjustment Settings

Set-Up Errors

GNSS

Error in Height of Antenna: 0.001 m

Centering Error: 0.001 m

Covariance Display

Horizontal:

Propagated Linear Error [E]: U.S.

Constant Term [C]: 0.000 m

Scale on Linear Error [S]: 1.960

Three-Dimensional

Propagated Linear Error [E]: U.S.

Constant Term [C]: 0.000 m

Scale on Linear Error [S]: 1.960

Adjustment Statistics

Number of Iterations for Successful Adjustment: 2

Network Reference Factor: 1.00

Chi Square Test (95%): Passed

Precision Confidence Level: 95%

Degrees of Freedom: 21

Post Processed Vector Statistics

Reference Factor: 1.00

Redundancy Number: 21.00

A Priori Scalar: 1.10

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Fixed
12514	4632.156	0.003	-1578.540	0.004	?	?	
40424	3129.488	0.004	-6665.561	0.006	?	?	
40435	2643.809	0.003	-3834.435	0.005	?	?	
40827	8925.258	0.004	139.224	0.006	?	?	
40828	4928.838	0.003	1566.461	0.004	?	?	
59005	1.977	0.004	1.168	0.004	?	?	

Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Fixed
12514	S27°33'52.53581"	E151°56'59.03418"	633.467	0.009	
40424	S27°36'37.81439"	E151°56'04.30334"	723.085	0.011	
40435	S27°35'05.84290"	E151°55'46.56860"	721.953	0.010	
40827	S27°32'56.65292"	E151°59'35.48939"	654.522	0.010	
40828	S27°32'10.35922"	E151°57'09.80324"	648.800	0.008	
59005	S27°33'01.24377"	E151°54'10.24526"	655.128	0.012	

Error Ellipse Components

Point ID	Semi-major axis (Meter)	Semi-minor axis (Meter)	Azimuth
12514	0.005	0.004	19°
40424	0.008	0.006	173°
40435	0.006	0.004	167°
40827	0.007	0.005	171°
40828	0.005	0.004	3°
59005	0.006	0.005	7°

Adjusted GPS Observations

Observation ID		Observation	A-posteriori Error	Residual	Standardized Residual
40828 --> 12514 (V8)	**Az.**	185°21'57"	0.314 sec	-0.106 sec	-0.732
	ΔHt.	-15.333 m	0.012 m	0.000 m	0.041
	Ellip Dist.	3158.963 m	0.006 m	-0.007 m	-2.270
40435 --> 40827 (V16)	**Az.**	57°40'12"	0.223 sec	-0.258 sec	-1.089
	ΔHt.	-67.431 m	0.016 m	0.011 m	0.903
	Ellip Dist.	7432.800 m	0.006 m	0.012 m	2.161
40435 --> 12514 (V6)	**Az.**	41°22'50"	0.364 sec	0.023 sec	0.132
	ΔHt.	-88.486 m	0.014 m	-0.009 m	-0.830
	Ellip Dist.	3007.089 m	0.005 m	-0.005 m	-1.799
40435 --> 40424 (V15)	**Az.**	170°15'12"	0.394 sec	0.146 sec	0.794
	ΔHt.	1.132 m	0.014 m	-0.008 m	-0.857
	Ellip Dist.	2872.482 m	0.009 m	-0.011 m	-1.620
40827 --> 59005 (V12)	**Az.**	269°04'19"	0.174 sec	0.089 sec	0.761
	ΔHt.	0.606 m	0.017 m	-0.028 m	-1.097
	Ellip Dist.	8924.346 m	0.007 m	-0.014 m	-1.619
59005 --> 12514 (V10)	**Az.**	108°50'18"	0.263 sec	0.102 sec	0.595
	ΔHt.	-21.662 m	0.016 m	-0.002 m	-0.092
	Ellip Dist.	4892.243 m	0.005 m	0.008 m	1.429
40827 --> 40828 (V2)	**Az.**	289°36'41"	0.325 sec	0.180 sec	1.324
	ΔHt.	-5.722 m	0.013 m	0.005 m	1.136
	Ellip Dist.	4243.625 m	0.006 m	0.000 m	-0.091
12514 --> 40424 (V9)	**Az.**	196°26'06"	0.232 sec	-0.139 sec	-1.264
	ΔHt.	89.618 m	0.014 m	0.000 m	0.065
	Ellip Dist.	5304.317 m	0.008 m	0.003 m	0.738
40828 --> 59005 (V3)	**Az.**	252°21'06"	0.251 sec	-0.209 sec	-1.243
	ΔHt.	6.329 m	0.014 m	0.003 m	0.430
	Ellip Dist.	5169.535 m	0.006 m	0.002 m	0.596
40435 --> 59005 (V5)	**Az.**	325°25'48"	0.252 sec	0.020 sec	0.139
	ΔHt.	-66.825 m	0.017 m	-0.003 m	-0.237
	Ellip Dist.	4657.374 m	0.006 m	-0.002 m	-0.648
40424 --> 40827 (V18)	**Az.**	40°24'25"	0.201 sec	0.036 sec	0.189
	ΔHt.	-68.563 m	0.017 m	0.005 m	0.413
	Ellip Dist.	8938.454 m	0.008 m	0.003 m	0.515
40435 --> 40828 (V14)	**Az.**	22°55'12"	0.201 sec	0.022 sec	0.073
	ΔHt.	-73.154 m	0.014 m	0.005 m	0.302
	Ellip Dist.	5864.386 m	0.007 m	-0.004 m	-0.401

