University of Southern Queensland

Faculty of Health, Engineering and Sciences

RTK GNSS in Cadastral Surveying

A dissertation submitted by

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ABSTRACT

Real Time Kinematic Global Navigation Satellite System observations have become an increasing prevalent method of surveying in all forms of the surveying and spatial science industry. One area where the use of RTK raises particular concern is for cadastral surveying, where it has been realised by many parties that clarification is needed with regards to how RTK technology is to be used. These concerns stem from a lack of understanding about the capabilities and limitations of RTK and also how it should be used in regards to best practice recommendations. The aim of this dissertation is to substantiate the Surveyors Board of Queensland guideline regarding the use of RTK for cadastral surveys. This dissertation will aim to augment several key areas of the guideline; short line observation, referencing and minimum backsight lengths with empirically tested data that will determine how and when RTK is applicable for these applications and recommend the best practices to achieve these. The aims of the testing are to determine what is the minimum length of a short line RTK is capable of accurately observing, what is the minimum observable length of a backsight line to accurately orientate a survey and at what lengths can RTK be used to accurately observe reference marks. Testing of these elements will be conducted with regard to the survey standards' accuracy referenced in the guideline and also compare the accuracy results to the capabilities of a total station (as the conventional method of cadastral surveying). Because the best practices for the observation of these three elements is yet unknown, various methods will be employed to ascertain which method yields the most accurate and precise results.

The results of the testing conducted found answers to meet the aims of this dissertation but it also served to identify the impact errors and inaccuracies can have on the observations. It was found that observation bias in the RTK measurements significantly affected the results of the observations and caused these to appear potentially far worse than the results may actually be. Moreover it was found that RTK is not an appropriate means of referencing; the errors in the distance led to errors in the bearing of the line that were too great to accept based on the 95% confidence interval. The minimum backsight length required for an RTK observation to meet TS bearing accuracy was identified as 180m which is slightly shorter than the recommendations of the SBQ. It was found though that in difficult circumstances where accuracy may allowably be reduced for the use of RTK, the minimum backsight length was determined to be 120m, which is slightly longer than the SBQ recommendations. Both of these minimum lengths were only found to be possible when using the most rigorous observation methods where anything less would not suit. Finally it was found that RTK observations of significantly shorter lengths than recommended by the survey standards' (640m) and adopted by some jurisdictions (120m) could still achieve the survey standards' accuracy; it was found that the length fell to just 40m. This was found to be observable when using only moderately rigorous methods and would be easily repeatable. Considering the effect observation bias had on the results, several recommendations were made regarding how best to minimise this impact, as well as the recommendation that a 99% confidence interval should be used when analysing the capability of RTK as the standard 95% confidence interval potentially allows for too great a degree of uncertainty. The conclusion of this dissertation found that the aims were met and the instances where RTK is applicable for short line and referencing observations and the minimum observable backsight length was established.

UNIVERSITY OF SOUTHERN QUEENSLAND
FACULTY OF HEALTH, ENGINEERING AND SCIENCES

ENG4111 & ENG4112 *RESEARCH PROJECT*

LIMITATIONS OF USE

CANDIDATES CERTIFICATIONS

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

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

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________________ *(Date)*

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MinStaff Survey

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ABBREVIATIONS & NOMENCLATURE

AR	–	Ambiguity Resolution (initialisation)
B&D	–	Bearing and distance
CI	–	Confidence Interval
CORS	–	Continuously Operating Reference Station
CQ	–	Co-ordinate Quality
DGPS	–	Differential Global Positioning System
EDM	–	Electronic Distance Measurement
FL/FR	–	Face Left/Face Right
FOC	–	Full Operational Capability
GNSS	–	Global Navigation Satellite System
GPS	–	Global Positioning System
ICSM	–	Intergovernmental Committee on Surveying and Mapping
MGA	–	Map Grid of Australia
PDOP	–	Position Dilution of Precision
PSM	–	Permanent Survey Mark
RTK	–	Real Time Kinematic
SBQ	–	Surveyors Board of Queensland
SF	–	Scale Factor
TBC	–	Trimble Business Centre
TS	–	Total station
USQ	–	University of Southern Queensland

"SBQ guideline accuracy" and "SBQ accuracy" actually refers to the accuracy reference made by the SBQ in the guidelines, which refers to the *Cadastral Survey Requirements* document released by the Department of Environment and Resource Management and referred to in certain other guidelines such as the NSW and ACT.

CHAPTER 1: INTRODUCTION

1.1 THE PROBLEM

Late in 2012 the Surveyors Board of Queensland (SBQ) released a document entitled *RTK GNSS for Cadastral Surveys* to be used as the guideline for, as the name suggests, the use of RTK for cadastral surveys. The publication of this document resulted from the realisation that clarification was needed for the Queensland surveying community (under the authority of SBQ) regarding how RTK GNSS (referred to from here forth as simply RTK) technology was to be used in accordance with the specifications and practices required for cadastral surveys. Craig Roberts clarifies the misunderstandings of surveyors in the area of RTK in *GPS for Cadastral Surveying – Practical Considerations*;

> "*This has been due to a number of reasons such…. a lapsed understanding of geodesy, confusion about GPS surveying capabilities and best practice techniques, uncertainty over how to best utilise existing GPS services and infrastructure, lack of time/resources to invest into GPS surveying training, and for the cadastral surveyor uncertainty over what is acceptable practice to satisfy current survey regulations in their particular state or territory*" (Roberts, 2005, pg. 1).

The term *realisation that clarification was needed* stems from the lack of knowledge about how and when RTK should be applied for cadastral purposes, as RTK is inherently not as simplistic as conventional methods due to the ambiguities in observations and the general misunderstandings within the surveying industry about RTK limitations and actual use. This guideline is not explicit in many areas and does not feature empirically tested data to substantiate its processes and practices, particularly *section C. Observation Techniques*, *section F. Grid and Ground Distances* and *section G. Connections and Radiations* for which this research is concerned. This is due in part to the limited jurisdiction of the SBQ and the means by which they can guide survey practices. Overall this testing is necessary so as to determine how and when RTK should be used for cadastral applications and once the suitable situations (if existent) are established, the findings of this dissertation can be used to create stability and similarity in how surveyors use RTK.

The guideline is a necessary publication due in part to the *errors* associated with RTK and the errors this has led to when using RTK and in part to facilitate the understanding of the limitations and use of RTK in the cadastral surveying process. In particular, RTK use has become more prominent in the cadastral field however there are industry misconceptions about how appropriate RTK is for this purpose and when and how it should be implemented. The use of RTK for cadastral purposes is considered a reasonably fledgling concept, as there is relatively limited research into the area and there is still much confusion and misunderstanding surrounding it. The fact that these misconceptions actually exist become apparent from the opening lines of the SBQ guidelines;

> "*The Surveyors Board of Queensland has recently become aware of some issues with the use of GNSS/GPS, particularly Real-Time Kinematic (RTK), on cadastral surveys.*"

What these issues are will be investigated in *Chapter 2: Literature Review*.

As opposed to independent surveying works (works where the surveyor may not need to rely on others work i.e. stockpile volume, detail and contour etc.) cadastral surveys are a function of a surveyors own work and of historical works. A cadastral plan is not maintained by the entity that creates it; it becomes a distributable document (under the Trade Practices Act 1974, Part IIIA – Access to services, Division 3) which others can and will rely upon in future instances. The lodgement of a cadastral plan can of course only be done by an endorsed cadastral surveyor of the SBQ. This concept worked well with total stations (TS) being the principal method of carrying out cadastral surveys, because while practices were not generally uniform throughout the industry per se, accuracy and precision were easily established, understood and all processes were easily repeatable. Now that RTK has been introduced into mainstream cadastral surveying there are greater misperceptions between practices, methods and results between TS and RTK. The problem that arises here is that there are not only problems with RTK observations themselves, but the cadastral database will be made up of a combination of TS and RTK data which is collected by through different practices and which may be inherently incompatible.

Given these differences the SBQ guidelines needs to be reconsidered and extended to clarify certain issues more detail so that;

a) there can again be practice uniformity in regard to minimum acceptable practices throughout the industry,
b) there can be greater understanding of the application of RTK for cadastral surveying
c) there can be greater understanding of how and when RTK should be applied
d) all surveyors observe appropriate measurement techniques,
e) so that there is a greater understanding of the limitations, processes and purposes of RTK surveying

These goals were met through the SBQ guideline which in a short overview were given;

> "*This document is designed to provide a summary of overarching principles that should govern how surveyors go about this task* [use of RTK]. *It is not exhaustive: rather it is essentially an interim document designed to bring attention to some common errors in practice and will be later supplemented by more detailed guidelines. It is also designed to be read in conjunction with best practice guidelines such as SP#1*)."
>
> (Surveyors Board of Queensland, pg. 2, 2012*)*

This basic description refers to the document as a *"summary of overarching principals*" (*Surveyor Board of Queensland, pg. 2, 2012)* as opposed to prescribed methods and practices that all surveyors should follow. This inherently causes problems because as the document is only a guideline rather than an enforced code, some surveyors will continue to observe their own practices and discontinuity will remain between the information collected and shown on cadastral plans – i.e. how one surveyor measures with RTK will be different to how another surveyor measures (this does not matter per se, so long as the methods are valid with respect to the SBQ guideline and other relevant standards). The guideline is realised as not being complete though, stating that it will be supplemented by more specific future guidelines.

While the guideline may not necessarily be complete or comprehensive, it does cover most areas regarding RTK use to varying degrees of detail – especially when read in conjunction with best practice guidelines as intended. The SBQ guideline covers multiple areas, but to further clarify (and where necessary quantify) every section of the guideline would be a dissertation in-and-of itself. The main focus of this project is concerned with *section C. Observation Techniques*, in part *section F. Grid and Ground Distances* and in part *section G. Connections and Radiations*. As mentioned before the guideline is non-explicit in many aspects due to the SBQ only being able to detail elements considered within their domain, so it is the intention of this dissertation to substantiate *sections C., F. and G.* with rigorously tested physical practices and empirical data. This guidelines does not require all observations to be done exactly the same so long as their practices are appropriate and meet legislative specifications, however there is a great deal of confusion and measurements of different *quality* (accuracy, precision, time etc.). Therefore it is again the intention of this dissertation to clarify these elements of the guidelines so that it can be utilised and easily integrated throughout the surveying community. There will be some overlap with other sections of the guideline however it is not the intention of this dissertation to fully explore these concepts. It should also be noted that this dissertation will be carried out with respect to the other sections of the guideline to overall function in a manner indicative of the aims of the guideline.

Observation techniques relate not only on the techniques a surveyor utilises to observe a point (observation type, duration, equipment, etc.) but also to how he observes in regards to other points and the rest of the survey. This includes the main aspects this dissertation aims to investigate;

- boundary line observations (referred to from here forth as short lines in accordance with the guidelines definition)
- referencing (particularly observation time length)
- backsight length (directly relating to TS)

These 3 elements are common tasks a surveyor will encounter in the conduct of a cadastral survey and are areas of great confusion which is where a great deal of the misunderstanding and improper use of RTK is generated from.

1.2 THE PROBLEM DEFINED

These three tasks will become the focus of this dissertation with the broad aim being to properly test and observe these in a manner which will provide the appropriate (accurate and precise) measurements and be applicable to real-world situations. But when these aspects are measured it is essential to understand just how good the results actually are, the obvious base of comparison being conventional methods; comparative to TS. When considering what answers will be generated in the end there must be a standard that surveyors can strive for to match or exceed.

From the methods detailed in the guideline and associated literature, this will form the basis of the practical standards. By reaching or exceeding the guidelines standards we are officially satisfying the requirements of the SBQ for utilising RTK GNSS in cadastral surveys. Furthermore given that TS observation quality is generally accepted to be more accurate than RTK over short distances (Gibbings, 2013) – and it is the conventional method for cadastral surveys – for the purposes of this dissertation it will be used as the standard against which to compare the RTK results; i.e. the observations will be of or not of TS quality. TS observations will be the base of comparison as, along with RTK, it is the most commonly used method of distance observation and the most common mean of performing cadastral surveys (it is essentially appreciated there will be differences between RTK and TS). Therefore there will be two quality standards, the absolute minimum standard to perform a cadastral survey as defined by the SBQ guidelines and the more rigorous TS quality standard.

- **Short Lines;**

Short lines generally refer to observations from one boundary corner to another. In all observations, whether by TS or RTK, there are inherent errors present which cause inaccuracies in the true (accurate and precise) position of the point. This ambiguity itself is a function of the errors in the observation; ranging from the propagated errors of the manufacturer's specification errors (measurement limitations), human errors, observation method errors and systematic, gross and random errors.

More specifically when considering RTK, the error of the observation will be a function of the ambiguity solution and environmental factors (multipath, ionosphere, troposphere etc.). All of these combine to create an error in the line of observation, a result affecting both the bearing and the distance. For RTK this ambiguity is manifested in the position of the point itself (error ellipse) and propagates between the two ends of the line to create an overall error. In TS this error manifests over the length of the line itself from an initial accuracy error given by the manufactures specifications combined with an error over the distance measured (i.e. 3mm + 3ppm). The accuracy error of a TS is of a lower magnitude than RTK over short distances, though the error increases in relation to distance (+ Xppm), so RTK will provide better results over long distances.

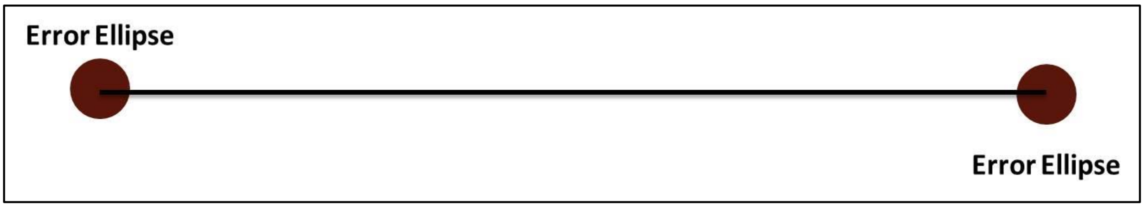

Figure 1.1 – Referencing diagram (Gibbings', 2013)

The concept behind testing short lines will be to determine what is the minimum length of a line that will be of similar accuracy to TS observed line, and hopefully, surpass the survey standards' accuracy; i.e. *SP1* or *Cadastral Survey Requirements*. Practically, determining this will be critical for the;

- re-measurement of existing short lines
    - so that distances similar to convention method accuracy are observed
    - so that cadastral plans are not falsely challenged/changed
- and the determination of new boundary lines
    - so that true bearing and distances (B&D) are given
    - no incorrect observations on plans are lodged

When TS and SBQ guideline accuracy is met, this will become the minimum distance and observation technique a surveyor should observe when measuring short lines, anything shorter than this (thus providing error outside of the standards) will need to be either a) observed more rigorously or b) observed in a manner similar to referencing or c) observed by convention methods.

- **Referencing**

Referencing refers to the measurement of a point, usually a corner mark, to reference and/or reinstate marks within close proximity to that cadastral mark. Generally these marks are less than 10-20m away and are used to verify the accuracy of an existing mark, for corner referencing and to assist in reinstating corners. There is no industry standard that defines within what proximity a mark must be to a corner to be called a reference mark, however for the purposes of this dissertation it was accepted to be up to 20m. This was chosen as any length greater than that 20m can be considered within the range of short lines (i.e. a boundary line).

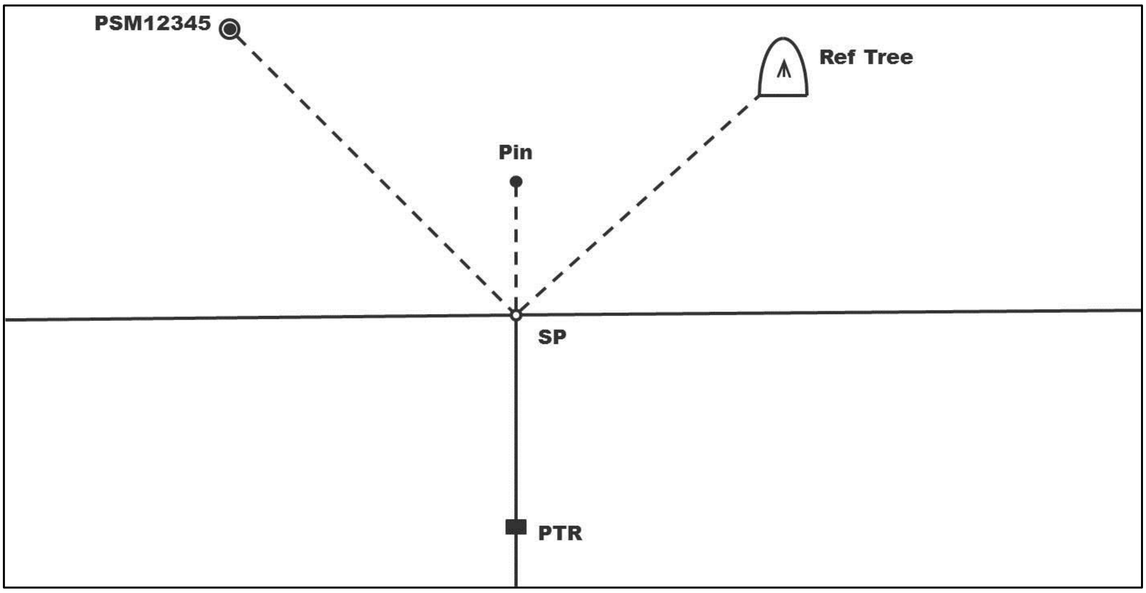

Figure 1.2 – A referencing diagram where SP represents the corner itself while PSM, Pin, Ref Tree and PTR represent the marks that would be observed to reference and reinstate SP (Gibbings', 2013)

It is similar to the concept of short lines however when referencing errors are accentuated by the short length of the baseline as opposed to being distributed over greater lengths. Contrary to short line observations, where the errors are a function of the length of the line, referencing is both a function of the length of the line (as errors are accentuated over that short distance) but also a function of the observation time, as a longer observation tends to lead the greater convergence of measurements around that true value (explored in *Chapter 2*). Note; while 2mm positioning error is still 2mm positioning error over 5m or 5000m (especially when bearings are a function of distances in RTK observations), that 2mm will have a much greater influence on the error and reality of the bearing and misclose over 5m as opposed to 5000m.

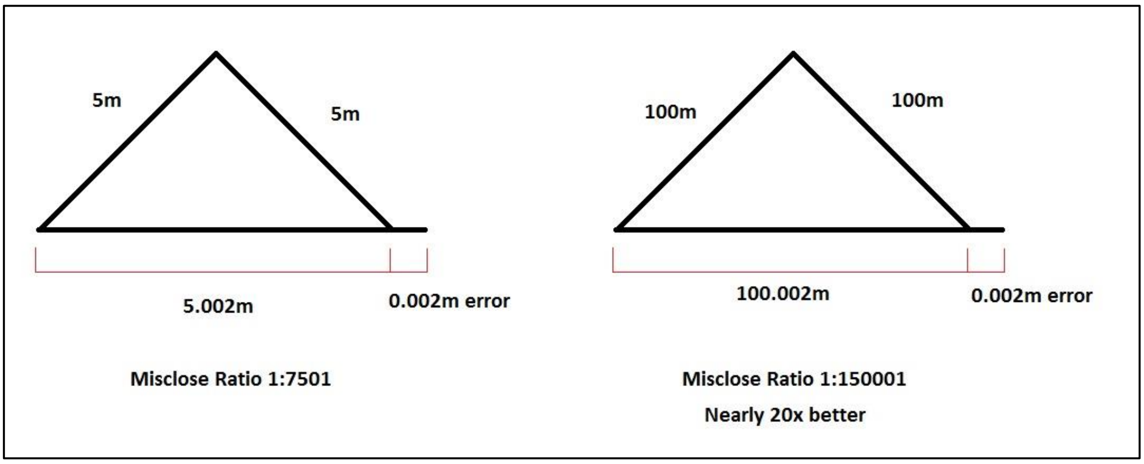

Figure 1.3 – A diagram illustrating the impact 2mm error has on closed figures or 5m and 100m lines

In short line observations a surveyor is able to measure longer minimum lengths so as to achieve the survey standards' recommended accuracy – where anything that falls under that minimum distance can be achieved by conventional methods, in the case of referencing the surveyor will be measuring the very short distances, therefore being unable to simply move further away to *stretch out* errors (thereby creating better closes). The thought process in this case is that surveyors will accept errors in the B&D of the observed short lines however these should not be of a greater magnitude than the errors measurable by TS. Therefore the question becomes what must a surveyor do when using RTK for referencing to achieve the standards? This will be a function of the observation method, time, process and equipment. Essentially a surveyor is not able to change the minimum distance so the question of how to reference with RTK transitions to what can be changed to improve results?

- **Backsight Distances**

When establishing the orientation and scale for a job in the local plane, appropriate backsight/s of a suitable length must be observed to. This task is absolutely critical to re-establishing the survey azimuth and, especially in regard to RTK surveys, scaling the RTK measured lengths to the survey plan lengths (i.e. real world). This task is related to short line observations to some degree however BS lengths essentially must be of a greater degree of accuracy so as to correctly establish the survey. More so than referencing or short lines, the horizontal bearing aspect of measurements is of critical importance here as it will establish the orientation of the survey. Moreover if the current cadastral survey needs to be scaled from one co-ordinate system to another – or between TS and GNSS – the distance observation must be true too. The general rule when establishing a survey is to utilise the longest backsight available – between good marks – thereby minimising the B&D errors as much as possible. This however is up to the discretion of the surveyor and the longest line might not necessarily be chosen as opposed to the most appropriate.

By quantifying and qualifying these 3 entities it is the hope of this dissertation to clarify the SBQ guideline as much as possible in regards to observation techniques and indeed the application of RTK for cadastral surveys. As mentioned before, while this is a relatively narrow project scope, there will be overlap into other sections of the guideline. It is not the intention of this dissertation however to prove the sections outside of the project scope and the aim of the testing will be to follow the guideline as much as possible.

1.3 RESEARCH AIMS

The overall aim of this dissertation is to physically test the three outlined surveying tasks; short line observation, referencing and minimum backsight lengths so as to determine the minimally acceptable practices and values of observation these entities. This dissertation will carry out testing in accordance with reasonable professional practice (as outlined by the *Surveyors Board of Queensland – Code of Practice (Surveyors Act 2003)*), discussed in greater depth later. Moreover the aim of the actual testing is to achieve SBQ guideline accuracy for the use of RTK GNSS for cadastral surveys and determine whether RTK can in fact achieve TS standard similar observation accuracy. Essentially the testing will result in the empirical determination of how and when RTK is applicable and its limitations.

1.4 RESEARCH OBJECTIVES

- To determine empirical results that will definitively establish what practices must be employed to achieve SBQ guideline and determine whether TS similar accuracy can be achieved with RTK
- To produce data which can be justified and substantiated so that this dissertation will have a basis in common practice – this will be achieved by conforming to the SBQ guideline
- To conduct testing in a manner which inherently covers the practices recommended by the SBQ guideline but also in a manner which is indicative of *reasonable professional practice* so that this research methodology can be carried over to real world situations
- Ultimately, to refer the finding of this dissertation to the SBQ to supplement the non-explicit and unquantified areas of *section C. Observation Techniques*, *section F. Grid and Ground Distances* and *section G. Connections and Radiations* of the guideline with empirically tested data

1.5 RESEARCH SCOPE AND LIMITATIONS

As was introduced in section *1.1 The Problem* this dissertation specifically target aspects of the SBQ guideline; *section C. Observation Techniques*, *section F. Grid and ground Distances* and *section G. Connections and Radiations*. It is therefore the intention to only research and produce data relevant on these sections, which can be directly integrated into these sections to supplement it (not necessarily redefine it). There is the allowance however that there will be overlap into various other sections of the guideline in the course of this research, work and testing and perhaps even into other areas of surveying. While this may occur, it is outside the scope of this project to delve deeper into these concepts than is needed to undertake the practices required to achieve the principal aims and objectives. Therefore these overlapping concepts may be researched for the benefit of the dissertation and/or the author/readers however it is not the intention to produce more information on each than is absolutely necessary.

This dissertation aims to extensively test the 3 entities; short line observations, referencing and minimum backsight lengths. The author acknowledges there are many other tasks required for a cadastral survey however given the limited time period, all testing is limited to empirically testing these 3 concepts.

Other concepts outside the scope of this dissertation include, but are not limited to (this is by no means an exhaustive list);

- Undertaking cadastral surveys
- Cadastral plan creation and lodgement
- GNSS operation – refer to manufacturers' specifications
- Error minimisation
- Ambiguity solutions
- Geoid and ellipsoid models
- Co-ordinate systems
- Ideal observation conditions
- Control establishment
- Control array establishment
- Equipment calibration, testing and maintenance
- Equipment validation
- Differential Global Positioning System (DGPS)
- Legal traceability of measurements and survey integration

Consideration has been taken to limit the scope of this dissertation as much as possible to ensure it is clear and focussed, and that it is not used outside of its intended purpose (refer to *Limitation of Use*) though there may be some instances where this dissertation is applicable. It must be stated that the scope of this project is to directly test short line observations, referencing and minimum backsight lengths in regards to clarifying *section C., F.* and *G.* of the SBQ guideline with empirically tested data that meets the SBQ guideline standards for practice, *reasonable profession practice* standards and where possible, will be applicable to real world situations that can be reproduced. This is the intended scope of this work, anything addition is unintended and purely coincidental.

1.6 JUSTIFICATION OF DISSERTATION

This dissertation is a worthwhile and valuable undertaking given the desired project outcomes. By the full completion of the aims and objectives this research, regardless of the outcomes, will make a meaningful contribution to the professional surveying community in accordance with the objectives of courses ENG4111 and ENG4112. The intention of this dissertation is not to be privatised or kept as an 'in-house' practice but rather to spread the knowledge so that all can benefit.

By contributing the findings of this project to the SBQ for review and possible inclusion into the guideline, this dissertation will aid the understanding of RTK use for cadastral purposes throughout the industry and to a degree, standardise the methods by with surveyor undertake this task.

1.7 IMPLICATIONS

1.7.1 CONSEQUENTIAL EFFECTS

As professional we must consider the impact we leave on society and the environment in the course of our professions and lives. With sustainability and preservation in mind, we should in no way disrupt, destroy, corrupt or endorse unsustainable practices, and we should take proactive strides to limit our impacts and footprints as much as possible. We do accept that in some situations where we will have an impact and we accept responsibility for that; however it is also our responsibility to find alternative less impactive methods, observe best practices and perform our work in a professional and sustainable manner.

The intentions and testing of this dissertation are in no way designed to interfere with, contact, restrict or otherwise inhibit any persons or property. This dissertation will not require any contact with or co-operation from the public and can be carried out solely without impact. Moreover the given project objectives will in no way will cause disruption or change within society. This work is designed for use by cadastral surveyors, not the public therefore even the knowledge of and use of this material is limited to professionals who understand the implications of their practice.

The main area of concern with regards to undertaking this study is the possible impact on the environment when field testing. The actual methods of testing are discussed later however it will be solely my responsibility to ensure the environment is not heavily impacted nor destroyed, to ensure it is not polluted or otherwise adversely affected. While environmental impact is expected to be very minimal it must be guaranteed that the environment is returned to its original state at the end of works and that no lasting impression is made.

1.7.2 ETHICAL RESPONSIBILITY

Additionally professionals have an ethical responsibility that they must adhere to under the requirements of their professions respective *Code of Ethics/Conduct/Practice*. It is therefore the intent of this dissertation to follow the standards as prescribed by the *Surveyors Board of Queensland – Code of Practice (Surveyors Act 2003)*. Importantly, in line with adhering to this Act, no work or impact can take the reaction of "it's not my worry if", "it's not illegal if" or "someone told me to"; I must take full responsibility for actions resulting from this dissertation and in no way act in a manner contradictory to the *Code of Practice*.

1.8 REASONABLE PROFESSIONAL PRACTICE

As it is the intention of this dissertation to be submitted to the SBQ to potentially substantiate their guidelines, it would follow that this dissertation must be performed with the SBQ recommended practices and Code regarding practice. *Reasonable professional practice* is the expected level of professionalism and knowledge to be displayed by a surveyor throughout the due course of his work. It represents not the maximum ability or the minimum ability, but rather what the average, qualified surveyor would be expected to do in the given situation. Because *reasonable professional practice* represents average ability there is some degree of freedom as to the choices that can be made. It provides the legal basis within which the surveyor should act so as to obey relevant surveying legislation and to ensure that all work is carried out in respect to the welfare of society.

As such, the SBQ guideline will be adhered to throughout the testing regime and *SP1* to which it refers. Moreover, when conducting this testing the SBQ *Code of Practice* will be strictly followed so as to ensure all testing is carried out in a manner indicative of the doctrines of the SBQ and it can be initially accepted on the basis that it was carried out with due care and regard.

1.9 CONCLUSIONS

The need to perform this dissertation arises from a fundamental misunderstanding within the surveying industry regarding the practices and minimum standards required to perform cadastral surveys by means of RTK GNSS. The SBQ attended to this need by releasing a guideline for the use of RTK however this guideline was very brief and non-explicit in many areas. One particular area where it failed to fully establish a complete guideline was *section C. Observation Techniques*, *section F. Grid and ground Distances* and *section G. Connections and Radiations*. This is not to say that the guideline is deficient per se, however this dissertation aims to add to and augment the guidelines to make it more thorough and empirically test some areas of the guideline.

While there are many task required to complete a full cadastral survey, 3 critical tasks that are commonly misunderstood were identified. These 3; short line observation, referencing and minimum backsight length are essential to cadastral surveying and if performed wrong, will result in incorrect observations and hence incorrect plans and existing plan challenges.

It is therefore the intention of this dissertation to explore these elements through field testing and reductions and definitively prove how these should be conducted in real world situations. More accurately, these elements will be explored to determine whether RTK can be used for cadastral purposes, and moreover, how and when it should be applied. The aim is to provide this through empirically tested data and by following reasonable professional practice as outlined by governing bodies, so that this testing is applicable to the real world and replicable. By achieving these goals it is then the aim to provide these findings to the SBQ for their internal review so that this research may become part of the guideline and supplement the inexplicit areas and further define the guideline.

By achieving these aims it is hoped that a meaningful and important contribution can be made to the surveying industry so there is greater uniformity in practices and methods. Furthermore it will hopefully ensure that surveyors have a minimum standard of how to use RTK (in regard to the 3 tested elements) to adhere to so as to achieve observational accuracy which meets the SBQ guideline and that is – or may be – similar to TS quality data.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is primarily concerned with establishing the existing background information for the use of RTK GNSS for cadastral surveying, to define *reasonable professional practice* (as this dissertation is very much focussed on this concept) and to identify any and all other information that may be relevant. Moreover this literature review serves to provide a great deal of background information so that should this dissertation be used for other purposes it is easy to identify where the information and basis of this research came from. Moreover the literature will provide a reliable and traceable base, consistent will recommended best practice techniques. The literature review for this dissertation will be somewhat different from others as rather than trying to define a new idea, development, research or entity (entity is used loosely here), this dissertation is focussed on describing and expanding an existing idea. The use of RTK for cadastral purposes is an idea that has been implemented and now, the research is trying to catch up so as to properly define its use and application.

The most important aspect of this chapter is investigating the SBQ guideline, in particular *section C. Observation Techniques*, *section F. Grid and ground Distances* and *section G. Connections and Radiations*. As these sections of the SBQ guidelines are the information around which this dissertation is built, it is critical that these sections in particular are analysed in depth. This will basically establish what practices and methods the SBQ recommend and what areas in particular need to be expanded. This will help to identify what exactly needs to done, though not necessarily how the testing regime would go about achieving which is why further research will be done into literature regarding this, particularly *Standards and Practices for Cadastral Surveys* (*SP1*) and the newest version of *SP1*.

The objective of this dissertation is to align all testing with *reasonable professional practice* therefore this concept needs to be defined too. Because this dissertation will eventually be submitted to the SBQ for their internal review, it is obviously prudent to conduct all testing in a manner indicative of their guidelines and practices.

2.2 *RTK GNSS for Cadastral Surveys*; Surveyors Board of Queensland

As introduced in *Section 1.1*, the SBQ guideline was created to bring attention to many of the common errors in practices that cause misunderstandings about the use of RTK and result in poor if not inaccurate field observations. The guideline is intended to be read in conjunction with best practice guidelines rather than be a stand-alone document. Overall the guideline does provide useful information to surveyors on how to conduct their practices however on the whole it is inexplicit and does not nearly contain nearly enough depth to fully guide a surveyor through the cadastral survey process. One of the conditions placed on the information provided within the guideline is that it is only an interim document for the time being, with more detailed version to follow. Given this premise, this dissertation will begin to supplement the guidelines particularly focussing on *section C. Observation Techniques*, *section F. Grid and ground Distances* and *section G. Connections and Radiations*.

Referencing sections *C. Observation Techniques* it is apparent that only the base work for this section has been laid as the section only covers about half a page. This section briefly outlines some of the absolute minimum requisite standards a surveyor needs to achieve for an accurate survey to be undertaken before moving onto base station positioning and co-ordination. In this brief overview, the guideline mentions that a fixed ambiguity solution must be achieved and that a fixed solution is required for all observations (initialisation loss and re-initialisation is accepted though) throughout the survey. The GNSS base station must be set on an appropriate control mark or with due reference to appropriate control marks, and the survey – especially the base station position – should be carried out so as to minimalize multipath (otherwise TS may be more appropriate) and comply with manufactures' recommendations and specifications. Additionally it mentions that it is a matter of the surveyors' discretion as to the surveying conditions with respect to the number of satellites used (a minimum of 4 – which is required for initialisation), satellite geometry, DOP's (suggested as not greater than 8), base station requirements, baseline lengths, elevation mask and expected point accuracy and precision. In the later *section G. Connections and Radiations* the guideline touches on some of the aspects of this dissertation however the information is unquantified and in regards to the guideline as a whole, it needs to be more descriptive than simply '*use professional judgement and discretion*'. From section *C.*, what can be taken away that is applicable to this dissertation is basically abiding by the suggestions of this section of the guideline. Paragraph 2 is applicable to this work however it falls back on proper survey planning and preparation to ensure that high order and class marks are used for base stations and the latest geoid models will of course be used to ensure the highest accuracy on the datum. Paragraph 3 can tentatively be ignored at this stage as it is the intention to only use one base station (as all works should be completed within range of a single base) for all testing to minimise the total amount of errors over the testing.

Section *F. Grid and Ground Distances* indicates the need for cadastral plans to show ground distances (s48 (B), Land Title Act 1994 & *Cadastral Survey Requirements,* DERM), and ground distances are not the same as geodetic plane distances, ellipsoidal distances or MGA grid distances which are measured by GNSS. It is integral that this is understood as there is a difference between these distances and while this difference may be negligible over short distances, cadastral plans must show ground distances. Therefore regardless of the length of the observed line, it must be reduced to the horizontal distance at mean terrain height. *Figure 2.1* shows the difference between MGA grid distance and the computed ground distance, and illustrates the importance of using the correct (ground) distance on a plan, lest the plans be incorrect.

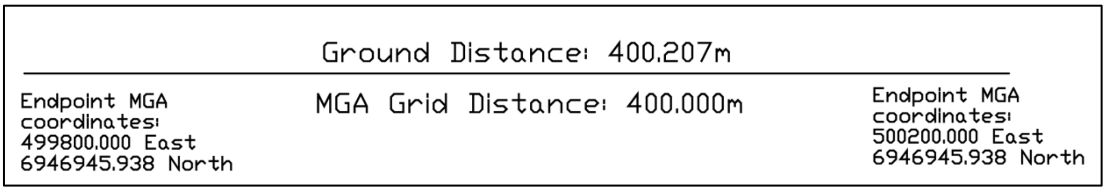

Figure 2.1 - Ground and MGA grid distance comparison

Paragraph 2 of section *F.* can, at this time, be disregarded as it is not the intention to conduct testing on a local ground-based co-ordinate system. Paragraph 3 on the other hand provides some very useful information regarding short line observation. The paragraph goes into quite some degree of detail providing that lines calculated from two RTK points will typically be of the several centimetre level of accuracy. The guidelines link to the *SP1* here stating that accuracy at 1σ was calculated to be 17mm and 2σ (95% confidence interval) was 42mm, and provides that vector (vector is used quite loosely here as the definition of vector is not described) accuracy is required as 10mm + 50ppm. From the guidelines' recommendations, this leads to a minimum distance of 640m below which distances should be observed by a conventional total station. 640m is a rather long distance line to observe and if this was to be the minimally accepted distance, RTK would serve no benefit for urban cadastral works or acreages. The guideline continues however that the precision of observations can be improved by means of longer observation times. This is justified by the work of *Janssen* and *Haasdyk*, who found through their research, indications of significant benefits to accuracy from averaging observations over longer time periods (one or two minutes) and reoccupation (10-30 minutes later). Subject to their findings some jurisdictions have adopted 120m as the minimum distance below which conventional total stations should be used.

With further regard to *section G.* the literature does delve briefly into corner referencing and backsight lengths. Firstly with referencing; the guideline promotes a best practice of making checks between radiated points particularly when working over small distances. The guideline suggests that this is done with conventional methods (i.e. TS and measuring tape) with these methods taking precedence over the RTK observations. This effectively defeats the point of conducting RTK surveys if the marks are to be re-surveyed by conventional methods which will be given precedence. When conducting this dissertation the focus will be to find a practice for referencing that can be conducted entirely with RTK (checks included) so that conventional methods aren't additionally needed. Operating under best practices it would be possible to check the observations at a later time (allowing satellite geometry change) through reoccupation and with a different ambiguity solution. The guideline does not expand on the methods or practices one should observe when measuring reference marks with RTK nor does it give an indication of minimum lengths or occupation times. Hence to fully clarify this issue it will be necessary to conduct a variety of tests so that the most appropriate method can be identified and used as the best practice. The guideline moves onto how to observe backsight lines where the guideline actually gives numeric solutions stating that for RTK surveys, backsight lengths should be greater than 200m and never less than 100m unless the situation is unavoidable. While this does to some degree give the user an indication of the practices he must observed, the guideline does not define how it arrived at these quantities, nor how the backsights should be observed so that these intervals will be applicable. This is one of the gaps in the guidelines this dissertation aims to fill, and establishes the need for this testing. Finally reference trees, as outlined in paragraph 3 is beyond the scope of this dissertation per se, as this dissertation is focussed more upon actual observations methods however it should be realised that the guidelines recommendations should be followed.

An important note in regards to how the guideline is structured is that it does not define ideal RTK conditions or the conditions in which this guideline is appropriate (the assumption being that it is universally applicable, dependent on the surveyors' professional judgement). In general the guideline is given as the general guide to RTK use for cadastral surveys however a great deal of the guideline is given under surveyors' discretion, it may be undesirable to use this in all situations. From the SBQ guideline it is can be concluded that a lot of faith is inferred to the surveyors' ability to judge conditions and situations accurately. Much of the decision making process is given over to the surveyors discretion rather than based on situation standards or professional practices. Different conditions will obviously cause different observations and there can be a great deal of contrast between two separate cadastral surveys, even if both were completed to the standards of this guideline based upon the conditions of the survey. A surveyor has no control over the conditions of the survey, however just like it is stated within the guidelines most errors with RTK can be overcome with *redundancies in observations* (section *A. General Requirements* paragraph 3) and, moreover it is essential that proper discretion be observed by the surveyor to determine whether RTK is in fact the appropriate means to complete the cadastral survey.

The literature covers a range of other information related to cadastral surveys by RTK however these are all outside the range of this dissertation. While there will be overlap into these sections to some degree it is not the intention of the dissertation to quantify or qualify these sections. In general the guidelines of these sections will be followed where applicable in conjunction with best practices.

While the SBQ has relied heavily on surveyors' discretion, this is not necessarily an entirely bad concept. The purpose of the guideline and indeed this dissertation is to guide surveyors in their methods so they may achieve accurate observations rather than enforce a practice system. Every situation will be different and there may be cases where the guideline – no matter how detailed and refined – is not applicable. It is important to allow the surveyor to consider what must be done and if certain conditions can be met rather than giving an 'all-inclusive' standard.

Therefore from the literature it is possible to conclude that the guideline, in its current form needs to be heavily detailed and supplemented before it can be considered comprehensive. While the document does touch on some key areas it does not provide quantified data to validate its suggestions nor does it provide methods of achieving cadastral survey standards'. The dissertation will focus on qualifying how to conduct short line observations, referencing and determining minimum backsight lengths and will validate this with physically tested, empirical data. By achieving this, the guideline can become much more succinct and useful and will provide surveyors with the knowledge and guidance they require.

2.3 *RTK GNSS for Cadastral Surveys…. plus!;* Peter Gibbings

The inclusion of this presentation within the literature review is a necessity given Dr Gibbings involvement and experience in the field of RTK for cadastral surveys and his involvement with the writing of the SBQ guidelines. This presentation has been made at numerous professional seminars and Dr Gibbings' knowledge is well regarded; the presentation aims to educate surveyors on the application of RTK for cadastral surveys and covers numerous areas related to its use and appropriate implementation. Indeed the presentation covers much the same ground as the SBQ guidelines – although this may seemingly have been the intent given the references to the guideline.

The first point raised is the finding of the SBQ and others of some issues with using RTK and cadastral surveys which are given (without greater detail) as independent checks, redundant observations, equipment reliability, validation, checking, staff training (and knowledge) and many issues not just GNSS specific. These issues or their countermeasures are not stated within this presentation however these issues mentioned are either beyond the scope of this dissertation (equipment reliability, validation, checking, staff training), will be eliminated through proper planning and practices (independent checks, redundant observations) or were previously examined in section *2.2* of this dissertation or in a later section (most of the issues related to GNSS such as multipath elimination, ambiguity solutions etc.). While these issues are not delved into within the dissertation it can again be seem how often these issues are raised in relation to RTK for cadastral surveys.

The importance of using ground distances at mean terrain height as opposed to MGA grid distance is reiterated in much the same way as the guidelines. The benefit this section does provide though is the practical means of converting an observed MGA grid distance to ground distance, by conversion through the combined (height SF and grid SF) scale factor.

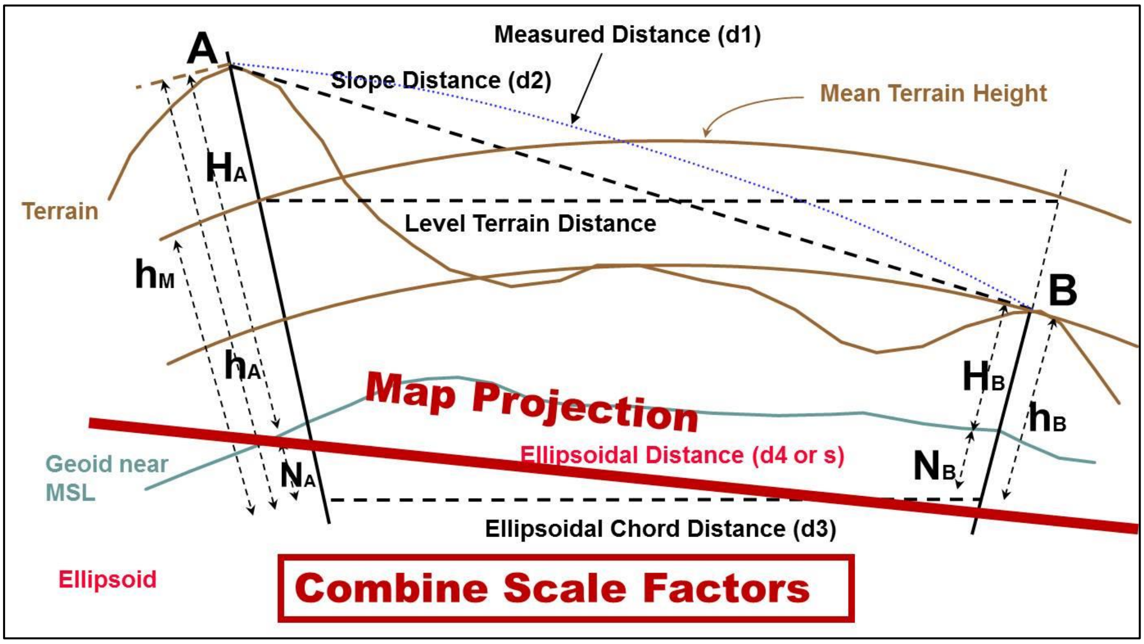

Figure 2.2 - Height play an important role in reducing a distance observed in the field to obtain the corrected distance on the ellipsoid (caption and figure Gibbings, 2013)

The accuracy specifications given by *SP1*; 10mm + 1-2ppm (1σ) are then referred to though this is a significantly more rigid accuracy standard then was given by the SBQ guideline and would require a significantly longer line to be observed to achieve this accuracy. Gibbings' extends this by stating that more accurate observations are possible, that 25mm at 2σ may be possible, which is consistent with empirical testings which is then provided. More evidence of this testing is provided by the work of Edwards et al 2010 and Janssen and Haasdyk 2011. When investigating RTK GNSS accuracy Gibbings' finds that accuracy to 1σ is not enough, it is better to look at the 95% confidence interval (2σ) however the remaining 5% and outliers should be remembered. This is a vexing predicament as at the 95% CI, 5 out of every 100 observations could potentially be erroneous, however if a 99% CI (3σ) was instead chosen, the acceptable accuracy may be too great.

An important detail taken from this presentation though is the need to check for *bad* initialisations, which can occur in about 1 in 1000 initialisations. There is no way to initially tell whether the ambiguity solution is in fact *bad*, which is why the need for reoccupation and redundant observations are required (reoccupation recommended to be about 30 minutes later). This must inherently be incorporated into the testing regime.

Finally Gibbings' reiterates the findings of the SBQ regarding short line observation and the premise that better minimum distances then 640m (based on the survey standards' vector accuracy 10mm + 50ppm) can be observed. The SBQ findings in regards to referencing and backsight lengths are also reiterated, requiring independent conventional measurements to substantiate the RTK observations and BS lengths greater than 200m, respectively.

2.4 *GPS FOR CADASTRAL SURVEYING – PRACTICAL CONSIDERATIONS;* C. ROBERTS

This paper covers a variety of aspects regarding GPS theory which are all obviously pertinent to the testing that will be conducting throughout this dissertation. More importantly though Roberts' work is primarily concerned with a similar theme as this dissertation so it should provide a great deal of relevant information.

The first section refers to the importance of GNSS *initialisation* in the role of achieving cm-level positioning and obviously this needs to be carried over into all testing practices. The paragraph is more an introduction and description of RTK initialisation than anything else however it does highlight the need for initialisation. It is important to remember that there is the possibility for *bad* ambiguity solutions periodically, and it would seem prudent, from Roberts' and Gibbings' work, to loss initialisation and determine a new ambiguity solution between each set of observations (i.e. between the first observations and the reoccupation). Coupled with the information from section *1.4 High Productivity Surveying*, Roberts' states that ambiguity resolution (AR) in ideal conditions is correct 99.9% of the time, confirming Gibbings' previous findings (1 in 1000). It is recommended that a known point be observed to confirm the AR as a *bad* AR will result in an incorrect position of a decimetre or more.