Covariance Terms

From Point	To Point		Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)
12514	40424	**Az.**	196°26'06"	0.232 sec	1 : 676488	1 : 674192
		ΔHt.	89.618 m	0.014 m		
		ΔElev.	?	?		
		Ellip Dist.	5304.317 m	0.008 m		
12514	40435	**Az.**	221°22'17"	0.365 sec	1 : 565020	1 : 560625
		ΔHt.	88.486 m	0.014 m		
		ΔElev.	?	?		
		Ellip Dist.	3007.089 m	0.005 m		
40435	40424	**Az.**	170°15'12"	0.393 sec	1 : 336234	1 : 336152
		ΔHt.	1.132 m	0.014 m		
		ΔElev.	?	?		
		Ellip Dist.	2872.482 m	0.009 m		
40827	40424	**Az.**	220°22'47"	0.201 sec	1 : 1073787	1 : 1072856
		ΔHt.	68.563 m	0.017 m		
		ΔElev.	?	?		
		Ellip Dist.	8938.454 m	0.008 m		
40827	40435	**Az.**	237°38'26"	0.224 sec	1 : 1166968	1 : 1165187
		ΔHt.	67.431 m	0.016 m		
		ΔElev.	?	?		
		Ellip Dist.	7432.800 m	0.006 m		
40827	40828	**Az.**	289°36'41"	0.326 sec	1 : 749733	1 : 750274
		ΔHt.	-5.722 m	0.013 m		
		ΔElev.	?	?		
		Ellip Dist.	4243.625 m	0.006 m		
40828	12514	**Az.**	185°21'57"	0.314 sec	1 : 513038	1 : 512934
		ΔHt.	-15.333 m	0.012 m		
		ΔElev.	?	?		
		Ellip Dist.	3158.963 m	0.006 m		
40828	40435	**Az.**	202°54'34"	0.201 sec	1 : 878541	1 : 875076
		ΔHt.	73.154 m	0.014 m		
		ΔElev.	?	?		