Survey planning is then explored however it is again, more an overview and history. This section does provide some valuable information on *full operational capability* (FOC) though, which guarantees a minimum of four satellites (usually five) are visible anywhere on the Earth at any one time. Four satellites will be sufficient to gain a fixed ambiguity solution (initialisation) and since FOC was declared in 1995, survey planning – being the checking that enough satellites will be available during a job – has been considered obsolete. It is recommended that an RTK surveyor should always consider the best time to work and consider the obstructions in the area. Furthermore with the full GPS, GLONASS (Russian) and Galileo (European) satellite systems, survey planning is rarely required except in the most difficult of conditions.

The second chapter of Roberts' work focusses on some of the practical considerations of using RTK for cadastral surveys. Interestingly he states that RTK is not a replacement for traditional techniques but rather an enhancement suitable for certain conditions. Base station location is reviewed with practical considerations a surveyor must implement; ensuring that the base has a clear skyview to ensure the maximum number of satellites are observed to at any one time, that the rover remains within radio link range (may require a repeater) and critically, that the base is located in a multipath free environment. In particular regard to cadastral surveys Roberts' recommends that the base should be set upon a control mark (tied to the relevant survey plan) with known MGA co-ordinates, provided that it fulfils the previous requirements.

> "*Modern GPS systems have improved satellite tracking technology such that weaker signals can be observed under trees with moderate foliage. (Note that dense foliage will still cause cycle slips). Despite this advanced tracking capability, the signals are noisier, weaker and therefore more likely to be subject to multipath and diffraction. The surveyor should be aware that positions may not be accurate despite quality indicators showing good solutions.*
>
> *To overcome this cadastral surveyors can place two or three marks in clearer locations, coordinate them using RTK GPS techniques and then radiate or intersect the cadastral detail required using a total station or theodolite.*" (Roberts, pg. 6, 2005)

Roberts' review of working under trees or high obstruction areas provides a good argument for the proper location of the base as well as an indication of the care that must be taken during RTK observations. While observing in high multipath/signal obstruction areas is beyond the scope of this dissertation it is important to consider the impact multipath/obstructions will have on measurements and plan accordingly – this may mean using integrated surveys to complete works.

The next few sections of Roberts' work actually looks at observation considerations. Section *2.3 Coordinating marks* recommends the use of a tripod or other stabilisation equipment when observing a point to ensure there is no movement during the occupation and that the receiver remains above the observation point of the mark. Roberts' then reiterates the importance of observational rigor, by reoccupation of the point after at least 20 minutes have elapsed, to allow the satellite geometry to change, with a new AR.

The elevation mask angle is the angle of elevation above the horizon below which satellite signals are filtered out, usually due to atmospheric noise of that satellite signal or which are likely to be obstructed (Trimble, 2013). Roberts' refers to the NSW Surveyor General's Directions (2004), *No.9 GPS for Cadastral Surveys* which recommends that an elevation mask of no less than 15° be used, so as to reduce the effects of systematic errors, namely tropospheric and ionospheric delays, multipath and complete signal obstruction.

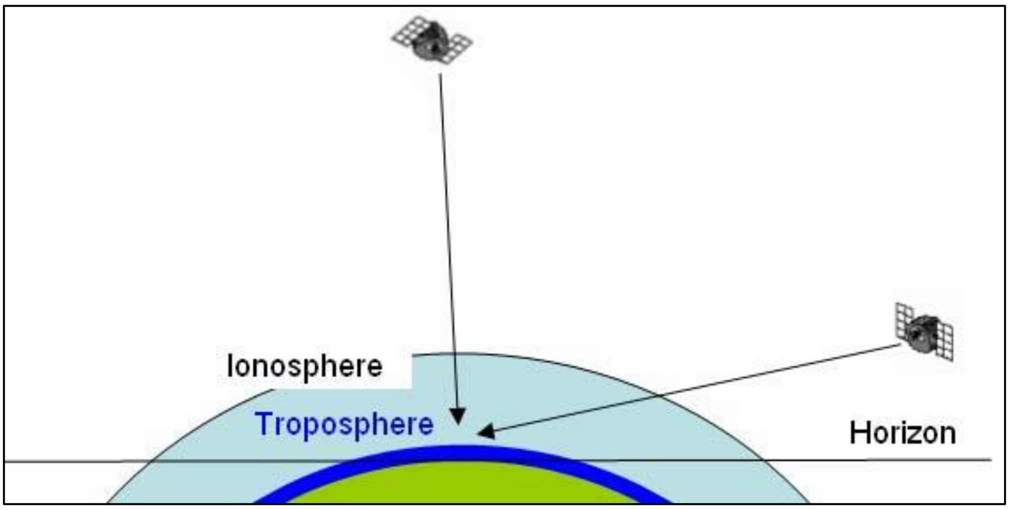

Figure 2.3 – Elevation mask angle showing satellite signal travel through the ionosphere and troposphere (Roberts, 2005)

Figure 2.3 gives an indication of the need for a suitable elevation mask; as can be seen, the overhead satellite signal travels through significantly less atmosphere than the right hand satellite. Multipath is also a concern here as the signal may bounce off the ground or other reflective surface (particularly water) before reaching the base and receiver antennas thereby making the signal path length longer than it should be. Adopting the correct elevation angle is therefore critical.

Finally Roberts explores a critical topic; grid vs ground distances needed for cadastral purposes which was previously examined in the work by the SBQ and Gibbings. Roberts doesn't really go into any more detail than was previously found, and focusses on how RTK can be configured to work on a local ground co-ordinate system, a topic beyond the scope of this dissertation.

2.5 *GNSS AND CADASTRAL SURVEYS*; SURVEYOR-GENERAL OF THE AUSTRALIAN CAPITAL TERRITORY

This guideline is very similar to the SBQ guideline and has been produced in much the same fashion as it too is non-explicit in some areas and does not contain actual recommended procedures or methods in some sections. It does however contain information regarding the use of RTK specifically for cadastral surveys and the information will be critical in determining the testing regime. The ACT guideline sets out to develop a method to ensure that the survey information observed using GNSS technology conforms to the standard as required within the ACT which would obviously be different than Queensland. Interestingly the guideline provides notice to surveyors that under the *Nation Measurements Act 1960* approved methods of establishing legal traceability of positions determined by GNSS do not exist, therefore GNSS should not be used as the sole method of observation during a survey. This is interesting as it would be the surveyor's intent to use RTK exclusively (where possible, integrated surveys may be required) or conventional methods exclusively for the survey otherwise why bother using RTK at all? This centres on the aim of this dissertation, as establishing reliable survey practices, legislation may be changed to allow for exclusive GNSS use throughout a survey.

The guideline is very shallow in detail regarding recommended observation techniques where it merely states the techniques acceptable for cadastral surveying and some performance requirements of the GNSS equipment. The latter at the very least can be followed here, ensuring that the equipment is dual frequency, multiple constellations are used (GPS, GLONASS and Galileo) where possible and ensuring that RTK techniques does not preclude the use of well-established, good cadastral survey practice (*working from the whole to the part; establishing a control framework for the project that is fit for purpose; "running the boundary" where appropriate* and avoiding unchecked radiations).

The guideline then provides some recommended best practices to observe when using RTK for cadastral surveys but these are mostly covered within *SP1*. Moreover these practices reflect *reasonable professional practices*, which is one of the major aims of this dissertation so these must be integrated to the testing regime. Following on, the guideline develops on these best practices for the purpose of RTK surveys. The ACT lists the accuracy expected at 2σ in the order of 20mm +2ppm which is much more lax then the survey standards' accuracy. The elevation mask is again cited as a minimum of

13° - 15°. The need for an open skyview for the base station is reiterated as well as the need for a fixed AR. A new AR must be gained and it is advised that at least 30 minutes have passed before reoccupation of a point. Also the base station must be located in a low multipath area.

Three critical points are introduced in this section which are important to remember in regards to the testing regime. Firstly is the recommendation that the receiver should be set to observe a 1-second data collection rate using the averaging technique, and secondly that to observe Class C positions (the quality of a cadastral survey) a rover pole with bipod can be used, in favour of the surveyor holding the pole and in exception to a tripod. It is recommended though that a tripod be used when connecting to established survey control marks and especially when observations are being used for a site transformation. And finally, it is advised that no observations should be taken when the PDOP as stated from the controller is greater than 6.

The most important piece of information to be taken away from this section however is the ACT recommendation for observation length over various survey marks, which is provided below in Figure *2.4*.

Type of Point	Occupation Duration
○ Survey control mark (connection to datum, site transformations, etc)	3 minutes
○ Survey control mark (RTK session checks) ○ Cadastral reference mark ○ Cadastral monument	1 minute
○ Occupations (eg: fencing) ○ Natural boundary	15 seconds → 1 minute
○ Height critical point	3 minutes

Figure 2.4 – Minimum recommended RTK occupation durations (Surveyor-General ACT, 2012)

This table gives an indication of the measurement techniques that should be implemented and this will form the basis of the testing regime. Similar to Gibbings' research, this occupation duration overview shows the importance that is placed upon the correct observation of survey control and critical marks and the consistent with the finding that there is a significant benefit to longer observation times, as opposed to brief *topo* observations.

The guideline also takes the time to differentiate between accuracy and precision in regards to using RTK;

Accuracy – level of alignment to a datum, as realised by the physical survey control mark infrastructure

Precision – the spread of results (at a certain confidence interval) relative to the base station

The final information of the ACT guidelines relevant to this dissertation is when the guidelines draw reference to the work of *Janssen and Haasdyk*, making aware to surveyors that the co-ordinate quality indicators provided by the rover are often overly optimistic and that the CQ indicators may report acceptable positions and observations even though a *bad* ambiguity resolution has occurred.

2.6 *No. 9 GNSS for Cadastral Surveys*; Surveyor General's Directions, NSW

This direction again is much the same as the SBQ guideline and the previous ACT Surveyor-General's directions, and outlines the recommended procedures for use of GNSS methods to undertake cadastral surveys in accordance with the *Surveying and Spatial Information Regulation 2012* (SSIR 2012) and the *Surveying and Spatial Information Act 2002* (SSIA 2002). As the SBQ guidelines, Gibbings' and Roberts' work and the ACT Surveyor-General's directions have already been reviewed, this review will only note important information that can be used for the purposes of this dissertation, rather than rehashing previous findings. It should be noted that most of this document is of a similar fashion as the Queensland and ACT guidelines so the importance of the guideline is in no way diminished. An interesting note though is the guideline stating that with increasing use of GPS surveying technology for cadastral surveys, the techniques involved do not provide the same field data records as traditional methods and it is becoming of greater concern to ensure that quality of field practices meet existing requirements or standards.

This guideline introduces the aspect of RTK observation bias which cannot be accounted for even by the most rigorous surveying practices, which results in increasing uncertainty in the computed baselines to the order of about 10mm. This is the accuracy threshold identified by the SSIR 2012 and so it is recommended that surveyors apply conventional methods in instances of short distances (below 100m). The guideline states that the use of RTK is necessary, these observations should be validated by including closed figures within the survey by TS or alternatively only using these for lower accuracy applications (the guideline does not specify whether a cadastral survey would qualify in this category though).

An interesting point the guideline raises is to only observe points for 2 minutes (at a one second data collection rate) to obtain an averaged position. The guideline through the work of the *NSW Land and Property Information* states that a 2 minute observation delivers *huge improvements* in positioning quality (than shorter observation times) whereas observations for longer than 2 minutes are generally not expected to provide any substantial further improvement.

The final aspect that this guideline raises is a RTK checklist. This checklist covers all aspects of surveying practice from equipment to best practices and is a useful additive to the testing regime. As the testing regime is intended to test within certain parameters some of the points outlined on this checklist may be disregarded. A copy of the checklist will be included in the *Appendix*.

2.7 *STANDARDS AND PRACTICES FOR CONTROL SURVEYS (SP1) V1.7*; ICSM

SP1 covers a range of surveying applications and is considered a comprehensive guide to surveying practices and methods. It was produced by the Intergovernmental Committee on Surveying and Mapping (ICSM) and is constantly referred to in surveyors' code of practices and practice guidelines. In particular it covers sections regarding a) *Standards of Accuracy*, b) *Best Practice Guidelines for Surveys and Reductions*, c) *Recommended Marking Practices* and d) *Recommended Documentation Practices*. Of this manual, this dissertation is concerned with *Part B, 2.6 Global Positioning System (GPS).* This manual covers a lot of best practice, most of which have been outlined in or reference drawn to in previous sections of the literature review. Most of the previous sections of this literature review have base in *SP1* and because *SP1* was conducted by the ICSM it is of course applicable to this dissertation.

The relevant chapter and section of *SP1* to be focussed upon here, *Part B, 2.6* (with the condition of being read in conjunction with *Part* A) presents principles in general terms appropriate for GNSS surveying applications (seemingly of an all-purpose nature), not specifically RTK for cadastral purposes. This is probably due in part to the difference between each state and territory's cadastral regulations. Given the previous literary reviews which are based on the recommendations of *SP1*, there are no new findings to be brought forward here. The inclusion of this document is critically important however as it will substantiate the testing regime and provide the basis of *reasonable professional practice*, for which this dissertation is concerned.

2.8 *CODE OF PRACTICE* - SBQ

The SBQ *Code of Practice* is included briefly to verify that the testing in this dissertation will align with the practice requirements of the SBQ. This *Code* provides benefits for consumers of spatial information including survey services specifically, by providing public confidence in the record of surveys and in surveyors themselves. The *Code* is primarily concerned with the profession and public interest by establishing the distinguishing characteristics of a professional surveyor and their obligation to the public respectively.

In regards to professional competence the *Code* requires a surveyor to abide by the principles and standards of professional practice and apply best practice, a standard which is covered by acting in accordance with the recommendations of the SBQ guideline and *SP1* (this is the portion of the *Code* which is inherently related to this dissertation). The *Code* states that the surveyor must assume professional responsibility for all works carried out; the *Code* would direct the testing to be completed in accordance with best practices but that it is the surveyor responsibility to properly and appropriately implement this, hence the lengthy literature review to ensure this is achieved. It is also stated that all work must be honest and as the surveyor actually observed so as to not knowingly make false or misleading statements, this statement obviously being applied to this dissertation.

2.9 CONCLUSIONS

The previous sections of this chapter have analysed all the necessary literature that will be required to provide an academic, factual and reliable basis for this dissertation. The review of the SBQ guideline, the ACT and NSW guidelines and *SP1* have justified the methodology that will be outline in *Chapter 3*, and the works of Gibbings and Roberts provide for the real world implementation of the testing regime. These findings have been found to be consistent with the standards and recommendations of *SP1*, for which all (except the SBQ *Code of Practice*) of the literature is concerned.

Important aspects to be taken away from this chapter to be implemented into the testing regime are;

- The requirement for a fixed ambiguity solution for all observations
- *Bad* ambiguity solutions will be solved by reoccupation
- Reoccupation of marks should be at least 30 minutes later with an independent AR

- The rover elevation mask angle shall be set no lower than 13°
- A 1 second data collection rate using observation averaging will be applied
- A bipod will be used to stabilise the rover for observations of 30 seconds or longer (in accordance with the Class-C requirements of cadastral surveys)
- No observations shall be taken when PDOP exceeds 6
- The base station will be placed with a clear skyview and with minimal multipath
- The observed MGA grid distances must be reduced to ground distances at mean terrain height
- The survey standards' suggests accuracy quality to be 10mm + 50ppm (this will be identified as the SBQ guidelines accuracy)
- The observation times should at least reach 2 minutes
- Due regard to the RTK checklist identified by *Surveyors General's Directions, NSW*

The above factors will form the testing regime and determine how the observations are completed. By incorporating these considerations into the testing, the observations will have been measured in a manner indicative of the SBQ guidelines and will be suitably repeatable to any who wish to verify the results that the testing yields.

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

The intention of this dissertation is to physically test the 3 elements outlined in *Chapter 1*; short line observations, referencing and backsight lengths, so that empirical data can be observed and referred to the SBQ for review. To achieve this, field testing must be completed so as to provide the data needed. This section will define the testing regime; how the findings of *Chapter 2* have determined how the testing will be undertaken and the considerations that need to be implemented throughout. Moreover this chapter will give an overview of the dissertation timeline, the resource planning scheme and the necessary equipment.

3.2 OBSERVATION METHODS

3.2.1 OBSERVATION LENGTH

In terms of observing the marks that will be established for the purposes of testing, there are many different techniques of observation and a variety of equipment that can be used to do so. The marks that will form the points of observation will henceforth be referred to as the 'control array', as the marks will be established and observed to create the control points for which RTK will observe. From *Chapter 2* the guidelines recommend at least a 2 minute occupation on the marks and that a bipod will be appropriate means of rover pole stabilisation. Because the actual means of observing short lines, referencing and minimum backsight lengths is unknown at this stage, the guidelines recommendations will be followed as a basis of testing. However because the methods of observing these three aspects is essentially unknown – and the aim of this dissertation is to establish a practice – simply following one set of directions isn't enough. The observation testing will therefore reflect the absolute minimum a surveyor can do to observe a mark, ranging upwards in rigor and incorporating the guidelines recommendations. Regarding RTK, different observation techniques are usually concerned with variable lengths of occupation as opposed to changing other factors, therefore the testing will range from very minimum rigor occupations to much greater; 3 second observations to 180 second observations.

Though the SBQ guideline does not prescribe a time length that marks need to be observed for – the guideline leaves it open to interpretation, from other literature this has been established. While the NSW guidelines recommends that 120 second observations are all that is required (as longer observations aren't expected to provide substantial further benefit) the longest observation length will be set at 180 seconds in accordance with the authors professional experience (*observed control points* are set to a default occupation time of 3 minutes) and in accordance with the findings of *Figure 2.4*; as longer occupation times will yield better accuracy. Conversely however surveyors can do the absolute minimum required to observe a point which would reflect a 3 second *topo* observation. This is the default observation time set for feature observation (from the author's experience) and reflects the least amount of rigor to obtain an averaged position; i.e. hold and measure. There is obviously a huge rigor difference between a 3 second observation and a 180 second observation which reflects the most and least a surveyor can do to measure a point via RTK. In accordance with *reasonable professional practice* it may not be necessary to use a 180 second occupation to get the desired results therefore observations within the middle of this range will be investigated. Practical the choices will be 30 seconds and 60 seconds; 30 seconds as from the findings of *Figure 2.4*, 15 - 60 second observations are recommended for lower accuracy occupations and 60 second observations are recommended for control marks.

Therefore the four different observation times will be tested;

- 3 second observations
- 30 second observations
- 60 second observations
- 180 second observations

The other aspect that must be considered in regards to the observations is the equipment used and how this will affect the results. In general RTK set up will consist of the receiver and pole (absolute minimum effort to reduce errors pertaining to movement during observations as this incorporates the human element), or include a bipod attachment (as recommended by the ACT guidelines) or use a tripod instead, depending on accuracy needs. This again has elements of absolute minimum and maximum – where the least a survey can do is hold the pole rather than set up a reliable bracing system.

Based on common workplace practices and the recommendations found through the literature review, observation equipment will either consist of a pole or a pole with bipod attachment. The thought of using a tripod was considered however given that

RTK is used because of its flexibility and because observation times are so short, it was discounted. It is acceptable to not use a tripod for the testing, and use a bipod instead as this method will still achieve the required accuracy standard, as defined by the ACT guideline.

Therefore testing will consist of combinations of equipment and observation times;

- 3sec ob. with held pole
- 30sec ob. with bipod
- 60sec ob. with bipod
- 180sec ob. with bipod

This will be used to represent the range of how an average surveyor would go about completing an RTK cadastral survey in the real world. While it is conceivable that a surveyor might observe a mark for 180sec with a tripod, this dissertation aims to reinforce the flexibility of RTK over TS so speed and efficiency will be considered more important than more rigorous testing methods.

Finally in regards to observations, it is mandatory as part of a cadastral survey to provide check and redundant observations so as to verify the accuracy of the survey. This is recommended in every article reviewed and will be adhered to here. It is not enough to simply observe all the test marks with different methods; the observations must be repeated to ensure that there are no errors in the data which can otherwise be eliminated (i.e. *bad* ambiguity solutions). From the literature review, all guidelines rely on a 95% confidence interval, therefore enough data must be collected so as to create a normal distribution and so that erroneous outriding observations can be identified and excluded. To establish a normal distribution the sample size must be greater than 25, therefore all variable observation techniques will be repeated 30 times, each with a different ambiguity solution – following the recommendation found previously. By observing each mark 30 times for each different observation time, this will collect data over a period of time, allowing the satellite geometry to change thereby satisfying the SBQ guideline requirements.

Moreover it is crucial that all distances are measured in the intended order of the control array, having completed done this the process will be repeated. This will be done as opposed to measuring the same mark 30 times then moving on to the next to ensure that the satellite geometry has changed and that by the end of testing there will certainly be enough geometry change to satisfy the minimum 30 minute requirement. This will align with best practice as repeatedly measuring the same point would not allow for that 30 minute time period to elapse. Moreover a surveyor would conduct the cadastral survey then reoccupy as a check rather than measuring each point twice then moving on.

3.2.2 Short Line, Referencing and Backsight Length

To actually conduct the testing it will be necessary to observe survey marks that have been established to meet the testing objectives of this dissertation and have suitable three dimensional co-ordinates. Therefore the actual requirements of the testing marks need to be established.

3.2.2.1 Referencing

It was previously identified in *Chapter 1* that reference marks could be considered any mark less than 20m away from the corner mark, based on the author’s professional experience and investigation of various cadastral plans. Commonly, reference marks are placed to directly reference that particular corner meaning the mark is within close proximity, i.e. 2m – 5m away; or the mark could be coincidental i.e. an existing mark or a mark placed for another purpose can be used to reference the corner. Whatever the case may be is irrelevant as once the corner is connected to these surrounding marks, the surrounding marks become reference marks of the corner. The testing regime concerning referencing aims to provide a practice for observing reference marks and determine if RTK can be used to observe all reference marks regardless of the distance from the corner. It may be found that RTK is applicable to all reference marks or only those over longer distances. As reference marks are considered to be anywhere from 2m – 20m away from the corner, marks at these distances will be observed as well as several marks in between to more accurately establish where RTK would be applicable to corner referencing.

Therefore the variable reference mark lengths will be established as;

- 2m
- 5m
- 10m
- 20m

3.2.2.2 Short Lines and Backsight Lengths

Just like referencing, it has previously been established what the guidelines (from the various states and SP1) recommend as best practice for the observation of short lines and the minimum distance of backsight lengths.

Discussing short distances first, the SBQ guideline states (based on SP1) that only distances greater than 640m should be observed by RTK which would satisfy the 95% CI. However the SBQ guidelines and the work of Gibbings' reference other jurisdictions believing that much better results can be achieved and significantly shorter distances can be observed with RTK; down to 120m, which these jurisdictions have adopted as the minimum. Therefore the testing for short lines will aim to determine whether 120m short lines can be accurately measured with a TS or whether this can in fact be improved upon, or conversely whether RTK cannot accurately measure 120m short lines. This would lead to a mark being established at 120m and observing it, but also establishing marks at shorter and longer distances, so as to determine the range of the RTK capability.

Moving onto backsight lengths, the SBQ guideline recommends that for the use of RTK backsight lengths should normally be 200m and greater and never less than 100m except in difficult terrain. Therefore a mark would be established at the recommended distance, 200m and marks would be established to determine how accurately RTK can determine a backsight bearing and distance at lengths less than the recommendation.

Therefore the lengths for short line and backsight length will be established as;

- 80m (test the limits of BS length and short line observation as it is below the recommended 120m minimum for short line observation and below the 100m minimum for RTK BS)
- 120m (recommended minimum distance for short line observation and around the minimum allowable length for RTK BS observation)
- 160m (determine accuracy of short line observations and BS lengths)
- 200m (recommended length for BS observations)

Furthermore it would seem prudent to determine the absolute maximum capabilities of RTK for measuring short lines and BS's. Therefore a 40m length will also be incorporated into the testing regime to determine if (although it may seem unlikely) RTK can be used to accurately measure a line of this length for cadastral purposes. In particular regard to urban situations, boundary lengths don't usually exceed 40m (in some cases the boundaries are less still) so is essential that this distance be observed to determine the appropriate application of RTK over particularly short lines. 40m lines would fall into the category of short lines rather than BS lengths because the surveyor would desire to use the longest BS possible and even when using TS, 40m BS's aren't recommended. It may be found that 40m short lines can effectively establish the orientation for a cadastral survey, however the surveyor is still advised to adopt best practice and seek a longer BS length.

Therefore the testing regime for short line and backsight length will be established as;

- 40m
- 80m
- 120m
- 160m
- 200m

3.2.3 CONTROL ARRAY

Having established the observation methods and having determined the necessary distances to be observed, the actual physical marks need to be identified. It would be ideal if the required marks existed in the real world from previous cadastral surveys, however it is unlikely that such a survey with these marks exists – and it would take too long to search for one that did. Therefore the required marks will be established for the purposes of this dissertation (refer to *Figure 3.3*), as the purpose of this dissertation is to replicate a cadastral survey from a practical perspective. Overall this probably represents the best course of action as the marks will be established exactly as need be and it can be placed in an area where the marks will not be interfered with. This does mean however that the marks need to be placed and then measured. While this means that extra work will be involved in the testing regime, it does mean that the aim of comparing RTK to TS accuracy can inherently be accomplished as the control array will be established by TS.

A consideration to be taken into account here is that the comparison of RTK and TS observations is not concerned with the co-ordinates of the observations but rather the measured lines (TS) and reduced baselines (RTK) to be compared. This reflects cadastral practice as cadastral plans show distances and bearings not co-ordinates at each end of the line. Therefore this means that the control array to be established does not need MGA co-ordinates per se, the co-ordinates can be arbitrary if desired. This would lead to the TS measuring on one co-ordinate system and RTK (of course) measuring on MGA. So long as the TS observes ground distances and the RTK GNSS observations are reduced to ground distances at mean terrain height there will be no trouble converting between the two systems and the primary analysis will be to reduce both sets of observations to distances and bearing and *forget* the co-ordinates. It would be essential to ensure that the co-ordinate system used by the TS is aligned to MGA grid north however so that there are no bearing difference arising from the different co-ordinate sets.

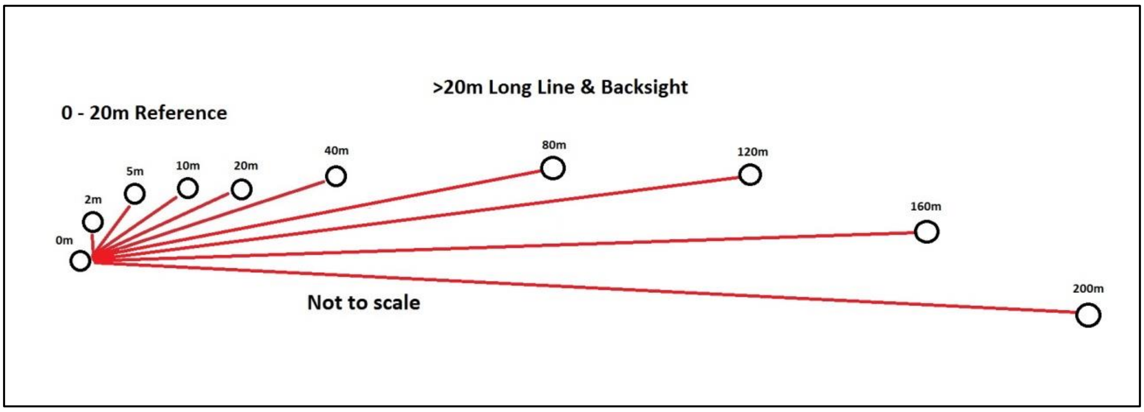

Figure 3.1 – Basic diagram of the control array

3.3 TESTING SITE

Before any testing can be started or indeed, before the control array can be established an appropriate location needs to be chosen to conduct the testing. From the findings of *Chapter 2* this location must allow a base station to be established that has a clear skyview and where multipath will not affect the return signal from satellites to the base. It has been decided that all marks of the control array will be established manually as it is unlikely that the necessary marks exist already. This means that a large open space will be required that is preferably unoccupied or at the very least, is unused by the public so that the testing will not conflict with any community interests.

As the survey marks need to be placed for the purposes of this dissertation, it is critical that the marks will pose no safety hazard to the public and that the placement of the marks has no environmental impact beyond regular survey mark placement for cadastral purposes. To address the public concern the marks will be driven flush at ground level with posting of each marks to identify the position, and the marks will be removed once testing is concluded. The environmental impact is harder to identify in this instance however overall there should be a very minimal impact. For testing purposes there needs to be about 10 marks established with 10 witness posts. With the placement of these, no vegetation will be removed or destroyed and at the end of testing all holes will be filled to completely reduce the impact of testing.

3.3.1 <u>CHOSEN TESTING SITE</u>

The area chosen to conduct all testing that meets the space requirements is the USQ Campus Grounds, Toowoomba; more specifically the open field fronted by West Street and the USQ main drive. This area provides over a hectare of open space within which survey testing for various classes is conducted (refer to the following *Figures* for site photos). The area has some scattered trees and the USQ Student Village adjoins the field however there are no significant obstructions in the area that would affect a base station or rover (unless under a tree).

Figure 3.2 – Aerial photograph of the testing field (Google Images, 2013)

Moreover the field has substantial existing survey control (on the *USQ Local Plane*) and the Ananga Continually Operating Reference Station (CORS) which can be used. The field has no specific use beyond survey testing and practical experiments so there is no public use beyond crossing the field to reach the university, meaning the marks placed are unlikely to be accidentally disturbed provided each is properly staked. Overall the field is an ideal area in which to conduct the testing.

Figure 3.3 – The testing field looking towards West Street

Figure 3.4 – The testing field looking back towards Baker Street

3.3.2 USE OF USQ'S CORS AS BASE STATION

USQ utilises the Ananga CORS as the base station for the majority of the universities RTK GNSS work. Given that Ananga is readily available and provides a reliable base station and radio link, this was be used for testing in preference to a stand-alone receiver as the base station set-up. As the survey mark (described as the 0m mark from *Figure 3.1*) is being treated as the corner or one end of the line it is the point from which the baseline is computed, thereby artificially creating an independent 'corner' position every round. Practically this means that the testing follows best practice recommendations as it simulates a new base position for every round of testing ensuring that one *bad* ambiguity solution doesn't affect the rounds of testing completed with that AR.

Ananga specifications:

- Software: Trimble GPS Base Version 2.5
- Receiver: NET R5
- Radio: Trimble TDL450H

3.3.3 USE OF USQ'S LOCAL PLANE CO-ORDINATE SYSTEM

The *USQ Local Plane* co-ordinate system is based on the Ananga base station as a central point and was used as a check to establish the control within the survey testing field. While it may be undesirable to work on two different co-ordinate systems, for the RTK observations and the TS measurements, the *USQ Local Plane* is aligned with the MGA system so the only difference is the co-ordinates of Ananga have been changed from real world to base the local plane and USQ control. The co-ordinates of the USQ control points have been reduced to ground distances so this co-ordinate system would be appropriate for the TS testing and provide an independent check for the base station set-up.

The implication of having the *USQ Local Plane* and a number of established control marks on this system within the testing field would be that real world co-ordinates don't need to be carried into the testing field. This means that the initial point (0m) can be an established USQ control point and to reinstate that point, other existing marks can be used as backsights.

3.3.4 ESTABLISH Control Array on USQ Local Plane

Therefore to initially establish the control array, an existing USQ control point will be used as the 0m and reinstated using other existing USQ control marks as backsights. The TS will be set-up on this mark and the testing marks will then be measured out and observed.

3.4 RESOURCE PLANNING

The majority of testing will be carried out using the resources available from the USQ surveying storeroom. Additional resources, such as calibrated TS, will be provided by MinStaff Survey who, as the sponsor of this dissertation, have graciously agreed to provide any required equipment that USQ does not previously own. This will mean that no testing costs will be incurred and prevent the need to purchase the equipment through the finance office.

If requests for equipment are lodge in a timely manner all equipment will be available to use, therefore it is unlikely that there will ever be a problem with needing equipment and not having access to it.

3.5 EQUIPMENT

3.5.1 FIELD TESTING

- Trimble S8 DR Plus total station (1” & 2mm + 2ppm machine) (validated)
- TSC3 handheld controller
- 4x traverse prisms
- Multitrack LED prism
- Trimble R8 GNSS receiver unit and battery kits
- 5x tripods
- Adjustable observation pole
- Bipod
- Tape measure (8m and 50m)
- ≈12x Dumpy pegs (or other suitable control point) and GI nails or equivalent
- Marker Stakes
- Sledge hammer
- Flagging tape

3.5.2 REDUCTIONS

- TSC3 handheld controller and connection kit
- Appropriate CAD software package – either Trimble Business Centre (TBC) or 12D
- Microsoft Excel software package

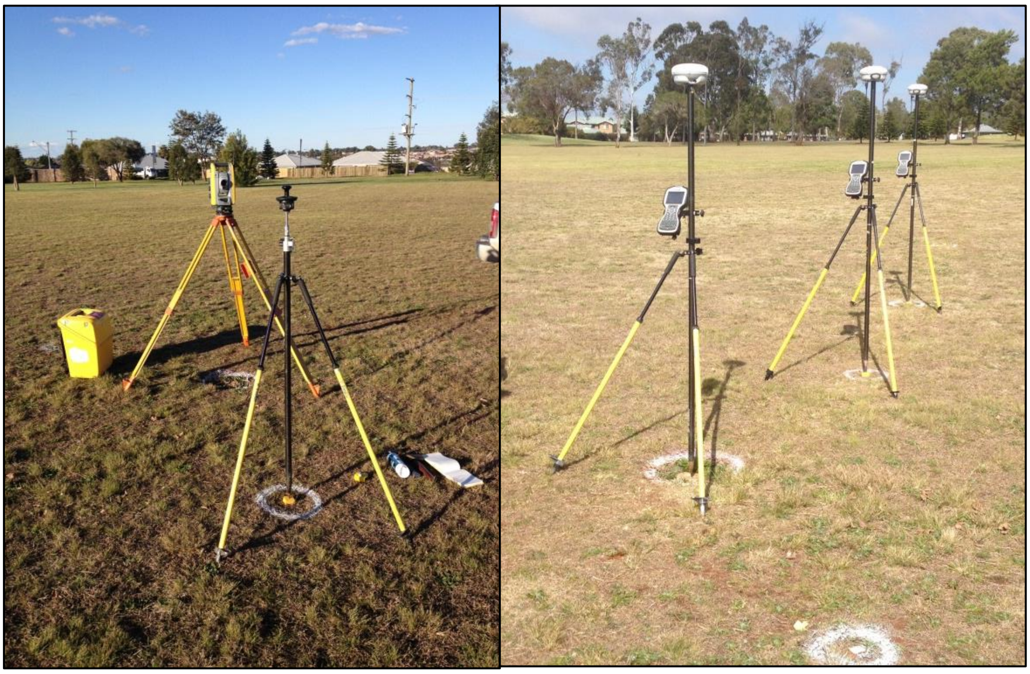

Figure 3.5 – Testing pictures of total station observation and RTK observations

3.6 TESTING REGIME

The testing regime section will give a detailed description of the practices which were previously determined to be used for the testing of short lines, referencing and determining the minimum backsight length. As stated in *Chapter 2*, all testing will be carried out in a manner that will allow real world replication and the practices to be implemented align with the recommended best practices as outlined by the various guidelines and *SP1*. No measures will be taken to create ideal observation conditions thereby minimising the environmental impact of this dissertation, outside of necessary action – though a different approach will be considered.

The methods for testing have been established from a combination of literature articles as well as industry standards, the author's professional experience, consultation with experienced professions and consultation with dissertation supervisor Mr Peter Gibbings. The purpose is to conduct this testing in such a way that it can be repeated at will and is within the means and abilities of any surveyor to repeat in the real world instance of short line observation, referencing and backsight length observation. Of course the circumstances might vary however the processes and methods are entirely repeatable.

When establishing the control array it will be critical to observe the network from an independent survey mark that has a unique station set-up, as this will verify the accuracy of the initial control array observations.

Trimble equipment has been used for the TS (S8 DR Plus) and RTK (R8) observations however the observation and equipment set-up procedures and functionality will be universal across all brands of equipment. It is not the intention of this dissertation to give a step-by-step description of every action but rather an overview of all major components to the testing.

3.6.1 ESTABLISH CONTROL ARRAY

i. The existing control in the USQ testing field will be used to re-establish a singular control point which has good horizontal and vertical co-ordinates so as to define a base position (0m) by means of a *station set-up* and reading rounds. In keeping with best practice all available survey marks within the USQ co-ordinate system will be observed to establish this central 0m mark.

ii. Having established the initial control point a dumpy and nail will be placed at every testing chainage (m); CH2, CH5, CH10, CH20, CH40, CH80, CH120, CH160 and CH200 (refer to *Figure 3.1*). It is not necessary that these distances are exact however CH2 and CH20 (referencing), CH120 (short lines) and CH200 (BS) should be as close as possible as these distances are specific to the respective minimum and maximum lengths. Of critical importance, the points must all must be observable from the initial point and the survey mark to be used for the independent measurements.

Figure 3.6 – Picture of the 2m testing mark

iii. Ensure that all marks have a clear point number and chainage so that there is no confusion as to what each mark represents.

iv. Once all the marks have been established, the TS will read rounds of observations (averaging 30 observations on FL and FR) to each test dumpy. Note that the distance observations to CH2 and CH5 must be verified with the tape measure given the minimum measuring distance of the TS. It is not essential that the marks be connected to one another however each must be related to the control.

Figure 3.7 – Picture of the control array with the reference marks in the foreground and the BS and short line lengths going into the background

3.6.2 <u>INDEPENDENT CONTROL ARRAY OBSERVATION</u>

The control array needs to be verified from a secondary survey mark with an independent *station set-up* resolution. The network check will follow the same procedure for observations as outlined in the previous subsection. After the check observations have been read, the measurements from the two rounds of independent testing will be compared to ensure that the distances and bearings between each survey mark is congruent and there have been no systematic or gross errors in the testing.

3.6.3 OBSERVATIONS

It is important to note in regards to testing:

- The observations must be carried out as quickly as possible (i.e. consecutive days) due to the control array being made up of non-permanent marks. This is to ensure that the observed co-ordinates of the job are less likely to be disturbed.
- Due care must be taken when setting-up all equipment and if interfered with, the process be started again from the beginning.
- It is possible to conduct testing for the 3 different tasks in one observation loop provided that the observation time and equipment is congruent throughout.
- It is possible to observe several test points at one time, with several rovers, for the longer observation lengths so that time is effectively managed
- When completing the 180s observations, once the referencing marks have been observed an independent AR will be gained and the 0m observed again before carrying on to ensure that the satellite geometry does not change significantly throughout that testing run
- Ensure that the point name convention for each observation of the same mark is different so there is no confusion, the controller does not override observations and the data can be easily interpreted – the name should be indicative of the observation time and equipment as well as the observation loop number, and will follow as;
    - *Observation length & equipment_observation round_control point name*
    - 3s obs; i.e. 3S_1_B32
    - 30s obs; i.e. 30BP_10_5M
    - 60s obs; i.e. 60BP_18_120M
    - 180s obs; i.e. 180BP_26_200M

3.6.3.1 CONTROLLER SETTINGS

In particular when establishing the survey the MGA co-ordinate system will be set to zone 56, the geoid model will be QLD geoid 09 with a project height set to 690m (the approximate height of the testing area based on the existing control).

3.6.3.2 SHORT LINE OBSERVATION AND BACKSIGHT LENGTH

i. The position and accuracy of Ananga was verified by measuring to several survey marks in the area with good class and order co-ordinates

ii. Observe the initial USQ control mark then control marks CH20, CH40, CH80, CH120, CH160 and CH200 for 3 seconds holding the pole by hand. Once the loop is completed return to the start (B32) and cause the rover receiver to lose initialisation (invert pole, cover receiver modem etc.). Wait until a new independent fixed ambiguity solution has been calculated and repeat the next loop.

iii. Complete *Step i.* a total of 30 times for the 3s observations
iv. Move onto the 30s observations and repeat *Step i.* however observe the CH's with the bipod attachment a total of 30 times
v. Move onto the 60s observations and repeat *Step i.* however observe the CH's with the bipod attachment a total of 30 times
vi. Move onto the 120s observations and repeat *Step i.* however observe the CH's with the bipod attachment a total of 30 times

3.6.3.3 REFERENCING

i. Observe the initial USQ control mark then control marks CH2, CH5, CH10, and CH20 for 3 seconds holding the pole by hand. Once the loop is completed return to the start (B32) and cause the rover receiver to lose initialisation (invert pole, cover receiver modem etc.). Wait until a new independent fixed ambiguity solution has been calculated and repeat the next loop.
ii. Complete *Step i.* a total of 30 times
iii. Move onto the 30s observations and repeat *Step i.* however observe the CH's with the bipod attachment a total of 30 times
iv. Move onto the 60s observations and repeat *Step i.* however observe the CH's with the bipod attachment a total of 30 times
v. Move onto the 120s observations and repeat *Step i.* however observe the CH's with the bipod attachment a total of 30 times

Remember that the testing can be conducted as the observation of B32, CH2, CH5, CH10, CH20, CH40, CH80, CH120, CH160 and CH200 rather than separately for each testing element.

3.6.4 TESTING CONCLUSION AND RESULT REDUCTIONS AND OUTPUT

i. Once the testing regime has been completed all survey marks and stakes that were placed for the purpose of this dissertation will be removed, in accordance with environmental considerations
ii. The observations as stored in the controllers will be reduced and produced as CSV files which can be manipulated in TBC, 12D and MS Excel (full output will consist of the *Survey Report* file, the JOB file and CSV)
iii. At this point the CSV's will be analysed in MS Excel to ensure the point name and feature code convention is correct and generally tidy the data (i.e. remove

redundant/ unnecessary observations) though the raw data will not be changed in any way

iv. The data will be brought into TBC and the baselines between the initial survey mark (B32) and each testing point will be established and from an *inverse analysis* the combined scale factor that needs to be applied to each line will be determined (grid → ground)

v. In MS Excel, the data will be input and converted from MGA and *USQ Local Plane* co-ordinates to ground distances and bearings

vi. Having determined these ground distances and bearings the necessary raw data results and analysis can be output

3.7 CONCLUSIONS

This section has outlined in great detail how the testing will be carried out to observe short lines, referencing and backsight lengths. Moreover this section, through the finding of *Chapter 2*, has justified why testing will be carried out in the manner proposed. This testing regime will firstly, enable the observation of the three elements that need to tested for this dissertation but secondly, ensure that testing has been carried out in a manner indicative of best practice and *reasonable professional practice*.

This methodology does not aim to give a detailed expression of how to conduct an RTK and TS survey based on the software used, as this will differ depending on the brand of equipment used and the software version. This methodology was aimed at providing a step-by-step overview of the testing that will be conducted for this dissertation and to ensure that should this testing need to be repeated, or should the testing need to be replicated, it will be within any surveyor’s ability to replicate and follow in whatever conditions. Basically it will now be clear to anyone who intends to use this dissertation or rely on the results, how these results were gained and exactly how the testing has gone about the testing practices.

CHAPTER 4: RESULTS

4.1 INTRODUCTION

The aim of this chapter will be to reduce the raw data of the testing regime to report the observation results in graphical form. The raw observation data from the RTK testing will not clearly show what was actually observed and hold little value to an observer, so it will only be reproduced in the appendices to verify the actual testing values. As the TS observations and Ananga position re-establishment is necessary to reproduce here both will be incorporated into this section so that it is possible to understand the true distances measured and ensure that Ananga was correctly re-established. The results will consist of ΔE and ΔN residual plots.

4.2 ESTABLISH THE CONTROL ARRAY WITH TOTAL STATION

Observation					Distance			Bearing
Point No.	Easting	Northing	Elevation	Point Code	ΔE	ΔN	Ground Distance	DMS
Establish Control Array								
999	5268.926	14702.834	684.680	SVYMARK_B32				
1008	5267.133	14701.736	684.827	SVYMARK_2M	1.793	1.098	2.102	58.3103
1007	5265.210	14699.580	684.895	SVYMARK_5M	3.716	3.254	4.939	48.4732
1006	5261.803	14695.743	684.999	SVYMARK_10M	7.123	7.091	10.051	45.0744
1005	5254.894	14688.084	685.165	SVYMARK_20M	14.032	14.750	20.358	43.3416
1004	5238.190	14676.994	685.756	SVYMARK_40M	30.736	25.840	40.155	49.5645
1003	5207.488	14651.465	686.583	SVYMARK_80M	61.438	51.369	80.084	50.0602
1002	5176.658	14625.951	687.613	SVYMARK_120M	92.268	76.883	120.102	50.1149
1001	5148.559	14597.077	688.367	SVYMARK_160M	120.367	105.757	160.227	48.4148
1000	5132.246	14556.608	688.787	SVYMARK_200M	136.680	146.226	200.159	43.0403
Independent Control Array								
1010	5268.919	14702.836	684.680	SVYMARK_B32				
1011	5267.121	14701.740	684.824	SVYMARK_2M	1.798	1.096	2.106	58.3806
1012	5265.200	14699.583	684.890	SVYMARK_5M	3.719	3.253	4.941	48.4926
1013	5261.795	14695.748	684.998	SVYMARK_10M	7.124	7.088	10.049	45.0842
1014	5254.887	14688.088	685.164	SVYMARK_20M	14.032	14.748	20.357	43.3430
1015	5238.184	14676.991	685.757	SVYMARK_40M	30.735	25.845	40.157	49.5623
1016	5207.483	14651.462	686.588	SVYMARK_80M	61.436	51.374	80.085	50.0549
1017	5176.652	14625.949	687.618	SVYMARK_120M	92.267	76.887	120.103	50.1143
1018	5148.557	14597.081	688.373	SVYMARK_160M	120.362	105.755	160.222	48.4146
1019	5132.244	14556.605	688.794	SVYMARK_200M	136.675	146.231	200.159	43.0355

Table 4.1 – The TS observations reduced to distances and bearings and a comparison between the control array establishment survey and the independent control array check

As can be seen from the table of results in *Table 4.1*, the observations all generally fall within reasonable consistency of the first set of observations that established the control and the independent set of observations that checked the control. There are several lengths such as the 2m and 160m lines which have a greater degree of error than would be desired (4mm and 5mm respectively) however the rest of the testing observations conform to the first round of testing which would indicate that at the very least there are no major errors present in the data. The survey control marks established within the USQ grounds aren't regularly maintained and the control file which listed the control co-ordinates was last updated in 2008 so it is possible that the control marks have been disturbed between then and now which might explain this discrepancy. Regardless, the 2m mark length was measured with a tape measure from the 0m (B32) mark and this confirmed that the original control establishment survey was correct (the tape measured distance being 2.103m). As the 200m mark length was found to be consistent through both rounds of testing, it was adopted as being the accurate and true length of the line and by using a 50m tape, the length from the 200m mark to the 160m mark was verified. The distance was found to be 39.931m, which would make the length of the 160m line 160.228m. The 50m tape was plastic and susceptible to stretching however it was relatively new and in good condition meaning that it could be reliably used to measure; therefore the length of the 160m line measured by the TS in the control establishment survey was adopted as true.