		Ellip Dist.	5864.386 m	0.007 m		
59005	12514	**Az.**	108°50'18"	0.263 sec	1 : 898715	1 : 896687
		ΔHt.	-21.662 m	0.016 m		
		ΔElev.	?	?		
		Ellip Dist.	4892.243 m	0.005 m		
59005	40435	**Az.**	145°26'32"	0.252 sec	1 : 740097	1 : 736816
		ΔHt.	66.825 m	0.017 m		
		ΔElev.	?	?		
		Ellip Dist.	4657.374 m	0.006 m		
59005	40827	**Az.**	89°06'49"	0.175 sec	1 : 1371420	1 : 1371363
		ΔHt.	-0.606 m	0.017 m		
		ΔElev.	?	?		
		Ellip Dist.	8924.346 m	0.007 m		
59005	40828	**Az.**	72°22'29"	0.252 sec	1 : 937279	1 : 937164
		ΔHt.	-6.329 m	0.014 m		
		ΔElev.	?	?		
		Ellip Dist.	5169.535 m	0.006 m		

Date: 14/10/2008 9:41:40 AM	Project: C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GPS Filtered.vce	Trimble Business Center

G5 - GNSS Filtered Fully Constrained

Project information		**Coordinate System**	
Name:	C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GNSS Fully Constrained.vce	Name:	Map Grid of Australia (GDA)
Size:	283 KB	Datum:	ITRF
Modified:	14/10/2008 1:46:41 PM	Zone:	Zone 56
Reference number:		Geoid:	AUSGEOID98 (Australia)
Description:		Vertical datum:	

Network Adjustment Report

Adjustment Settings

Set-Up Errors

GNSS

Error in Height of Antenna: 0.001 m

Centering Error: 0.001 m

Covariance Display

Horizontal:

Propagated Linear Error [E]: U.S.

Constant Term [C]: 0.000 m

Scale on Linear Error [S]: 1.960

Three-Dimensional

Propagated Linear Error [E]: U.S.

Constant Term [C]: 0.000 m

Scale on Linear Error [S]: 1.960

Adjustment Statistics

Number of Iterations for Successful Adjustment: 3

Network Reference Factor: 1.00

Chi Square Test (95%): Passed

Precision Confidence Level: 95%

Degrees of Freedom: 24

Post Processed Vector Statistics

Reference Factor:	1.00
Redundancy Number:	24.00
A Priori Scalar:	1.67

Control Coordinate Comparisons

Values shown are control coordinates minus adjusted coordinates.

Point ID	ΔNorthing (Meter)	ΔEasting (Meter)	ΔElevation (Meter)	ΔHeight (Meter)
40435	-0.009	-0.001	?	?

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Fixed
12514	396317.287	0.006	6950588.058	0.007	593.542	0.015	
40424	394860.174	?	6945489.266	?	683.293	?	NEe
40435	394349.533	0.007	6948315.233	0.009	682.050	?	e
40827	400593.839	?	6952343.303	?	614.622	?	NEe
40828	396586.030	?	6953734.721	?	608.797	?	NEe
59005	391674.508	0.009	6952126.284	0.010	615.137	0.027	

Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Fixed
12514	S27°33'52.55197"	E151°56'58.95191"	635.602	0.015	
40424	S27°36'37.83052"	E151°56'04.22078"	725.232	?	NEe
40435	S27°35'05.85884"	E151°55'46.48617"	724.061	?	e
40827	S27°32'56.66936"	E151°59'35.40740"	656.668	?	NEe
40828	S27°32'10.37535"	E151°57'09.72110"	650.931	?	NEe
59005	S27°33'01.25973"	E151°54'10.16304"	657.229	0.027	

Error Ellipse Components

Point ID	Semi-major axis (Meter)	Semi-minor axis (Meter)	Azimuth
12514	0.009	0.007	10°
40435	0.011	0.008	164°
59005	0.013	0.011	15°

Adjusted GPS Observations

Transformation Parameters

Deflection in Latitude:	-0.481 sec	**(95%)**	0.776 sec
Deflection in Longitude:	-1.381 sec	**(95%)**	0.613 sec
Azimuth Rotation:	-0.243 sec	**(95%)**	0.217 sec
Scale Factor:	1.00000051	**(95%)**	0.00000105

Observation ID		Observation	A-posteriori Error	Residual	Standardized Residual
40827 --> 40828 (V2)	**Az.**	289°36'41"	0.217 sec	0.252 sec	0.826
	ΔHt.	-5.707 m	0.017 m	0.020 m	2.420
	Ellip Dist.	4243.630 m	0.004 m	0.006 m	1.204
40435 --> 12514 (V6)	**Az.**	41°22'50"	0.513 sec	0.169 sec	0.654
	ΔHt.	-88.467 m	0.016 m	0.011 m	0.635
	Ellip Dist.	3007.086 m	0.007 m	-0.007 m	-1.822
40828 --> 12514 (V8)	**Az.**	185°21'57"	0.429 sec	-0.185 sec	-0.906
	ΔHt.	-15.335 m	0.017 m	-0.003 m	-0.424
	Ellip Dist.	3158.962 m	0.008 m	-0.007 m	-1.688
40435 --> 40424 (V15)	**Az.**	170°15'12"	0.548 sec	0.103 sec	0.354
	ΔHt.	1.162 m	0.009 m	0.027 m	1.670
	Ellip Dist.	2872.486 m	0.010 m	-0.004 m	-0.423
40435 --> 40828 (V14)	**Az.**	22°55'12"	0.277 sec	0.149 sec	0.344
	ΔHt.	-73.132 m	0.014 m	0.034 m	1.436
	Ellip Dist.	5864.381 m	0.008 m	-0.009 m	-0.680
40435 --> 40827 (V16)	**Az.**	57°40'13"	0.255 sec	0.022 sec	0.058
	ΔHt.	-67.425 m	0.021 m	0.020 m	1.035

	Ellip Dist.	7432.798 m	0.008 m	0.010 m	1.239
40827 --> 59005 (V12)	**Az.**	269°04'19"	0.206 sec	0.207 sec	1.220
	ΔHt.	0.620 m	0.025 m	-0.027 m	-0.792
	Ellip Dist.	8924.347 m	0.008 m	-0.012 m	-1.082
12514 --> 40424 (V9)	**Az.**	196°26'06"	0.313 sec	-0.182 sec	-1.167
	ΔHt.	89.629 m	0.020 m	0.009 m	0.793
	Ellip Dist.	5304.316 m	0.009 m	0.004 m	0.643
40435 --> 59005 (V5)	**Az.**	325°25'47"	0.354 sec	-0.038 sec	-0.180
	ΔHt.	-66.805 m	0.022 m	0.012 m	0.535
	Ellip Dist.	4657.368 m	0.009 m	-0.005 m	-1.030
40828 --> 59005 (V3)	**Az.**	252°21'06"	0.336 sec	-0.266 sec	-1.012
	ΔHt.	6.327 m	0.021 m	0.000 m	-0.038
	Ellip Dist.	5169.533 m	0.008 m	0.001 m	0.221
59005 --> 12514 (V10)	**Az.**	108°50'18"	0.368 sec	0.088 sec	0.356
	ΔHt.	-21.662 m	0.023 m	0.001 m	0.024
	Ellip Dist.	4892.240 m	0.008 m	0.006 m	0.752
40424 --> 40827 (V18)	**Az.**	40°24'25"	0.216 sec	0.176 sec	0.580
	ΔHt.	-68.586 m	0.022 m	-0.015 m	-0.751
	Ellip Dist.	8938.452 m	0.009 m	0.001 m	0.053

Covariance Terms

From Point	To Point		Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)
12514	40424	**Az.**	196°26'06"	0.222 sec	1 : 738803	1 : 739421
		ΔHt.	89.630 m	0.015 m		
		ΔElev.	89.751 m	0.015 m		
		Ellip Dist.	5304.318 m	0.007 m		
12514	40435	**Az.**	221°22'17"	0.555 sec	1 : 379192	1 : 379754
		ΔHt.	88.459 m	0.015 m		
		ΔElev.	88.508 m	0.015 m		
		Ellip Dist.	3007.087 m	0.008 m		
40435	40424	**Az.**	170°15'12"	0.468 sec	1 : 315692	1 : 315692