The bearing inconsistencies were harder to eliminate or justify. The most likely cause of the discrepancies will be a function of the *station set-up* and the survey control co-ordinates. Errors in the co-ordinates (from the survey marks being potentially inaccurate or disturbed) will contribute to a different *station set-up* that will change the position of the TS (only to the mm level). This discrepancy is particularly pronounced over the 2m, 5m, and 10m distances as can be seen from the results where there is about 7' bearing difference in the 2m length (over 4mm), about 2' bearing difference in the 5m length (over 2mm) and 1' difference in the 10m length (over 2mm). This serves to highlight the importance of referencing and reinforce the impact small distance errors have on bearings over short distances. From the *survey report* of the TS observations the control array establishment survey will be taken as the true bearings to all points, as on review of the *survey report* it was found to have a lower *observation standard error* and the general *station set-up* observations were on a higher accuracy than the independent check survey. It should be noted that the vertical observations to control mark B26 in the control establishment survey have large delta values, however this was found to be because of a mis-transcribed vertical control value, which was rectified for the independent check survey. Moreover the B26 observations in the establishment survey were excluded from the *station set-up* solution.

It should be noted from the *survey report* that there is evidence of several or more marks being been disturbed. It is important to remember however that the bearings and distances as measured by the TS are area of interest, not the co-ordinates. It makes absolutely no difference what the co-ordinates happen to be; in this case the co-ordinates are literally thousands of kilometers different due to the difference between the *USQ Local Plane* and MGA co-ordinate systems, so long as the observed bearings and ground distances are accurate.

Station setup

Station	B32	**Instrument height**	1.718	**Station type**	Station setup plus	**Scale factor**	1.00000000	**Std Error**	?

Orientation

Station	B32	**Backsight point**	B21	**Orientation correction**	-0°00'01"	**Orient. Std Err**	0°00'10"	

Residuals (stations)

Point	B21	**ΔE**	-0.014	**ΔN**	0.002	**ΔElev**	0.005	**Used for**	Horizontal only
		ΔHA	-0°00'27"	**ΔVA**	-0°00'14"	**ΔSD**	0.009		
Point	B21	**ΔE**	-0.013	**ΔN**	0.001	**ΔElev**	0.003	**Used for**	Horizontal only
		ΔHA	-0°00'28"	**ΔVA**	-0°00'07"	**ΔSD**	0.008		
Point	B22	**ΔE**	-0.005	**ΔN**	0.006	**ΔElev**	0.007	**Used for**	Horizontal only
		ΔHA	-0°00'17"	**ΔVA**	-0°00'18"	**ΔSD**	-0.005		
Point	B22	**ΔE**	-0.004	**ΔN**	0.006	**ΔElev**	0.004	**Used for**	Horizontal only
		ΔHA	-0°00'17"	**ΔVA**	-0°00'10"	**ΔSD**	-0.004		
Point	B52	**ΔE**	-0.003	**ΔN**	0.007	**ΔElev**	-0.001	**Used for**	Horizontal only
		ΔHA	0°00'07"	**ΔVA**	0°00'02"	**ΔSD**	-0.007		
Point	B52	**ΔE**	-0.002	**ΔN**	0.007	**ΔElev**	-0.006	**Used for**	Horizontal only
		ΔHA	0°00'06"	**ΔVA**	0°00'14"	**ΔSD**	-0.007		
Point	B26	**ΔE**	-0.009	**ΔN**	0.009	**ΔElev**	2.992	**Used for**	Horizontal only
		ΔHA	0°00'30"	**ΔVA**	-2°14'02"	**ΔSD**	0.121		
Point	B26	**ΔE**	-0.010	**ΔN**	0.009	**ΔElev**	2.989	**Used for**	Horizontal only
		ΔHA	0°00'32"	**ΔVA**	-2°13'52"	**ΔSD**	0.122		
Point	B35	**ΔE**	-0.004	**ΔN**	0.001	**ΔElev**	0.001	**Used for**	Horizontal only
		ΔHA	0°00'07"	**ΔVA**	-0°00'01"	**ΔSD**	0.003		

Point	B35	**ΔE**	-0.005	**ΔN**	0.001	**ΔElev**	-0.007	**Used for**	Horizontal only
		ΔHA	0°00'07"	**ΔVA**	0°00'13"	**ΔSD**	0.004		

Table 4.2 – The observation residuals and orientation correction for the control array establishment survey

Station setup

Station	B35	**Instrument height**	1.714	**Station type**	Station setup plus	**Scale factor**	1.00000000	**Std Error**	?

Orientation

Station	B35	**Backsight point**	B24	**Orientation correction**	-0°00'01"	**Orient. Std Err**	0°00'14"	

Residuals (stations)

Point	B24	**ΔE**	-0.010	**ΔN**	0.002	**ΔElev**	-0.013	**Used for**	Horizontal only
		ΔHA	0°00'32"	**ΔVA**	0°00'59"	**ΔSD**	0.007		
Point	B24	**ΔE**	-0.009	**ΔN**	0.002	**ΔElev**	-0.015	**Used for**	Horizontal only
		ΔHA	0°00'32"	**ΔVA**	0°01'04"	**ΔSD**	0.006		
Point	B26	**ΔE**	-0.004	**ΔN**	0.011	**ΔElev**	-0.008	**Used for**	Horizontal only
		ΔHA	-0°00'32"	**ΔVA**	0°00'43"	**ΔSD**	0.009		
Point	B26	**ΔE**	-0.005	**ΔN**	0.004	**ΔElev**	-0.010	**Used for**	Horizontal only
		ΔHA	-0°00'34"	**ΔVA**	0°00'03"	**ΔSD**	0.009		
Point	B52	**ΔE**	-0.001	**ΔN**	0.004	**ΔElev**	-0.001	**Used for**	Horizontal only
		ΔHA	-0°00'10"	**ΔVA**	0°00'15"	**ΔSD**	-0.001		
Point	B52	**ΔE**	-0.001	**ΔN**	-0.001	**ΔElev**	-0.006	**Used for**	Horizontal only
		ΔHA	-0°00'09"	**ΔVA**	-0°00'00"	**ΔSD**	-0.001		
Point	B32	**ΔE**	0.007	**ΔN**	0.000	**ΔElev**	0.000	**Used for**	Horizontal only
		ΔHA	0°00'10"	**ΔVA**	-0°00'00"	**ΔSD**	0.004		
Point	B32	**ΔE**	0.009	**ΔN**	0.000	**ΔElev**	-0.007	**Used for**	Horizontal only
		ΔHA	0°00'12"	**ΔVA**	0°00'13"	**ΔSD**	0.007		

Table 4.3 – The observation residuals and orientation correction for the independent control check survey

The control array will then be established as follows, note in particular the ground distances and bearings;

Observation					Distance			Bearing
Point No.	Easting	Northing	Elevation	Point Code	ΔE	ΔN	Ground Distance	DMS
Establish Control array								
999	5268.926	14702.834	684.680	SVYMARK_B32				
1008	5267.133	14701.736	684.827	SVYMARK_2M	1.793	1.098	2.102	58.3103
1007	5265.210	14699.580	684.895	SVYMARK_5M	3.716	3.254	4.939	48.4732
1006	5261.803	14695.743	684.999	SVYMARK_10M	7.123	7.091	10.051	45.0744
1005	5254.894	14688.084	685.165	SVYMARK_20M	14.032	14.750	20.358	43.3416
1004	5238.190	14676.994	685.756	SVYMARK_40M	30.736	25.840	40.155	49.5645
1003	5207.488	14651.465	686.583	SVYMARK_80M	61.438	51.369	80.084	50.0602
1002	5176.658	14625.951	687.613	SVYMARK_120M	92.268	76.883	120.102	50.1149
1001	5148.559	14597.077	688.367	SVYMARK_160M	120.367	105.757	160.227	48.4148
1000	5132.246	14556.608	688.787	SVYMARK_200M	136.680	146.226	200.159	43.0403

Table 4.4 – The TS observations adopted as the true distances and bearings for the RTK control array

4.3 RE-ESTABLISH ANANGA CORS

As was established in in the Methodology it is important to ensure that the USQ Ananga CORS is producing accurate MGA co-ordinates. Therefore before any testing is conducted on the established control array, Ananga will be used to measure several existing PSM's to ensure its accuracy. Several PSM's in the local area will be observed and the accuracy of the measurements will be confirmed (the project height will be set at 690m).

Point	42253	**East**	394487.240	**North**	6946073.744	**Elevation**	690.691	**Code**	PSM
Point	40956	**East**	394651.683	**North**	6945868.391	**Elevation**	689.794	**Code**	PSM
Point	40403	**East**	394940.388	**North**	6945984.562	**Elevation**	684.598	**Code**	PSM
Point	40424	**East**	394860.174	**North**	6945489.267	**Elevation**	683.293	**Code**	PSM
Point	38566	**East**	394970.986	**North**	6946480.878	**Elevation**	681.007	**Code**	PSM

Table 4.5 – The PSM co-ordinates of the control marks that will be used to establish the accuracy of Ananga

Point	1000	**East**	394651.716	**North**	6945868.368	**Elevation**	689.506	**Code**	STN_40956_L
Point	1001	**East**	394651.715	**North**	6945868.369	**Elevation**	689.520	**Code**	STN_40956_S
Point	1002	**East**	394487.231	**North**	6946073.766	**Elevation**	690.429	**Code**	STN_42253_S
Point	1003	**East**	394487.232	**North**	6946073.767	**Elevation**	690.425	**Code**	STN_42253_L
Point	1004	**East**	394860.190	**North**	6945489.261	**Elevation**	683.028	**Code**	STN_40424_L
Point	1005	**East**	394860.192	**North**	6945489.249	**Elevation**	683.014	**Code**	STN_40424_S

Point	1006	**East**	394940.394	**North**	6945984.558	**Elevation**	684.312	**Code**	STN_40403_S
Point	1007	**East**	394940.393	**North**	6945984.555	**Elevation**	684.320	**Code**	STN_40403_L

Table 4.6 – The RTK observations of the PSM's; PSM 38566 was found to be gone and observations denoted by an '_L' and '_S' represent *3 min observed control points* and *30s topo shot* respectively

The discrepancies found in the vertical observations are obviously of concern. Upon rigorous investigation it has been found that these discrepancy were actually caused by the geoid model used; QLD geoid 09. This geoid is actually based upon the AUSgeoid98 model and has now been made out-dated by the AUSgeoid09 model – the geoid that should have been used. Upon investigation of the differences between the two geoid models (in ICSM and TBC) it was found that the differences in the observations between *Table 4.5* and *Table 4.6* were actually just the differences between the two geoid models. Therefore it can be concluded that the AUSgeoid09 geoid model should have been used for the testing, but the discrepancies are explainable. Finally the geoid model used makes little difference as this does not affect the horizontal co-ordinates for which this dissertation is concerned.

4.4 DETERMINE COMBINED SCALE FACTORS

To determine ground distances, the RTK observations need to be reduced to the mean terrain height and converted by the combined scale factor. The CSF needs to be calculated for each line and can be determined in a variety of ways, i.e. various software packages or the ICSM spreadsheets. For the purposes of this dissertation the CSF was determined from the *inverse report* in the TBC software. Every line from every observation set has a different CSF based on the height observed and the distance of the observation, but the changes between the CSF of each line length only differed minutely. Therefore the CSF's were checked and one set of CSF's was chosen; this will be appropriate as the differences in the CSF's is so small it will not affect the data at the sub-millimeter or sub-second level.

Line Length	Combined Scale Factor
2m	0.9996225056
5m	0.9996224023
10m	0.9996223594
20m	0.9996223375
40m	0.9996223710
80m	0.9996223477

120m	0.9996223069
160m	0.9996222682
200m	0.9996221984

Table 4.7 – The combined scale factors that will be used to reduce the RTK observations to ground distances

4.5 3s RTK Observations

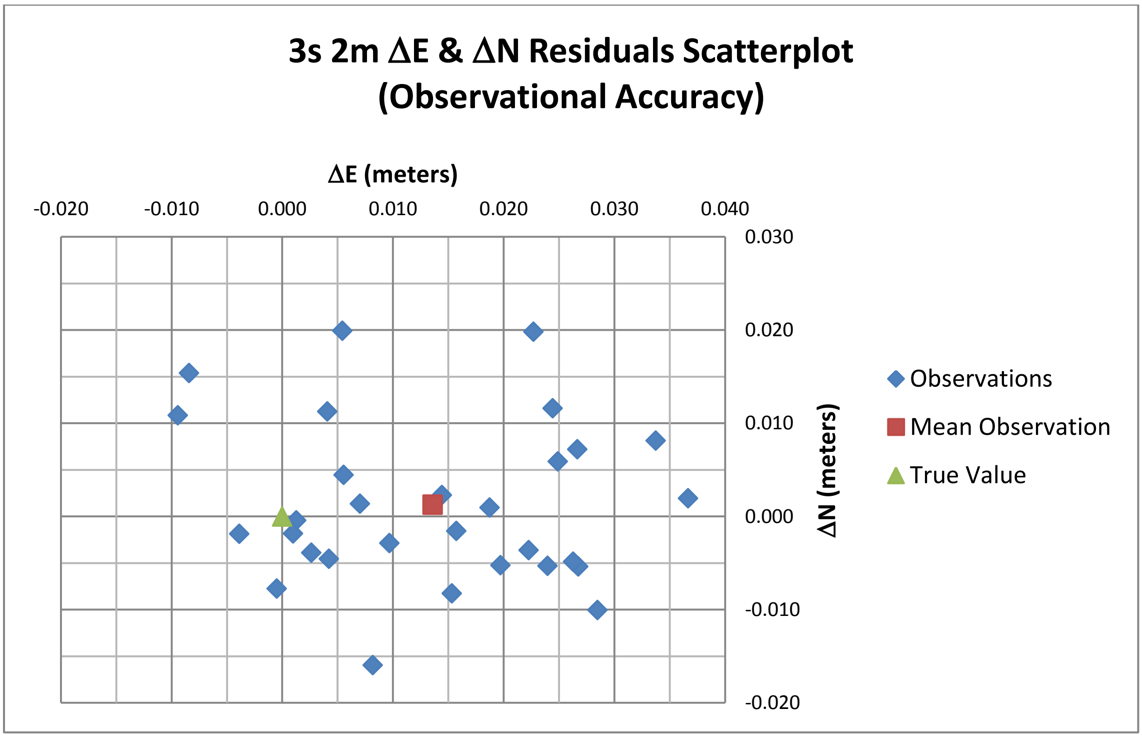

Figure 4.1 – The 3s RTK observations ΔE and ΔN residual plot of the 2m marks

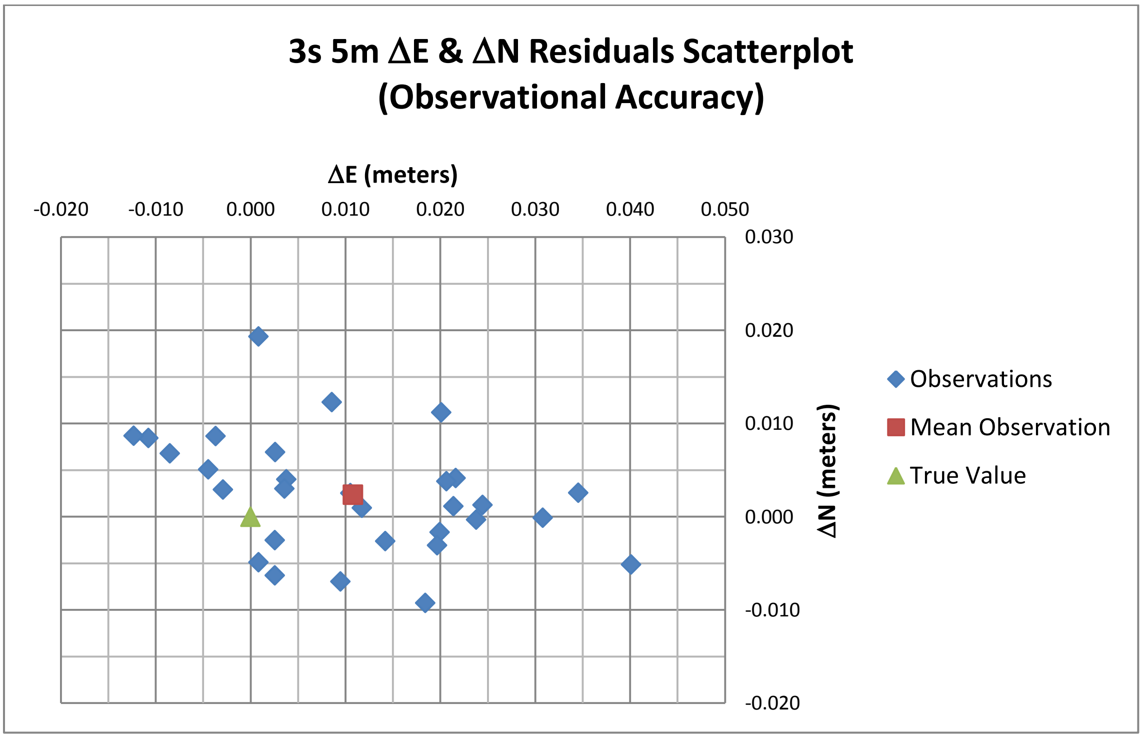

Figure 4.2 – The 3s RTK observations ΔE and ΔN residual plot of the 5m marks

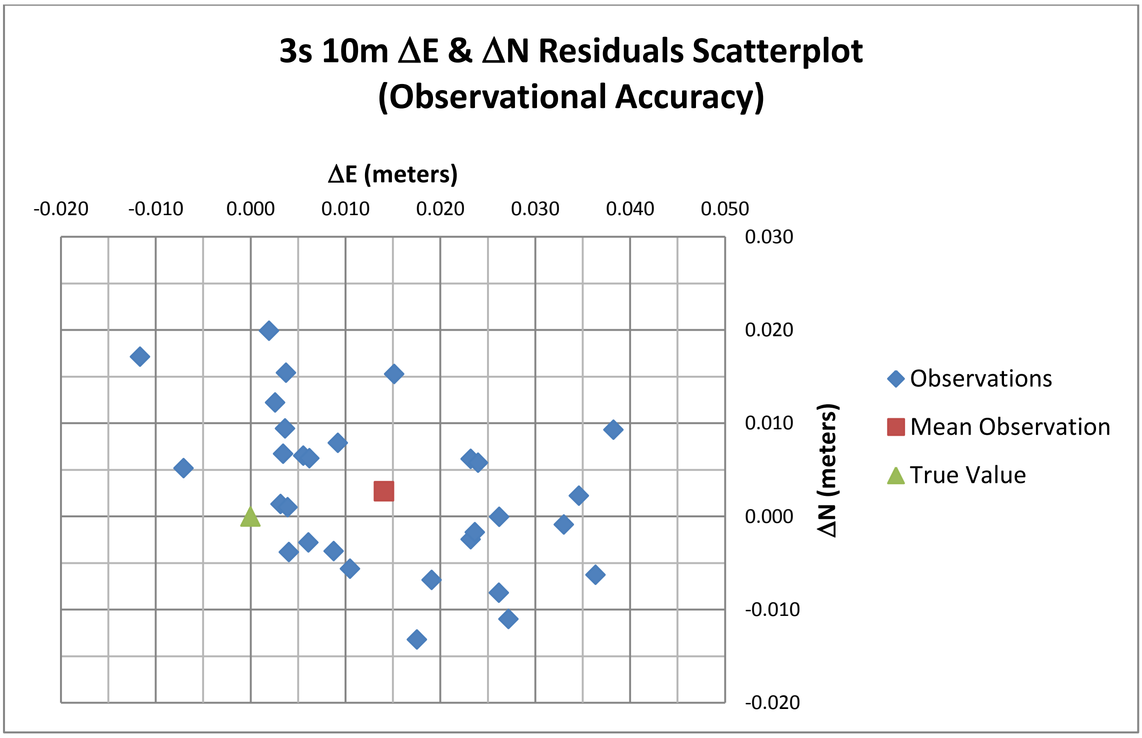

Figure 4.3 – The 3s RTK observations ΔE and ΔN residual plot of the 10m marks

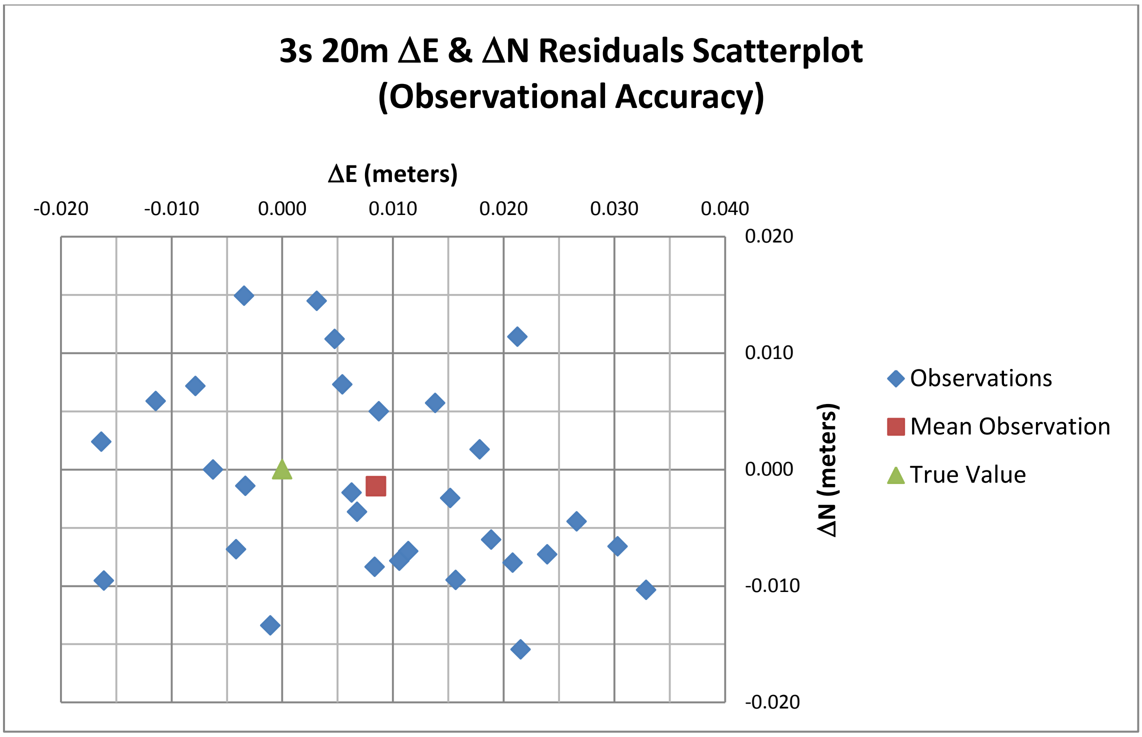

Figure 4.4 – The 3s RTK observations ΔE and ΔN residual plot of the 20m marks

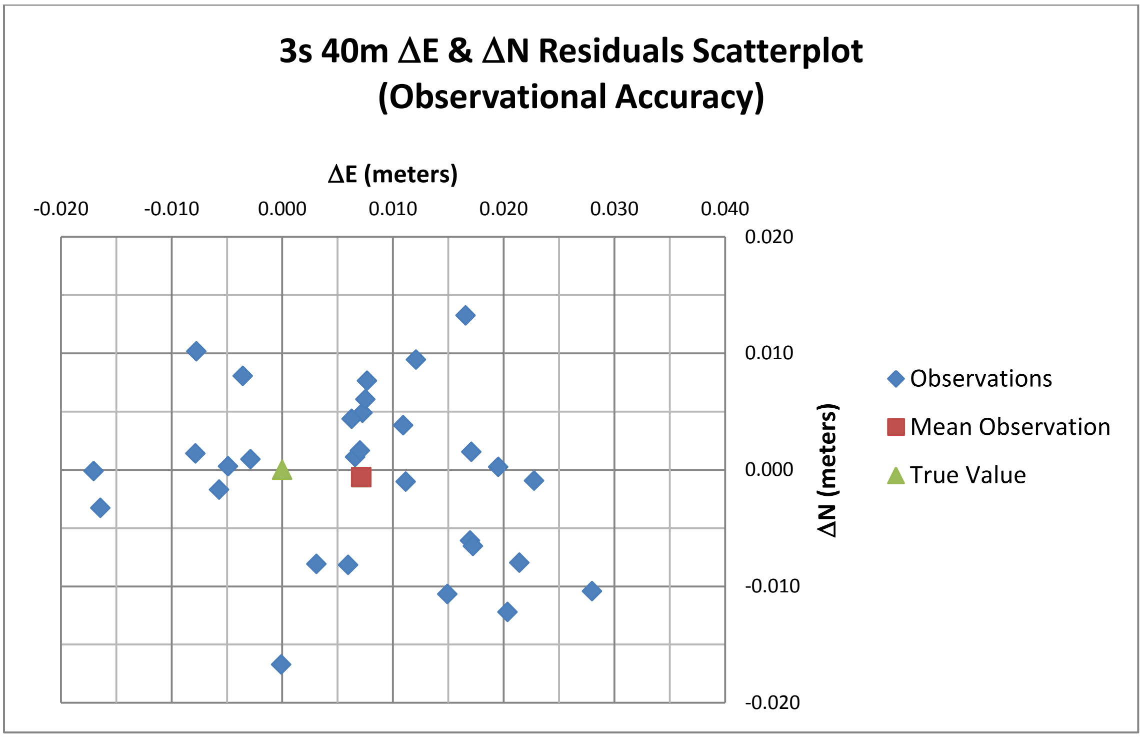

Figure 4.5 – The 3s RTK observations ΔE and ΔN residual plot of the 40m marks

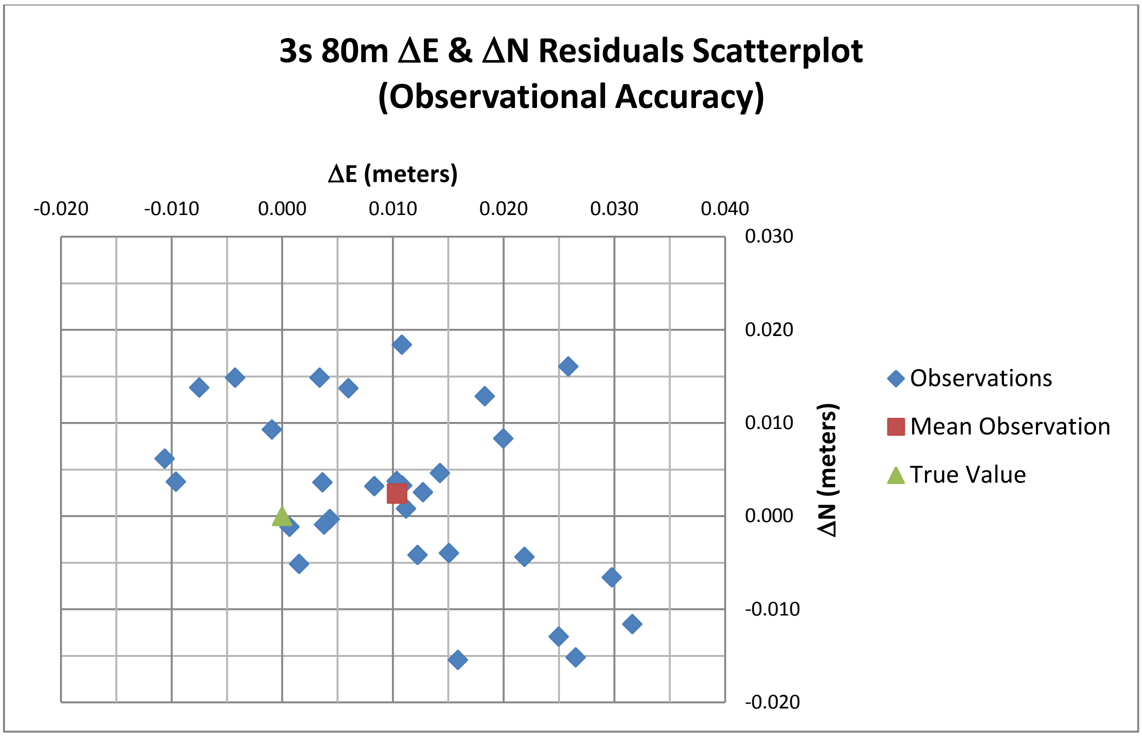

Figure 4.6 – The 3s RTK observations ΔE and ΔN residual plot of the 80m marks

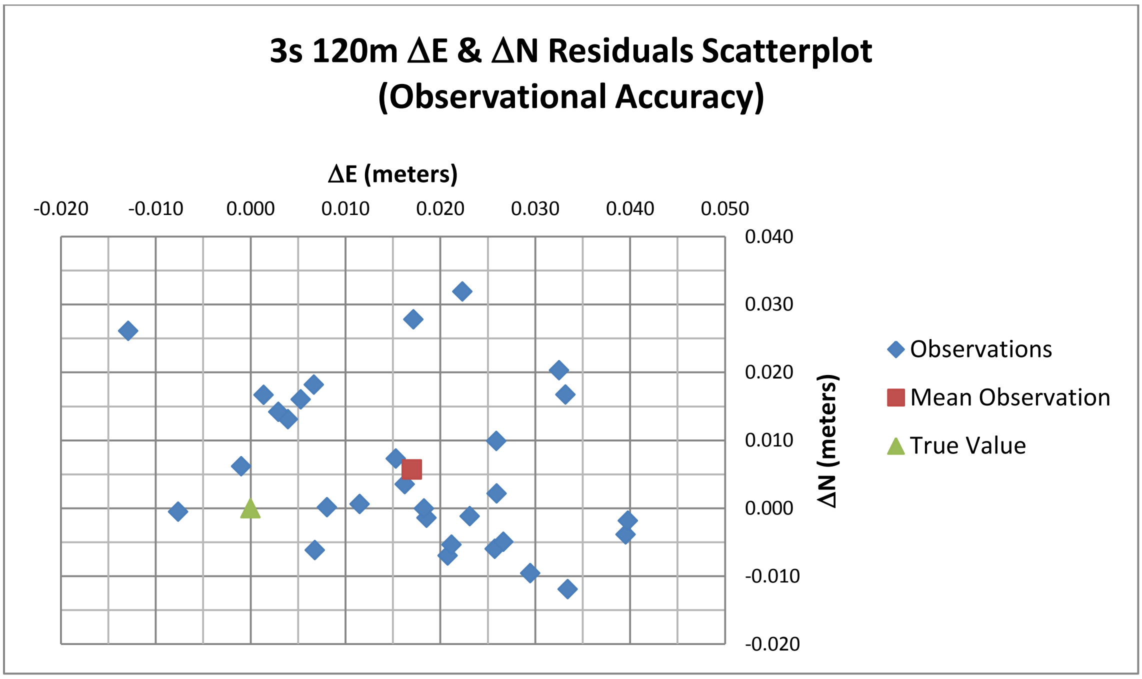

Figure 4.7 – The 3s RTK observations ΔE and ΔN residual plot of the 120m marks

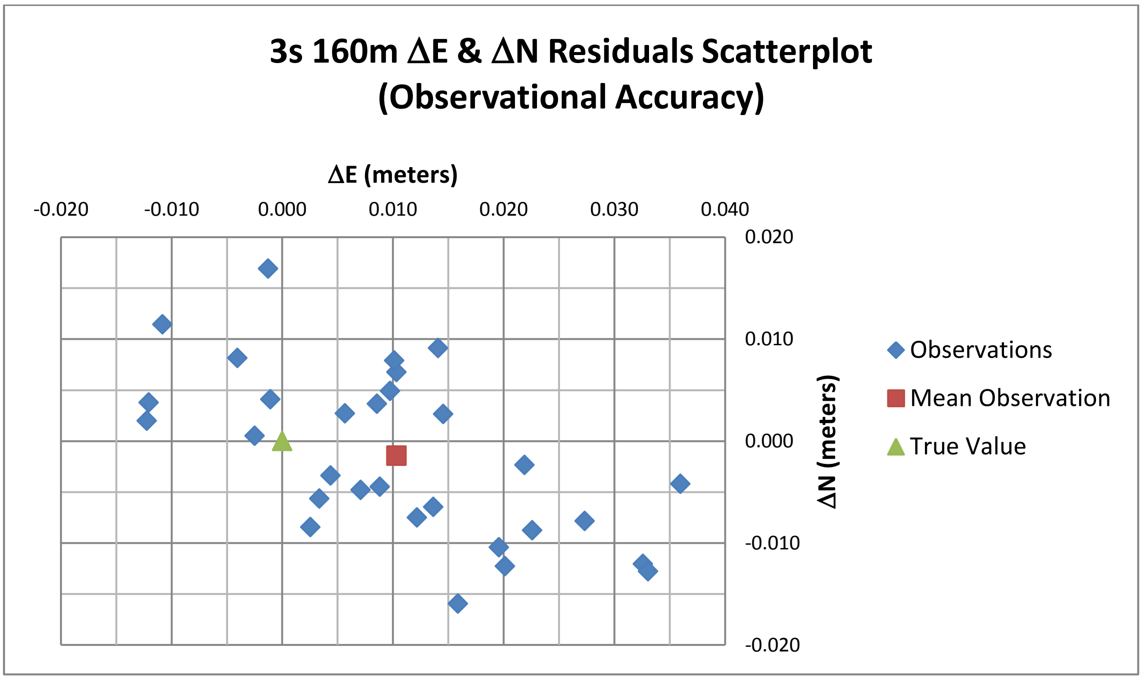

Figure 4.8 – The 3s RTK observations ΔE and ΔN residual plot of the 160m marks

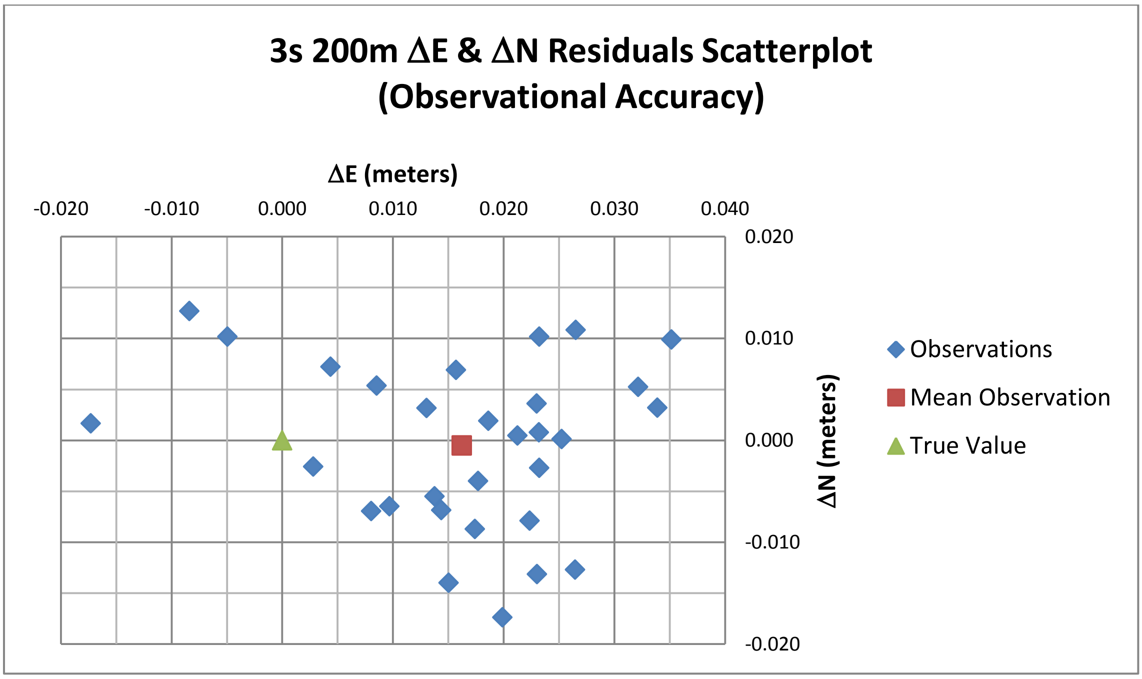

Figure 4.9 – The 3s RTK observations ΔE and ΔN residual plot of the 200m marks

4.5.1 <u>3S ANALYSIS</u>

As can be seen from the residual graphs of the observations, there is quite a large scattering of data generally up to 15mm from the true value. The 3s data observations were taken over several hours in one day. The mean of the data always tending towards the east (positive ΔE values) would reflect observation bias as the satellite geometry has not changed significantly over the several observation hours. There is a slight bias of observations fall towards the north of the true value, though this is most likely caused by the satellite geometry in Australia tending towards satellites in the northern sky (Roberts, 2005). The large scattering of data reflects the conclusions of the *Literature Review*; there is little data being observed and averaged so the weighted average observation technique doesn't have enough epochs of data to start to converge around a true mean. Moreover as the satellite geometry hasn't changed significantly the observations are focussed towards the east slightly, rather than a random distribution. Looking at the mean observation values as a representation of their respective data sets, the means all fall about 10mm – 15mm away from the true value, which, especially for those 10mm means, would suggest that 3s observations could in fact meet the accuracy recommendations referenced in the SBQ guidelines. This is a very early analysis but still interesting to note. Given the scattering of the data though it would be ill advised to accept a 3s observation as opposed to a more rigorous observation technique – should these be found to be more appropriate (as the research would suggest).

4.6 30s RTK Observations

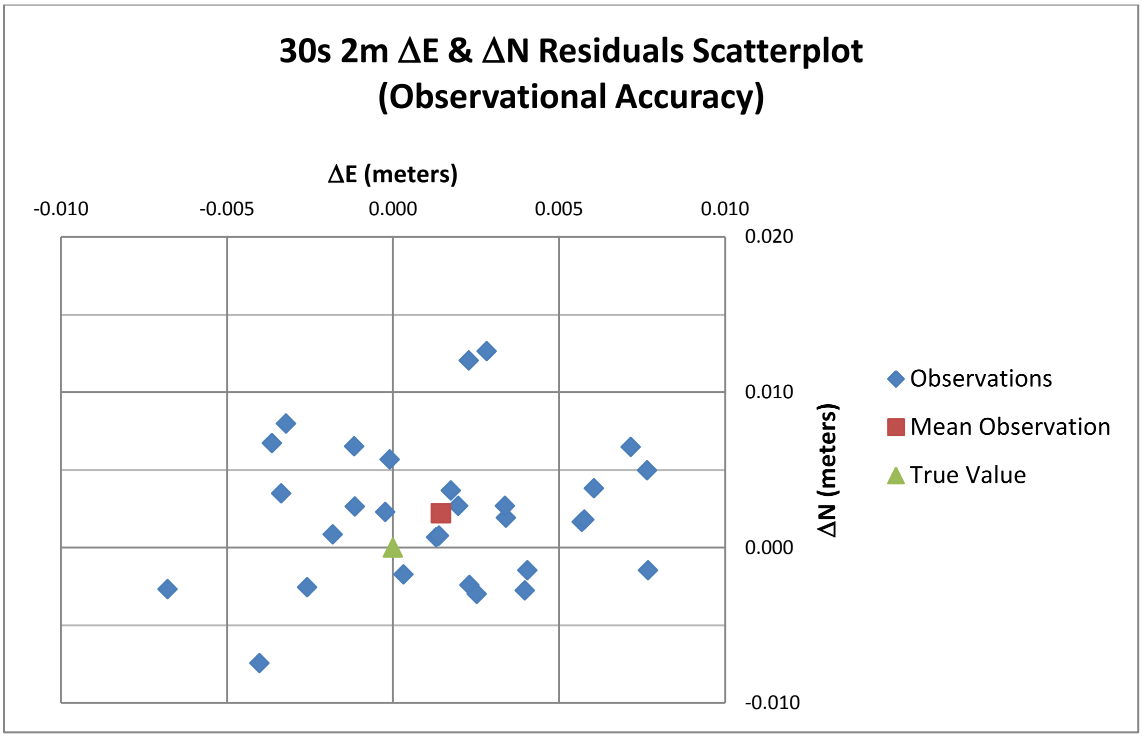

Figure 4.10 – The 30s RTK observations ΔE and ΔN residual plot of the 2m marks

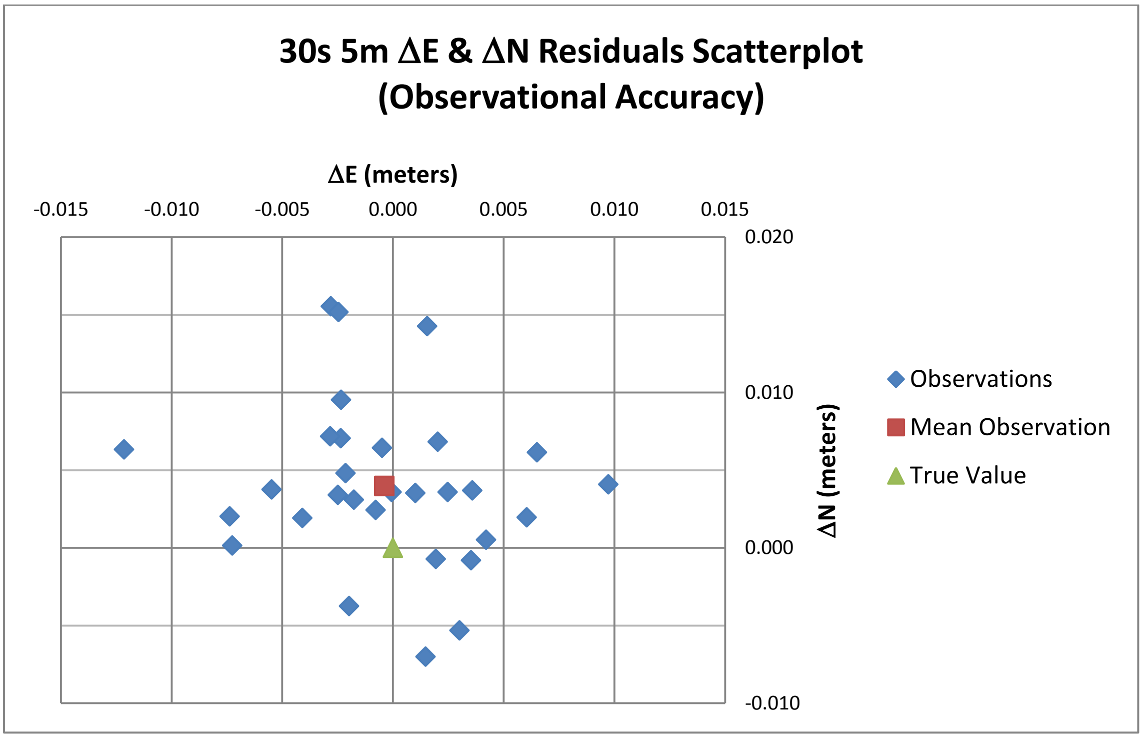

Figure 4.11 – The 30s RTK observations ΔE and ΔN residual plot of the 5m marks

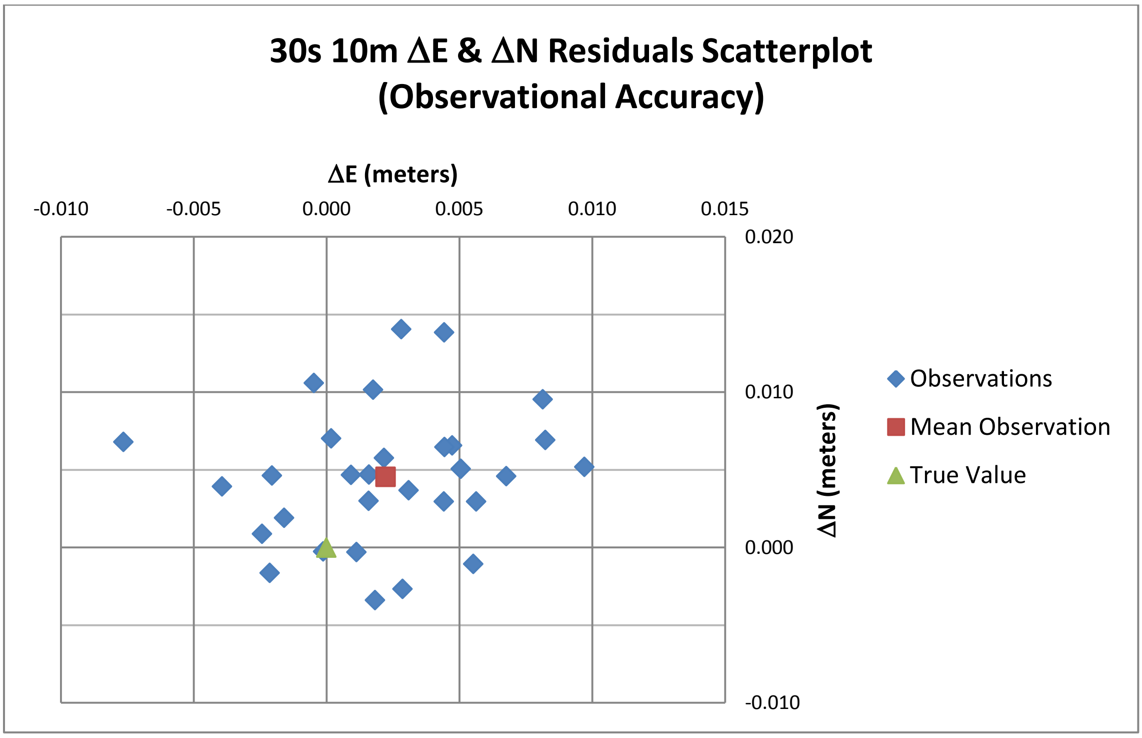

Figure 4.12 – The 30s RTK observations ΔE and ΔN residual plot of the 10m marks

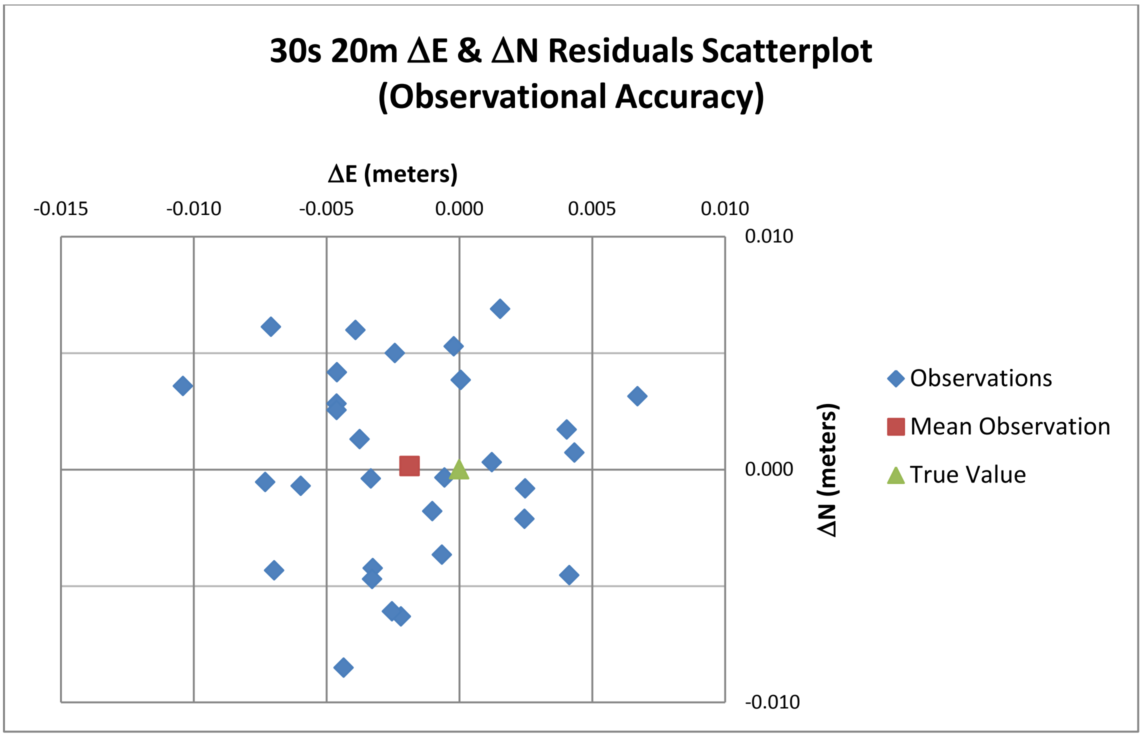

Figure 4.13 – The 30s RTK observations ΔE and ΔN residual plot of the 20m marks

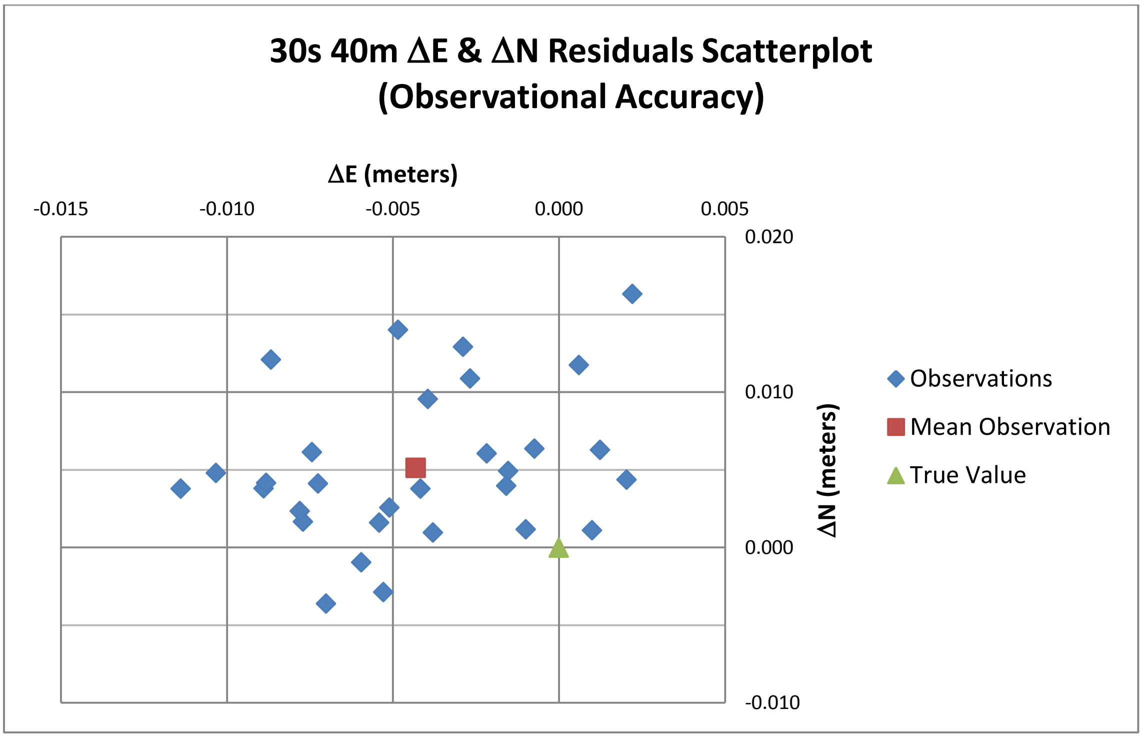

Figure 4.14 – The 30s RTK observations ΔE and ΔN residual plot of the 40m marks

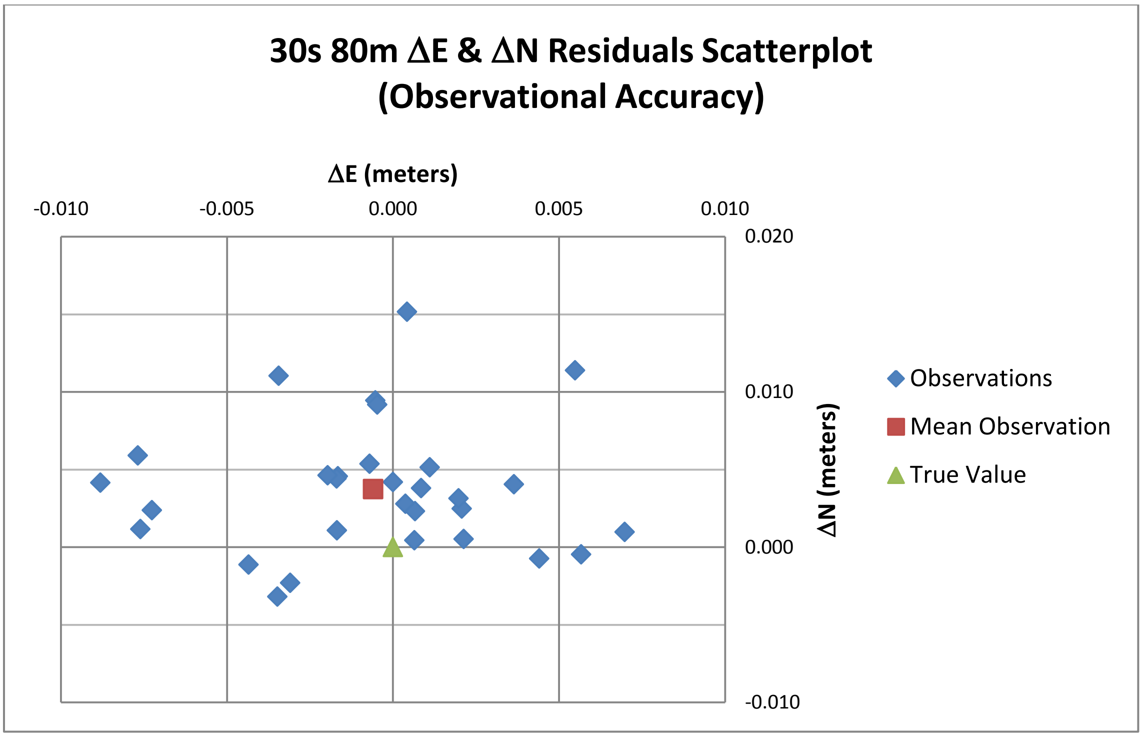

Figure 4.15 – The 30s RTK observations ΔE and ΔN residual plot of the 80m marks

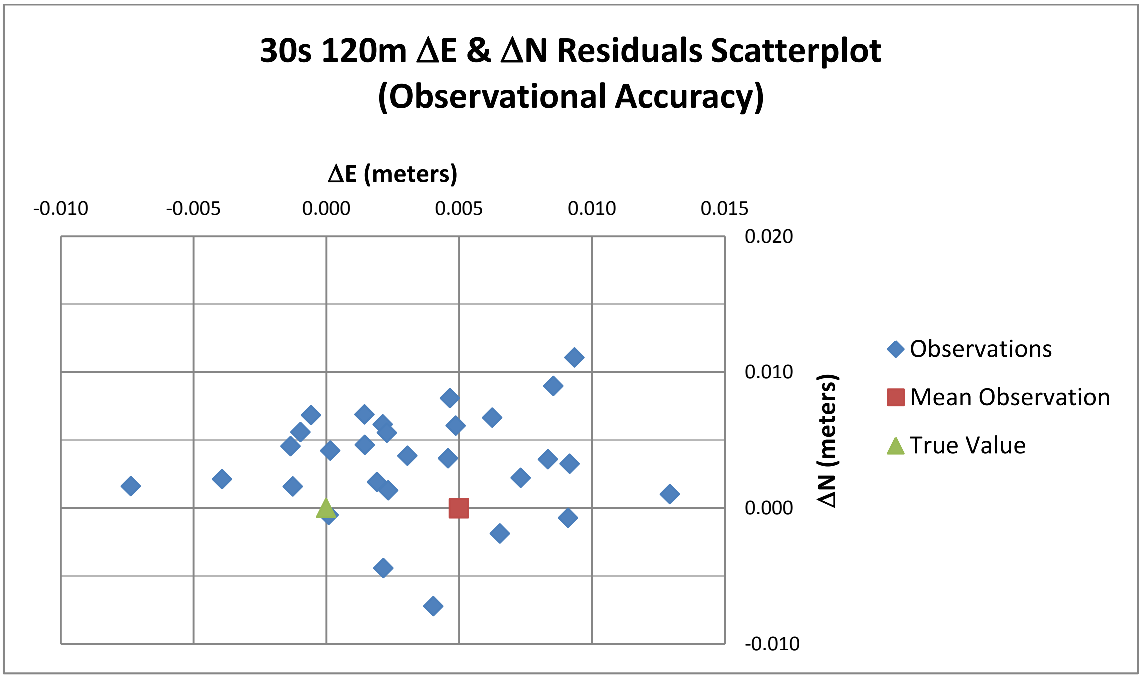

Figure 4.16 – The 30s RTK observations ΔE and ΔN residual plot of the 120m marks

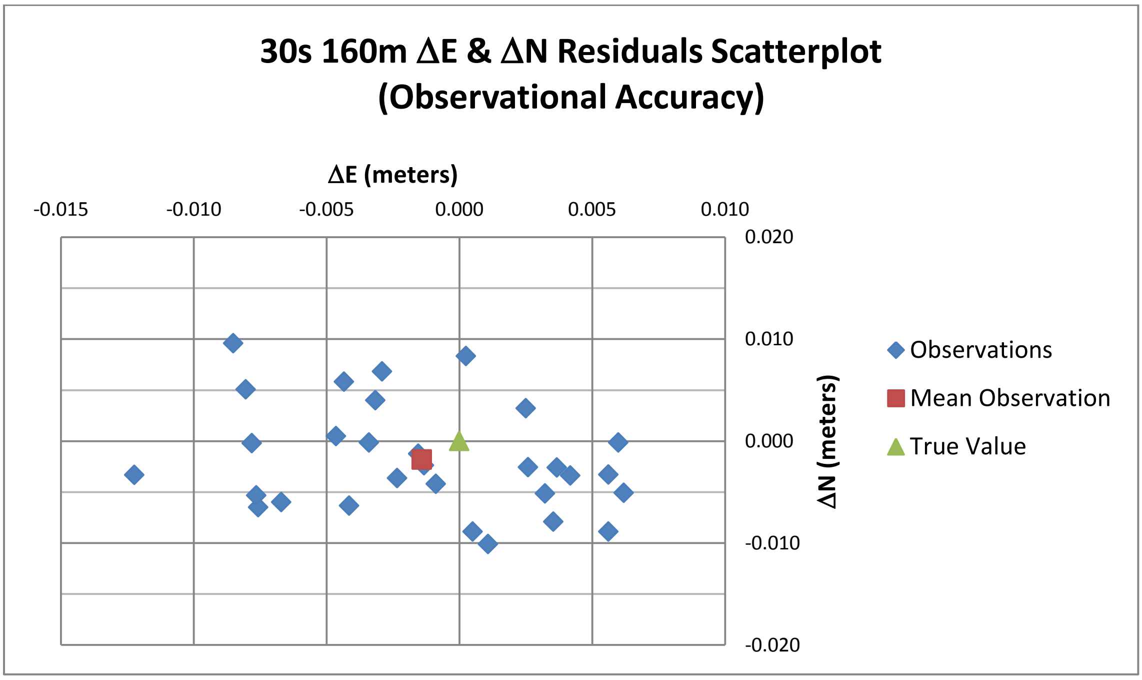

Figure 4.17 – The 30s RTK observations ΔE and ΔN residual plot of the 160m marks

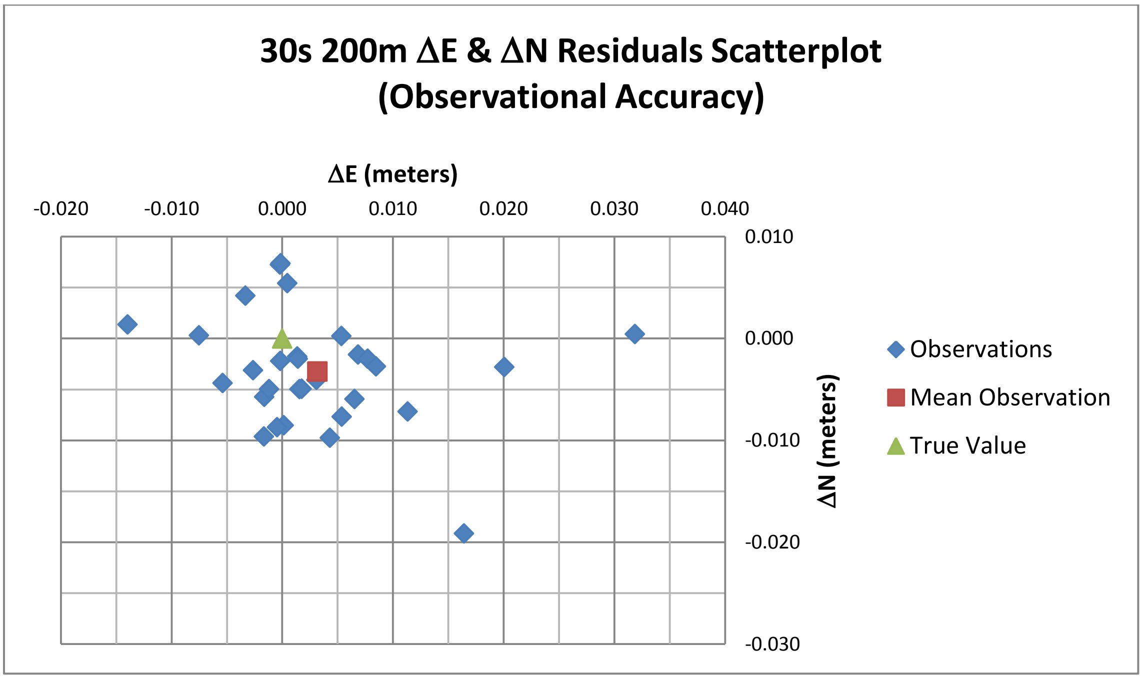

Figure 4.18 – The 30s RTK observations ΔE and ΔN residual plot of the 200m marks

4.6.1 30s Analysis

The immediate, striking characteristic of the 30s observations residual plots is the observations are much less scattered and converge around the true value much better that the 3s. These observations were taken over several consecutive days and there appears to be an even spread either side of the y-axis and no apparent observation bias. Again looking at the mean as a representation, the average observation distance is significantly closer to the true value; falling from 10mm – 15mm in the 3s observations to around or less than 5mm in this instance. This result is to be anticipated though, as from the literature a longer occupation would lead to better observation averaging. This is not to say the observations are all perfect though, there are instances of residuals over 30mm from the true value, however these are much less frequent than occurred when observing for 3s and appear to be outriding observations in comparison to the majority which focus around the true value.

Given the survey standards' accuracy require a vector accuracy of 10mm + 50ppm, the mean observations of all these sets pass this standard which lends weight to the argument that RTK may be appropriate for cadastral purposes. It would also stand that the accuracy recommendation could stand too be far more rigorous if 30s observations meet these standards. The significant improvement in accuracy is not only apparent in line length, as the bearing will also be significantly improved as a result. It should be remembered that small errors over short distances will have large effects on the bearing and these should be minimised as much as possible when reinstating boundaries and especially when describing new ones.

4.7 60s RTK Observations

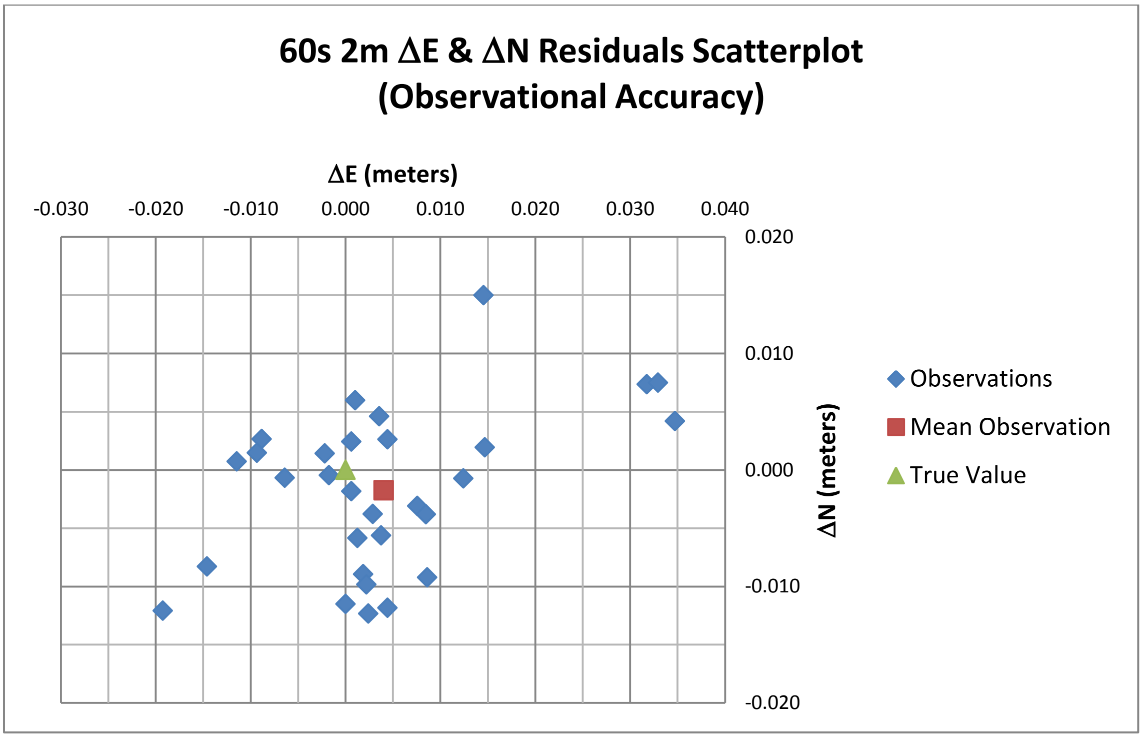

Figure 4.19 – The 60s RTK observations ΔE and ΔN residual plot of the 2m marks

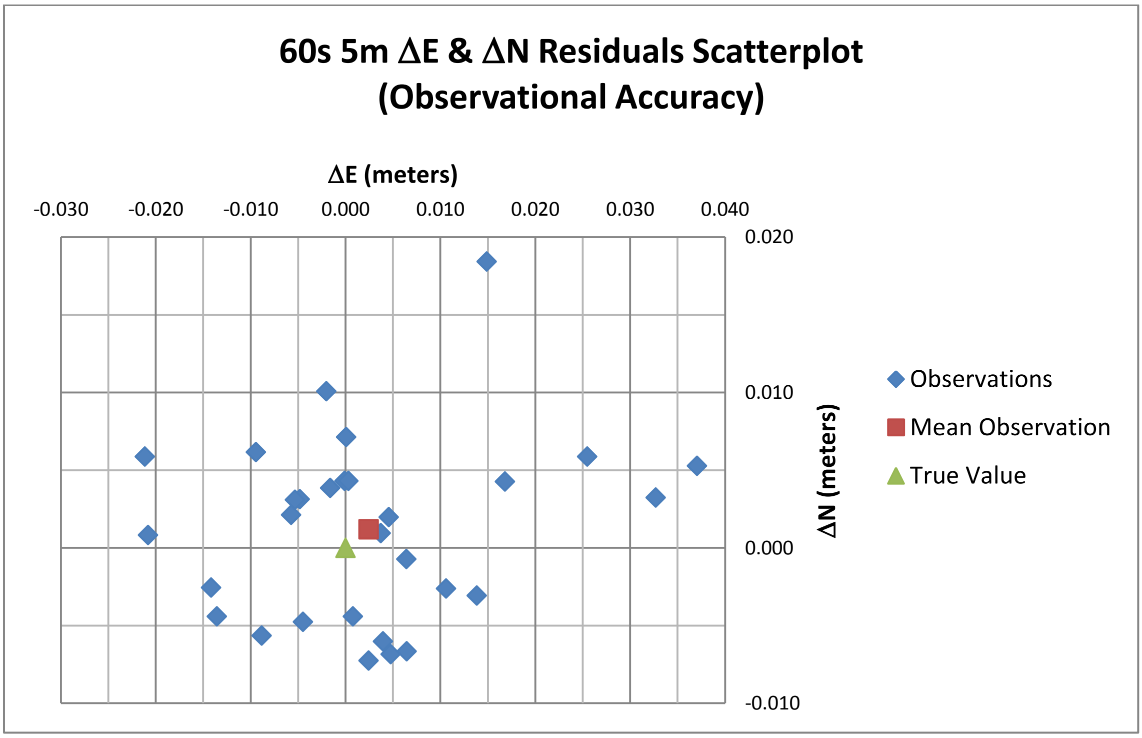

Figure 4.20 – The 60s RTK observations ΔE and ΔN residual plot of the 5m marks

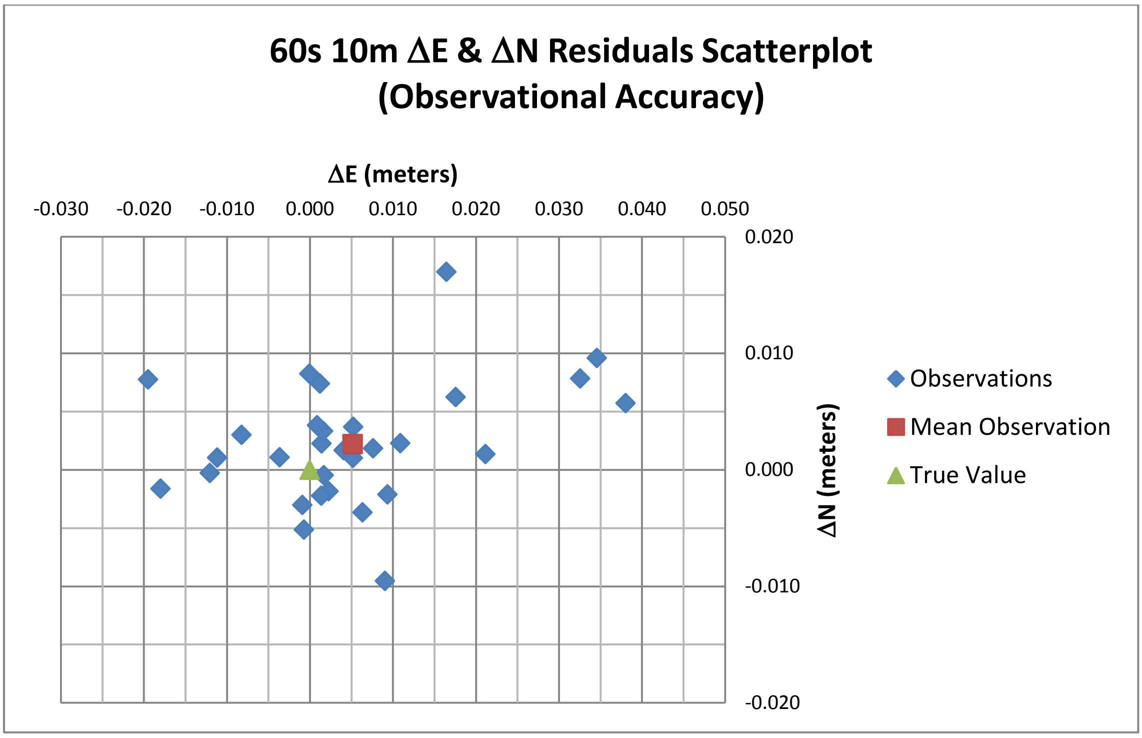

Figure 4.21 – The 60s RTK observations ΔE and ΔN residual plot of the 10m marks

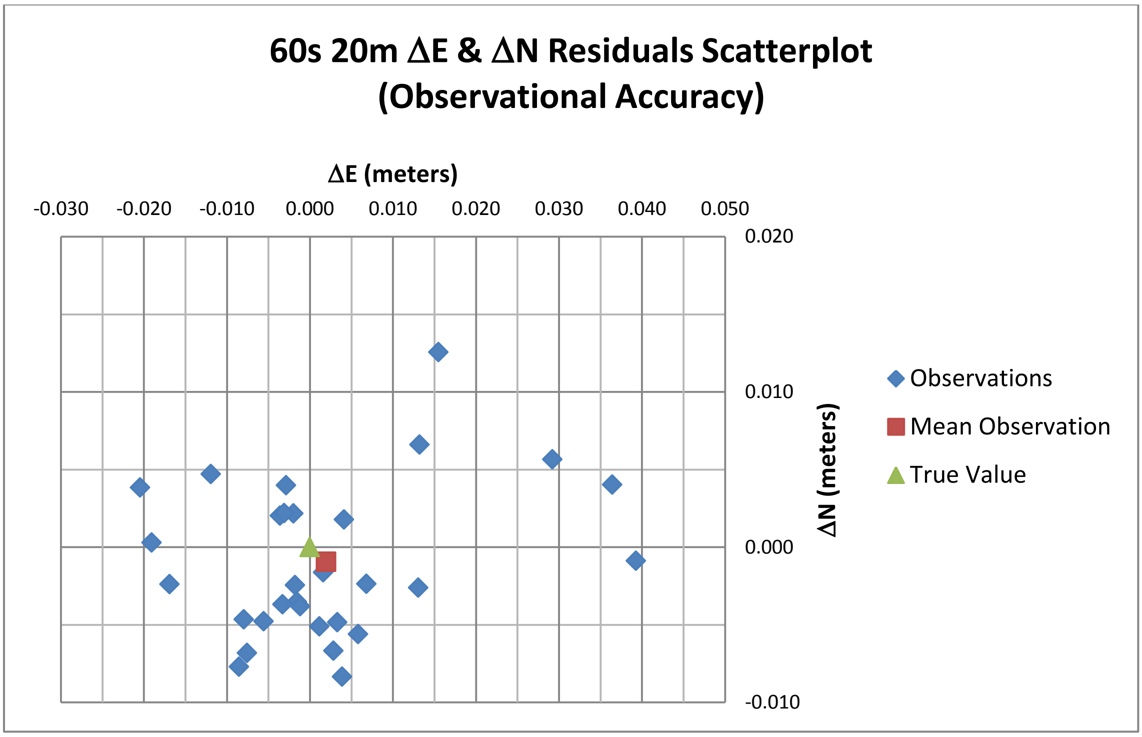

Figure 4.22 – The 60s RTK observations ΔE and ΔN residual plot of the 20m marks

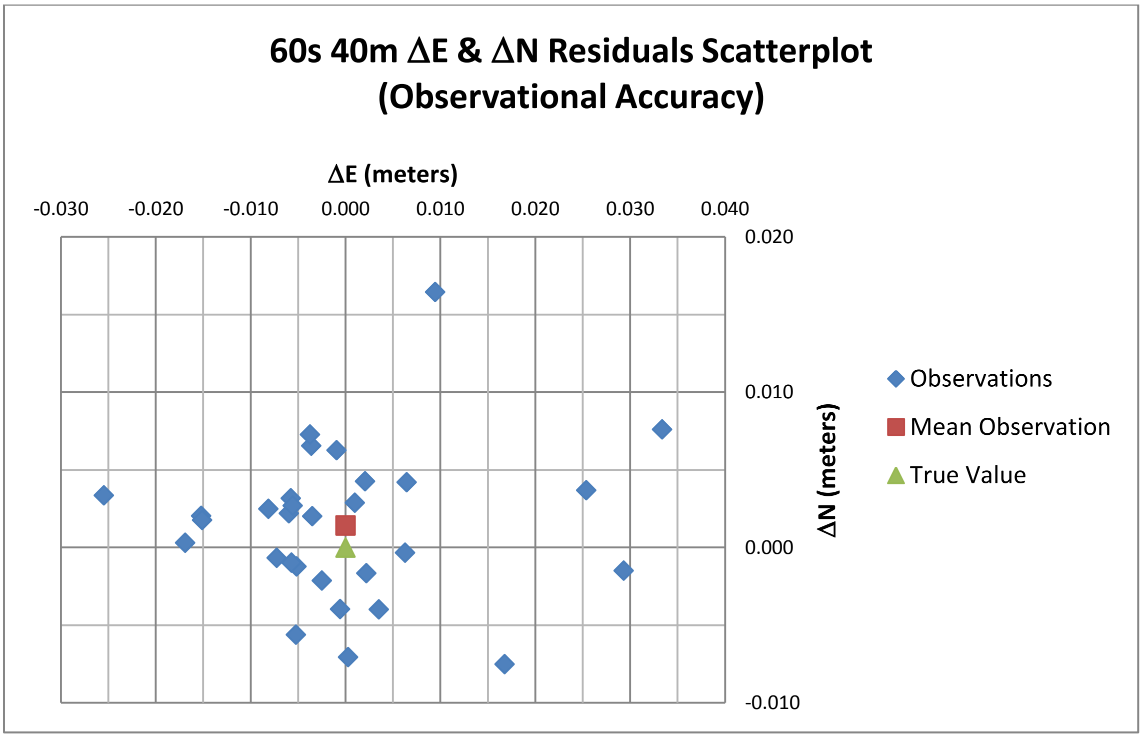

Figure 4.23 – The 60s RTK observations ΔE and ΔN residual plot of the 40m marks

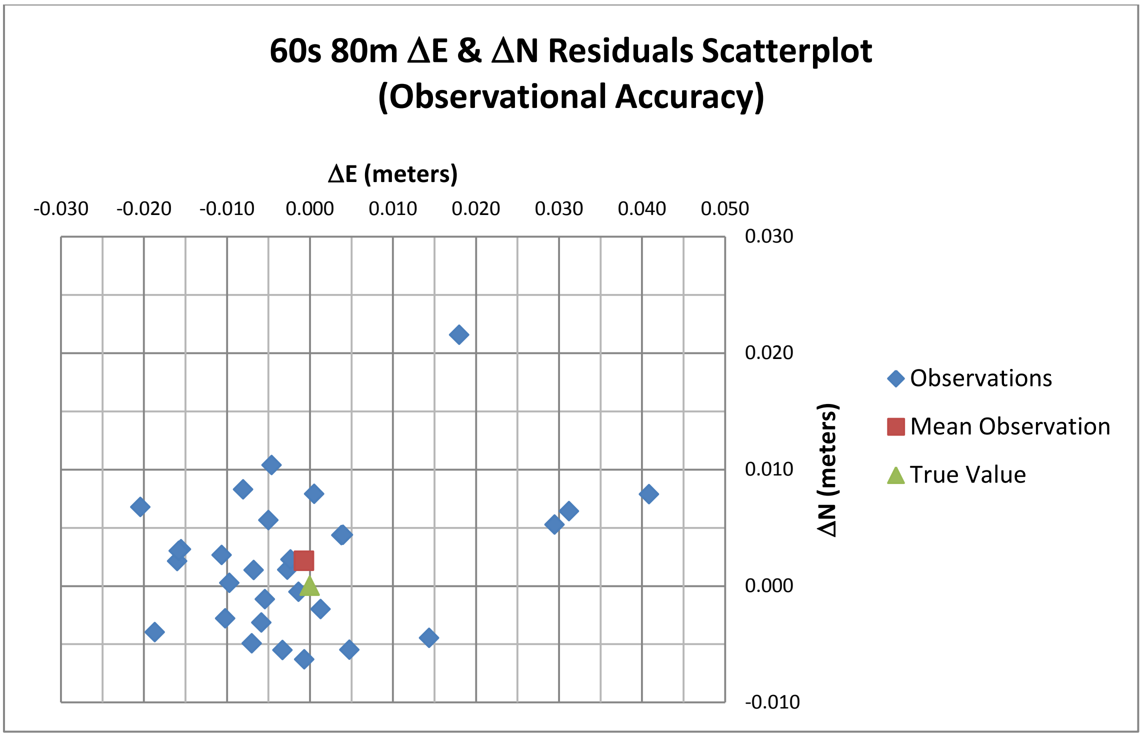

Figure 4.24 – The 60s RTK observations ΔE and ΔN residual plot of the 80m marks

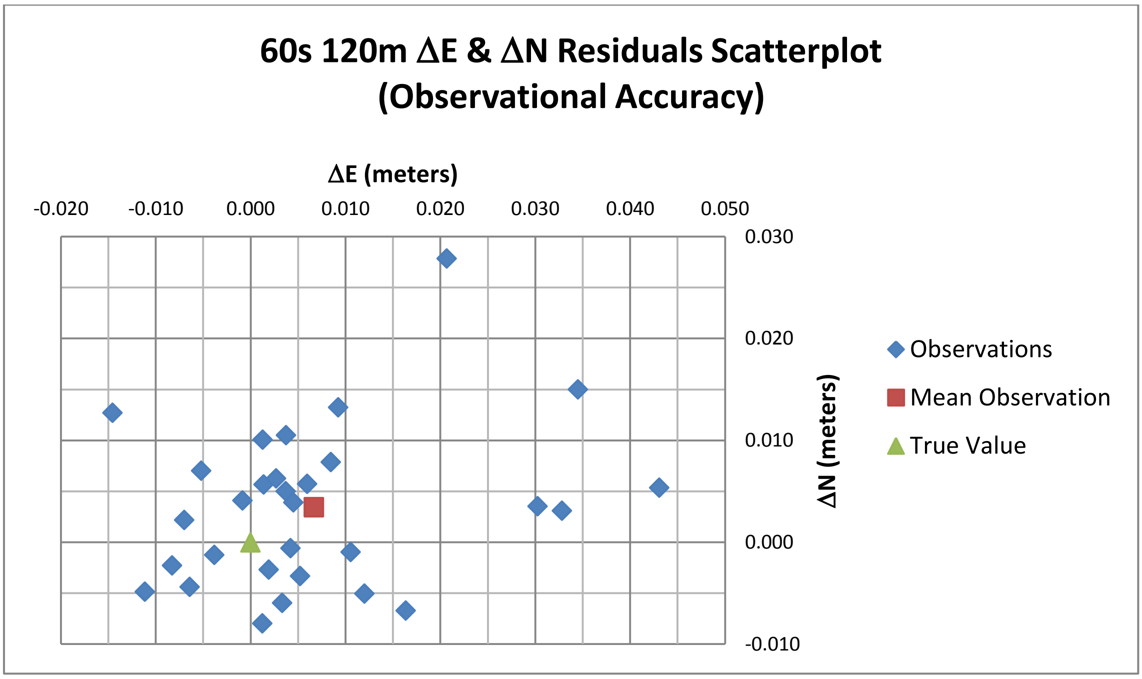

Figure 4.25 – The 60s RTK observations ΔE and ΔN residual plot of the 120m marks

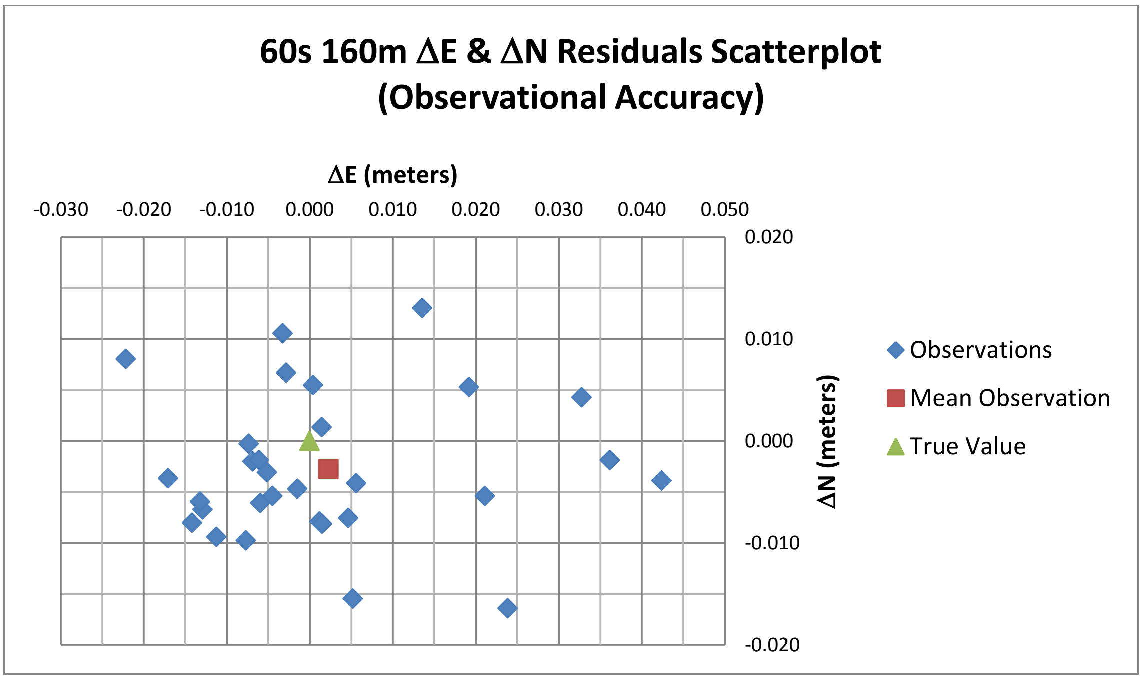

Figure 4.26 – The 60s RTK observations ΔE and ΔN residual plot of the 160m marks

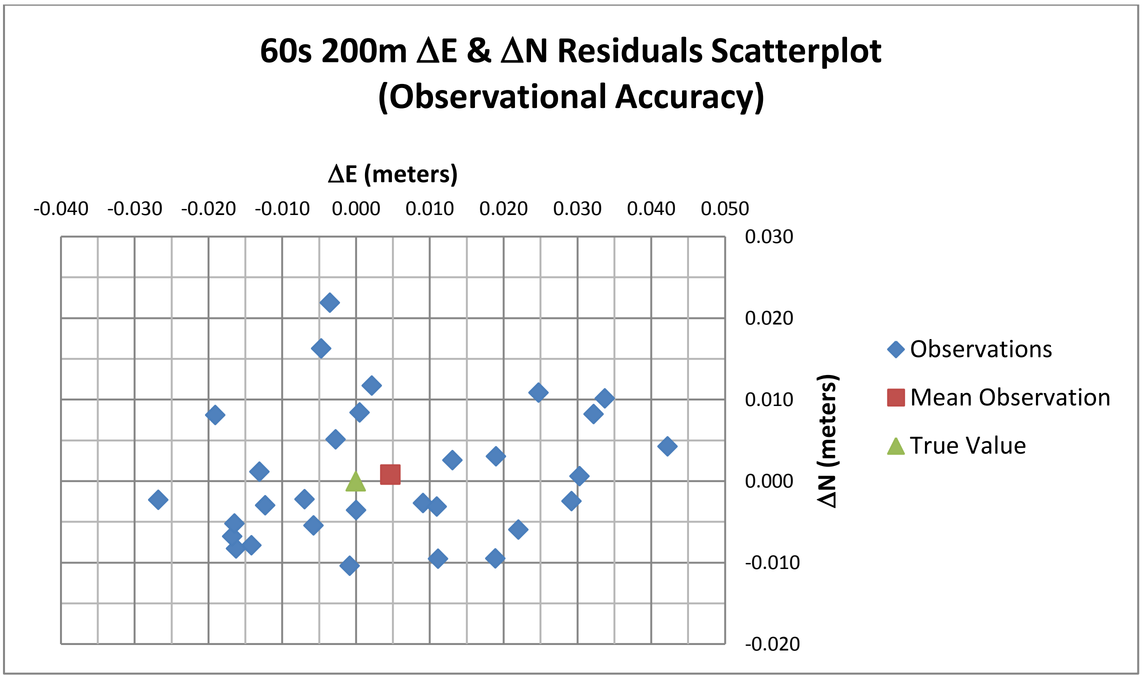

Figure 4.27 – The 60s RTK observations ΔE and ΔN residual plot of the 200m marks

4.7.1 <u>60s Analysis</u>

The results of the 60s observations are much the same as the 30s observations; there is a significant improvement in the accuracy of the data than the 3s observations. The means of the 60s observations all fall to within around 5mm of the true observation which reflects the improvement in accuracy however the observations are more scattered than the 30s observations. This is rather interesting because just as with the 30s observations, the data for these sets was collected over several days there appears to no indication of bias. The survey style and method and remain consistent. Moreover, while most of the data still converges around the true value, in these sets there are more observations falling significantly far from the true value than in the 30s observations. This is important to realise as a longer occupation does not guarantee better accuracy and even for longer observations it is possible to get measurements which have significant errors.

The cause for these errors again comes back to satellite geometry at the time of the observations. For the 30s day the observations were taken fairly rapidly over a few days but generally within the same time window each day. As the satellite constellation has a 12 hour cycle, for the 30sec observations the satellite geometry would have remained relatively consistent. For the 60sec observations on the other hand which took much longer, the satellite geometry would have changed quite significantly throughout, which leads to a greater distribution of the data as opposed to being focussed in a direction by the observation bias.