		ΔHt.	1.172 m	0.000 m		
		ΔElev.	1.243 m	0.000 m		
		Ellip Dist.	2872.487 m	0.009 m		
40827	40424	**Az.**	220°22'48"	0.000 sec	1 : 0	1 : 0
		ΔHt.	68.564 m	0.000 m		
		ΔElev.	68.671 m	0.000 m		
		Ellip Dist.	8938.457 m	0.000 m		
40827	40435	**Az.**	237°38'27"	0.248 sec	1 : 1102480	1 : 1102570
		ΔHt.	67.392 m	0.000 m		
		ΔElev.	67.428 m	0.000 m		
		Ellip Dist.	7432.802 m	0.007 m		
40827	40828	**Az.**	289°36'41"	0.000 sec	1 : 0	1 : 0
		ΔHt.	-5.737 m	0.000 m		
		ΔElev.	-5.825 m	0.000 m		
		Ellip Dist.	4243.632 m	0.000 m		
40828	12514	**Az.**	185°21'58"	0.372 sec	1 : 439496	1 : 439398
		ΔHt.	-15.330 m	0.015 m		
		ΔElev.	-15.255 m	0.015 m		
		Ellip Dist.	3158.964 m	0.007 m		
40828	40435	**Az.**	202°54'34"	0.268 sec	1 : 715609	1 : 715720
		ΔHt.	73.129 m	0.000 m		
		ΔElev.	73.253 m	0.000 m		
		Ellip Dist.	5864.384 m	0.008 m		
59005	12514	**Az.**	108°50'19"	0.443 sec	1 : 518258	1 : 517243
		ΔHt.	-21.627 m	0.031 m		
		ΔElev.	-21.595 m	0.031 m		
		Ellip Dist.	4892.243 m	0.009 m		
59005	40435	**Az.**	145°26'32"	0.398 sec	1 : 485097	1 : 485961
		ΔHt.	66.831 m	0.027 m		
		ΔElev.	66.913 m	0.027 m		
		Ellip Dist.	4657.370 m	0.010 m		
59005	40827	**Az.**	89°06'49"	0.236 sec	1 : 969758	1 : 969749

		ΔHt.	-0.561 m	0.027 m		
		ΔElev.	-0.515 m	0.027 m		
		Ellip Dist.	8924.351 m	0.009 m		
59005	40828	**Az.**	72°22'29"	0.398 sec	1 : 545665	1 : 545685
		ΔHt.	-6.298 m	0.027 m		
		ΔElev.	-6.340 m	0.027 m		
		Ellip Dist.	5169.536 m	0.009 m		

Date: 14/10/2008 1:49:15 PM	Project: C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GNSS Fully Constrained.vce	Trimble Business Center

G6 - GNSS Filtered less Two Minutes

Project information		**Coordinate System**	
Name:	C:\Documents and Settings\lcurran\My Documents\Trimble Business Center\LC GNSS Filtered Time.vce	Name:	Default
Size:	269 KB	Datum:	WGS 1984
Modified:	15/10/2008 12:08:15 PM	Zone:	Default
Reference number:		Geoid:	
Description:		Vertical datum:	

Network Adjustment Report

Adjustment Settings

Set-Up Errors

GNSS

Error in Height of Antenna: 0.001 m

Centering Error: 0.001 m

Covariance Display

Horizontal:

Propagated Linear Error [E]: U.S.

Constant Term [C]: 0.000 m

Scale on Linear Error [S]: 1.960

Three-Dimensional

Propagated Linear Error [E]: U.S.