4.8 180s RTK Observations

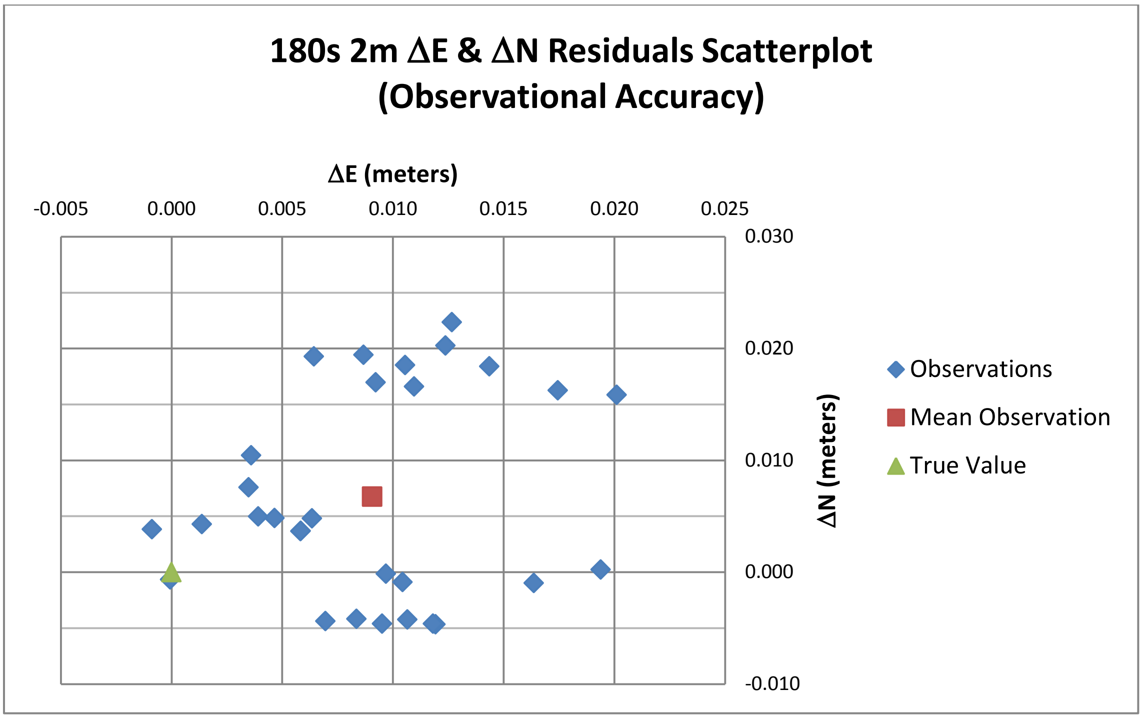

Figure 4.28 – The 180s RTK observations ΔE and ΔN residual plot of the 2m marks

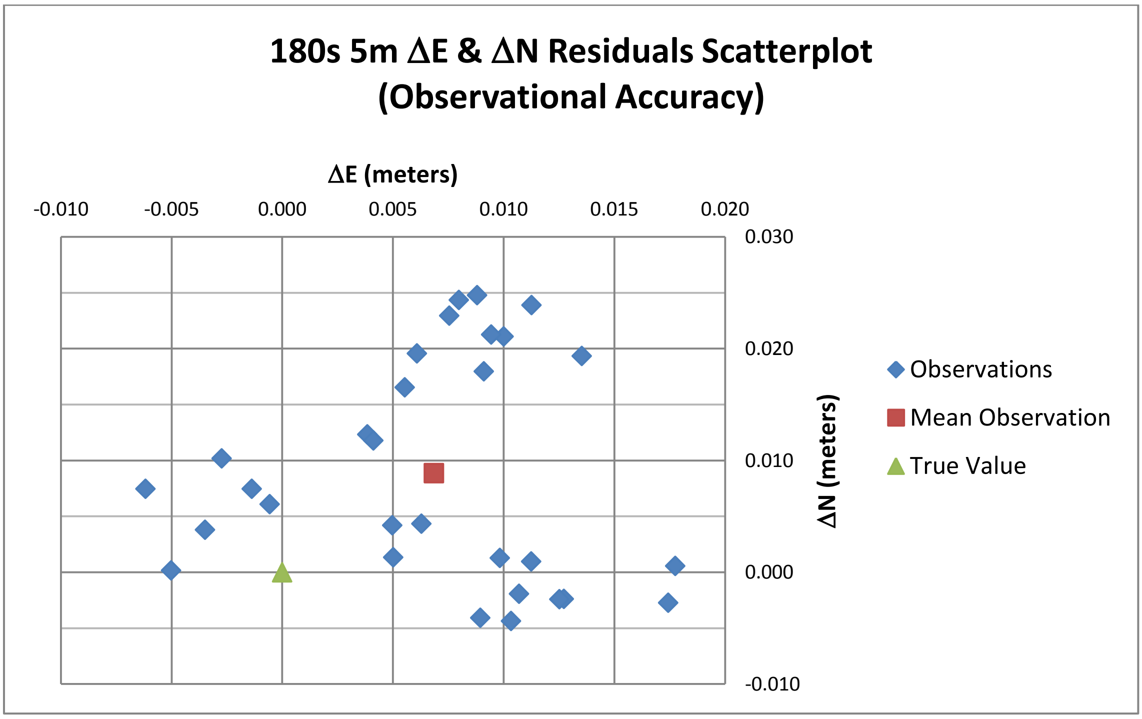

Figure 4.29 – The 180s RTK observations ΔE and ΔN residual plot of the 5m marks

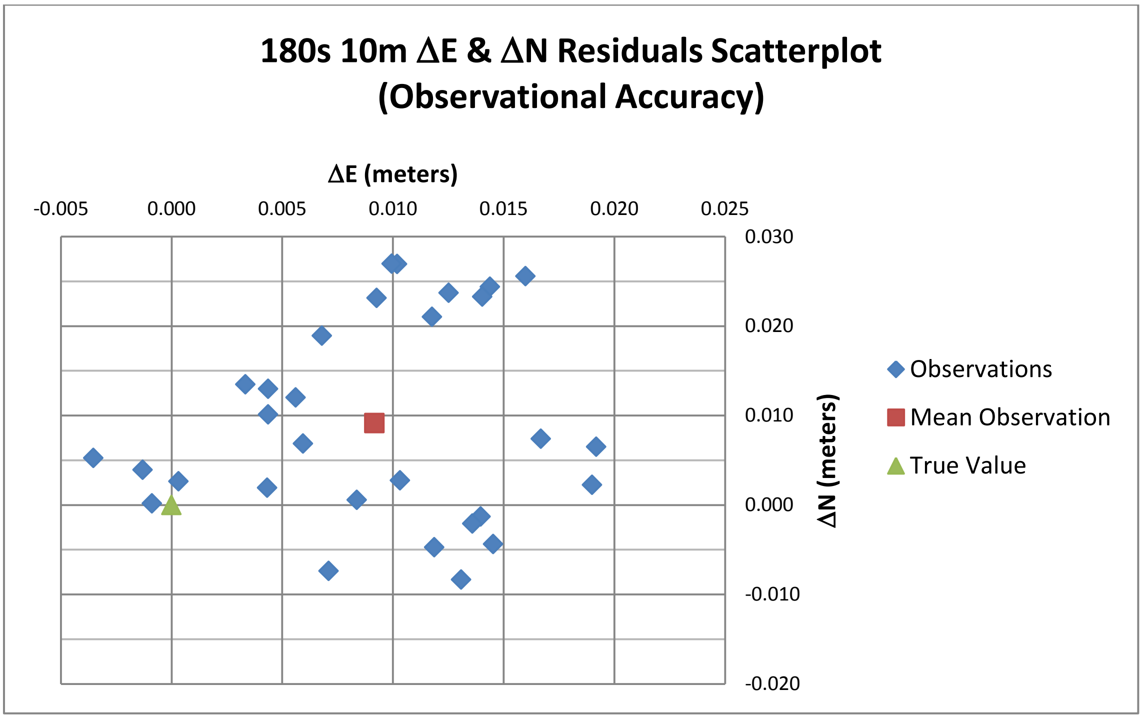

Figure 4.30 – The 180s RTK observations ΔE and ΔN residual plot of the 10m marks

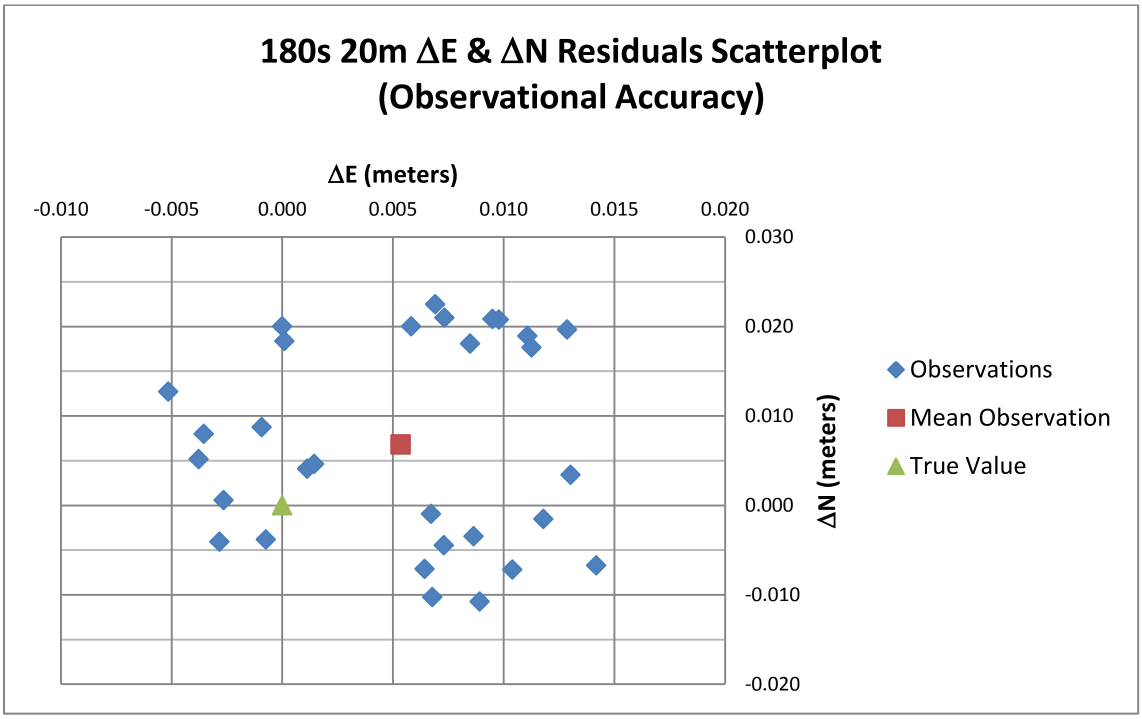

Figure 4.31 – The 180s RTK observations ΔE and ΔN residual plot of the 20m marks

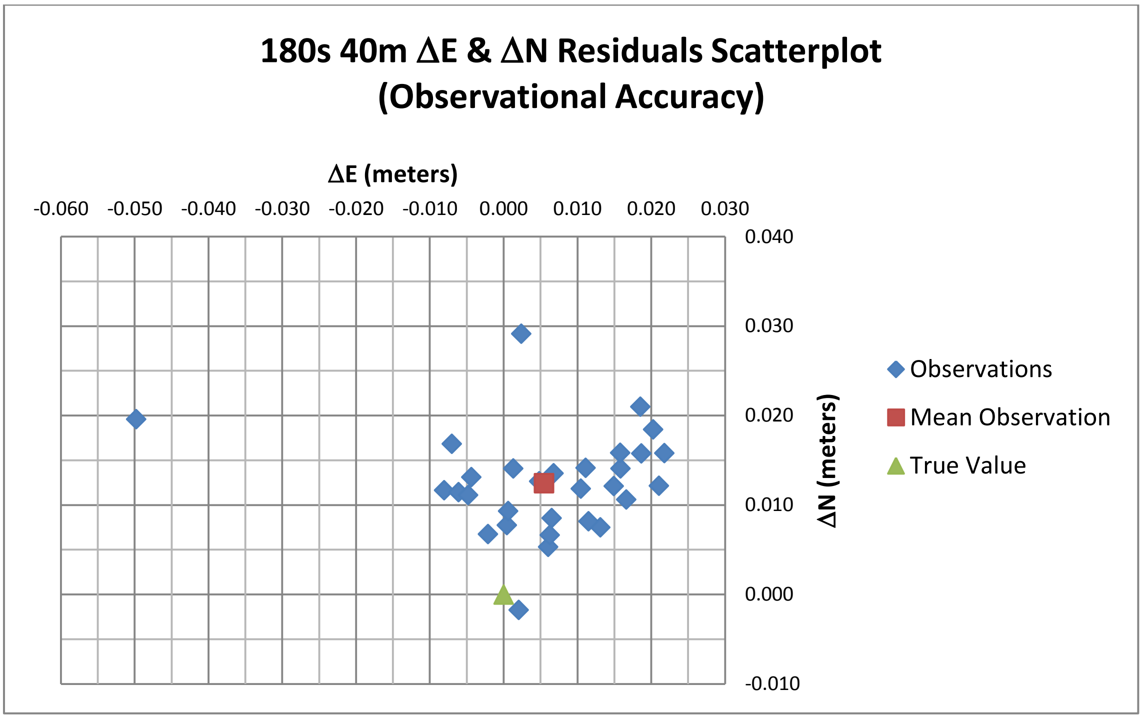

Figure 4.32 – The 180s RTK observations ΔE and ΔN residual plot of the 40m marks

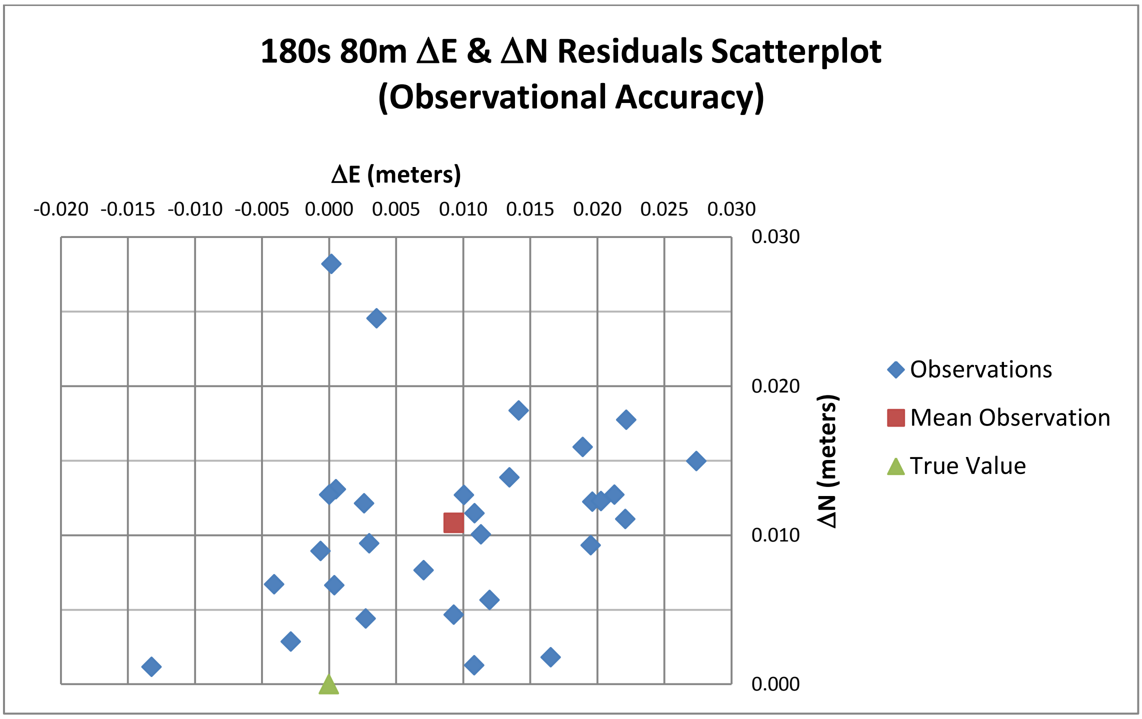

Figure 4.33 – The 180s RTK observations ΔE and ΔN residual plot of the 80m marks

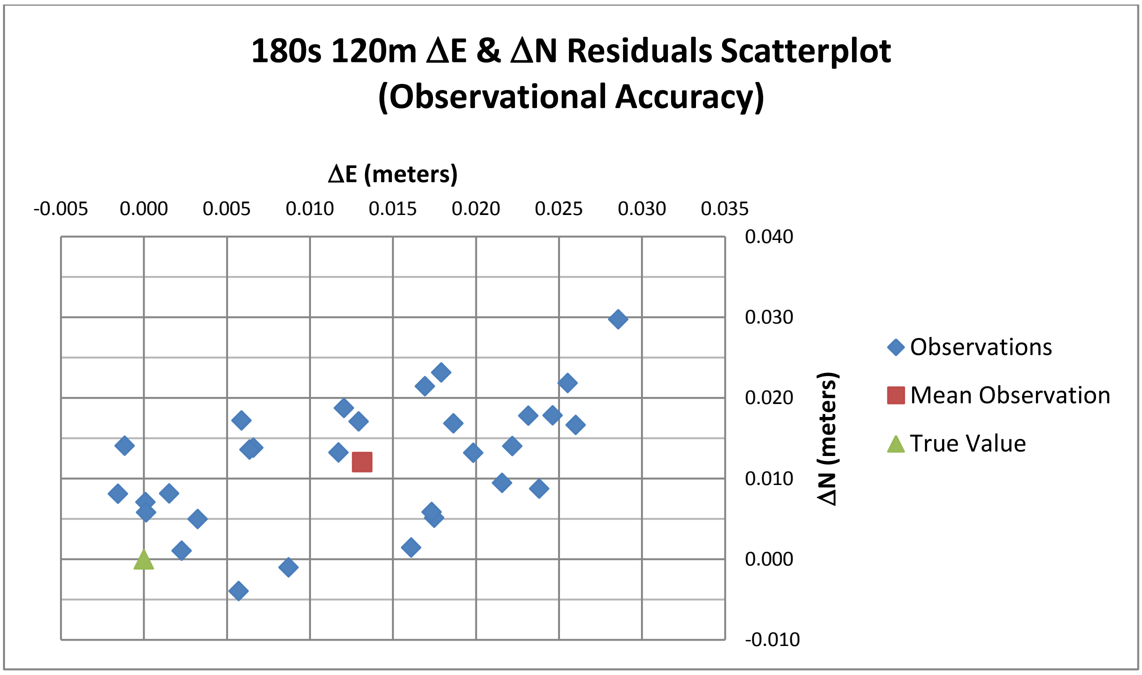

Figure 4.34 – The 180s RTK observations ΔE and ΔN residual plot of the 120m marks

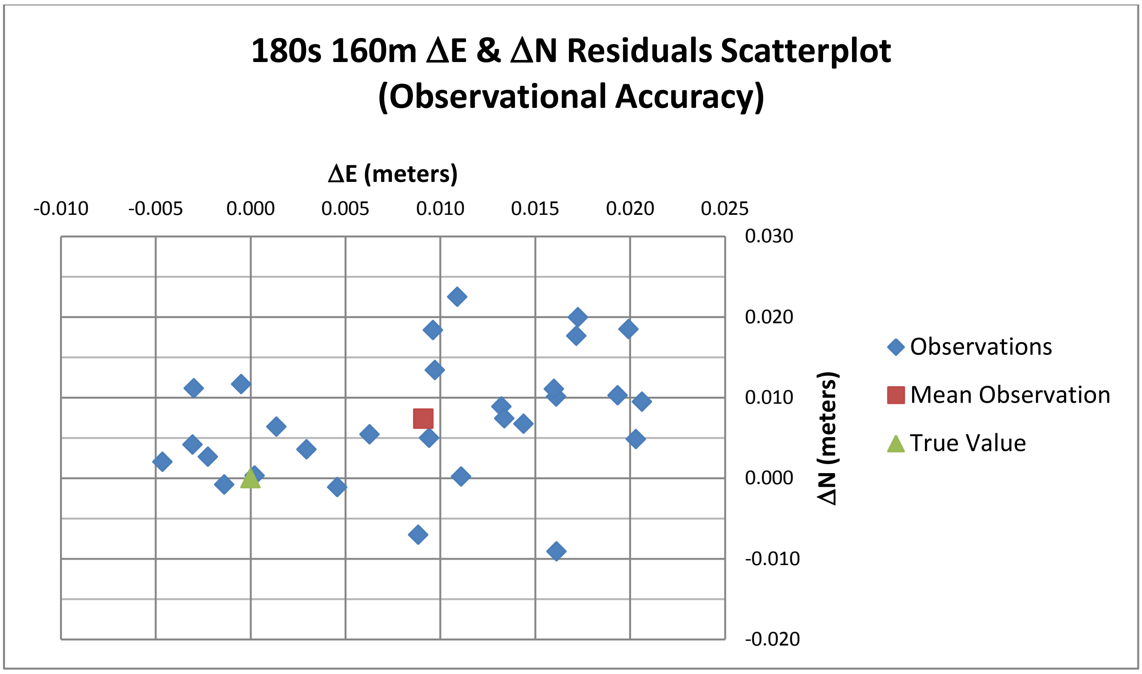

Figure 4.35 – The 180s RTK observations ΔE and ΔN residual plot of the 160m marks

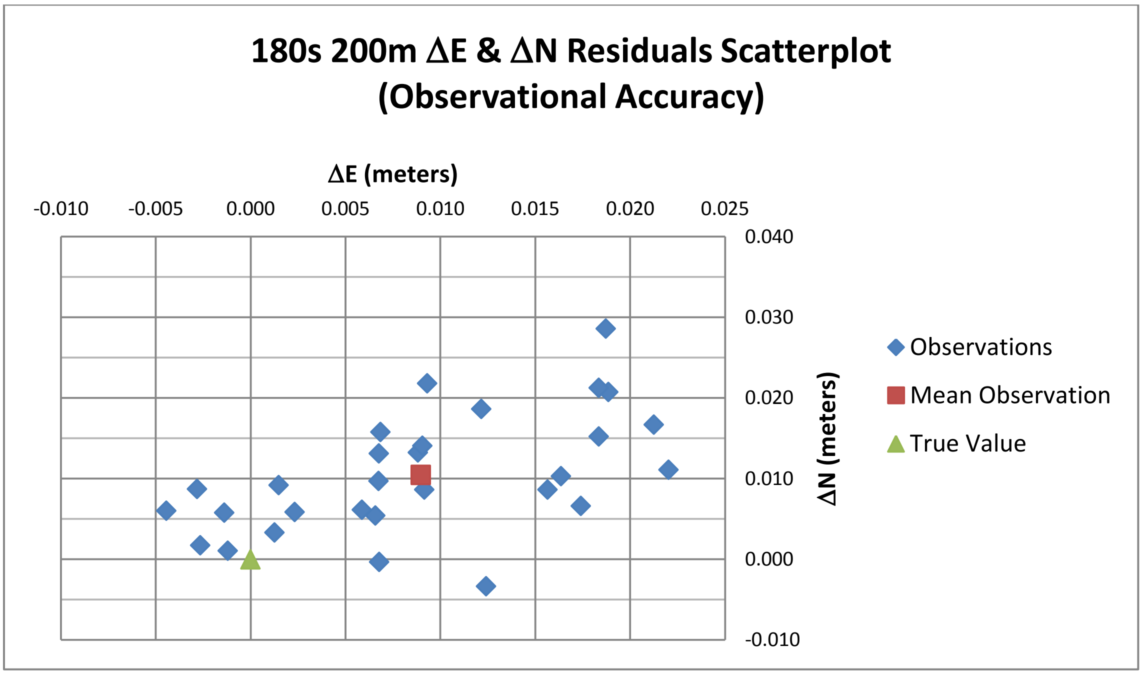

Figure 4.36 – The 180s RTK observations ΔE and ΔN residual plot of the 200m marks

4.8.1 180S ANALYSIS

The 180sec observations provide surprising results when compared to the improvements found in the 30sec and 60sec observations. Rather than a greater convergence of data around the true value or even a reduced scattering of data, the observations have diverged quite significantly towards the east of the true value and the mean observations are further from the true value than the 30sec and 60sec observations. Overall the 180sec observations have greater accuracy than the 3sec observations however it is not to the significant level that would be expected. While the accuracy may not be significantly better than the 3sec observations, the precision is which, at the very least, lends support to the recommendation that observing for longer has significant benefits.

When looking at the observations there appear to be three clusters of observations (particularly pronounced in the 2m, 5m, 20m and 200m observations) which would reflect the changing days and satellite geometry over which the testing occurred. This serves to highlight two important factors regarding RTK observations; 1) the impact changing satellite geometries over time has on the observation of RTK measurements and 2) that even rigorous testing methods can potentially provide inaccurate results, based on the RTK conditions. This testing regime consisted of rigorous practices over many rounds of testing over many hours and even days, yet the results are still inaccurate in regards to the true value, are not precise and not even of the accuracy of the 30sec or 60sec observations.

4.9 CONCLUSIONS

The testing provided some varied and unexpected results to say the least. It was found that longer occupations did result in better accuracy than the short 3sec observations, as expected from the *Literature Review* however it was found that even rigorous observation techniques can produce results that are not of high accuracy or precision based on the effects of observation bias. When the 180sec observations are considered as three groups of observations based on the days of observation, it shows that while accuracy is still subject to errors such as observation bias, precision increases dramatically with more rigorous observation lengths. When inspecting the data there is evidence in the 30sec and 60sec observations that the outriding observations have a greater degree of error than the corresponding 180sec observations. While there is evidence that extraordinarily bad outriding observations can occur in any data set (take 180sec observations on the 40m mark for example), the results show that longer observation times will result in more precise data. Furthermore all observation sets there is evidence of outriding observations and this, at the very least highlights the critical importance of reoccupation at a later time, given a change in the satellite geometry and a new AR.

The key finding from the results is not so much the actual observations – or by extension the calculated residuals – but the impact of observation bias on the measurements. Observation bias is the effect satellite geometry has on the triangulation of GNSS co-ordinates depending on the current satellite geometry at that time of observation. It is because of the effect of satellite geometry that GNSS observations are not randomly scattered (i.e. when compared to a true value the observations are to the south, north, east and west in equal distribution) but will be biased towards a certain direction. Satellite path cycles are just under 12 hours long; if GNSS observations were taken over a 24 hour period (i.e. 2 full cycles) the results would appear to be randomly and evenly scattered, though the actual answer would be equal satellite bias in all directions as satellite bias changes as satellite geometry changes.

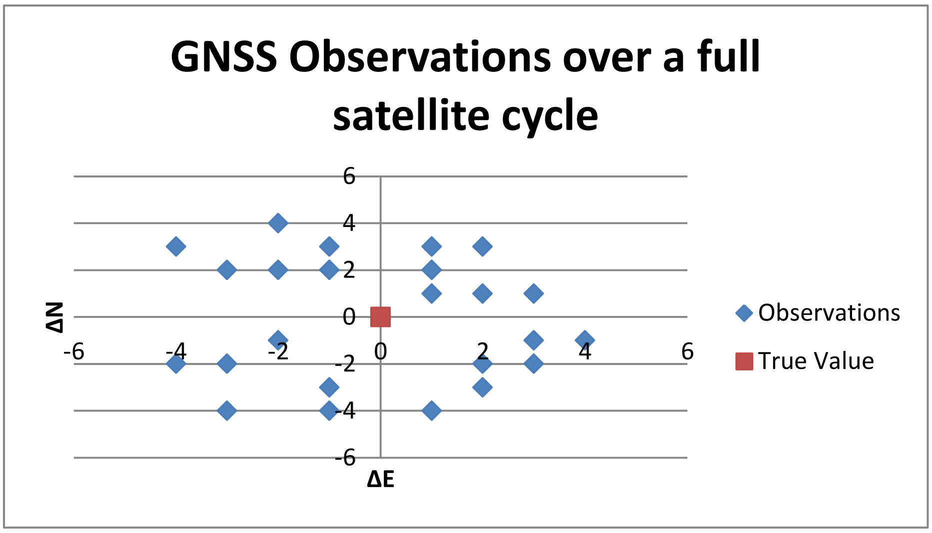

Figure 4.37 – A stylised residual plot of GNSS observations over a full satellite cycle used to highlight observation bias in all directions over the satellite cycle

The testing would support the findings of the *Literature Review* as the measurements certainly became more precise over longer observation times (regarding the 180sec observations as separate sets per day) and the accuracy did converge around the true value for the 30sec and 60 sec observations. It is well established that longer occupation times will provide significant benefits and this was confirmed through the testing. This was not the finding for the 180sec observations though and it went entirely against the findings of the results to that point. This would lead to the conclusion that the 30sec and 60sec observations are not as accurate as the residual plots would lead the observer to believe. It may in fact be a case of the observation bias and satellite geometry aligning to provide a result that appears accurate. This is interesting to consider as it could potentially mean that regardless of the observation practices implemented, the results can still be skewed based on the bias. Moreover this may mean that 180sec observations are the practice to adopt – as suggested by the article reviewed – even though the test results of this dissertation do not support that claim.

It is important to realise that outriding observations will always creep into RTK observations as was the case in all these observation sets. Whether these inconsistencies are caused by a *bad* ambiguity solution or rather by some other factor, this serves to highlight the importance of reoccupation and adopting best practices to reduce their occurrence and identify these when they occur. The testing was successfully completed in accordance with the aims of this dissertation and the testing method complied with best practice recommendations; the control array was established accurately and the testing rounds were completed so as to give the desired results.

CHAPTER 5: ANALYSIS AND DISCUSSION

5.1 INTRODUCTION

This chapter aims to analysis and discuss the results of the previous chapter and seeks to meet the aims of this dissertation, answering whether RTK can be used for cadastral purposes and to what accuracy standards RTK is capable. This will involve creating graphs for referencing and short lines that illustrate the accuracy of the observation data sets against the survey standard accuracy and TS accuracy. This will determine at what length these accuracies are either met or not and whether it is appropriate to use RTK to observe these. The BS length analysis will examine how much the angular perpendicular offset affects the bearing of the line observed and whether RTK can measure a line to a suitable degree of accuracy to confirm a boundary line. From the findings of the analysis, recommendations will be made about the application of RTK for these purposes and in what situations it is appropriate.

5.2 TOTAL STATION ACCURACY STANDARD

For this dissertation it is the intention to compare the accuracy of the observations against the accuracy expected from a TS. Unlike RTK, TS's have an established accuracy to which it can measure, as outlined in the manufacturer's specifications. Because the accuracy of a total station depends on its make and model there is no standard accuracy which TS's are expected to meet. For this testing, a high accuracy TS (*Trimble S8 DR Plus*) was used however the accuracy of this machine is not indicative of the accuracy of all TS's. Upon review of various models of TS from various manufacturers, a general accuracy of 3mm + 3ppm for distance measurements and 5" for angular observations has been chosen to represent TS accuracy. While there are plenty of machines capable of better accuracy and many that don't reach this level this accuracy was chosen as it arguably represents the average machine and provides a standard of comparison.

5.3 ANALYSING THE DISTRIBUTION OF DATA

It was previously identified in the *Literature Review* that all accuracy standards are concerned with a 95% confidence interval – setting an accuracy standard which 95% of observations can meet. The number of rounds of observations completed during testing reflects this as the population size of the data is greater than 25. When working with a sample size at or below 25, the student-T distribution should be used for statistical analysis and as the size approaches 25 the distribution more closely represents a normal distribution. For this dissertation, 30 rounds of testing were completed to ensure that a normal distribution could be used to analyse the data. It is from this normal distribution and the 95% CI that the errors of the observations sets (2σ) will be calculated and this will be used to determine whether the observation methods meet the survey accuracy standards. Moreover the actual distribution of the data will be determined to ensure that the data being used to come to these conclusions satisfies the 95% CI (the majority of these will be included in the *Appendix*).

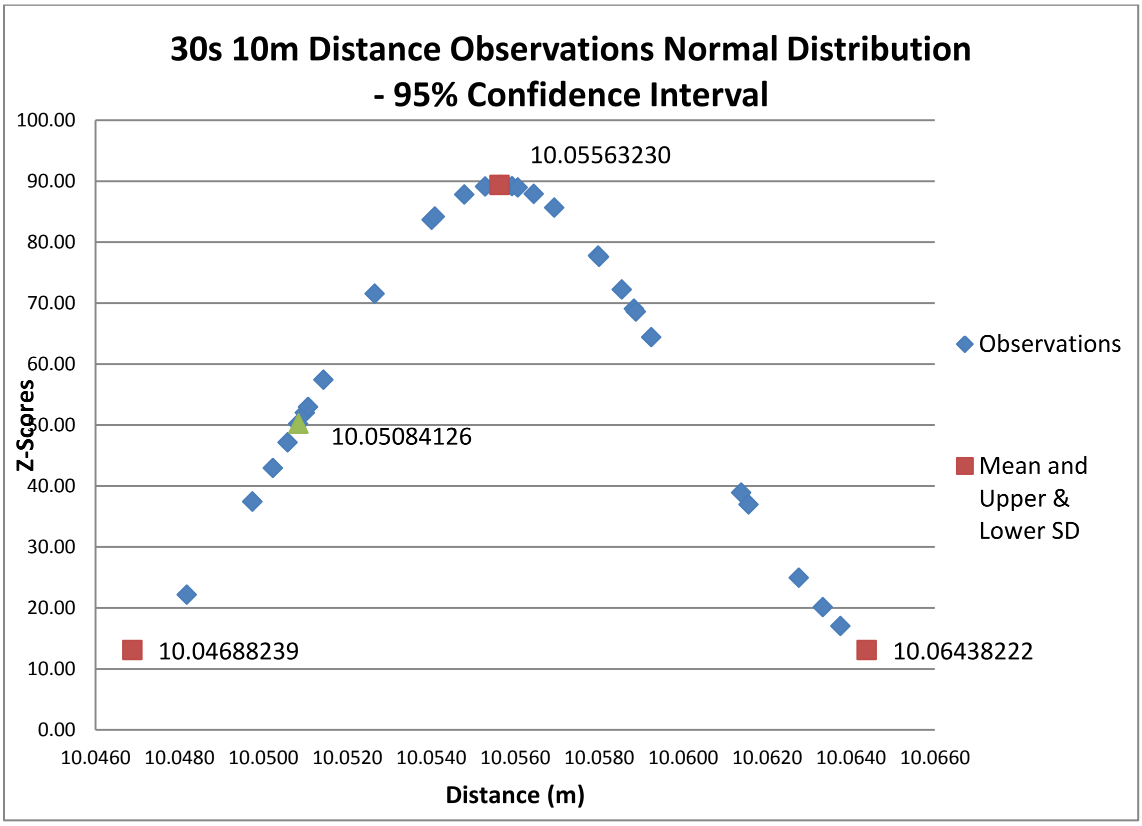

Figure 5.1 – The normal distribution of the 30s observations on the 10m mark with the upper and lower 2σ values

The graph identified in *Figure 5.1* is a typical representation of the normal distribution of the line length observations showing how the data falls within 2σ of the mean as does the true value. The results are quite accuracy in this case as there is less than 20mm between the upper and lower SD limits.

The 2σ value represents the accuracy limits within which 95% of observations would be expected to fall. It is important to remember though that this is the 2σ error from the mean value of the observations, where it is in fact 2σ from the true value which would represent the range in which acceptable observations should occur. If the mean and true observations were aligned this would signify that there was an even distribution of data around the true value – i.e. that there was no observation bias. From the *Results* though, it has been proven that there is observation bias present in the results and this needs to be realised by incorporating this error into the total accuracy error of the line.

5.3.1 INCORPORATING THE OBSERVATION BIAS INTO THE RESULTS

From the *Results* it is clear that observation bias has affected the results and that *normal* (i.e. multipath, atmospheric conditions, ambiguity solution, number of satellites etc.) error is not the only error present in the data. To determine whether RTK is appropriate for cadastral purposes it is essential that the errors in the observations are based off the true value of the line rather than the mean observed distance of the line. This would mean that based on the observation bias present in the observations the line error would not just be 2σ, but 2σ plus the difference between the mean and true values of the line. It is possible for anyone to go and measure a line repeatedly using any methods and determine a line length and average measurement, which all fall within 2σ of each other, however this does not mean that the true value of the line falls within that 2σ.

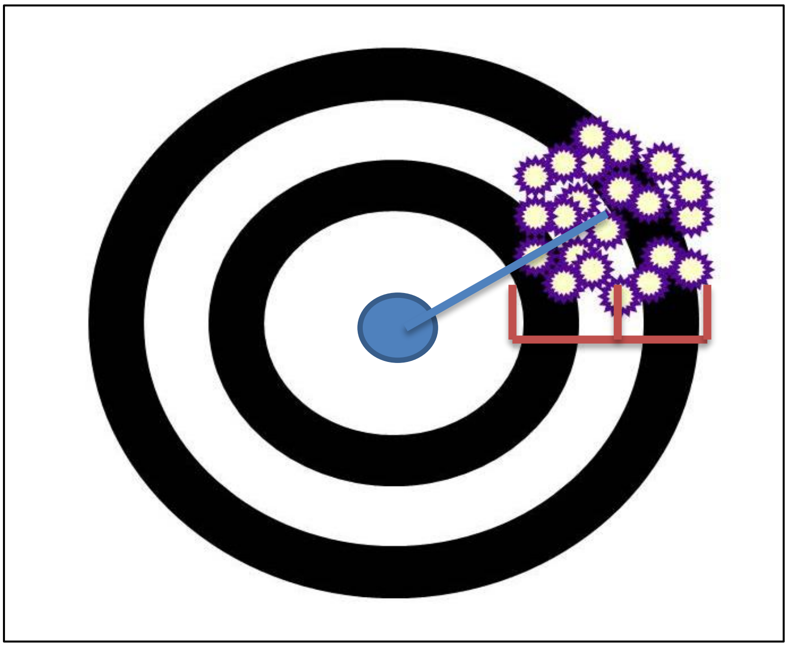

Figure 5.2 – Highly precise observations that are low accuracy

Consider *Figure 5.2* for example; the observations are highly precise and there appear to be no outriders therefore the observations would all fall within 2σ of the mean. This is not acceptable though as none of the observations are actually within 2σ of the true value of the line length. If the mean observation and 2σ was related to the true value of the line it would in fact be found that the observations are highly inaccurate and should not be used for high accuracy applications. Therefore it is essential that the true-mean value difference be incorporated into the error to ensure that the true error in the observations is compared to the accuracy standards. This can be achieved by using the formula;

$$True\ error = True\ value - Mean\ observation + 2\sigma$$

This will be applied to all analyses to follow.

5.4 REFERENCING BY RTK

This analysis serves to determine whether RTK can in fact be used for referencing in terms of line length accuracy and the observed bearing. To determine whether the line lengths meet the accuracy of a TS or *SP1* the difference between the observed and true lines needs to be determined (accounting for observation bias) and then apply 2σ to determine in what range 95% of data will be observed. It is important to ensure that the absolute difference between the mean and true lines is calculated, as the error is still the error regardless of whether the line itself is shorter or longer than the mean. The total mean is calculated as the;

$$Absolute\ difference + 2\sigma$$

The below *Table 5.1* provides the numeric values of the total error in the observation lines. This severs to outline the mathematic process conducted to achieve these results and show how the errors differ between each observation time.

3sec Observations						
Distance	True Distance	Average Distance	Error	Absolute Difference	2σ	Total Error
2	2.102487336	2.114771861	-0.01228	0.01228	0.01128382	0.02357
5	4.93934935	4.949051325	-0.00970	0.00970	0.00943239	0.01913
10	10.05084126	10.06272948	-0.01189	0.01189	0.00855128	0.02044
20	20.35828	20.36308	-0.00480	0.00480	0.00926	0.01406

30sec Observations						
Distance	True Distance	Average Distance	Error	Absolute Difference	2σ	Total Error
2	2.102487336	2.104879611	-0.00239	0.00239	0.00420117	0.00659
5	4.93934935	4.94167951	-0.00233	0.00233	0.00443481	0.00676
10	10.05084126	10.0556323	-0.00479	0.00479	0.00446424	0.00926
20	20.35828	20.35709	0.00119	0.00119	0.00408	0.00527

60sec Observations						
Distance	True Distance	Average Distance	Error	Absolute Difference	2σ	Total Error
2	2.102487336	2.105034641	-0.00255	0.00255	0.01277026	0.01532
5	4.93934935	4.941976917	-0.00263	0.00263	0.01163885	0.01427
10	10.05084126	10.0560529	-0.00521	0.00521	0.01146872	0.01668
20	20.35828	20.35895	-0.00067	0.00067	0.01126	0.01193

180sec Observations						
Distance	True Distance	Average Distance	Error	Absolute Difference	2σ	Total Error
2	2.102487336	2.113761273	-0.01127	0.01127	0.00724698	0.01852
5	4.93934935	4.950353995	-0.01100	0.01100	0.00792166	0.01893
10	10.05084126	10.06380861	-0.01297	0.01297	0.00939289	0.02236
20	20.35828	20.36690	-0.00862	0.00862	0.00922	0.01784

Table 5.1– The calculation of the total error in the referencing observations at 95% confidence interval

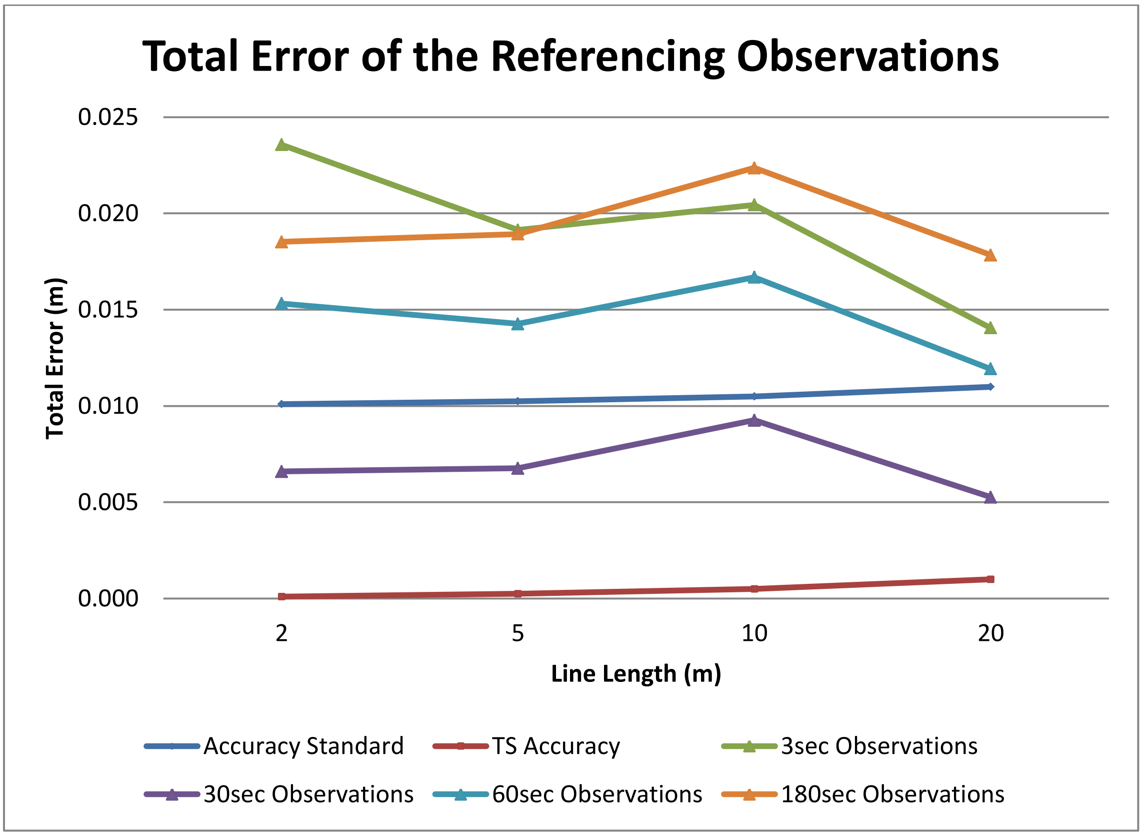

Figure 5.3 – The total error of the observation sets which show at what point RTK is appropriate for referencing in terms of the accuracy standards and TS accuracy

From the above analysis it is absolutely clear that RTK observational accuracy cannot meet the accuracy standard of a total station for referencing accuracy. It is apparent however that RTK is capable of observing very short line lengths to the acceptable accuracy of the survey standards'. In this instance the 30sec observations meet this accuracy standard for every length and the 60sec observations very nearly approached this at the 20m length. Considering the short length of the line this basically means that RTK observation accuracy needs to be within 10mm (and 11mm at 20m) of the true value to fall within these accuracy standards. It is interesting to again consider the more rigorous observations methods here, where accounting for the observation bias has put these observations well outside the accuracy limits of the surveys standards. Though the precision of these observations might be greater (hence the SD will be less) than the shorter observations the observation bias has caused the observations to be outside the accuracy limits. Considering the degree to which small errors are accentuated over short distances it would not be advised to use RTK for referencing purposes. Although it may meet the survey standards'' accuracy requirements, the errors in the observations would lead to massive bearing errors in the referencing. Moreover it is apparent that even the more rigorous testing methods do not meet the accuracy standards based on the observation bias and while the 30sec observations do meet these standards, that does not mean that that is the observation method that should be adopted by the industry.

5.4.1 REFERENCING BEARINGS BY RTK

At this point it would be prudent to consider the effect the errors in the observations would have on the observed bearing when referencing over such short distances. This will be achieved by investigating the perpendicular offset distance of the bearing difference between the true and observed bearing using trigonometry (the *sine rule*). From this investigation it will be possible to determine the perpendicular distance between the true and observed bearings. The perpendicular angle offset distance can be calculated as;

$$= Observed\ distance * \sin(Observed\ bearing - True\ bearing)$$

This perpendicular distance will still be affected by the observation bias; the above equation will give the difference between the bearings however the data still needs to meet the 95% confidence interval, therefore 2σ of the offsets will be applied. In the case of errors over such short distances the bearing becomes less important as even small errors can dramatically affect the data, more emphasis is placed on measuring the correct distance and ensuring the reference mark has not been disturbed. These distance errors will then be compared to some general angular miscloses to establish just how accuracy the referencing bearings would be. The angular miscloses to be chosen are 10" as a representation of good bearing accuracy, 30" as a representation of moderate but still acceptable bearing accuracy and 1' and 5' as a representation of very poor observational accuracy.

Perpendicular Angle Offset				
Distance	**3sec Offset**	**30sec Offset**	**60sec Offset**	**180sec Offset**
2	0.015839477	0.005165924	0.010006806	0.008715814
5	0.035305851	0.034492645	0.03649105	0.010721463
10	0.021068905	0.005416823	0.011193101	0.008537715
20	0.019822053	0.005541538	0.011976483	0.00966895

Line Length	Angular Misclose 10"	Angular Misclose 30"	Angular Misclose 1'	Angular Misclose 5'
Distance	Distance	Distance	Distance	Distance
2	0.000137	0.000411	0.000823	0.004117
5	0.000343	0.001028	0.002057	0.010292
10	0.000687	0.002057	0.004114	0.020584
20	0.001371	0.004114	0.008228	0.041168

Table 5.2– The calculation of the perpendicular angle offset distance between the observed and true bearing at the 95% confidence interval for referencing observations

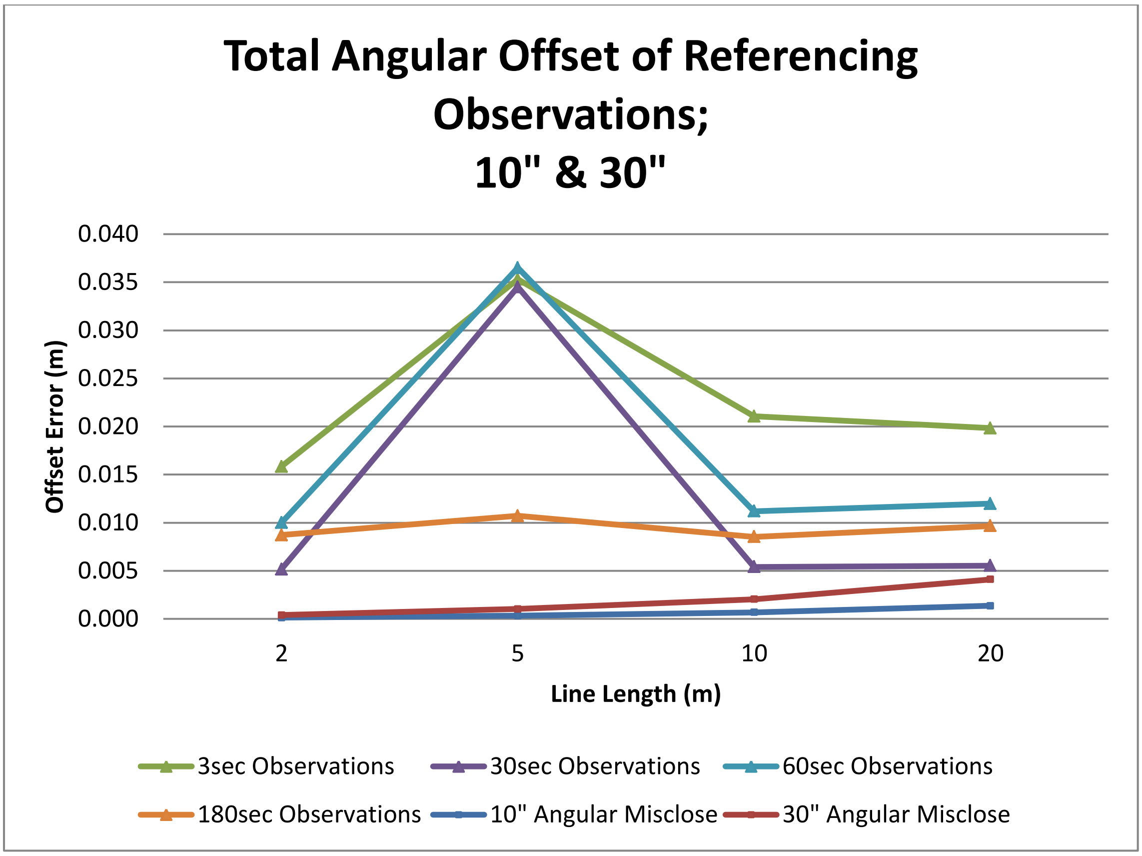

Figure 5.4 – The perpendicular angle offset distance of the referencing observations as compared to 10" and 30" accuracy

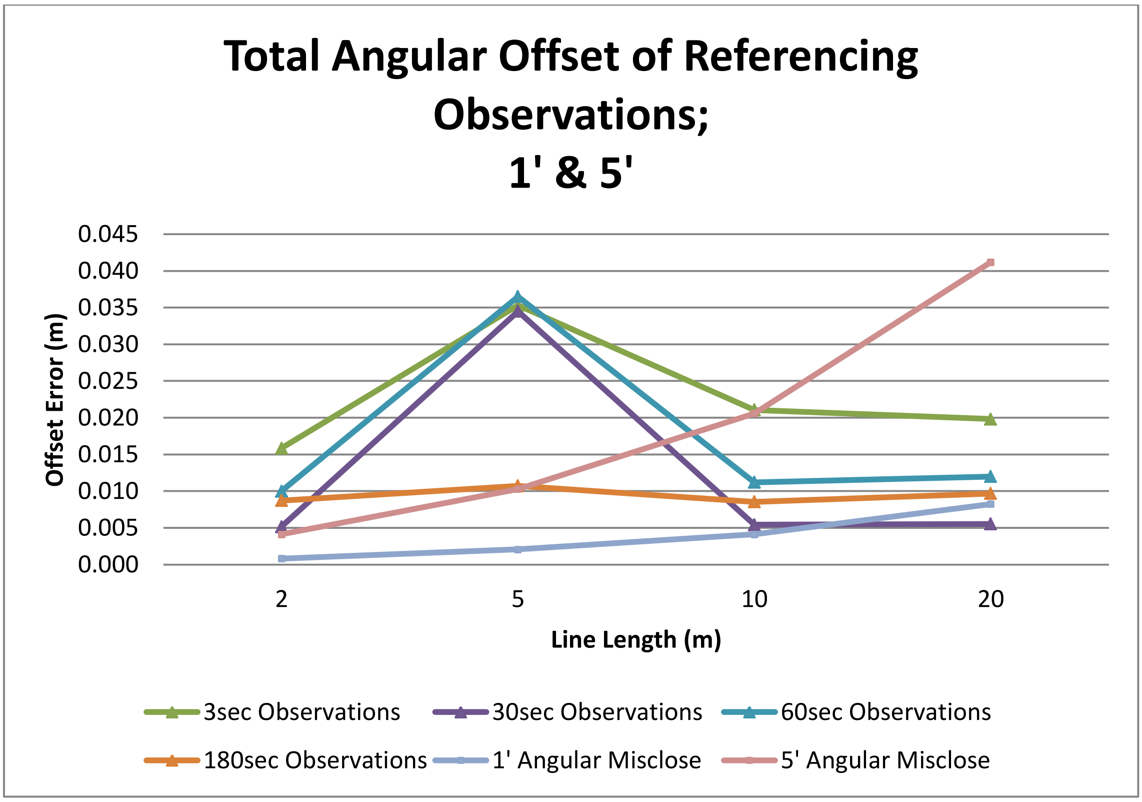

Figure 5.5 – The perpendicular angle offset distance of the referencing observations as compared to 1’ and 5’ accuracy

The analysis of the perpendicular angle offset distances has shown just how poor the bearing accuracy of the RTK observations actually is. The 30sec observations approached 30” accuracy towards the 20m length however none of the bearings were within an acceptable accuracy range. Indeed the observations were generally only able to meet 5’ bearing accuracy which is completely unacceptable when reporting on cadastral plans. It appears that RTK should not be used for referencing in any circumstances using any practices outlined in this dissertation.

5.5 <u>Minimum Short Line Length that can be observed by RTK</u>

This analysis will seek to determine the minimum length of a short line that RTK can measure and achieve the *SP1* standard accuracy and if it can potentially meet TS accuracy. It has previously been defined that the survey standards’’ accuracy is 10mm + 50ppm while the TS accuracy will be represented as 3mm + 3ppm; the acceptable accuracies will be calculated over the length of the short lines. To determine the actual line error the same method as referencing will be used.

3sec Observations						
Distance	**True Distance**	**Average Distance**	**Difference**	**Absolute Difference**	**2σ**	**Total Error**
20	20.35828	20.36308	-0.00480	0.00480	0.00926	0.01406
40	40.15479	40.15986	-0.00507	0.00507	0.00910	0.01417
80	80.08372	80.09320	-0.00948	0.00948	0.00810	0.01759
120	120.10154	120.11826	-0.01673	0.01673	0.01056	0.02729
160	160.22721	160.23403	-0.00683	0.00683	0.00769	0.01451
200	200.15860	200.16932	-0.01072	0.01072	0.00954	0.02026

30sec Observations						
Distance	**True Distance**	**Average Distance**	**Difference**	**Absolute Difference**	**2σ**	**Total Error**
20	20.35828	20.35709	0.00119	0.00119	0.00408	0.00527
40	40.15479	40.15480	-0.00001	0.00001	0.00483	0.00484
80	80.08372	80.08565	-0.00193	0.00193	0.00414	0.00606
120	120.10154	120.10537	-0.00383	0.00383	0.00649	0.01032
160	160.22721	160.22496	0.00225	0.00225	0.00437	0.00662
200	200.15860	200.15842	0.00018	0.00018	0.00633	0.00651

60sec Observations						
Distance	**True Distance**	**Average Distance**	**Difference**	**Absolute Difference**	**2σ**	**Total Error**
20	20.35828	20.35895	-0.00067	0.00067	0.01126	0.01193
40	40.15479	40.15571	-0.00092	0.00092	0.01058	0.01150
80	80.08372	80.08455	-0.00083	0.00083	0.01292	0.01375
120	120.10154	120.10886	-0.00732	0.00732	0.01283	0.02015
160	160.22721	160.22706	0.00014	0.00014	0.01304	0.01319
200	200.15860	200.16237	-0.00377	0.00377	0.01495	0.01872

180sec Observations						
Distance	**True Distance**	**Average Distance**	**Difference**	**Absolute Difference**	**2σ**	**Total Error**
20	20.35828	20.36690	-0.00862	0.00862	0.00922	0.01784
40	40.15479	40.16701	-0.01222	0.01222	0.01103	0.02324
80	80.08372	80.09779	-0.01408	0.01408	0.00929	0.02337
120	120.10154	120.11935	-0.01781	0.01781	0.01065	0.02847
160	160.22721	160.23891	-0.01171	0.01171	0.00916	0.02087
200	200.15860	200.17237	-0.01377	0.01377	0.00949	0.02326

Table 5.3– The calculation of the total error in the short line observations, determined as before for referencing

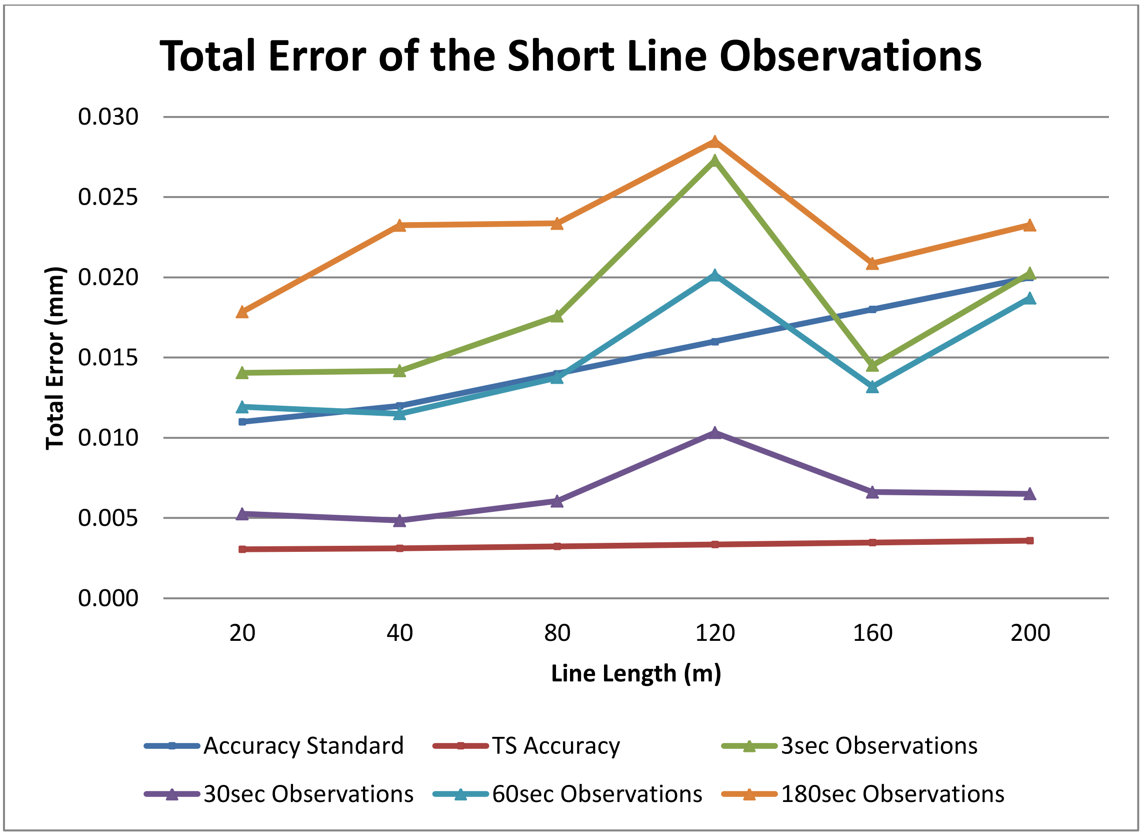

Figure 5.6 – The total error of the observation sets which show at what point RTK is appropriate for short line observation in terms of the accuracy standards and TS accuracy

Again it has been found from the testing the RTK observations cannot meet TS accuracy over such short distances. Conversely the analysis of the short line observations actually provides results which would move to disprove the recommendations of some jurisdictions that RTK can only be used to observe lines over 120m. Moreover it certainly dismisses the survey standards'' recommendation that RTK should only be used to measure lines greater than 640m.

From the testing of this dissertation it would appear that RTK can in fact be used to measure lines as short as 40m. Previously it was stated that in regard to referencing, RTK should not be recommended as the measurement method as the line errors were so substantial over such short distances. However when observing these longer lines it becomes apparent that the observations would meet the survey standards'' accuracy recommendations and the errors would not be so effecting over longer distances.

Moreover in this case both the 30sec and 60sec observations meet the accuracy standards' accuracy recommendations when observing lines greater than 40m – though the 60sec observations tetter right on the brink of remaining within the accuracy standard. The 120m mark observations are of particular concern in this case as there is a spike in the errors for all observation sets however this can arguably be contributed to the environmental conditions, as it is a constant factor throughout all data sets, meaning that the same cause of error is likely in all instances. In particular around the 160m mark all but the 180sec observations meet the accuracy standard, which at the very least confirms that RTK can be used to observe lines much shorter than 640m.

5.5.1 Establish when RTK observations will meet TS Accuracy

SP1 identified where RTK observations would meet and surpass the accuracy capable by conventional TS observations as 640m. It would therefore be prudent to repeat this based on the results of this dissertation to determine if the point where RTK would meet the proposed TS accuracy is actually less – just as the minimum line length was found to be less. By overlaying linear trend lines on the RTK observation results and extending these lines it will be possible to determine when RTK will meet TS accuracy.

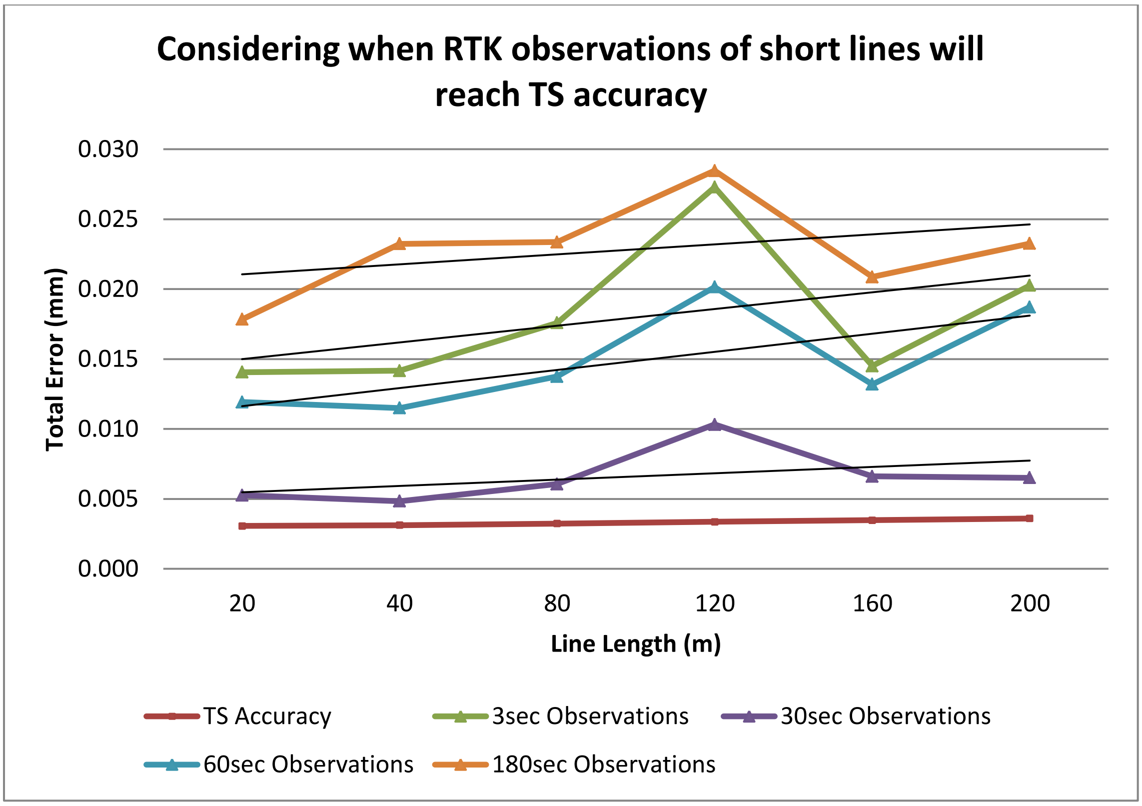

Figure 5.7 – The total error of the observation over the various distances with a linear trend line set to establish at what distance RTK observations will meet TS accuracy

From the trend line analysis is becomes apparent that the RTK observations of this dissertation will never meet TS accuracy as the gradient of the trend lines is steeper than the gradient of the TS accuracy. This is quite disappointing because it means for the testing of this dissertation at least, it is hypothesised that the observations will never surpass TS accuracy. From the *Literature Review* this is obviously not the case however more testing would be required to determine this point.

5.6 MINIMUM LENGTH OF A BACKSIGHT MEASURED BY RTK

From the short line analysis it has been determined that RTK can in fact be used to accurately observe short lines of lengths greater than 40m, significantly less than the recommended 640m and 120m recommended by the *SP1* and adopted by various jurisdictions respectively. While RTK may be capable of measuring short lines to an acceptable accuracy over 40m, this does not mean that RTK can potentially be used to observe backsights over such a short distance. This is important to consider as backsights are not just concerned with line length accuracy but also the accuracy of the bearing. Therefore to determine whether RTK can be used for observing BS's at lengths shorter than the recommended 200m (SBQ guideline) another perpendicular angle offset distance analysis will be conducted for this data set.

When considering orientation, the observation of the BS's would require a far more rigorous accuracy standard than was adopted for referencing. In regards to referencing it is possible to observe a small error and find a very large bearing error, even though that bearing error is not actually present; so bearings become less significant in these instances. When observing BS's to orientate a survey, the surveyor must strive to achieve the greatest degree of accuracy possible. For this analysis the angular offset will be compared to TS accuracy and shown against less rigorous standards to determine how RTK should be used to observe BS's.

Perpendicular Angle Offset				
Distance	**5sec Offset**	**30sec Offset**	**60sec Offset**	**180sec Offset**
40	0.015276	0.010544	0.009964	0.016009
80	0.017231	0.007293	0.011189	0.009307
120	0.021018	0.023456	0.010901	0.006722
160	0.021032	0.006303	0.015224	0.006895
200	0.023232	0.012522	0.016529	0.005742

Line Length	**Angular Misclose 5"**	**Angular Misclose 10"**	**Angular Misclose 20"**	**Angular Misclose 45"**
Distance	Distance	Distance	Distance	Distance
40	0.001373	0.002743	0.005485	0.012345
80	0.002746	0.005485	0.010971	0.024685
120	0.004114	0.008228	0.016456	0.037028
160	0.005485	0.010970	0.021941	0.049371
200	0.006856	0.013713	0.027427	0.061713

Table 5.4– The calculation of the perpendicular angle offset distance between the observed and true bearing at the 95% confidence interval for backsight observations

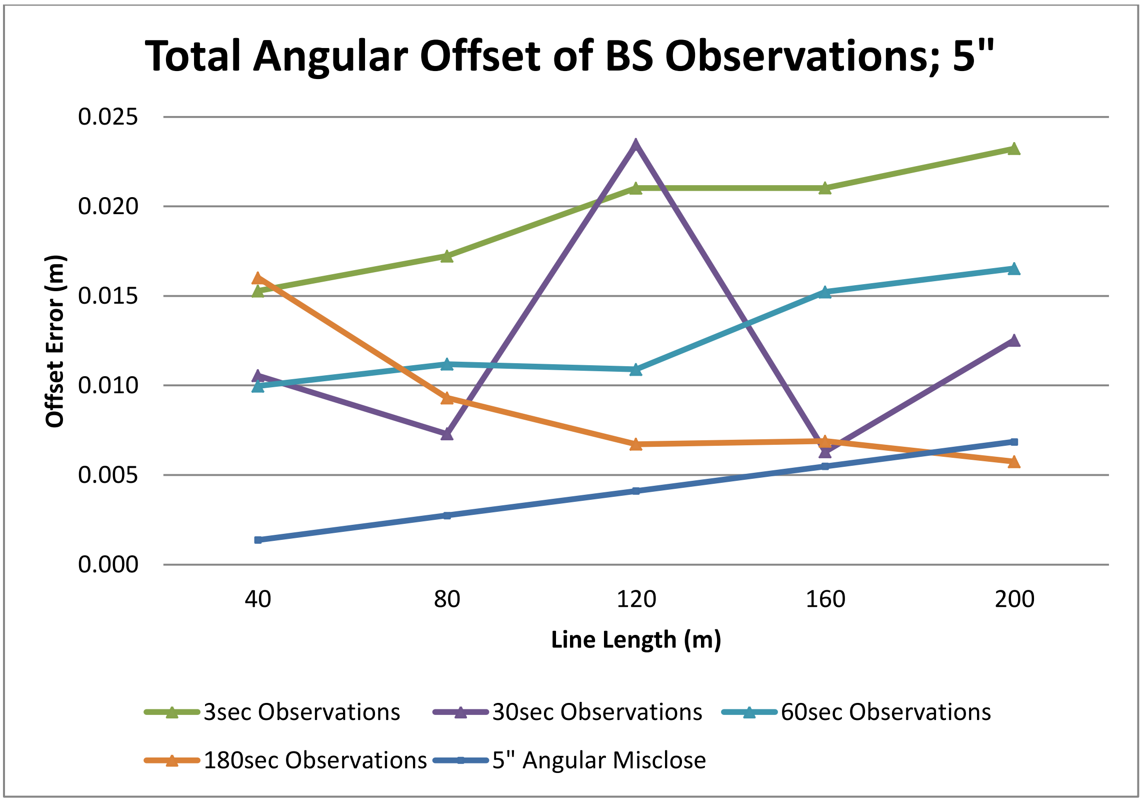

Figure 5.8 – The perpendicular angle offset distance of the BS observations as compared to TS (5”) accuracy

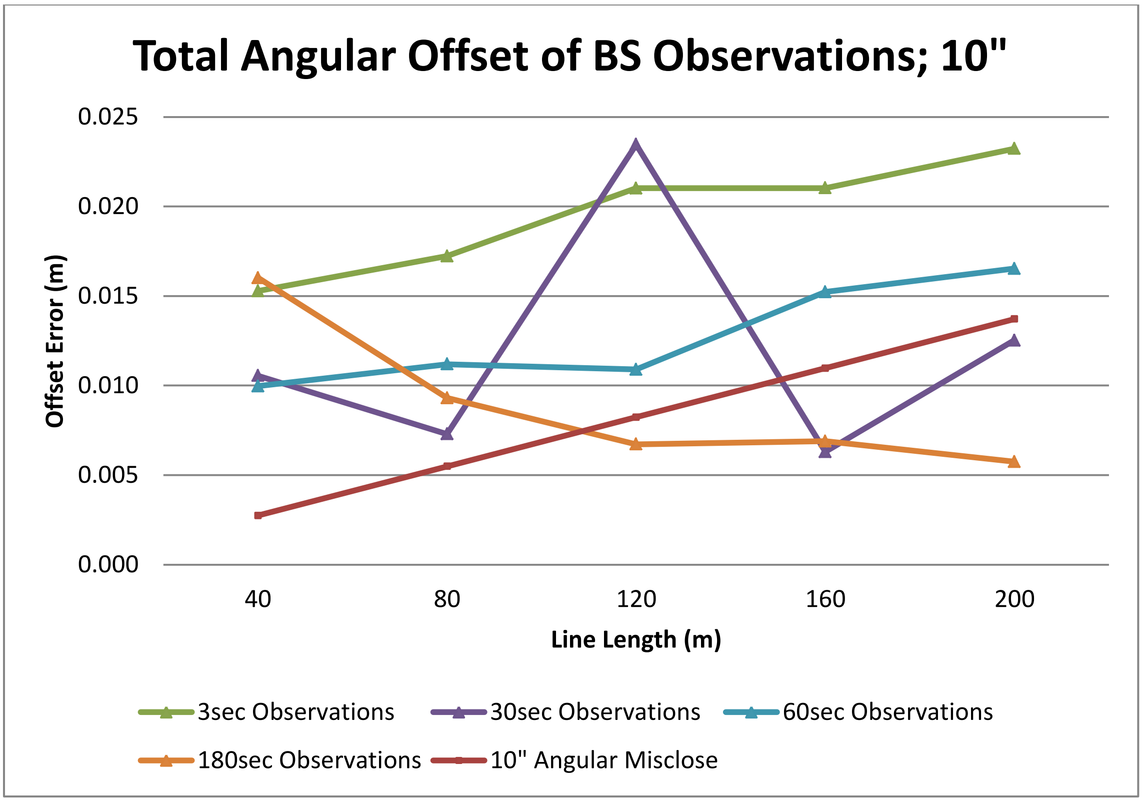

Figure 5.9 – The perpendicular angle offset distance of the BS observations as compared to 10” accuracy

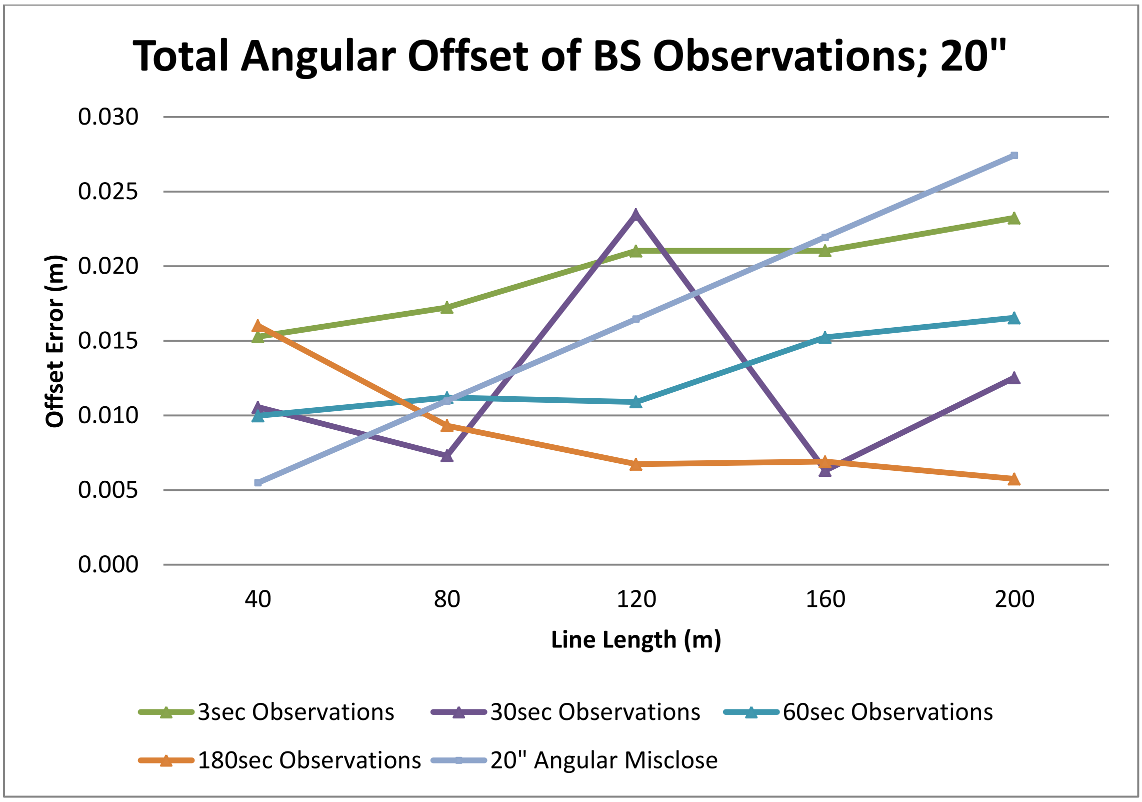

Figure 5.10 – The perpendicular angle offset distance of the BS observations as compared to 20” accuracy; 160m appears to be the value at which bearing observation accuracy will be at least 20” – which is reasonably undesirable

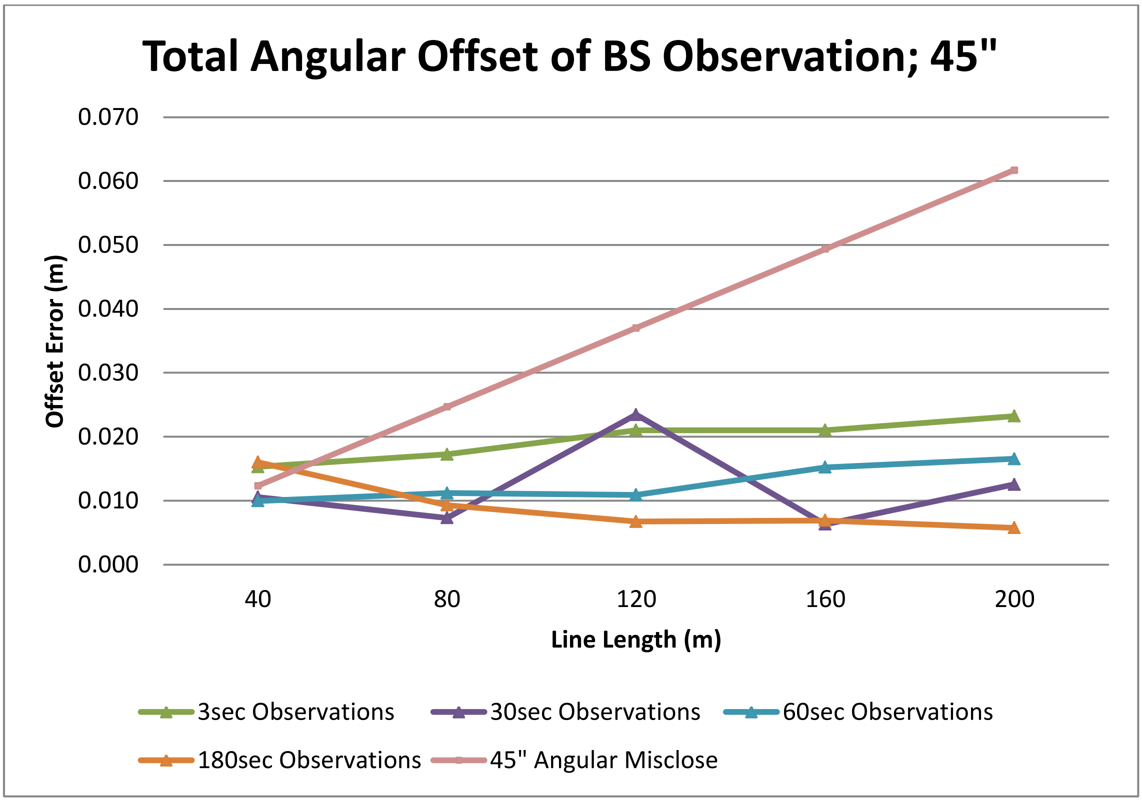

Figure 5.11 – The perpendicular angle offset distance of the BS observations as compared to 45” accuracy; though this will probably never be used in practice it is interesting top outline an accuracy standard all observations can meet

The analysis of the backsight angle offset supports the findings in the *Literature Review* that RTK observations can be used to establish a cadastral survey. The 180sec observations proved to be the best method for observing minimum BS lengths as the offset error actually met the TS accuracy over about 180m, which is slightly shorter than the recommended 200m. Therefore the testing of this dissertation has at least proved that the survey standards'' recommendations regarding minimum BS lengths are accurate. The guidelines also suggests that in difficult conditions this minimum length can be reduced to 100m, however from the analysis of these results it becomes apparent that RTK cannot meet TS accuracy over such a short length. Why the guidelines would allow a shorter BS length in difficult conditions is not explicitly stated, though it could be to potentially allow for a lesser degree of accuracy – say 10". If this were to be the case, from the results of this testing a 100m BS would still not be sufficiently long to accurately observe the bearing of the line. Considering a lesser degree of accuracy is required in the observations, the testing shows that a minimum BS length of around 120m should be observed.

As the requirement for bearing accuracy diminishes though, it can be seen that any observation method will meet this standard over increasingly short lines. Given the necessary accuracy required to correctly establish the orientation of a survey plan, it is recommended that the surveyor should seek to meet TS quality accuracy and measure backsights of greater than 180m. It would obviously be prudent to follow best practices and observe longer BS's if the option is available, however the testing has established that when observing for 180 seconds, a minimum BS length of 180m meets TS accuracy and a minimum length of 120m can be used when accuracy is to a lower required standard (i.e. repeating a cadastral survey achieved by compass or to a minute level).

It is interesting and again necessary to consider the actual data in this analysis, as in the previous analyses of the results the 180sec observations tend to have poor accuracy whereas the 30sec observations tend to be much better. This comes back to observation precision where the observations of longer length have greater precision than the shorter observations. This results in a smaller spread of data and a lower standard deviation therefore while the actual results may be inaccurate the observations are much more precise. This means that although the observation bias correction may be larger than the other data sets the 2σ value is lower (the 95% confidence interval is tighter) resulting in a smaller total error in the line. This is apparent in both the angle offsets for referencing and backsight observations. This does not necessarily mean that the total error in more precise observations will always be less than the other data sets (apparent in the short line observations); it means the 2σ value will be less.

5.7 USE OF A 99% CONFIDENCE INTERVAL

The findings of the *Literature Review* have consistently stated that a 95% confidence interval should be used when analysing the accuracy of the observations. This means that based on the above analysis in all cases a surveyor can be 95% certain that his observations will be within 2σ of the true value (though the CI incorporates the observation bias too). In practical terms it means that 95 of 100 observations will be within the acceptable accuracy of the survey standards''. The literature requires as 95% confidence as this means that it is highly unlikely that an observation will fall outside this range, however the surveyor must also consider a 5 observations that could potentially be fall outside the acceptable accuracy range.

For this dissertation a 95% confidence interval was adopted based on the recommendations of the reviewed literature and to ensure continuity between the testing in this dissertation and the recommendations of existing guidelines. If a 99% CI (3σ) had been adopted for this testing it would have been found that RTK would not be appropriate for short line observation in the same circumstances as identified in the above analysis and that the minimum backsight length could potentially be required to be longer. It would seem prudent however to adopt a 99% CI because while it may mean that RTK's application to surveying tasks is reduced and/or limited, it would ensure that all but the most significant outriding observations fall into an acceptable accuracy range.

5.8 CONCLUSION

The analysis of the results has led to the determination of how and when RTK is applicable to cadastral survey purposes; short line observations, referencing and minimum backsight length.

Looking at short line observations first it is apparent that RTK can meet the survey standards' accuracy for lines when observing much shorter than the recommended 640m (*SP1*) and 120m adopted by some jurisdictions. The testing makes it apparent that RTK can in fact observe lines of 40m or greater. Though the 180sec observations failed to meet the accuracy standards because of the effect of observation bias, it is recommended that observations of 30sec or greater with a bipod used to stabilise the pole be incorporated as the testing method. Observing by this method would confirm the recommendations made by the ACT guidelines in *Figure 2.4* of the *Literature Review*. Longer observation lengths are particularly recommended based on the precision benefits.

Minimum backsight lengths were found to confirm the recommendations of the SBQ guidelines. The recommended minimum length of backsight lines in ideal conditions was found to be 180m or greater and the absolute minimum length in difficult conditions was found to 120m, as opposed to 200m and 100m respectively. From the testing the ideal observation technique was found to be 180 seconds with a bipod for stabilisation as this lead to significant precision improvements and allowed for a much narrower 2σ value. Based on the observation of control marks, this recommended survey method would again confirm the ACT guidelines recommendations.

Finally from the results of the testing it has become apparent that RTK is not appropriate for referencing in any situation given any observation technique. It was basically found that while the observations may meet *SP1* accuracy standards, the impact the error in the line would have on the bearing of the reference mark would simply be too great to accept the line.

From this evaluation the application of RTK for cadastral purposes has been successfully identified. Through the results of the testing it has become apparent the observation bias has made a critical impact of the results of this dissertation and that it is important to account for the errors and discrepancies this bias will introduce into the data. Based on this research it is now possible to make recommendations about how and when RTK should be used and address the issues regarding how it should be used.

CHAPTER 6: CONCLUSION

6.1 INTRODUCTION

This section will aim to conclude this dissertation by summarising the work that was completed, address how the dissertation met the original aims, establish the further work required to develop and improve this work and conclude how and when RTK is appropriate for cadastral surveys.

6.2 MEETING THE AIMS AND OBJECTIVES

This dissertation encompassed the complete testing of short line observations, referencing and minimum backsight lengths so as to determine how these should be completed in cadastral surveys. The dissertation moved from describing the concept of these three aspects, to finding and critiquing the existing information regarding these aspects, to determining and implementing a comprehensive testing regime to represent *reasonable professional practice* that would allow the replication of this testing by any surveyor, to an analysis and determination of how and when RTK is appropriate to finally stating RTK’s applicability to cadastral surveys. From this the minimally acceptable practices for observing these three aspects have been determined. All testing was completed empirically with physically tested data making up the results and analysis of this dissertation.

The testing was conducting with the aim of determining whether RTK observations could actually achieve the accuracy vector of 10mm + 50ppm from the *Cadastral Survey Requirements*, referenced to in the SBQ guidelines and whether it could potentially meet TS accuracy too. By incorporating these accuracy standards into the results it was determined in what instances RTK would meet or fail the accuracy. Moreover because the testing was conducted in a manner indicative of best practice, the research findings of this dissertation can be submitted to the Surveyors Board of Queensland to substantiate their guideline in respect to the three aspects of this dissertation.

6.3 FINDINGS AND RECOMMENDATIONS

This dissertation has established, through the comprehensive testing regime, how and when RTK is appropriate for observing short lines, referencing and minimum backsight lengths. From the analysis of the results it is now possible to conclude with how and when RTK should be used.

6.3.1 SHORT LINES

Based on the findings of this dissertation, short lines of 40m or more can be measured with RTK provided that the two ends of the line are observed for greater than 30 seconds. This method of observation will meet the accuracy recommendation of the survey standards'. The surveyor must ensure that the marks are reoccupied at least 30 minutes later to allow for a sufficient change in satellite geometry. It is recommended that the rover pole be stabilised by a bipod and that the reoccupation occurs with a new ambiguity resolution – if not a new base station set-up (based on best practice recommendations).

6.3.2 BACKSIGHT LENGTH

The results of this dissertation have led to the finding that backsight lengths for TS should ideally be 180m or greater in length, to meet rigorous TS accuracy bearings. As an absolute minimum RTK can be used to measure BS lengths of 120m however this should only be done in difficult conditions and upon the surveyor accepting that the bearing will not be of TS accuracy, but rather within 10". If a surveyor were to measure BS's with RTK he is advised to occupy the station for 180 seconds and use a bipod to stabilise the rover pole. Furthermore a surveyor should seek longer BS lengths if these are available.

6.3.3 REFERENCING

The findings of this dissertation indicate that RTK should not be used for referencing in any circumstance as RTK simply cannot observe the mark to within an acceptable bearing accuracy. While it may be possible to observe the reference mark to an accuracy which satisfies survey standards'' accuracy, the error in the short line will cause a massive bearing error in the observation over such a short distance. Regardless of the observation technique used, RTK failed to meet an acceptable accuracy standard.

6.3.4 OBSERVATION TECHNIQUE

It is recommended that surveyors follow survey guidelines first and foremost, and the findings of this dissertation when considering observation techniques. An important recommendation regarding observation technique based on the findings of this dissertation is that a surveyor should leave at least 30 minutes before reoccupying the survey marks but should consider reoccupation a third time or perhaps on a different day to minimise the impact of observation bias.

6.4 FURTHER WORK

This research, testing and analysis of this dissertation have completed the outlined aims and objectives however the results and outcomes are by no means perfect. It was found that a significant error in the observations was the effect of observation bias. This cannot be minimised in the field by any means of observation technique as the bias is a function of the satellite geometry at the time. This bias it is means that the distribution of GNSS observations is not randomly scattered, that the distribution is too, a function of observation bias. Based on this understanding it is possible to predict observation bias, but more importantly it is also possible to implement observation procedures that will minimise the effect of observation bias. From the various survey guidelines it is recommended that reoccupation occur at least 30 minutes after the initial observation of the point. It would be interesting to investigate how leaving the reoccupation for a longer time period, i.e. 2 or 3 hours, and reoccupying more than once would improve the accuracy of the data and diminish observation bias. An extension of this would be to investigate how reoccupation up to several days later would improve the results.

Another area that has already been addressed in this dissertation is the consideration of using a 99% confidence interval (3σ) to analyse the data rather than a 95% CI. Considering that 5 of every 100 observations could potentially fail to meet the accuracy standards, it is important to investigate ways of reducing sources of possible error. If the acceptable error was to be set to 3σ this would lead to a different set of recommendations regarding how and when RTK is applicable for cadastral works; potentially it may mean that RTK is not at all appropriate at this stage giving its accuracy limitations.

The final consideration towards future work would be the consideration of developing a stricter guideline. At the moment 10mm + 50ppm is a fairly loose accuracy guideline and a surveyor should consider observing a more rigid accuracy standard coupled with a 99% CI for future RTK surveys. This could potentially limit RTK's use however it would result in much more accurate data.

6.5 IMPROVEMENTS ON THIS DISSERTATION

If this dissertation were to be repeated the primary change to be made would be to stagger the testing observations over several days in different time windows. In this manner it would be hoped that observations from the complete satellite cycle could be observed to reduce the impact of observation bias. The number of rounds of testing and the actual procedures meet the requirements of *SP1* however it would be interesting to consider the accuracy of the data if the observation bias was reduced or eliminated from the data sets. Moreover it could potentially mean that a different observation regime could be developed which inherently eliminates the effect of observation bias.

6.6 CONCLUSIONS

This dissertation set out to establish how to observe short lines, referencing and minimum backsight lengths in regards to adopting *reasonable professional practice* so as to refer the findings of this dissertation to the SBQ to fill in some of the non-explicit areas of their guidelines. Based on the testing regime and analysis outcomes this dissertation has successfully fulfilled this aim. Based on the previous recommendations outlined in this chapter and the *Analysis*, these can now be referred to the SBQ in the hopes of this information gaining inclusion into the guidelines for use.

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APPENDIX A: Project Specifications

University of Southern Queensland

FACULTY OF ENGINEERING & SURVEYING

ENG4111/4112 Research Project

PROJECT SPECIFICATION

FOR: Michael Zahl

TOPIC: RTK GPS/GNSS for Cadastral Surveying

SUPERVISOR/S: A. Prof. Peter Gibbings

ENROLMENT: ENG4111 Research Project Part 1 – S1, ONC, 2013

ENG4112 Research Project Part 2 – S2, ONC, 2013

BACKGROUND: Because of the evolution and improvement of RTK GPS/GNSS, current surveying tasks are becoming more regularly performed by this method. Once it was considered that point positioning technology would never reach the measuring standards of conventional theodolites/total stations. Today RTK GPS/GNSS is being more closely incorporated into the industry in all forms – one particular instance being cadastral surveying. On the 30th of November last year, the Surveyors Board of Queensland (SBQ) released a guideline document regarding the use of RTK GNSS on cadastral surveys. While this document cleared much of the confusion around the issue there are still elements in which the document was not explicit, therefore this research project will be used to define these areas empirically.

PROJECT AIM: This project aims to define the inexplicit aspects of the recently released guidelines by the SBQ; *RTK GNSS for Cadastral Surveys*, empirically through field testing and office reductions and through theoretical analysis, via literature reviews of existing research on the subject. SBQ has provided a guideline on the use of RTK GNSS. This research aims to provide minimum standards, limitations and precautions for use of RTK and will supplement the recently released guideline. More broadly, the research can be used to further clarify the guidelines. It is important to note that this research will not cover every element of the guidelines but rather specifically chosen aspects.

SPONSORSHIP: MinStaff Survey

PROGRAMME: Issue C, 27/03/2013

1. Research existing background and historical information relating to the use of RTK GPS/GNSS in cadastral surveying: what current research exists and the findings and evaluations made by these sources and how this ties in with the research I will do.
2. Critically analyse existing research and confirm exactly what information exists and what will be required to find the results needed to answer the project questions.
3. Design a practical field measurement programme that will provide data that can be analysed and evaluated. This field work may be carried out over existing cadastral boundaries or known points so that measurements can be compared to real world, accurate data. Specifically;

   a. the overall accuracy of RTK GPS/GNSS
   b. minimum lengths of lines
   c. close corner referencing
   d. areas of uncertainty around measured points and how it corresponds to other points
   e. observation time/type/technique (3s v 30s v 2min/topo) v OCP/bipod v tripod v tribrach/Continuously Operating Reference Stations (CORS) can be added to the mix)
   f. at what length are conventional methods more appropriate as well as minimum backsight lengths

   Measuring these will be carried out over baselines of varying lengths and by adjusting the observation time and type of the measurements. In particular, by setting up two rovers on a corner mark and the corresponding reference mark the accuracy of the created baseline will be easily observable. Different lengths will be used to examine whether errors increase over longer baselines, all the while different observation techniques will be employed. Even if the data appears reliable in the field, it will still be post-processed and the areas of uncertainty around each observation point will be examined.

   This project has to essentially be reverse engineered to give the outcomes and results I am looking for. I will need to start with what the final outcome will look like (and the associated questions/answers which will come from the literature review and gaps in the SBQ guidelines) and manufacture what testing and analysis would be necessary to make those conclusions. Then I would need to determine what data is necessary for this step and finally create a testing regime to provide that data. This is not a case of falsifying the data to give the answers I want but rather determining what conditions are required to provide a chance to draw the conclusions I want.
4. Analyse field data, provide an evaluation and present findings in a manner suitable for professional evaluation or submission to key stakeholders such as the SBQ.
5. Based on results from examining field data identify practical solutions to the causes of the inaccuracies in RTK cadastral work and what measurement methods have provided the most reliable data. The objective being to take this data and expand on the SBQ guidelines and provide more detail to the practical components of the guidelines.
6. Analyse how these findings can be implemented into the current surveying industry and what benefits it will provide. Critically assess whether the research is necessary and provides a practical solution to the inexplicit aspects of the SBQ guidelines.