Constant Term [C]: 0.000 m

Scale on Linear Error [S]: 1.960

Adjustment Statistics

Number of Iterations for Successful Adjustment:	2
Network Reference Factor:	1.00
Chi Square Test (95%):	Passed
Precision Confidence Level:	95%
Degrees of Freedom:	21

Post Processed Vector Statistics

Reference Factor:	1.00
Redundancy Number:	21.00
A Priori Scalar:	1.18

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Fixed
12514	4632.160	0.003	-1578.539	0.004	?	?	
40424	3129.492	0.005	-6665.558	0.007	?	?	
40435	2643.813	0.003	-3834.434	0.005	?	?	
40827	8925.262	0.005	139.228	0.006	?	?	
40828	4928.842	0.004	1566.464	0.005	?	?	
59005	1.980	0.004	1.169	0.005	?	?	

Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Fixed
12514	S27°33'52.53577"	E151°56'59.03432"	633.451	0.009	
40424	S27°36'37.81431"	E151°56'04.30346"	723.069	0.012	
40435	S27°35'05.84285"	E151°55'46.56876"	721.940	0.010	
40827	S27°32'56.65282"	E151°59'35.48956"	654.504	0.011	
40828	S27°32'10.35912"	E151°57'09.80339"	648.784	0.008	
59005	S27°33'01.24373"	E151°54'10.24538"	655.115	0.012	

Error Ellipse Components

Point ID	Semi-major axis (Meter)	Semi-minor axis (Meter)	Azimuth
12514	0.005	0.004	13°
40424	0.008	0.006	169°
40435	0.006	0.004	163°

40827	0.007	0.006	169°
40828	0.006	0.004	179°
59005	0.006	0.005	5°

Adjusted GPS Observations

Observation ID		Observation	A-posteriori Error	Residual	Standardized Residual
40827 --> 59005 (V12)	**Az.**	269°04'19"	0.183 sec	0.094 sec	0.843
	ΔHt.	0.610 m	0.019 m	-0.044 m	-1.770
	Ellip Dist.	8924.347 m	0.007 m	-0.018 m	-2.172
40828 --> 12514 (V8)	**Az.**	185°21'57"	0.325 sec	-0.116 sec	-0.817
	ΔHt.	-15.333 m	0.013 m	-0.001 m	-0.145
	Ellip Dist.	3158.964 m	0.006 m	-0.006 m	-2.070
40435 --> 40827 (V16)	**Az.**	57°40'12"	0.237 sec	-0.174 sec	-0.661
	ΔHt.	-67.436 m	0.017 m	0.009 m	0.682
	Ellip Dist.	7432.802 m	0.007 m	0.011 m	1.921
40435 --> 12514 (V6)	**Az.**	41°22'50"	0.387 sec	0.026 sec	0.143
	ΔHt.	-88.489 m	0.015 m	-0.010 m	-0.800
	Ellip Dist.	3007.089 m	0.005 m	-0.005 m	-1.816
12514 --> 40424 (V9)	**Az.**	196°26'06"	0.244 sec	-0.160 sec	-1.508
	ΔHt.	89.618 m	0.016 m	0.000 m	0.030
	Ellip Dist.	5304.316 m	0.008 m	0.002 m	0.618
40435 --> 40424 (V15)	**Az.**	170°15'12"	0.415 sec	0.186 sec	0.900
	ΔHt.	1.129 m	0.015 m	-0.006 m	-0.631
	Ellip Dist.	2872.481 m	0.009 m	-0.010 m	-1.407
40828 --> 59005 (V3)	**Az.**	252°21'06"	0.267 sec	-0.230 sec	-1.237
	ΔHt.	6.331 m	0.015 m	0.007 m	0.891
	Ellip Dist.	5169.537 m	0.006 m	0.003 m	0.878
40827 --> 40828 (V2)	**Az.**	289°36'41"	0.351 sec	0.155 sec	0.965
	ΔHt.	-5.721 m	0.014 m	0.006 m	1.183
	Ellip Dist.	4243.625 m	0.006 m	-0.001 m	-0.228
59005 --> 12514 (V10)	**Az.**	108°50'18"	0.273 sec	0.086 sec	0.479
	ΔHt.	-21.664 m	0.017 m	-0.003 m	-0.169

	Ellip Dist.	4892.243 m	0.006 m	0.007 m	1.163
40435 --> 59005 (V5)	**Az.**	325°25'47"	0.261 sec	0.044 sec	0.289
	ΔHt.	-66.825 m	0.018 m	-0.009 m	-0.561
	Ellip Dist.	4657.374 m	0.007 m	-0.001 m	-0.348
40435 --> 40828 (V14)	**Az.**	22°55'12"	0.217 sec	0.072 sec	0.224
	ΔHt.	-73.156 m	0.015 m	0.008 m	0.466
	Ellip Dist.	5864.387 m	0.007 m	-0.005 m	-0.498
40424 --> 40827 (V18)	**Az.**	40°24'25"	0.216 sec	0.077 sec	0.365
	ΔHt.	-68.565 m	0.018 m	0.005 m	0.348
	Ellip Dist.	8938.456 m	0.009 m	0.003 m	0.469

Covariance Terms

From Point	To Point		Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)
12514	40424	**Az.**	196°26'06"	0.244 sec	1 : 670901	1 : 668184
		ΔHt.	89.618 m	0.016 m		
		ΔElev.	?	?		
		Ellip Dist.	5304.316 m	0.008 m		
12514	40435	**Az.**	221°22'17"	0.388 sec	1 : 552264	1 : 548785
		ΔHt.	88.489 m	0.015 m		
		ΔElev.	?	?		
		Ellip Dist.	3007.089 m	0.005 m		
40435	40424	**Az.**	170°15'12"	0.415 sec	1 : 322659	1 : 322577
		ΔHt.	1.129 m	0.015 m		
		ΔElev.	?	?		
		Ellip Dist.	2872.481 m	0.009 m		
40827	40424	**Az.**	220°22'48"	0.216 sec	1 : 1044927	1 : 1044101
		ΔHt.	68.565 m	0.018 m		
		ΔElev.	?	?		
		Ellip Dist.	8938.456 m	0.009 m		
40827	40435	**Az.**	237°38'26"	0.238 sec	1 : 1118258	1 : 1116900

		ΔHt.	67.436 m	0.017 m		
		ΔElev.	?	?		
		Ellip Dist.	7432.802 m	0.007 m		
40827	40828	**Az.**	289°36'41"	0.352 sec	1 : 693666	1 : 694205
		ΔHt.	-5.721 m	0.014 m		
		ΔElev.	?	?		
		Ellip Dist.	4243.625 m	0.006 m		
40828	12514	**Az.**	185°21'57"	0.324 sec	1 : 501572	1 : 501527
		ΔHt.	-15.333 m	0.013 m		
		ΔElev.	?	?		
		Ellip Dist.	3158.964 m	0.006 m		
40828	40435	**Az.**	202°54'34"	0.217 sec	1 : 854170	1 : 850682
		ΔHt.	73.156 m	0.015 m		
		ΔElev.	?	?		
		Ellip Dist.	5864.387 m	0.007 m		
59005	12514	**Az.**	108°50'18"	0.273 sec	1 : 862749	1 : 860168
		ΔHt.	-21.664 m	0.017 m		
		ΔElev.	?	?		
		Ellip Dist.	4892.243 m	0.006 m		
59005	40435	**Az.**	145°26'32"	0.261 sec	1 : 702853	1 : 701112
		ΔHt.	66.825 m	0.018 m		
		ΔElev.	?	?		
		Ellip Dist.	4657.374 m	0.007 m		
59005	40827	**Az.**	89°06'49"	0.184 sec	1 : 1301289	1 : 1301225
		ΔHt.	-0.610 m	0.019 m		
		ΔElev.	?	?		
		Ellip Dist.	8924.347 m	0.007 m		
59005	40828	**Az.**	72°22'29"	0.268 sec	1 : 883718	1 : 883532
		ΔHt.	-6.331 m	0.015 m		
		ΔElev.	?	?		
		Ellip Dist.	5169.537 m	0.006 m		

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