APPENDIX B: CORS RTK Checklist

Surveyor General's Directions

CORS RTK CHECKLIST

ISSUE	GUIDELINE	Yes/No or n/a
Equipment	Is the GNSS receiver capable of Class C or better (10mm + 50ppm)	
	Single frequency receiver must only measure lines under 10km	
	Single frequency for surveys not requiring strict accuracy	
	Dual frequency recommended	
Verification	Receiver, method and software verified annually against GNSS test network, an approved local network or minimum 4 established permanent marks of Class B order 2 or better	
Validation	every day and at each survey location by connection to a minimum of 2 established permanent marks	
	or by comparison with a measured EDM baseline	
	Or against two AUSPOS stations (if >500m apart,>2hrs data, rapid orbits)	
	Or against a static GNSS measured line done to Class C standard or better	
Orientation	MGA orientation from two independent connections to established permanent marks (can be CORS station if Class 3 or better),	
	Or, for rural surveys only, from a minimum two CORS RTK coordinated survey marks if they are 1000m from established permanent survey marks, >500m apart and permanent survey or reference marks	
	Or, from plan on record showing comparison distance between at least two existing survey monuments	
Best Practice	Never to be used to derive a line or distance to a reference mark under 100m	
	Working from the whole to the part within a closed figure	
	Always "run the boundary" where appropriate	
	minimum 2 minutes observation	
	Multipath, obstructions or height required always increase observation times	
	Minimum of two independent observations (i.e. using two CORS stations)	
	Independent observations at least 30 minutes apart	
	Use correctly adjusted tripods or bipods only	
	Check antenna height independently (mm & inches)	
	Use the best antenna models available	
	PDOP should be <5	
	At least 4 satellites should be available (more is always better)	
	Weather conditions should be stable	
	Ensure ambiguities are resolved	
	Elevation mask minimum 15°	
	Always use AUSGeoid09 parameters	
	CORS correction signal must be continuous during observation	
	Range poles only to be used for defining natural boundaries	
Plan	Lines derived from GNSS should be clearly indicated on plan	
	distances shown over 5 km should be Grid distances	
	Distances shown under 5 km should be ground distances	
	SCIMS coordinate box should indicate an estimate of class for placed and surveyed permanent marks	

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APPENDIX C: Raw Data Survey Reports

Appendix C1: Total Station Observations 21 Aug 2013

Survey Controller Reduced Points

Point	B32	**East**	5268.926	**North**	14702.834	**Elevation**	684.680	**Code**	PSM
Point	B21	**East**	5226.460	**North**	14769.760	**Elevation**	686.040	**Code**	PSM
Point	B22	**East**	5344.963	**North**	14708.080	**Elevation**	682.950	**Code**	PSM
Point	B52	**East**	5265.825	**North**	14619.162	**Elevation**	685.560	**Code**	PSM
Point	B26	**East**	5197.401	**North**	14675.343	**Elevation**	686.370	**Code**	PSM
Point	B35	**East**	5183.581	**North**	14631.412	**Elevation**	687.305	**Code**	PSM
Point	B24	**East**	5146.210	**North**	14602.933	**Elevation**	688.355	**Code**	PSM
Point	1000	**East**	5132.246	**North**	14556.608	**Elevation**	688.787	**Code**	SVYMARK_200M
Point	1001	**East**	5148.559	**North**	14597.077	**Elevation**	688.367	**Code**	SVYMARK_160M
Point	1002	**East**	5176.658	**North**	14625.951	**Elevation**	687.613	**Code**	SVYMARK_120M
Point	1003	**East**	5207.488	**North**	14651.465	**Elevation**	686.583	**Code**	SVYMARK_80M
Point	1004	**East**	5238.190	**North**	14676.994	**Elevation**	685.756	**Code**	SVYMARK_40M
Point	1005	**East**	5254.894	**North**	14688.084	**Elevation**	685.165	**Code**	SVYMARK_20M
Point	1006	**East**	5261.803	**North**	14695.743	**Elevation**	684.999	**Code**	SVYMARK_10M
Point	1007	**East**	5265.210	**North**	14699.580	**Elevation**	684.895	**Code**	SVYMARK_5M
Point	1008	**East**	5267.133	**North**	14701.736	**Elevation**	684.827	**Code**	SVYMARK_2M
Point	1009	**East**	5183.582	**North**	14631.413	**Elevation**	687.307	**Code**	B35
Point	1010	**East**	5268.919	**North**	14702.836	**Elevation**	684.680	**Code**	SVYMARK_B32
Point	1011	**East**	5267.121	**North**	14701.740	**Elevation**	684.824	**Code**	SVYMARK_2M
Point	1012	**East**	5265.200	**North**	14699.583	**Elevation**	684.890	**Code**	SVYMARK_5M
Point	1013	**East**	5261.795	**North**	14695.748	**Elevation**	684.998	**Code**	SVYMARK_10M
Point	1014	**East**	5254.887	**North**	14688.088	**Elevation**	685.164	**Code**	SVYMARK_20M
Point	1015	**East**	5238.184	**North**	14676.991	**Elevation**	685.757	**Code**	SVYMARK_40M
Point	1016	**East**	5207.483	**North**	14651.462	**Elevation**	686.588	**Code**	SVYMARK_80M
Point	1017	**East**	5176.652	**North**	14625.949	**Elevation**	687.618	**Code**	SVYMARK_120M
Point	1018	**East**	5148.557	**North**	14597.081	**Elevation**	688.373	**Code**	SVYMARK_160M
Point	1019	**East**	5132.244	**North**	14556.605	**Elevation**	688.794	**Code**	SVYMARK_200M
Point	1020	**East**	5146.221	**North**	14602.930	**Elevation**	688.369	**Code**	B24

Appendix C2: RTK Observations 8 Aug 2013

Survey Controller Reduced Points

Point	42253	**East**	394487.240	**North**	6946073.744	**Elevation**	690.691	**Code**	PSM
Point	40956	**East**	394651.683	**North**	6945868.391	**Elevation**	689.794	**Code**	PSM
Point	40403	**East**	394940.388	**North**	6945984.562	**Elevation**	684.598	**Code**	PSM
Point	40424	**East**	394860.174	**North**	6945489.267	**Elevation**	683.293	**Code**	PSM
Point	38566	**East**	394970.986	**North**	6946480.878	**Elevation**	681.007	**Code**	PSM
Point	ANANGA1	**East**	394586.985	**North**	6946490.639	**Elevation**	718.427	**Code**	1
Point	1000	**East**	394651.716	**North**	6945868.368	**Elevation**	689.506	**Code**	STN_40956_L
Point	1001	**East**	394651.715	**North**	6945868.369	**Elevation**	689.520	**Code**	STN_40956_S
Point	1002	**East**	394487.231	**North**	6946073.766	**Elevation**	690.429	**Code**	STN_42253_S
Point	1003	**East**	394487.232	**North**	6946073.767	**Elevation**	690.425	**Code**	STN_42253_L
Point	1004	**East**	394860.190	**North**	6945489.261	**Elevation**	683.028	**Code**	STN_40424_L
Point	1005	**East**	394860.192	**North**	6945489.249	**Elevation**	683.014	**Code**	STN_40424_S
Point	1006	**East**	394940.394	**North**	6945984.558	**Elevation**	684.312	**Code**	STN_40403_S
Point	1007	**East**	394940.393	**North**	6945984.555	**Elevation**	684.320	**Code**	STN_40403_L
Point	B32_1	**East**	394855.808	**North**	6946193.598	**Elevation**	684.439	**Code**	3S RUN1
Point	2M_1	**East**	394854.009	**North**	6946192.499	**Elevation**	684.567	**Code**	3S RUN1
Point	5M_1	**East**	394852.096	**North**	6946190.342	**Elevation**	684.630	**Code**	3S RUN1
Point	10M_1	**East**	394848.684	**North**	6946186.503	**Elevation**	684.734	**Code**	3S RUN1
Point	20M_1	**East**	394841.797	**North**	6946178.863	**Elevation**	684.911	**Code**	3S RUN1
Point	40M_1	**East**	394825.076	**North**	6946167.763	**Elevation**	685.501	**Code**	3S RUN1
Point	80M_1	**East**	394794.404	**North**	6946142.242	**Elevation**	686.325	**Code**	3S RUN1
Point	120M_1	**East**	394763.567	**North**	6946116.744	**Elevation**	687.370	**Code**	3S RUN1
Point	160M_1	**East**	394735.476	**North**	6946087.874	**Elevation**	688.130	**Code**	3S RUN1
Point	200M_1	**East**	394719.177	**North**	6946047.430	**Elevation**	688.537	**Code**	3S RUN1
Point	200M_2	**East**	394719.176	**North**	6946047.425	**Elevation**	688.545	**Code**	3S RUN2
Point	160M_2	**East**	394735.481	**North**	6946087.884	**Elevation**	688.116	**Code**	3S RUN2
Point	120M_2	**East**	394763.555	**North**	6946116.756	**Elevation**	687.379	**Code**	3S RUN2
Point	80M_2	**East**	394794.383	**North**	6946142.250	**Elevation**	686.348	**Code**	3S RUN2
Point	40M_2	**East**	394825.078	**North**	6946167.769	**Elevation**	685.507	**Code**	3S RUN2
Point	20M_2	**East**	394841.767	**North**	6946178.861	**Elevation**	684.934	**Code**	3S RUN2
Point	10M_2	**East**	394848.665	**North**	6946186.517	**Elevation**	684.770	**Code**	3S RUN2
Point	5M_2	**East**	394852.080	**North**	6946190.353	**Elevation**	684.651	**Code**	3S RUN2
Point	2M_2	**East**	394854.001	**North**	6946192.514	**Elevation**	684.573	**Code**	3S RUN2
Point	B32_2	**East**	394855.808	**North**	6946193.603	**Elevation**	684.439	**Code**	3S RUN2
Point	B32_3	**East**	394855.804	**North**	6946193.605	**Elevation**	684.435	**Code**	3S RUN3
Point	2M_3	**East**	394854.015	**North**	6946192.509	**Elevation**	684.573	**Code**	3S RUN3
Point	5M_3	**East**	394852.097	**North**	6946190.345	**Elevation**	684.654	**Code**	3S RUN3

Point	10M_3	**East**	394848.681	**North**	6946186.504	**Elevation**	684.764	**Code**	3S RUN3
Point	20M_3	**East**	394841.780	**North**	6946178.845	**Elevation**	684.933	**Code**	3S RUN3
Point	40M_3	**East**	394825.071	**North**	6946167.767	**Elevation**	685.497	**Code**	3S RUN3
Point	80M_3	**East**	394794.390	**North**	6946142.246	**Elevation**	686.336	**Code**	3S RUN3
Point	120M_3	**East**	394763.569	**North**	6946116.734	**Elevation**	687.379	**Code**	3S RUN3
Point	160M_3	**East**	394735.494	**North**	6946087.884	**Elevation**	688.140	**Code**	3S RUN3
Point	200M_3	**East**	394719.167	**North**	6946047.429	**Elevation**	688.562	**Code**	3S RUN3
Point	200M_4	**East**	394719.159	**North**	6946047.438	**Elevation**	688.544	**Code**	3S RUN4
Point	160M_4	**East**	394735.456	**North**	6946087.890	**Elevation**	688.131	**Code**	3S RUN4
Point	120M_4	**East**	394763.538	**North**	6946116.745	**Elevation**	687.417	**Code**	3S RUN4
Point	80M_4	**East**	394794.366	**North**	6946142.252	**Elevation**	686.342	**Code**	3S RUN4
Point	40M_4	**East**	394825.065	**North**	6946167.773	**Elevation**	685.527	**Code**	3S RUN4
Point	20M_4	**East**	394841.768	**North**	6946178.860	**Elevation**	684.913	**Code**	3S RUN4
Point	10M_4	**East**	394848.663	**North**	6946186.518	**Elevation**	684.756	**Code**	3S RUN4
Point	5M_4	**East**	394852.072	**North**	6946190.343	**Elevation**	684.648	**Code**	3S RUN4
Point	2M_4	**East**	394853.998	**North**	6946192.503	**Elevation**	684.587	**Code**	3S RUN4
Point	B32_4	**East**	394855.810	**North**	6946193.595	**Elevation**	684.454	**Code**	3S RUN4
Point	B32_5	**East**	394855.811	**North**	6946193.615	**Elevation**	684.434	**Code**	3S RUN5
Point	2M_5	**East**	394854.014	**North**	6946192.497	**Elevation**	684.572	**Code**	3S RUN5
Point	5M_5	**East**	394852.096	**North**	6946190.343	**Elevation**	684.657	**Code**	3S RUN5
Point	10M_5	**East**	394848.687	**North**	6946186.511	**Elevation**	684.753	**Code**	3S RUN5
Point	20M_5	**East**	394841.780	**North**	6946178.859	**Elevation**	684.932	**Code**	3S RUN5
Point	40M_5	**East**	394825.075	**North**	6946167.775	**Elevation**	685.519	**Code**	3S RUN5
Point	80M_5	**East**	394794.386	**North**	6946142.247	**Elevation**	686.352	**Code**	3S RUN5
Point	120M_5	**East**	394763.546	**North**	6946116.741	**Elevation**	687.381	**Code**	3S RUN5
Point	160M_5	**East**	394735.480	**North**	6946087.890	**Elevation**	688.132	**Code**	3S RUN5
Point	200M_5	**East**	394719.160	**North**	6946047.434	**Elevation**	688.556	**Code**	3S RUN5
Point	200M_6	**East**	394719.164	**North**	6946047.433	**Elevation**	688.550	**Code**	3S RUN6
Point	160M_6	**East**	394735.464	**North**	6946087.887	**Elevation**	688.129	**Code**	3S RUN6
Point	120M_6	**East**	394763.546	**North**	6946116.739	**Elevation**	687.406	**Code**	3S RUN6
Point	80M_6	**East**	394794.372	**North**	6946142.253	**Elevation**	686.325	**Code**	3S RUN6
Point	40M_6	**East**	394825.077	**North**	6946167.767	**Elevation**	685.495	**Code**	3S RUN6
Point	20M_6	**East**	394841.759	**North**	6946178.857	**Elevation**	684.920	**Code**	3S RUN6
Point	10M_6	**East**	394848.672	**North**	6946186.511	**Elevation**	684.759	**Code**	3S RUN6
Point	5M_6	**East**	394852.073	**North**	6946190.339	**Elevation**	684.655	**Code**	3S RUN6
Point	2M_6	**East**	394853.999	**North**	6946192.499	**Elevation**	684.565	**Code**	3S RUN6
Point	B32_6	**East**	394855.819	**North**	6946193.591	**Elevation**	684.413	**Code**	3S RUN6
Point	B32_7	**East**	394855.814	**North**	6946193.594	**Elevation**	684.425	**Code**	3S RUN7
Point	2M_7	**East**	394854.020	**North**	6946192.497	**Elevation**	684.563	**Code**	3S RUN7
Point	5M_7	**East**	394852.096	**North**	6946190.348	**Elevation**	684.637	**Code**	3S RUN7

Point	10M_7	**East**	394848.687	**North**	6946186.509	**Elevation**	684.736	**Code**	3S RUN7
Point	20M_7	**East**	394841.788	**North**	6946178.863	**Elevation**	684.905	**Code**	3S RUN7
Point	40M_7	**East**	394825.083	**North**	6946167.772	**Elevation**	685.491	**Code**	3S RUN7
Point	80M_7	**East**	394794.388	**North**	6946142.244	**Elevation**	686.329	**Code**	3S RUN7
Point	120M_7	**East**	394763.562	**North**	6946116.742	**Elevation**	687.379	**Code**	3S RUN7
Point	160M_7	**East**	394735.490	**North**	6946087.886	**Elevation**	688.125	**Code**	3S RUN7
Point	200M_7	**East**	394719.163	**North**	6946047.431	**Elevation**	688.546	**Code**	3S RUN7
Point	200M_8	**East**	394719.172	**North**	6946047.440	**Elevation**	688.540	**Code**	3S RUN8
Point	160M_8	**East**	394735.464	**North**	6946087.895	**Elevation**	688.109	**Code**	3S RUN8
Point	120M_8	**East**	394763.558	**North**	6946116.759	**Elevation**	687.345	**Code**	3S RUN8
Point	80M_8	**East**	394794.378	**North**	6946142.259	**Elevation**	686.322	**Code**	3S RUN8
Point	40M_8	**East**	394825.076	**North**	6946167.782	**Elevation**	685.522	**Code**	3S RUN8
Point	20M_8	**East**	394841.768	**North**	6946178.862	**Elevation**	684.924	**Code**	3S RUN8
Point	10M_8	**East**	394848.674	**North**	6946186.507	**Elevation**	684.762	**Code**	3S RUN8
Point	5M_8	**East**	394852.072	**North**	6946190.351	**Elevation**	684.648	**Code**	3S RUN8
Point	2M_8	**East**	394853.987	**North**	6946192.504	**Elevation**	684.588	**Code**	3S RUN8
Point	B32_8	**East**	394855.783	**North**	6946193.612	**Elevation**	684.431	**Code**	3S RUN8
Point	B32_9	**East**	394855.790	**North**	6946193.610	**Elevation**	684.435	**Code**	3S RUN9
Point	2M_9	**East**	394854.007	**North**	6946192.502	**Elevation**	684.585	**Code**	3S RUN9
Point	5M_9	**East**	394852.086	**North**	6946190.349	**Elevation**	684.661	**Code**	3S RUN9
Point	10M_9	**East**	394848.677	**North**	6946186.517	**Elevation**	684.762	**Code**	3S RUN9
Point	20M_9	**East**	394841.780	**North**	6946178.863	**Elevation**	684.935	**Code**	3S RUN9
Point	40M_9	**East**	394825.082	**North**	6946167.783	**Elevation**	685.518	**Code**	3S RUN9
Point	80M_9	**East**	394794.379	**North**	6946142.246	**Elevation**	686.339	**Code**	3S RUN9
Point	120M_9	**East**	394763.570	**North**	6946116.730	**Elevation**	687.379	**Code**	3S RUN9
Point	160M_9	**East**	394735.481	**North**	6946087.891	**Elevation**	688.132	**Code**	3S RUN9
Point	200M_9	**East**	394719.170	**North**	6946047.427	**Elevation**	688.544	**Code**	3S RUN9
Point	200M_10	**East**	394719.167	**North**	6946047.432	**Elevation**	688.546	**Code**	3S RUN10
Point	160M_10	**East**	394735.464	**North**	6946087.884	**Elevation**	688.128	**Code**	3S RUN10
Point	120M_10	**East**	394763.568	**North**	6946116.739	**Elevation**	687.357	**Code**	3S RUN10
Point	80M_10	**East**	394794.383	**North**	6946142.248	**Elevation**	686.326	**Code**	3S RUN10
Point	40M_10	**East**	394825.065	**North**	6946167.764	**Elevation**	685.511	**Code**	3S RUN10
Point	20M_10	**East**	394841.767	**North**	6946178.855	**Elevation**	684.915	**Code**	3S RUN10
Point	10M_10	**East**	394848.666	**North**	6946186.505	**Elevation**	684.750	**Code**	3S RUN10
Point	5M_10	**East**	394852.077	**North**	6946190.340	**Elevation**	684.641	**Code**	3S RUN10
Point	2M_10	**East**	394853.998	**North**	6946192.500	**Elevation**	684.578	**Code**	3S RUN10
Point	B32_10	**East**	394855.812	**North**	6946193.594	**Elevation**	684.438	**Code**	3S RUN10
Point	B32_11	**East**	394855.812	**North**	6946193.595	**Elevation**	684.445	**Code**	3S RUN11
Point	2M_11	**East**	394854.020	**North**	6946192.505	**Elevation**	684.588	**Code**	3S RUN11
Point	5M_11	**East**	394852.097	**North**	6946190.347	**Elevation**	684.662	**Code**	3S RUN11

Point	10M_11	**East**	394848.689	**North**	6946186.505	**Elevation**	684.754	**Code**	3S RUN11
Point	20M_11	**East**	394841.790	**North**	6946178.857	**Elevation**	684.923	**Code**	3S RUN11
Point	40M_11	**East**	394825.096	**North**	6946167.763	**Elevation**	685.502	**Code**	3S RUN11
Point	80M_11	**East**	394794.394	**North**	6946142.241	**Elevation**	686.335	**Code**	3S RUN11
Point	120M_11	**East**	394763.575	**North**	6946116.728	**Elevation**	687.380	**Code**	3S RUN11
Point	160M_11	**East**	394735.487	**North**	6946087.883	**Elevation**	688.129	**Code**	3S RUN11
Point	200M_11	**East**	394719.166	**North**	6946047.428	**Elevation**	688.557	**Code**	3S RUN11
Point	200M_12	**East**	394719.172	**North**	6946047.440	**Elevation**	688.559	**Code**	3S RUN12
Point	160M_12	**East**	394735.472	**North**	6946087.884	**Elevation**	688.129	**Code**	3S RUN12
Point	120M_12	**East**	394763.559	**North**	6946116.746	**Elevation**	687.384	**Code**	3S RUN12
Point	80M_12	**East**	394794.375	**North**	6946142.242	**Elevation**	686.353	**Code**	3S RUN12
Point	40M_12	**East**	394825.067	**North**	6946167.772	**Elevation**	685.518	**Code**	3S RUN12
Point	20M_12	**East**	394841.768	**North**	6946178.854	**Elevation**	684.927	**Code**	3S RUN12
Point	10M_12	**East**	394848.673	**North**	6946186.500	**Elevation**	684.761	**Code**	3S RUN12
Point	5M_12	**East**	394852.072	**North**	6946190.347	**Elevation**	684.656	**Code**	3S RUN12
Point	2M_12	**East**	394853.991	**North**	6946192.495	**Elevation**	684.579	**Code**	3S RUN12
Point	B32_12	**East**	394855.808	**North**	6946193.604	**Elevation**	684.424	**Code**	3S RUN12
Point	B32_13	**East**	394855.812	**North**	6946193.596	**Elevation**	684.423	**Code**	3S RUN13
Point	2M_13	**East**	394853.997	**North**	6946192.478	**Elevation**	684.559	**Code**	3S RUN13
Point	5M_13	**East**	394852.086	**North**	6946190.342	**Elevation**	684.645	**Code**	3S RUN13
Point	10M_13	**East**	394848.687	**North**	6946186.501	**Elevation**	684.747	**Code**	3S RUN13
Point	20M_13	**East**	394841.792	**North**	6946178.851	**Elevation**	684.922	**Code**	3S RUN13
Point	40M_13	**East**	394825.094	**North**	6946167.767	**Elevation**	685.515	**Code**	3S RUN13
Point	80M_13	**East**	394794.405	**North**	6946142.232	**Elevation**	686.345	**Code**	3S RUN13
Point	120M_13	**East**	394763.557	**North**	6946116.710	**Elevation**	687.391	**Code**	3S RUN13
Point	160M_13	**East**	394735.482	**North**	6946087.883	**Elevation**	688.151	**Code**	3S RUN13
Point	200M_13	**East**	394719.161	**North**	6946047.421	**Elevation**	688.545	**Code**	3S RUN13
Point	200M_14	**East**	394719.159	**North**	6946047.425	**Elevation**	688.542	**Code**	3S RUN14
Point	160M_14	**East**	394735.462	**North**	6946087.888	**Elevation**	688.136	**Code**	3S RUN14
Point	120M_14	**East**	394763.560	**North**	6946116.744	**Elevation**	687.374	**Code**	3S RUN14
Point	80M_14	**East**	394794.384	**North**	6946142.243	**Elevation**	686.311	**Code**	3S RUN14
Point	40M_14	**East**	394825.075	**North**	6946167.770	**Elevation**	685.512	**Code**	3S RUN14
Point	20M_14	**East**	394841.762	**North**	6946178.863	**Elevation**	684.923	**Code**	3S RUN14
Point	10M_14	**East**	394848.664	**North**	6946186.510	**Elevation**	684.751	**Code**	3S RUN14
Point	5M_14	**East**	394852.070	**North**	6946190.345	**Elevation**	684.642	**Code**	3S RUN14
Point	2M_14	**East**	394853.990	**North**	6946192.501	**Elevation**	684.585	**Code**	3S RUN14
Point	B32_14	**East**	394855.819	**North**	6946193.601	**Elevation**	684.423	**Code**	3S RUN14
Point	B32_15	**East**	394855.815	**North**	6946193.593	**Elevation**	684.433	**Code**	3S RUN15
Point	2M_15	**East**	394854.022	**North**	6946192.497	**Elevation**	684.579	**Code**	3S RUN15
Point	5M_15	**East**	394852.098	**North**	6946190.343	**Elevation**	684.647	**Code**	3S RUN15

Point	10M_15	**East**	394848.691	**North**	6946186.495	**Elevation**	684.745	**Code**	3S RUN15
Point	20M_15	**East**	394841.778	**North**	6946178.856	**Elevation**	684.906	**Code**	3S RUN15
Point	40M_15	**East**	394825.091	**North**	6946167.779	**Elevation**	685.505	**Code**	3S RUN15
Point	80M_15	**East**	394794.399	**North**	6946142.249	**Elevation**	686.333	**Code**	3S RUN15
Point	120M_15	**East**	394763.583	**North**	6946116.733	**Elevation**	687.367	**Code**	3S RUN15
Point	160M_15	**East**	394735.486	**North**	6946087.881	**Elevation**	688.123	**Code**	3S RUN15
Point	200M_15	**East**	394719.164	**North**	6946047.425	**Elevation**	688.551	**Code**	3S RUN15
Point	200M_16	**East**	394719.150	**North**	6946047.423	**Elevation**	688.555	**Code**	3S RUN16
Point	160M_16	**East**	394735.477	**North**	6946087.887	**Elevation**	688.122	**Code**	3S RUN16
Point	120M_16	**East**	394763.553	**North**	6946116.749	**Elevation**	687.370	**Code**	3S RUN16
Point	80M_16	**East**	394794.381	**North**	6946142.263	**Elevation**	686.336	**Code**	3S RUN16
Point	40M_16	**East**	394825.073	**North**	6946167.778	**Elevation**	685.498	**Code**	3S RUN16
Point	20M_16	**East**	394841.774	**North**	6946178.860	**Elevation**	684.913	**Code**	3S RUN16
Point	10M_16	**East**	394848.673	**North**	6946186.516	**Elevation**	684.748	**Code**	3S RUN16
Point	5M_16	**East**	394852.077	**North**	6946190.346	**Elevation**	684.643	**Code**	3S RUN16
Point	2M_16	**East**	394854.010	**North**	6946192.503	**Elevation**	684.574	**Code**	3S RUN16
Point	B32_16	**East**	394855.812	**North**	6946193.597	**Elevation**	684.426	**Code**	3S RUN16
Point	B32_17	**East**	394855.813	**North**	6946193.605	**Elevation**	684.426	**Code**	3S RUN17
Point	2M_17	**East**	394854.006	**North**	6946192.505	**Elevation**	684.580	**Code**	3S RUN17
Point	5M_17	**East**	394852.088	**North**	6946190.349	**Elevation**	684.647	**Code**	3S RUN17
Point	10M_17	**East**	394848.687	**North**	6946186.510	**Elevation**	684.746	**Code**	3S RUN17
Point	20M_17	**East**	394841.780	**North**	6946178.862	**Elevation**	684.917	**Code**	3S RUN17
Point	40M_17	**East**	394825.081	**North**	6946167.768	**Elevation**	685.511	**Code**	3S RUN17
Point	80M_17	**East**	394794.386	**North**	6946142.253	**Elevation**	686.341	**Code**	3S RUN17
Point	120M_17	**East**	394763.563	**North**	6946116.723	**Elevation**	687.384	**Code**	3S RUN17
Point	160M_17	**East**	394735.493	**North**	6946087.883	**Elevation**	688.130	**Code**	3S RUN17
Point	200M_17	**East**	394719.162	**North**	6946047.433	**Elevation**	688.548	**Code**	3S RUN17
Point	200M_18	**East**	394719.173	**North**	6946047.431	**Elevation**	688.547	**Code**	3S RUN18
Point	160M_18	**East**	394735.471	**North**	6946087.887	**Elevation**	688.135	**Code**	3S RUN18
Point	120M_18	**East**	394763.555	**North**	6946116.747	**Elevation**	687.389	**Code**	3S RUN18
Point	80M_18	**East**	394794.375	**North**	6946142.259	**Elevation**	686.334	**Code**	3S RUN18
Point	40M_18	**East**	394825.070	**North**	6946167.778	**Elevation**	685.515	**Code**	3S RUN18
Point	20M_18	**East**	394841.767	**North**	6946178.867	**Elevation**	684.915	**Code**	3S RUN18
Point	10M_18	**East**	394848.659	**North**	6946186.514	**Elevation**	684.755	**Code**	3S RUN18
Point	5M_18	**East**	394852.060	**North**	6946190.348	**Elevation**	684.643	**Code**	3S RUN18
Point	2M_18	**East**	394853.994	**North**	6946192.508	**Elevation**	684.576	**Code**	3S RUN18
Point	B32_18	**East**	394855.815	**North**	6946193.596	**Elevation**	684.432	**Code**	3S RUN18
Point	B32_19	**East**	394855.813	**North**	6946193.592	**Elevation**	684.426	**Code**	3S RUN19
Point	2M_19	**East**	394854.017	**North**	6946192.499	**Elevation**	684.572	**Code**	3S RUN19
Point	5M_19	**East**	394852.096	**North**	6946190.332	**Elevation**	684.640	**Code**	3S RUN19

Point	10M_19	**East**	394848.689	**North**	6946186.508	**Elevation**	684.747	**Code**	3S RUN19
Point	20M_19	**East**	394841.778	**North**	6946178.856	**Elevation**	684.914	**Code**	3S RUN19
Point	40M_19	**East**	394825.086	**North**	6946167.770	**Elevation**	685.509	**Code**	3S RUN19
Point	80M_19	**East**	394794.386	**North**	6946142.247	**Elevation**	686.336	**Code**	3S RUN19
Point	120M_19	**East**	394763.562	**North**	6946116.738	**Elevation**	687.373	**Code**	3S RUN19
Point	160M_19	**East**	394735.479	**North**	6946087.883	**Elevation**	688.118	**Code**	3S RUN19
Point	200M_19	**East**	394719.165	**North**	6946047.439	**Elevation**	688.549	**Code**	3S RUN19
Point	200M_20	**East**	394719.170	**North**	6946047.428	**Elevation**	688.552	**Code**	3S RUN20
Point	160M_20	**East**	394735.472	**North**	6946087.886	**Elevation**	688.110	**Code**	3S RUN20
Point	120M_20	**East**	394763.546	**North**	6946116.750	**Elevation**	687.385	**Code**	3S RUN20
Point	80M_20	**East**	394794.372	**North**	6946142.258	**Elevation**	686.348	**Code**	3S RUN20
Point	40M_20	**East**	394825.060	**North**	6946167.772	**Elevation**	685.507	**Code**	3S RUN20
Point	20M_20	**East**	394841.762	**North**	6946178.855	**Elevation**	684.917	**Code**	3S RUN20
Point	10M_20	**East**	394848.669	**North**	6946186.506	**Elevation**	684.755	**Code**	3S RUN20
Point	5M_20	**East**	394852.080	**North**	6946190.349	**Elevation**	684.651	**Code**	3S RUN20
Point	2M_20	**East**	394853.997	**North**	6946192.500	**Elevation**	684.593	**Code**	3S RUN20
Point	B32_20	**East**	394855.813	**North**	6946193.592	**Elevation**	684.436	**Code**	3S RUN20
Point	B32_21	**East**	394855.808	**North**	6946193.604	**Elevation**	684.431	**Code**	3S RUN21
Point	2M_21	**East**	394854.011	**North**	6946192.502	**Elevation**	684.578	**Code**	3S RUN21
Point	5M_21	**East**	394852.098	**North**	6946190.346	**Elevation**	684.649	**Code**	3S RUN21
Point	10M_21	**East**	394848.671	**North**	6946186.529	**Elevation**	684.751	**Code**	3S RUN21
Point	20M_21	**East**	394841.790	**North**	6946178.852	**Elevation**	684.918	**Code**	3S RUN21
Point	40M_21	**East**	394825.088	**North**	6946167.766	**Elevation**	685.500	**Code**	3S RUN21
Point	80M_21	**East**	394794.390	**North**	6946142.240	**Elevation**	686.333	**Code**	3S RUN21
Point	120M_21	**East**	394763.570	**North**	6946116.734	**Elevation**	687.370	**Code**	3S RUN21
Point	160M_21	**East**	394735.491	**North**	6946087.879	**Elevation**	688.120	**Code**	3S RUN21
Point	200M_21	**East**	394719.164	**North**	6946047.426	**Elevation**	688.550	**Code**	3S RUN21
Point	200M_22	**East**	394719.155	**North**	6946047.430	**Elevation**	688.545	**Code**	3S RUN22
Point	160M_22	**East**	394735.475	**North**	6946087.895	**Elevation**	688.127	**Code**	3S RUN22
Point	120M_22	**East**	394763.552	**North**	6946116.739	**Elevation**	687.364	**Code**	3S RUN22
Point	80M_22	**East**	394794.378	**North**	6946142.245	**Elevation**	686.332	**Code**	3S RUN22
Point	40M_22	**East**	394825.078	**North**	6946167.767	**Elevation**	685.502	**Code**	3S RUN22
Point	20M_22	**East**	394841.771	**North**	6946178.854	**Elevation**	684.906	**Code**	3S RUN22
Point	10M_22	**East**	394848.660	**North**	6946186.513	**Elevation**	684.749	**Code**	3S RUN22
Point	5M_22	**East**	394852.084	**North**	6946190.346	**Elevation**	684.649	**Code**	3S RUN22
Point	2M_22	**East**	394853.993	**North**	6946192.504	**Elevation**	684.575	**Code**	3S RUN22
Point	B32_22	**East**	394855.819	**North**	6946193.610	**Elevation**	684.430	**Code**	3S RUN22
Point	B32_23	**East**	394855.820	**North**	6946193.593	**Elevation**	684.425	**Code**	3S RUN23
Point	2M_23	**East**	394854.011	**North**	6946192.497	**Elevation**	684.566	**Code**	3S RUN23
Point	5M_23	**East**	394852.080	**North**	6946190.339	**Elevation**	684.642	**Code**	3S RUN23

Point	10M_23	**East**	394848.690	**North**	6946186.508	**Elevation**	684.747	**Code**	3S RUN23
Point	20M_23	**East**	394841.775	**North**	6946178.847	**Elevation**	684.919	**Code**	3S RUN23
Point	40M_23	**East**	394825.089	**North**	6946167.761	**Elevation**	685.508	**Code**	3S RUN23
Point	80M_23	**East**	394794.400	**North**	6946142.244	**Elevation**	686.340	**Code**	3S RUN23
Point	120M_23	**East**	394763.571	**North**	6946116.731	**Elevation**	687.365	**Code**	3S RUN23
Point	160M_23	**East**	394735.488	**North**	6946087.871	**Elevation**	688.127	**Code**	3S RUN23
Point	200M_23	**East**	394719.166	**North**	6946047.422	**Elevation**	688.542	**Code**	3S RUN23
Point	200M_24	**East**	394719.161	**North**	6946047.426	**Elevation**	688.544	**Code**	3S RUN24
Point	160M_24	**East**	394735.478	**North**	6946087.878	**Elevation**	688.125	**Code**	3S RUN24
Point	120M_24	**East**	394763.549	**North**	6946116.735	**Elevation**	687.382	**Code**	3S RUN24
Point	80M_24	**East**	394794.383	**North**	6946142.246	**Elevation**	686.320	**Code**	3S RUN24
Point	40M_24	**East**	394825.077	**North**	6946167.767	**Elevation**	685.504	**Code**	3S RUN24
Point	20M_24	**East**	394841.776	**North**	6946178.847	**Elevation**	684.905	**Code**	3S RUN24
Point	10M_24	**East**	394848.665	**North**	6946186.504	**Elevation**	684.740	**Code**	3S RUN24
Point	5M_24	**East**	394852.073	**North**	6946190.342	**Elevation**	684.630	**Code**	3S RUN24
Point	2M_24	**East**	394853.991	**North**	6946192.496	**Elevation**	684.565	**Code**	3S RUN24
Point	B32_24	**East**	394855.808	**North**	6946193.599	**Elevation**	684.427	**Code**	3S RUN24
Point	B32_25	**East**	394855.810	**North**	6946193.597	**Elevation**	684.431	**Code**	3S RUN25
Point	2M_25	**East**	394854.016	**North**	6946192.503	**Elevation**	684.574	**Code**	3S RUN25
Point	5M_25	**East**	394852.092	**North**	6946190.340	**Elevation**	684.640	**Code**	3S RUN25
Point	10M_25	**East**	394848.681	**North**	6946186.500	**Elevation**	684.744	**Code**	3S RUN25
Point	20M_25	**East**	394841.787	**North**	6946178.854	**Elevation**	684.914	**Code**	3S RUN25
Point	40M_25	**East**	394825.091	**North**	6946167.766	**Elevation**	685.511	**Code**	3S RUN25
Point	80M_25	**East**	394794.392	**North**	6946142.248	**Elevation**	686.335	**Code**	3S RUN25
Point	120M_25	**East**	394763.574	**North**	6946116.728	**Elevation**	687.368	**Code**	3S RUN25
Point	160M_25	**East**	394735.490	**North**	6946087.863	**Elevation**	688.116	**Code**	3S RUN25
Point	200M_25	**East**	394719.156	**North**	6946047.415	**Elevation**	688.542	**Code**	3S RUN25
Point	200M_26	**East**	394719.162	**North**	6946047.428	**Elevation**	688.541	**Code**	3S RUN26
Point	160M_26	**East**	394735.474	**North**	6946087.881	**Elevation**	688.111	**Code**	3S RUN26
Point	120M_26	**East**	394763.545	**North**	6946116.737	**Elevation**	687.368	**Code**	3S RUN26
Point	80M_26	**East**	394794.370	**North**	6946142.261	**Elevation**	686.335	**Code**	3S RUN26
Point	40M_26	**East**	394825.068	**North**	6946167.769	**Elevation**	685.510	**Code**	3S RUN26
Point	20M_26	**East**	394841.755	**North**	6946178.850	**Elevation**	684.917	**Code**	3S RUN26
Point	10M_26	**East**	394848.663	**North**	6946186.501	**Elevation**	684.747	**Code**	3S RUN26
Point	5M_26	**East**	394852.083	**North**	6946190.348	**Elevation**	684.641	**Code**	3S RUN26
Point	2M_26	**East**	394854.001	**North**	6946192.496	**Elevation**	684.575	**Code**	3S RUN26
Point	B32_26	**East**	394855.785	**North**	6946193.609	**Elevation**	684.432	**Code**	3S RUN26
Point	B32_27	**East**	394855.811	**North**	6946193.592	**Elevation**	684.433	**Code**	3S RUN27
Point	2M_27	**East**	394854.010	**North**	6946192.510	**Elevation**	684.575	**Code**	3S RUN27
Point	5M_27	**East**	394852.093	**North**	6946190.336	**Elevation**	684.642	**Code**	3S RUN27

Point	10M_27	**East**	394848.687	**North**	6946186.502	**Elevation**	684.749	**Code**	3S RUN27
Point	20M_27	**East**	394841.777	**North**	6946178.851	**Elevation**	684.909	**Code**	3S RUN27
Point	40M_27	**East**	394825.089	**North**	6946167.760	**Elevation**	685.504	**Code**	3S RUN27
Point	80M_27	**East**	394794.382	**North**	6946142.237	**Elevation**	686.338	**Code**	3S RUN27
Point	120M_27	**East**	394763.571	**North**	6946116.744	**Elevation**	687.365	**Code**	3S RUN27
Point	160M_27	**East**	394735.485	**North**	6946087.878	**Elevation**	688.126	**Code**	3S RUN27
Point	200M_27	**East**	394719.168	**North**	6946047.435	**Elevation**	688.550	**Code**	3S RUN27
Point	200M_28	**East**	394719.162	**North**	6946047.433	**Elevation**	688.554	**Code**	3S RUN28
Point	160M_28	**East**	394735.474	**North**	6946087.903	**Elevation**	688.119	**Code**	3S RUN28
Point	120M_28	**East**	394763.555	**North**	6946116.751	**Elevation**	687.371	**Code**	3S RUN28
Point	80M_28	**East**	394794.389	**North**	6946142.251	**Elevation**	686.344	**Code**	3S RUN28
Point	40M_28	**East**	394825.076	**North**	6946167.775	**Elevation**	685.512	**Code**	3S RUN28
Point	20M_28	**East**	394841.758	**North**	6946178.864	**Elevation**	684.922	**Code**	3S RUN28
Point	10M_28	**East**	394848.667	**North**	6946186.510	**Elevation**	684.748	**Code**	3S RUN28
Point	5M_28	**East**	394852.089	**North**	6946190.339	**Elevation**	684.645	**Code**	3S RUN28
Point	2M_28	**East**	394854.001	**North**	6946192.505	**Elevation**	684.578	**Code**	3S RUN28
Point	B32_28	**East**	394855.812	**North**	6946193.604	**Elevation**	684.438	**Code**	3S RUN28
Point	B32_29	**East**	394855.815	**North**	6946193.604	**Elevation**	684.444	**Code**	3S RUN29
Point	2M_29	**East**	394853.996	**North**	6946192.512	**Elevation**	684.589	**Code**	3S RUN29
Point	5M_29	**East**	394852.091	**North**	6946190.359	**Elevation**	684.649	**Code**	3S RUN29
Point	10M_29	**East**	394848.684	**North**	6946186.522	**Elevation**	684.760	**Code**	3S RUN29
Point	20M_29	**East**	394841.780	**North**	6946178.855	**Elevation**	684.927	**Code**	3S RUN29
Point	40M_29	**East**	394825.080	**North**	6946167.770	**Elevation**	685.511	**Code**	3S RUN29
Point	80M_29	**East**	394794.394	**North**	6946142.241	**Elevation**	686.340	**Code**	3S RUN29
Point	120M_29	**East**	394763.561	**North**	6946116.756	**Elevation**	687.372	**Code**	3S RUN29
Point	160M_29	**East**	394735.479	**North**	6946087.878	**Elevation**	688.119	**Code**	3S RUN29
Point	200M_29	**East**	394719.174	**North**	6946047.431	**Elevation**	688.549	**Code**	3S RUN29
Point	200M_30	**East**	394719.177	**North**	6946047.430	**Elevation**	688.550	**Code**	3S RUN30
Point	160M_30	**East**	394735.473	**North**	6946087.890	**Elevation**	688.129	**Code**	3S RUN30
Point	120M_30	**East**	394763.552	**North**	6946116.750	**Elevation**	687.373	**Code**	3S RUN30
Point	80M_30	**East**	394794.378	**North**	6946142.250	**Elevation**	686.344	**Code**	3S RUN30
Point	40M_30	**East**	394825.073	**North**	6946167.771	**Elevation**	685.502	**Code**	3S RUN30
Point	20M_30	**East**	394841.767	**North**	6946178.858	**Elevation**	684.914	**Code**	3S RUN30
Point	10M_30	**East**	394848.661	**North**	6946186.507	**Elevation**	684.748	**Code**	3S RUN30
Point	5M_30	**East**	394852.081	**North**	6946190.345	**Elevation**	684.638	**Code**	3S RUN30
Point	2M_30	**East**	394853.996	**North**	6946192.490	**Elevation**	684.569	**Code**	3S RUN30
Point	B32_30	**East**	394855.815	**North**	6946193.595	**Elevation**	684.431	**Code**	3S RUN30
Point	30BP_1_B32	**East**	394855.814	**North**	6946193.596	**Elevation**	684.441	**Code**	30SBP RUN1
Point	30BP_1_2M	**East**	394854.014	**North**	6946192.492	**Elevation**	684.574	**Code**	30SBP RUN1

Point	30BP_1_5M	**East**	394852.089	**North**	6946190.339	**Elevation**	684.640	**Code**	30SBP RUN1
Point	30BP_1_10M	**East**	394848.685	**North**	6946186.498	**Elevation**	684.745	**Code**	30SBP RUN1
Point	30BP_1_20M	**East**	394841.786	**North**	6946178.851	**Elevation**	684.916	**Code**	30SBP RUN1
Point	30BP_1_40M	**East**	394825.093	**North**	6946167.762	**Elevation**	685.506	**Code**	30SBP RUN1
Point	30BP_1_80M	**East**	394794.393	**North**	6946142.235	**Elevation**	686.337	**Code**	30SBP RUN1
Point	30BP_1_120M	**East**	394763.572	**North**	6946116.738	**Elevation**	687.371	**Code**	30SBP RUN1
Point	30BP_1_160M	**East**	394735.490	**North**	6946087.881	**Elevation**	688.126	**Code**	30SBP RUN1
Point	30BP_1_200M	**East**	394719.181	**North**	6946047.435	**Elevation**	688.538	**Code**	30SBP RUN1
Point	30BP_2_B32	**East**	394855.811	**North**	6946193.597	**Elevation**	684.437	**Code**	30SBP RUN2
Point	30BP_2_2M	**East**	394854.017	**North**	6946192.487	**Elevation**	684.567	**Code**	30SBP RUN2
Point	30BP_2_5M	**East**	394852.100	**North**	6946190.328	**Elevation**	684.636	**Code**	30SBP RUN2
Point	30BP_2_10M	**East**	394848.689	**North**	6946186.498	**Elevation**	684.749	**Code**	30SBP RUN2
Point	30BP_2_20M	**East**	394841.792	**North**	6946178.846	**Elevation**	684.910	**Code**	30SBP RUN2
Point	30BP_2_40M	**East**	394825.085	**North**	6946167.750	**Elevation**	685.509	**Code**	30SBP RUN2
Point	30BP_2_80M	**East**	394794.396	**North**	6946142.232	**Elevation**	686.337	**Code**	30SBP RUN2
Point	30BP_2_120M	**East**	394763.576	**North**	6946116.736	**Elevation**	687.374	**Code**	30SBP RUN2
Point	30BP_2_160M	**East**	394735.498	**North**	6946087.870	**Elevation**	688.117	**Code**	30SBP RUN2
Point	30BP_2_200M	**East**	394719.172	**North**	6946047.433	**Elevation**	688.548	**Code**	30SBP RUN2
Point	30BP_3_B32	**East**	394855.805	**North**	6946193.589	**Elevation**	684.438	**Code**	30SBP RUN3
Point	30BP_3_2M	**East**	394854.017	**North**	6946192.485	**Elevation**	684.574	**Code**	30SBP RUN3
Point	30BP_3_5M	**East**	394852.093	**North**	6946190.333	**Elevation**	684.638	**Code**	30SBP RUN3
Point	30BP_3_10M	**East**	394848.685	**North**	6946186.494	**Elevation**	684.754	**Code**	30SBP RUN3
Point	30BP_3_20M	**East**	394841.783	**North**	6946178.839	**Elevation**	684.919	**Code**	30SBP RUN3
Point	30BP_3_40M	**East**	394825.086	**North**	6946167.756	**Elevation**	685.505	**Code**	30SBP RUN3
Point	30BP_3_80M	**East**	394794.398	**North**	6946142.234	**Elevation**	686.334	**Code**	30SBP RUN3
Point	30BP_3_120M	**East**	394763.571	**North**	6946116.731	**Elevation**	687.362	**Code**	30SBP RUN3

Point	30BP_3_160M	**East**	394735.492	**North**	6946087.867	**Elevation**	688.121	**Code**	30SBP RUN3
Point	30BP_3_200M	**East**	394719.161	**North**	6946047.438	**Elevation**	688.542	**Code**	30SBP RUN3
Point	30BP_4_B32	**East**	394855.813	**North**	6946193.593	**Elevation**	684.428	**Code**	30SBP RUN4
Point	30BP_4_2M	**East**	394854.018	**North**	6946192.494	**Elevation**	684.575	**Code**	30SBP RUN4
Point	30BP_4_5M	**East**	394852.099	**North**	6946190.337	**Elevation**	684.638	**Code**	30SBP RUN4
Point	30BP_4_10M	**East**	394848.686	**North**	6946186.500	**Elevation**	684.747	**Code**	30SBP RUN4
Point	30BP_4_20M	**East**	394841.783	**North**	6946178.853	**Elevation**	684.919	**Code**	30SBP RUN4
Point	30BP_4_40M	**East**	394825.090	**North**	6946167.756	**Elevation**	685.508	**Code**	30SBP RUN4
Point	30BP_4_80M	**East**	394794.398	**North**	6946142.241	**Elevation**	686.336	**Code**	30SBP RUN4
Point	30BP_4_120M	**East**	394763.578	**North**	6946116.738	**Elevation**	687.359	**Code**	30SBP RUN4
Point	30BP_4_160M	**East**	394735.488	**North**	6946087.884	**Elevation**	688.116	**Code**	30SBP RUN4
Point	30BP_4_200M	**East**	394719.178	**North**	6946047.428	**Elevation**	688.546	**Code**	30SBP RUN4
Point	30BP_5_B32	**East**	394855.812	**North**	6946193.600	**Elevation**	684.428	**Code**	30SBP RUN5
Point	30BP_5_2M	**East**	394854.023	**North**	6946192.495	**Elevation**	684.573	**Code**	30SBP RUN5
Point	30BP_5_5M	**East**	394852.100	**North**	6946190.333	**Elevation**	684.643	**Code**	30SBP RUN5
Point	30BP_5_10M	**East**	394848.692	**North**	6946186.502	**Elevation**	684.747	**Code**	30SBP RUN5
Point	30BP_5_20M	**East**	394841.784	**North**	6946178.849	**Elevation**	684.921	**Code**	30SBP RUN5
Point	30BP_5_40M	**East**	394825.096	**North**	6946167.758	**Elevation**	685.501	**Code**	30SBP RUN5
Point	30BP_5_80M	**East**	394794.401	**North**	6946142.240	**Elevation**	686.326	**Code**	30SBP RUN5
Point	30BP_5_120M	**East**	394763.580	**North**	6946116.740	**Elevation**	687.359	**Code**	30SBP RUN5
Point	30BP_5_160M	**East**	394735.494	**North**	6946087.877	**Elevation**	688.121	**Code**	30SBP RUN5
Point	30BP_5_200M	**East**	394719.183	**North**	6946047.431	**Elevation**	688.550	**Code**	30SBP RUN

Appendix C3: RTK Observations 13 Aug 2013

Survey Controller Reduced Points

Point	ANANGA1	**East**	394586.985	**North**	6946490.639	**Elevation**	718.427	**Code**	1
Point	30BP_6_B32	**East**	394855.808	**North**	6946193.593	**Elevation**	684.427	**Code**	30SBP RUN6
Point	30BP_6_2M	**East**	394854.016	**North**	6946192.497	**Elevation**	684.577	**Code**	30SBP RUN6
Point	30BP_6_5M	**East**	394852.092	**North**	6946190.341	**Elevation**	684.640	**Code**	30SBP RUN6
Point	30BP_6_10M	**East**	394848.688	**North**	6946186.505	**Elevation**	684.751	**Code**	30SBP RUN6
Point	30BP_6_20M	**East**	394841.789	**North**	6946178.853	**Elevation**	684.913	**Code**	30SBP RUN6
Point	30BP_6_40M	**East**	394825.093	**North**	6946167.759	**Elevation**	685.511	**Code**	30SBP RUN6
Point	30BP_6_80M	**East**	394794.395	**North**	6946142.243	**Elevation**	686.337	**Code**	30SBP RUN6
Point	30BP_6_120M	**East**	394763.575	**North**	6946116.735	**Elevation**	687.376	**Code**	30SBP RUN6
Point	30BP_6_160M	**East**	394735.490	**North**	6946087.876	**Elevation**	688.127	**Code**	30SBP RUN6
Point	30BP_6_200M	**East**	394719.180	**North**	6946047.425	**Elevation**	688.546	**Code**	30SBP RUN6
Point	30BP_7_B32	**East**	394855.808	**North**	6946193.589	**Elevation**	684.428	**Code**	30SBP RUN7
Point	30BP_7_2M	**East**	394854.014	**North**	6946192.494	**Elevation**	684.569	**Code**	30SBP RUN7
Point	30BP_7_5M	**East**	394852.091	**North**	6946190.342	**Elevation**	684.636	**Code**	30SBP RUN7
Point	30BP_7_10M	**East**	394848.685	**North**	6946186.504	**Elevation**	684.749	**Code**	30SBP RUN7
Point	30BP_7_20M	**East**	394841.782	**North**	6946178.849	**Elevation**	684.918	**Code**	30SBP RUN7
Point	30BP_7_40M	**East**	394825.089	**North**	6946167.762	**Elevation**	685.504	**Code**	30SBP RUN7
Point	30BP_7_80M	**East**	394794.396	**North**	6946142.242	**Elevation**	686.339	**Code**	30SBP RUN7
Point	30BP_7_120M	**East**	394763.576	**North**	6946116.734	**Elevation**	687.378	**Code**	30SBP RUN7
Point	30BP_7_160M	**East**	394735.493	**North**	6946087.878	**Elevation**	688.125	**Code**	30SBP RUN7
Point	30BP_7_200M	**East**	394719.178	**North**	6946047.424	**Elevation**	688.557	**Code**	30SBP RUN7
Point	30BP_8_B32	**East**	394855.810	**North**	6946193.595	**Elevation**	684.433	**Code**	30SBP RUN8
Point	30BP_8_2M	**East**	394854.018	**North**	6946192.495	**Elevation**	684.570	**Code**	30SBP RUN8
Point	30BP_8_5M	**East**	394852.094	**North**	6946190.335	**Elevation**	684.648	**Code**	30SBP RUN8
Point	30BP_8_10M	**East**	394848.685	**North**	6946186.500	**Elevation**	684.755	**Code**	30SBP RUN8

Point	30BP_8_20M	**East**	394841.783	**North**	6946178.847	**Elevation**	684.912	**Code**	30SBP RUN8
Point	30BP_8_40M	**East**	394825.087	**North**	6946167.760	**Elevation**	685.508	**Code**	30SBP RUN8
Point	30BP_8_80M	**East**	394794.403	**North**	6946142.244	**Elevation**	686.349	**Code**	30SBP RUN8
Point	30BP_8_120M	**East**	394763.568	**North**	6946116.730	**Elevation**	687.368	**Code**	30SBP RUN8
Point	30BP_8_160M	**East**	394735.486	**North**	6946087.875	**Elevation**	688.131	**Code**	30SBP RUN8
Point	30BP_8_200M	**East**	394719.180	**North**	6946047.426	**Elevation**	688.548	**Code**	30SBP RUN8
Point	30BP_9_2M	**East**	394854.019	**North**	6946192.502	**Elevation**	684.574	**Code**	30SBP RUN9
Point	30BP_9_5M	**East**	394852.095	**North**	6946190.337	**Elevation**	684.645	**Code**	30SBP RUN9
Point	30BP_9_10M	**East**	394848.686	**North**	6946186.499	**Elevation**	684.749	**Code**	30SBP RUN9
Point	30BP_9_20M	**East**	394841.784	**North**	6946178.847	**Elevation**	684.914	**Code**	30SBP RUN9
Point	30BP_9_40M	**East**	394825.091	**North**	6946167.760	**Elevation**	685.510	**Code**	30SBP RUN9
Point	30BP_9_80M	**East**	394794.400	**North**	6946142.240	**Elevation**	686.347	**Code**	30SBP RUN9
Point	30BP_9_120M	**East**	394763.576	**North**	6946116.734	**Elevation**	687.376	**Code**	30SBP RUN9
Point	30BP_9_160M	**East**	394735.493	**North**	6946087.882	**Elevation**	688.120	**Code**	30SBP RUN9
Point	30BP_9_200M	**East**	394719.184	**North**	6946047.426	**Elevation**	688.549	**Code**	30SBP RUN9
Point	30BP_10_B32	**East**	394855.813	**North**	6946193.593	**Elevation**	684.436	**Code**	30SBP RUN10
Point	30BP_10_2M	**East**	394854.015	**North**	6946192.492	**Elevation**	684.569	**Code**	30SBP RUN10
Point	30BP_10_5M	**East**	394852.092	**North**	6946190.338	**Elevation**	684.642	**Code**	30SBP RUN10
Point	30BP_10_10M	**East**	394848.687	**North**	6946186.502	**Elevation**	684.755	**Code**	30SBP RUN10
Point	30BP_10_20M	**East**	394841.784	**North**	6946178.851	**Elevation**	684.915	**Code**	30SBP RUN10
Point	30BP_10_40M	**East**	394825.088	**North**	6946167.762	**Elevation**	685.506	**Code**	30SBP RUN10
Point	30BP_10_80M	**East**	394794.396	**North**	6946142.241	**Elevation**	686.338	**Code**	30SBP RUN10
Point	30BP_10_120M	**East**	394763.572	**North**	6946116.737	**Elevation**	687.363	**Code**	30SBP RUN10
Point	30BP_10_160M	**East**	394735.486	**North**	6946087.885	**Elevation**	688.122	**Code**	30SBP RUN10
Point	30BP_10_200M	**East**	394719.179	**North**	6946047.430	**Elevation**	688.540	**Code**	30SBP RUN10
Point	30BP_11_B32	**East**	394855.809	**North**	6946193.593	**Elevation**	684.431	**Code**	30SBP RUN11

Point	30BP_11_2M	**East**	394854.018	**North**	6946192.493	**Elevation**	684.576	**Code**	30SBP RUN11
Point	30BP_11_5M	**East**	394852.093	**North**	6946190.337	**Elevation**	684.647	**Code**	30SBP RUN11
Point	30BP_11_10M	**East**	394848.687	**North**	6946186.505	**Elevation**	684.748	**Code**	30SBP RUN11
Point	30BP_11_20M	**East**	394841.789	**North**	6946178.849	**Elevation**	684.917	**Code**	30SBP RUN11
Point	30BP_11_40M	**East**	394825.092	**North**	6946167.759	**Elevation**	685.506	**Code**	30SBP RUN11
Point	30BP_11_80M	**East**	394794.398	**North**	6946142.245	**Elevation**	686.340	**Code**	30SBP RUN11
Point	30BP_11_120M	**East**	394763.569	**North**	6946116.733	**Elevation**	687.363	**Code**	30SBP RUN11
Point	30BP_11_B32_2	**East**	394855.807	**North**	6946193.592	**Elevation**	684.427	**Code**	30SBP RUN11
Point	30BP_11_160M_2	**East**	394735.484	**North**	6946087.881	**Elevation**	688.125	**Code**	30SBP RUN11
Point	30BP_11_200M_2	**East**	394719.177	**North**	6946047.427	**Elevation**	688.553	**Code**	30SBP RUN11
Point	30BP_12_B32	**East**	394855.810	**North**	6946193.599	**Elevation**	684.430	**Code**	30SBP RUN12
Point	30BP_12_2M	**East**	394854.018	**North**	6946192.495	**Elevation**	684.580	**Code**	30SBP RUN12
Point	30BP_12_5M	**East**	394852.093	**North**	6946190.342	**Elevation**	684.655	**Code**	30SBP RUN12
Point	30BP_12_10M	**East**	394848.688	**North**	6946186.504	**Elevation**	684.764	**Code**	30SBP RUN12
Point	30BP_12_20M	**East**	394841.788	**North**	6946178.850	**Elevation**	684.919	**Code**	30SBP RUN12
Point	30BP_12_40M	**East**	394825.095	**North**	6946167.764	**Elevation**	685.506	**Code**	30SBP RUN12
Point	30BP_12_80M	**East**	394794.397	**North**	6946142.244	**Elevation**	686.334	**Code**	30SBP RUN12
Point	30BP_12_120M	**East**	394763.572	**North**	6946116.739	**Elevation**	687.388	**Code**	30SBP RUN12
Point	30BP_12_160M	**East**	394735.490	**North**	6946087.883	**Elevation**	688.120	**Code**	30SBP RUN12
Point	30BP_12_200M	**East**	394719.182	**North**	6946047.421	**Elevation**	688.551	**Code**	30SBP RUN12
Point	30BP_13_B32	**East**	394855.806	**North**	6946193.600	**Elevation**	684.429	**Code**	30SBP RUN13
Point	30BP_13_2M	**East**	394854.010	**North**	6946192.500	**Elevation**	684.569	**Code**	30SBP RUN13
Point	30BP_13_5M	**East**	394852.092	**North**	6946190.341	**Elevation**	684.636	**Code**	30SBP RUN13
Point	30BP_13_10M	**East**	394848.681	**North**	6946186.498	**Elevation**	684.750	**Code**	30SBP RUN13
Point	30BP_13_20M	**East**	394841.782	**North**	6946178.851	**Elevation**	684.922	**Code**	30SBP RUN13
Point	30BP_13_40M	**East**	394825.086	**North**	6946167.756	**Elevation**	685.513	**Code**	30SBP RUN13

Point	30BP_13_80M	**East**	394794.390	**North**	6946142.245	**Elevation**	686.338	**Code**	30SBP RUN13
Point	30BP_13_120M	**East**	394763.571	**North**	6946116.739	**Elevation**	687.364	**Code**	30SBP RUN13
Point	30BP_13_160M	**East**	394735.489	**North**	6946087.877	**Elevation**	688.121	**Code**	30SBP RUN13
Point	30BP_13_200M	**East**	394719.181	**North**	6946047.425	**Elevation**	688.558	**Code**	30SBP RUN13
Point	30BP_14_B32	**East**	394855.809	**North**	6946193.591	**Elevation**	684.444	**Code**	30SBP RUN14
Point	30BP_14_2M	**East**	394854.013	**North**	6946192.496	**Elevation**	684.579	**Code**	30SBP RUN14
Point	30BP_14_5M	**East**	394852.093	**North**	6946190.345	**Elevation**	684.647	**Code**	30SBP RUN14
Point	30BP_14_10M	**East**	394848.683	**North**	6946186.504	**Elevation**	684.749	**Code**	30SBP RUN14
Point	30BP_14_20M	**East**	394841.785	**North**	6946178.853	**Elevation**	684.915	**Code**	30SBP RUN14
Point	30BP_14_40M	**East**	394825.087	**North**	6946167.755	**Elevation**	685.511	**Code**	30SBP RUN14
Point	30BP_14_80M	**East**	394794.392	**North**	6946142.238	**Elevation**	686.342	**Code**	30SBP RUN14
Point	30BP_14_120M	**East**	394763.571	**North**	6946116.729	**Elevation**	687.381	**Code**	30SBP RUN14
Point	30BP_14_160M	**East**	394735.487	**North**	6946087.883	**Elevation**	688.133	**Code**	30SBP RUN14
Point	30BP_14_200M	**East**	394719.181	**North**	6946047.429	**Elevation**	688.540	**Code**	30SBP RUN14
Point	30BP_15_B32	**East**	394855.809	**North**	6946193.597	**Elevation**	684.430	**Code**	30SBP RUN15
Point	30BP_15_2M	**East**	394854.015	**North**	6946192.498	**Elevation**	684.574	**Code**	30SBP RUN15
Point	30BP_15_5M	**East**	394852.097	**North**	6946190.334	**Elevation**	684.644	**Code**	30SBP RUN15
Point	30BP_15_10M	**East**	394848.687	**North**	6946186.505	**Elevation**	684.745	**Code**	30SBP RUN15
Point	30BP_15_20M	**East**	394841.785	**North**	6946178.858	**Elevation**	684.915	**Code**	30SBP RUN15
Point	30BP_15_40M	**East**	394825.092	**North**	6946167.770	**Elevation**	685.498	**Code**	30SBP RUN15
Point	30BP_15_80M	**East**	394794.393	**North**	6946142.245	**Elevation**	686.338	**Code**	30SBP RUN15
Point	30BP_15_120M	**East**	394763.574	**North**	6946116.741	**Elevation**	687.371	**Code**	30SBP RUN15
Point	30BP_15_160M	**East**	394735.486	**North**	6946087.890	**Elevation**	688.132	**Code**	30SBP RUN15
Point	30BP_15_200M	**East**	394719.182	**North**	6946047.432	**Elevation**	688.549	**Code**	30SBP RUN15
Point	30BP_16_B32	**East**	394855.809	**North**	6946193.592	**Elevation**	684.428	**Code**	30SBP RUN16
Point	30BP_16_2M	**East**	394854.014	**North**	6946192.498	**Elevation**	684.576	**Code**	30SBP RUN16

Point	30BP_16_5M	**East**	394852.096	**North**	6946190.343	**Elevation**	684.641	**Code**	30SBP RUN16
Point	30BP_16_10M	**East**	394848.690	**North**	6946186.506	**Elevation**	684.750	**Code**	30SBP RUN16
Point	30BP_16_20M	**East**	394841.786	**North**	6946178.856	**Elevation**	684.918	**Code**	30SBP RUN16
Point	30BP_16_40M	**East**	394825.090	**North**	6946167.763	**Elevation**	685.505	**Code**	30SBP RUN16
Point	30BP_16_80M	**East**	394794.397	**North**	6946142.246	**Elevation**	686.339	**Code**	30SBP RUN16
Point	30BP_16_120M	**East**	394763.571	**North**	6946116.746	**Elevation**	687.372	**Code**	30SBP RUN16
Point	30BP_16_160M	**East**	394735.489	**North**	6946087.879	**Elevation**	688.128	**Code**	30SBP RUN16
Point	30BP_16_200M	**East**	394719.160	**North**	6946047.424	**Elevation**	688.546	**Code**	30SBP RUN16
Point	30BP_17_B32	**East**	394855.811	**North**	6946193.601	**Elevation**	684.433	**Code**	30SBP RUN17
Point	30BP_17_2M	**East**	394854.017	**North**	6946192.500	**Elevation**	684.572	**Code**	30SBP RUN17
Point	30BP_17_5M	**East**	394852.099	**North**	6946190.341	**Elevation**	684.639	**Code**	30SBP RUN17
Point	30BP_17_10M	**East**	394848.686	**North**	6946186.506	**Elevation**	684.747	**Code**	30SBP RUN17
Point	30BP_17_20M	**East**	394841.785	**North**	6946178.851	**Elevation**	684.910	**Code**	30SBP RUN17
Point	30BP_17_40M	**East**	394825.089	**North**	6946167.759	**Elevation**	685.510	**Code**	30SBP RUN17
Point	30BP_17_80M	**East**	394794.395	**North**	6946142.247	**Elevation**	686.340	**Code**	30SBP RUN17
Point	30BP_17_120M	**East**	394763.569	**North**	6946116.738	**Elevation**	687.368	**Code**	30SBP RUN17
Point	30BP_17_160M	**East**	394735.494	**North**	6946087.883	**Elevation**	688.128	**Code**	30SBP RUN17
Point	30BP_17_200M	**East**	394719.183	**North**	6946047.422	**Elevation**	688.549	**Code**	30SBP RUN17
Point	30BP_18_B32	**East**	394855.817	**North**	6946193.594	**Elevation**	684.419	**Code**	30SBP RUN18
Point	30BP_18_2M	**East**	394854.019	**North**	6946192.494	**Elevation**	684.561	**Code**	30SBP RUN18
Point	30BP_18_5M	**East**	394852.099	**North**	6946190.342	**Elevation**	684.639	**Code**	30SBP RUN18
Point	30BP_18_10M	**East**	394848.688	**North**	6946186.498	**Elevation**	684.747	**Code**	30SBP RUN18
Point	30BP_18_20M	**East**	394841.783	**North**	6946178.846	**Elevation**	684.915	**Code**	30SBP RUN18
Point	30BP_18_40M	**East**	394825.090	**North**	6946167.759	**Elevation**	685.497	**Code**	30SBP RUN18
Point	30BP_18_80M	**East**	394794.395	**North**	6946142.243	**Elevation**	686.342	**Code**	30SBP RUN18
Point	30BP_18_120M	**East**	394763.571	**North**	6946116.739	**Elevation**	687.369	**Code**	30SBP RUN18

Point	30BP_18_160M	**East**	394735.489	**North**	6946087.877	**Elevation**	688.127	**Code**	30SBP RUN18
Point	30BP_18_200M	**East**	394719.157	**North**	6946047.422	**Elevation**	688.545	**Code**	30SBP RUN18
Point	30BP_19_B32	**East**	394855.810	**North**	6946193.604	**Elevation**	684.430	**Code**	30SBP RUN19
Point	30BP_19_2M	**East**	394854.015	**North**	6946192.494	**Elevation**	684.572	**Code**	30SBP RUN19
Point	30BP_19_5M	**East**	394852.094	**North**	6946190.337	**Elevation**	684.645	**Code**	30SBP RUN19
Point	30BP_19_10M	**East**	394848.687	**North**	6946186.502	**Elevation**	684.756	**Code**	30SBP RUN19
Point	30BP_19_20M	**East**	394841.788	**North**	6946178.857	**Elevation**	684.915	**Code**	30SBP RUN19
Point	30BP_19_40M	**East**	394825.089	**North**	6946167.761	**Elevation**	685.509	**Code**	30SBP RUN19
Point	30BP_19_80M	**East**	394794.396	**North**	6946142.245	**Elevation**	686.338	**Code**	30SBP RUN19
Point	30BP_19_120M	**East**	394763.575	**North**	6946116.745	**Elevation**	687.372	**Code**	30SBP RUN19
Point	30BP_19_160M	**East**	394735.488	**North**	6946087.879	**Elevation**	688.124	**Code**	30SBP RUN19
Point	30BP_19_200M	**East**	394719.181	**North**	6946047.428	**Elevation**	688.546	**Code**	30SBP RUN19
Point	30BP_20_B32	**East**	394855.807	**North**	6946193.597	**Elevation**	684.430	**Code**	30SBP RUN20
Point	30BP_20_2M	**East**	394854.011	**North**	6946192.501	**Elevation**	684.571	**Code**	30SBP RUN20
Point	30BP_20_5M	**East**	394852.095	**North**	6946190.340	**Elevation**	684.639	**Code**	30SBP RUN20
Point	30BP_20_10M	**East**	394848.689	**North**	6946186.507	**Elevation**	684.747	**Code**	30SBP RUN20
Point	30BP_20_20M	**East**	394841.787	**North**	6946178.854	**Elevation**	684.912	**Code**	30SBP RUN20
Point	30BP_20_40M	**East**	394825.090	**North**	6946167.761	**Elevation**	685.503	**Code**	30SBP RUN20
Point	30BP_20_80M	**East**	394794.393	**North**	6946142.244	**Elevation**	686.326	**Code**	30SBP RUN20
Point	30BP_20_120M	**East**	394763.578	**North**	6946116.741	**Elevation**	687.357	**Code**	30SBP RUN20
Point	30BP_20_160M	**East**	394735.494	**North**	6946087.881	**Elevation**	688.124	**Code**	30SBP RUN20
Point	30BP_20_200M	**East**	394719.179	**North**	6946047.435	**Elevation**	688.547	**Code**	30SBP RUN20
Point	30BP_21_B32	**East**	394855.814	**North**	6946193.599	**Elevation**	684.431	**Code**	30SBP RUN21
Point	30BP_21_2M	**East**	394854.016	**North**	6946192.499	**Elevation**	684.571	**Code**	30SBP RUN21
Point	30BP_21_5M	**East**	394852.093	**North**	6946190.340	**Elevation**	684.639	**Code**	30SBP RUN21
Point	30BP_21_10M	**East**	394848.691	**North**	6946186.507	**Elevation**	684.749	**Code**	30SBP RUN21

Point	30BP_21_20M	**East**	394841.783	**North**	6946178.853	**Elevation**	684.916	**Code**	30SBP RUN21
Point	30BP_21_40M	**East**	394825.088	**North**	6946167.762	**Elevation**	685.506	**Code**	30SBP RUN21
Point	30BP_21_80M	**East**	394794.396	**North**	6946142.245	**Elevation**	686.337	**Code**	30SBP RUN21
Point	30BP_21_120M	**East**	394763.528	**North**	6946116.842	**Elevation**	687.359	**Code**	30SBP RUN21
Point	30BP_21_160M	**East**	394735.487	**North**	6946087.885	**Elevation**	688.126	**Code**	30SBP RUN21
Point	30BP_21_200M	**East**	394719.184	**North**	6946047.433	**Elevation**	688.543	**Code**	30SBP RUN21
Point	30BP_22_B32	**East**	394855.812	**North**	6946193.598	**Elevation**	684.432	**Code**	30SBP RUN22
Point	30BP_22_2M	**East**	394854.020	**North**	6946192.494	**Elevation**	684.571	**Code**	30SBP RUN22
Point	30BP_22_5M	**East**	394852.098	**North**	6946190.343	**Elevation**	684.643	**Code**	30SBP RUN22
Point	30BP_22_10M	**East**	394848.690	**North**	6946186.505	**Elevation**	684.749	**Code**	30SBP RUN22
Point	30BP_22_20M	**East**	394841.788	**North**	6946178.854	**Elevation**	684.919	**Code**	30SBP RUN22
Point	30BP_22_40M	**East**	394825.093	**North**	6946167.766	**Elevation**	685.504	**Code**	30SBP RUN22
Point	30BP_22_80M	**East**	394794.397	**North**	6946142.243	**Elevation**	686.328	**Code**	30SBP RUN22
Point	30BP_22_120M	**East**	394763.575	**North**	6946116.740	**Elevation**	687.363	**Code**	30SBP RUN22
Point	30BP_22_160M	**East**	394735.486	**North**	6946087.883	**Elevation**	688.126	**Code**	30SBP RUN22
Point	30BP_22_200M	**East**	394719.176	**North**	6946047.429	**Elevation**	688.543	**Code**	30SBP RUN22
Point	30BP_23_B32	**East**	394855.809	**North**	6946193.595	**Elevation**	684.427	**Code**	30SBP RUN23
Point	30BP_23_2M	**East**	394854.015	**North**	6946192.493	**Elevation**	684.573	**Code**	30SBP RUN23
Point	30BP_23_5M	**East**	394852.100	**North**	6946190.338	**Elevation**	684.637	**Code**	30SBP RUN23
Point	30BP_23_10M	**East**	394848.691	**North**	6946186.505	**Elevation**	684.745	**Code**	30SBP RUN23
Point	30BP_23_20M	**East**	394841.786	**North**	6946178.854	**Elevation**	684.911	**Code**	30SBP RUN23
Point	30BP_23_40M	**East**	394825.095	**North**	6946167.760	**Elevation**	685.503	**Code**	30SBP RUN23
Point	30BP_23_80M	**East**	394794.396	**North**	6946142.241	**Elevation**	686.331	**Code**	30SBP RUN23
Point	30BP_23_120M	**East**	394763.576	**North**	6946116.741	**Elevation**	687.363	**Code**	30SBP RUN23
Point	30BP_23_160M	**East**	394735.492	**North**	6946087.884	**Elevation**	688.126	**Code**	30SBP RUN23
Point	30BP_23_200M	**East**	394719.182	**North**	6946047.433	**Elevation**	688.547	**Code**	30SBP RUN23

Point	30BP_24_B32	**East**	394855.808	**North**	6946193.601	**Elevation**	684.427	**Code**	30SBP RUN24
Point	30BP_24_2M	**East**	394854.018	**North**	6946192.502	**Elevation**	684.566	**Code**	30SBP RUN24
Point	30BP_24_5M	**East**	394852.097	**North**	6946190.341	**Elevation**	684.638	**Code**	30SBP RUN24
Point	30BP_24_10M	**East**	394848.690	**North**	6946186.508	**Elevation**	684.748	**Code**	30SBP RUN24
Point	30BP_24_20M	**East**	394841.786	**North**	6946178.854	**Elevation**	684.915	**Code**	30SBP RUN24
Point	30BP_24_40M	**East**	394825.088	**North**	6946167.761	**Elevation**	685.502	**Code**	30SBP RUN24
Point	30BP_24_80M	**East**	394794.394	**North**	6946142.242	**Elevation**	686.335	**Code**	30SBP RUN24
Point	30BP_24_120M	**East**	394763.576	**North**	6946116.741	**Elevation**	687.352	**Code**	30SBP RUN24
Point	30BP_24_160M	**East**	394735.490	**North**	6946087.880	**Elevation**	688.113	**Code**	30SBP RUN24
Point	30BP_24_200M	**East**	394719.181	**North**	6946047.435	**Elevation**	688.535	**Code**	30SBP RUN24
Point	30BP_25_B32	**East**	394855.812	**North**	6946193.594	**Elevation**	684.427	**Code**	30SBP RUN25
Point	30BP_25_2M	**East**	394854.023	**North**	6946192.499	**Elevation**	684.576	**Code**	30SBP RUN25
Point	30BP_25_5M	**East**	394852.102	**North**	6946190.339	**Elevation**	684.641	**Code**	30SBP RUN25
Point	30BP_25_10M	**East**	394848.690	**North**	6946186.509	**Elevation**	684.748	**Code**	30SBP RUN25
Point	30BP_25_20M	**East**	394841.787	**North**	6946178.851	**Elevation**	684.912	**Code**	30SBP RUN25
Point	30BP_25_40M	**East**	394825.090	**North**	6946167.759	**Elevation**	685.494	**Code**	30SBP RUN25
Point	30BP_25_80M	**East**	394794.395	**North**	6946142.244	**Elevation**	686.327	**Code**	30SBP RUN25
Point	30BP_25_120M	**East**	394763.577	**North**	6946116.744	**Elevation**	687.363	**Code**	30SBP RUN25
Point	30BP_25_160M	**East**	394735.492	**North**	6946087.879	**Elevation**	688.123	**Code**	30SBP RUN25
Point	30BP_25_200M	**East**	394719.187	**North**	6946047.426	**Elevation**	688.541	**Code**	30SBP RUN25
Point	30BP_26_B32	**East**	394855.813	**North**	6946193.601	**Elevation**	684.429	**Code**	30SBP RUN26
Point	30BP_26_2M	**East**	394854.013	**North**	6946192.505	**Elevation**	684.571	**Code**	30SBP RUN26
Point	30BP_26_5M	**East**	394852.095	**North**	6946190.348	**Elevation**	684.641	**Code**	30SBP RUN26
Point	30BP_26_10M	**East**	394848.689	**North**	6946186.510	**Elevation**	684.746	**Code**	30SBP RUN26
Point	30BP_26_20M	**East**	394841.782	**North**	6946178.856	**Elevation**	684.918	**Code**	30SBP RUN26
Point	30BP_26_40M	**East**	394825.088	**North**	6946167.759	**Elevation**	685.504	**Code**	30SBP RUN26

Point	30BP_26_80M	**East**	394794.393	**North**	6946142.252	**Elevation**	686.325	**Code**	30SBP RUN26
Point	30BP_26_120M	**East**	394763.571	**North**	6946116.748	**Elevation**	687.355	**Code**	30SBP RUN26
Point	30BP_26_160M	**East**	394735.486	**North**	6946087.889	**Elevation**	688.124	**Code**	30SBP RUN26
Point	30BP_26_200M	**East**	394719.177	**North**	6946047.432	**Elevation**	688.550	**Code**	30SBP RUN26

Appendix C4: RTK Observations 14 Aug 2013 – Set 1

Survey Controller Reduced Points

Point	ANANGA1	**East**	394586.985	**North**	6946490.639	**Elevation**	718.427	**Code**	1
Point	30BP_27_B32	**East**	394855.802	**North**	6946193.609	**Elevation**	684.434	**Code**	30SBP RUN27
Point	30BP_27_2M	**East**	394854.002	**North**	6946192.506	**Elevation**	684.581	**Code**	30SBP RUN27
Point	30BP_27_5M	**East**	394852.084	**North**	6946190.352	**Elevation**	684.647	**Code**	30SBP RUN27
Point	30BP_27_10M	**East**	394848.672	**North**	6946186.515	**Elevation**	684.760	**Code**	30SBP RUN27
Point	30BP_27_20M	**East**	394841.773	**North**	6946178.865	**Elevation**	684.923	**Code**	30SBP RUN27
Point	30BP_27_40M	**East**	394825.078	**North**	6946167.777	**Elevation**	685.519	**Code**	30SBP RUN27
Point	30BP_27_80M	**East**	394794.383	**North**	6946142.260	**Elevation**	686.350	**Code**	30SBP RUN27
Point	30BP_27_120M	**East**	394763.559	**North**	6946116.751	**Elevation**	687.380	**Code**	30SBP RUN27
Point	30BP_27_160M	**East**	394735.476	**North**	6946087.895	**Elevation**	688.122	**Code**	30SBP RUN27
Point	30BP_27_200M	**East**	394719.165	**North**	6946047.441	**Elevation**	688.559	**Code**	30SBP RUN27
Point	30BP_28_B32	**East**	394855.795	**North**	6946193.606	**Elevation**	684.435	**Code**	30SBP RUN28
Point	30BP_28_2M	**East**	394854.010	**North**	6946192.511	**Elevation**	684.580	**Code**	30SBP RUN28
Point	30BP_28_5M	**East**	394852.088	**North**	6946190.351	**Elevation**	684.648	**Code**	30SBP RUN28
Point	30BP_28_10M	**East**	394848.670	**North**	6946186.513	**Elevation**	684.756	**Code**	30SBP RUN28
Point	30BP_28_20M	**East**	394841.772	**North**	6946178.866	**Elevation**	684.923	**Code**	30SBP RUN28
Point	30BP_28_40M	**East**	394825.079	**North**	6946167.773	**Elevation**	685.512	**Code**	30SBP RUN28
Point	30BP_28_80M	**East**	394794.380	**North**	6946142.256	**Elevation**	686.340	**Code**	30SBP RUN28
Point	30BP_28_120M	**East**	394763.556	**North**	6946116.754	**Elevation**	687.376	**Code**	30SBP RUN28
Point	30BP_28_160M	**East**	394735.475	**North**	6946087.893	**Elevation**	688.126	**Code**	30SBP RUN28
Point	30BP_28_200M	**East**	394719.162	**North**	6946047.435	**Elevation**	688.562	**Code**	30SBP RUN28
Point	180BP_1_B32	**East**	394855.807	**North**	6946193.604	**Elevation**	684.437	**Code**	180SBP RUN1
Point	180BP_1_2M	**East**	394854.004	**North**	6946192.511	**Elevation**	684.578	**Code**	180SBP RUN1
Point	180BP_1_5M	**East**	394852.083	**North**	6946190.350	**Elevation**	684.645	**Code**	180SBP RUN1
Point	180BP_1_10M	**East**	394848.678	**North**	6946186.515	**Elevation**	684.754	**Code**	180SBP RUN1

Point	180BP_1_20M	**East**	394841.772	**North**	6946178.863	**Elevation**	684.921	**Code**	180SBP RUN1
Point	180BP_2_B32	**East**	394855.799	**North**	6946193.609	**Elevation**	684.437	**Code**	180SBP RUN2
Point	180BP_2_2M	**East**	394854.003	**North**	6946192.511	**Elevation**	684.578	**Code**	180SBP RUN2
Point	180BP_2_5M	**East**	394852.080	**North**	6946190.354	**Elevation**	684.648	**Code**	180SBP RUN2
Point	180BP_2_10M	**East**	394848.675	**North**	6946186.521	**Elevation**	684.753	**Code**	180SBP RUN2
Point	180BP_2_20M	**East**	394841.774	**North**	6946178.867	**Elevation**	684.922	**Code**	180SBP RUN2
Point	180BP_3_B32	**East**	394855.801	**North**	6946193.608	**Elevation**	684.438	**Code**	180SBP RUN3
Point	180BP_3_2M	**East**	394854.006	**North**	6946192.511	**Elevation**	684.578	**Code**	180SBP RUN3
Point	180BP_3_10M	**East**	394852.075	**North**	6946190.351	**Elevation**	684.646	**Code**	180SBP RUN3_ACT_5M
Point	180BP_3_20M	**East**	394848.670	**North**	6946186.509	**Elevation**	684.747	**Code**	180SBP RUN3_ACT_10M
Point	180BP_3_20M_ACT	**East**	394841.767	**North**	6946178.856	**Elevation**	684.917	**Code**	180SBP RUN3
Point	180BP_4_B32	**East**	394855.797	**North**	6946193.604	**Elevation**	684.433	**Code**	180SBP RUN4
Point	180BP_4_2M	**East**	394854.005	**North**	6946192.507	**Elevation**	684.584	**Code**	180SBP RUN4
Point	180BP_4_5M	**East**	394852.083	**North**	6946190.356	**Elevation**	684.649	**Code**	180SBP RUN4
Point	180BP_4_10M	**East**	394848.672	**North**	6946186.520	**Elevation**	684.752	**Code**	180SBP RUN4
Point	180BP_4_20M	**East**	394841.768	**North**	6946178.861	**Elevation**	684.920	**Code**	180SBP RUN4
Point	180BP_5_B32	**East**	394855.801	**North**	6946193.601	**Elevation**	684.437	**Code**	180SBP RUN5
Point	180BP_5_2M	**East**	394853.998	**North**	6946192.508	**Elevation**	684.589	**Code**	180SBP RUN5
Point	180BP_5_5M	**East**	394852.075	**North**	6946190.354	**Elevation**	684.657	**Code**	180SBP RUN5
Point	180BP_5_10M	**East**	394848.668	**North**	6946186.514	**Elevation**	684.752	**Code**	180SBP RUN5
Point	180BP_5_20M	**East**	394841.773	**North**	6946178.864	**Elevation**	684.928	**Code**	180SBP RUN5
Point	180BP_6_B32	**East**	394855.803	**North**	6946193.606	**Elevation**	684.455	**Code**	180SBP RUN6
Point	180BP_6_2M	**East**	394854.005	**North**	6946192.511	**Elevation**	684.583	**Code**	180SBP RUN6
Point	180BP_6_5M	**East**	394852.086	**North**	6946190.332	**Elevation**	684.651	**Code**	180SBP RUN6
Point	180BP_6_10M	**East**	394848.674	**North**	6946186.524	**Elevation**	684.763	**Code**	180SBP RUN6
Point	180BP_6_20M	**East**	394841.771	**North**	6946178.871	**Elevation**	684.931	**Code**	180SBP RUN6

Point	180BP_7_B32	**East**	394855.801	**North**	6946193.612	**Elevation**	684.440	**Code**	180SBP RUN7
Point	180BP_7_2M	**East**	394854.004	**North**	6946192.508	**Elevation**	684.582	**Code**	180SBP RUN7
Point	180BP_7_5M	**East**	394852.082	**North**	6946190.356	**Elevation**	684.647	**Code**	180SBP RUN7
Point	180BP_7_10M	**East**	394848.673	**North**	6946186.517	**Elevation**	684.756	**Code**	180SBP RUN7
Point	180BP_7_20M	**East**	394841.766	**North**	6946178.867	**Elevation**	684.923	**Code**	180SBP RUN7
Point	180BP_8_B32	**East**	394855.802	**North**	6946193.607	**Elevation**	684.437	**Code**	180SBP RUN8
Point	180BP_8_2M	**East**	394854.008	**North**	6946192.511	**Elevation**	684.586	**Code**	180SBP RUN8
Point	180BP_8_5M	**East**	394852.082	**North**	6946190.353	**Elevation**	684.647	**Code**	180SBP RUN8
Point	180BP_8_10M	**East**	394848.680	**North**	6946186.523	**Elevation**	684.746	**Code**	180SBP RUN8
Point	180BP_8_20M	**East**	394841.770	**North**	6946178.867	**Elevation**	684.915	**Code**	180SBP RUN8
Point	180BP_9_B32	**East**	394855.793	**North**	6946193.607	**Elevation**	684.431	**Code**	180SBP RUN9
Point	180BP_9_2M	**East**	394854.003	**North**	6946192.511	**Elevation**	684.574	**Code**	180SBP RUN9
Point	180BP_9_5M	**East**	394852.081	**North**	6946190.351	**Elevation**	684.645	**Code**	180SBP RUN9
Point	180BP_9_10M	**East**	394848.676	**North**	6946186.513	**Elevation**	684.743	**Code**	180SBP RUN9
Point	180BP_9_20M	**East**	394841.773	**North**	6946178.870	**Elevation**	684.921	**Code**	180SBP RUN9
Point	180BP_10_B32	**East**	394855.797	**North**	6946193.609	**Elevation**	684.433	**Code**	180SBP RUN10
Point	180BP_10_2M	**East**	394853.995	**North**	6946192.506	**Elevation**	684.579	**Code**	180SBP RUN10
Point	180BP_10_5M	**East**	394852.080	**North**	6946190.354	**Elevation**	684.648	**Code**	180SBP RUN10
Point	180BP_10_10M	**East**	394848.667	**North**	6946186.509	**Elevation**	684.744	**Code**	180SBP RUN10
Point	180BP_10_20M	**East**	394841.774	**North**	6946178.861	**Elevation**	684.922	**Code**	180SBP RUN10
Point	180BP_1.2_B32	**East**	394855.802	**North**	6946193.612	**Elevation**	684.428	**Code**	180SBP RUN1
Point	180BP_1.2_40M	**East**	394825.080	**North**	6946167.776	**Elevation**	685.507	**Code**	180SBP RUN1
Point	180BP_1.2_80M	**East**	394794.376	**North**	6946142.253	**Elevation**	686.346	**Code**	180SBP RUN1
Point	180BP_1.2_120M	**East**	394763.565	**North**	6946116.751	**Elevation**	687.368	**Code**	180SBP RUN1
Point	180BP_1.2_160M	**East**	394735.469	**North**	6946087.896	**Elevation**	688.127	**Code**	180SBP RUN1
Point	180BP_1.2_200M	**East**	394719.161	**North**	6946047.427	**Elevation**	688.557	**Code**	180SBP RUN1

Point	180BP_2.2_B32	**East**	394855.798	**North**	6946193.602	**Elevation**	684.435	**Code**	180SBP RUN2
Point	180BP_2.2_40M	**East**	394825.076	**North**	6946167.769	**Elevation**	685.504	**Code**	180SBP RUN2
Point	180BP_2.2_80M	**East**	394794.381	**North**	6946142.253	**Elevation**	686.350	**Code**	180SBP RUN2
Point	180BP_2.2_120M	**East**	394763.568	**North**	6946116.754	**Elevation**	687.357	**Code**	180SBP RUN2
Point	180BP_2.2_160M	**East**	394735.477	**North**	6946087.894	**Elevation**	688.123	**Code**	180SBP RUN2
Point	180BP_2.2_200M	**East**	394719.166	**North**	6946047.437	**Elevation**	688.564	**Code**	180SBP RUN2

Appendix C5: RTK Observations 14 Aug 2013 – Set 2

Survey Controller Reduced Points

Point	ANANGA1	**East**	394586.985	**North**	6946490.639	**Elevation**	718.427	**Code**	1
Point	30BP_29_B32	**East**	394855.789	**North**	6946193.586	**Elevation**	684.433	**Code**	30SBP RUN29
Point	30BP_29_2M	**East**	394854.000	**North**	6946192.485	**Elevation**	684.580	**Code**	30SBP RUN29
Point	30BP_29_5M	**East**	394852.086	**North**	6946190.327	**Elevation**	684.649	**Code**	30SBP RUN29
Point	30BP_29_10M	**East**	394848.676	**North**	6946186.491	**Elevation**	684.753	**Code**	30SBP RUN29
Point	30BP_29_20M	**East**	394841.772	**North**	6946178.838	**Elevation**	684.921	**Code**	30SBP RUN29
Point	30BP_29_40M	**East**	394825.076	**North**	6946167.752	**Elevation**	685.512	**Code**	30SBP RUN29
Point	30BP_29_80M	**East**	394794.383	**North**	6946142.232	**Elevation**	686.351	**Code**	30SBP RUN29
Point	30BP_29_120M	**East**	394763.563	**North**	6946116.730	**Elevation**	687.370	**Code**	30SBP RUN29
Point	30BP_29_160M	**East**	394735.479	**North**	6946087.872	**Elevation**	688.120	**Code**	30SBP RUN29
Point	30BP_29_200M	**East**	394719.174	**North**	6946047.414	**Elevation**	688.549	**Code**	30SBP RUN29
Point	30BP_30_B32	**East**	394855.793	**North**	6946193.584	**Elevation**	684.433	**Code**	30SBP RUN30
Point	30BP_30_2M	**East**	394853.999	**North**	6946192.486	**Elevation**	684.584	**Code**	30SBP RUN30
Point	30BP_30_5M	**East**	394852.085	**North**	6946190.331	**Elevation**	684.648	**Code**	30SBP RUN30
Point	30BP_30_10M	**East**	394848.676	**North**	6946186.492	**Elevation**	684.755	**Code**	30SBP RUN30
Point	30BP_30_20M	**East**	394841.767	**North**	6946178.840	**Elevation**	684.924	**Code**	30SBP RUN30
Point	30BP_30_40M	**East**	394825.072	**North**	6946167.753	**Elevation**	685.514	**Code**	30SBP RUN30
Point	30BP_30_80M	**East**	394794.380	**North**	6946142.230	**Elevation**	686.340	**Code**	30SBP RUN30
Point	30BP_30_120M	**East**	394763.555	**North**	6946116.727	**Elevation**	687.370	**Code**	30SBP RUN30
Point	30BP_30_160M	**East**	394735.479	**North**	6946087.872	**Elevation**	688.122	**Code**	30SBP RUN30
Point	30BP_30_200M	**East**	394719.172	**North**	6946047.413	**Elevation**	688.554	**Code**	30SBP RUN30
Point	180BP_11_B32	**East**	394855.790	**North**	6946193.582	**Elevation**	684.433	**Code**	180SBP RUN11
Point	180BP_11_2M	**East**	394854.002	**North**	6946192.486	**Elevation**	684.577	**Code**	180SBP RUN11
Point	180BP_11_5M	**East**	394852.083	**North**	6946190.334	**Elevation**	684.644	**Code**	180SBP RUN11
Point	180BP_11_10M	**East**	394848.674	**North**	6946186.492	**Elevation**	684.752	**Code**	180SBP RUN11

Point	180BP_11_20M	**East**	394841.773	**North**	6946178.839	**Elevation**	684.914	**Code**	180SBP RUN11
Point	180BP_12_B32	**East**	394855.789	**North**	6946193.581	**Elevation**	684.437	**Code**	180SBP RUN12
Point	180BP_12_2M	**East**	394853.997	**North**	6946192.490	**Elevation**	684.575	**Code**	180SBP RUN12
Point	180BP_12_5M	**East**	394852.081	**North**	6946190.328	**Elevation**	684.645	**Code**	180SBP RUN12
Point	180BP_12_10M	**East**	394848.680	**North**	6946186.497	**Elevation**	684.750	**Code**	180SBP RUN12
Point	180BP_12_20M	**East**	394841.772	**North**	6946178.842	**Elevation**	684.920	**Code**	180SBP RUN12
Point	180BP_13_B32	**East**	394855.795	**North**	6946193.585	**Elevation**	684.437	**Code**	180SBP RUN13
Point	180BP_13_2M	**East**	394854.002	**North**	6946192.484	**Elevation**	684.578	**Code**	180SBP RUN13
Point	180BP_13_5M	**East**	394852.084	**North**	6946190.327	**Elevation**	684.642	**Code**	180SBP RUN13
Point	180BP_13_10M	**East**	394848.672	**North**	6946186.492	**Elevation**	684.751	**Code**	180SBP RUN13
Point	180BP_13_20M	**East**	394841.770	**North**	6946178.839	**Elevation**	684.914	**Code**	180SBP RUN13
Point	180BP_14_B32	**East**	394855.795	**North**	6946193.582	**Elevation**	684.438	**Code**	180SBP RUN14
Point	180BP_14_2M	**East**	394854.000	**North**	6946192.488	**Elevation**	684.584	**Code**	180SBP RUN14
Point	180BP_14_5M	**East**	394852.082	**North**	6946190.330	**Elevation**	684.650	**Code**	180SBP RUN14
Point	180BP_14_10M	**East**	394848.673	**North**	6946186.493	**Elevation**	684.750	**Code**	180SBP RUN14
Point	180BP_14_20M	**East**	394841.767	**North**	6946178.840	**Elevation**	684.934	**Code**	180SBP RUN14
Point	180BP_15_B32	**East**	394855.798	**North**	6946193.579	**Elevation**	684.434	**Code**	180SBP RUN15
Point	180BP_15_2M	**East**	394854.008	**North**	6946192.487	**Elevation**	684.585	**Code**	180SBP RUN15
Point	180BP_15_5M	**East**	394852.083	**North**	6946190.330	**Elevation**	684.647	**Code**	180SBP RUN15
Point	180BP_15_10M	**East**	394848.676	**North**	6946186.489	**Elevation**	684.762	**Code**	180SBP RUN15
Point	180BP_15_20M	**East**	394841.780	**North**	6946178.840	**Elevation**	684.930	**Code**	180SBP RUN15
Point	180BP_16_B32	**East**	394855.793	**North**	6946193.581	**Elevation**	684.434	**Code**	180SBP RUN16
Point	180BP_16_2M	**East**	394853.995	**North**	6946192.491	**Elevation**	684.581	**Code**	180SBP RUN16
Point	180BP_16_5M	**East**	394852.088	**North**	6946190.339	**Elevation**	684.656	**Code**	180SBP RUN16
Point	180BP_16_10M	**East**	394848.673	**North**	6946186.518	**Elevation**	684.756	**Code**	180SBP RUN16
Point	180BP_16_20M	**East**	394841.774	**North**	6946178.840	**Elevation**	684.922	**Code**	180SBP RUN16

Point	180BP_17_B32	**East**	394855.800	**North**	6946193.590	**Elevation**	684.436	**Code**	180SBP RUN17
Point	180BP_17_2M	**East**	394854.004	**North**	6946192.488	**Elevation**	684.576	**Code**	180SBP RUN17
Point	180BP_17_5M	**East**	394852.087	**North**	6946190.335	**Elevation**	684.641	**Code**	180SBP RUN17
Point	180BP_17_10M	**East**	394848.675	**North**	6946186.495	**Elevation**	684.743	**Code**	180SBP RUN17
Point	180BP_17_20M	**East**	394841.771	**North**	6946178.839	**Elevation**	684.924	**Code**	180SBP RUN17
Point	180BP_18_B32	**East**	394855.789	**North**	6946193.587	**Elevation**	684.434	**Code**	180SBP RUN18
Point	180BP_18_2M	**East**	394854.005	**North**	6946192.490	**Elevation**	684.586	**Code**	180SBP RUN18
Point	180BP_18_5M	**East**	394852.084	**North**	6946190.327	**Elevation**	684.641	**Code**	180SBP RUN18
Point	180BP_18_10M	**East**	394848.677	**North**	6946186.489	**Elevation**	684.754	**Code**	180SBP RUN18
Point	180BP_18_20M	**East**	394841.773	**North**	6946178.837	**Elevation**	684.907	**Code**	180SBP RUN18
Point	180BP_19_B32	**East**	394855.799	**North**	6946193.582	**Elevation**	684.433	**Code**	180SBP RUN19
Point	180BP_19_2M	**East**	394854.006	**North**	6946192.487	**Elevation**	684.574	**Code**	180SBP RUN19
Point	180BP_19_5M	**East**	394852.085	**North**	6946190.329	**Elevation**	684.637	**Code**	180SBP RUN19
Point	180BP_19_10M	**East**	394848.677	**North**	6946186.493	**Elevation**	684.758	**Code**	180SBP RUN19
Point	180BP_19_20M	**East**	394841.769	**North**	6946178.841	**Elevation**	684.920	**Code**	180SBP RUN19
Point	180BP_20_B32	**East**	394855.800	**North**	6946193.581	**Elevation**	684.424	**Code**	180SBP RUN20
Point	180BP_20_2M	**East**	394854.004	**North**	6946192.490	**Elevation**	684.579	**Code**	180SBP RUN20
Point	180BP_20_5M	**East**	394852.079	**North**	6946190.332	**Elevation**	684.651	**Code**	180SBP RUN20
Point	180BP_20_10M	**East**	394848.671	**North**	6946186.490	**Elevation**	684.752	**Code**	180SBP RUN20
Point	180BP_20_20M	**East**	394841.769	**North**	6946178.842	**Elevation**	684.904	**Code**	180SBP RUN20
Point	180BP_11.2_B32	**East**	394855.798	**North**	6946193.575	**Elevation**	684.431	**Code**	180SBP RUN11
Point	180BP_11.2_40M	**East**	394825.080	**North**	6946167.745	**Elevation**	685.513	**Code**	180SBP RUN11
Point	180BP_11.2_80M	**East**	394794.389	**North**	6946142.230	**Elevation**	686.331	**Code**	180SBP RUN11
Point	180BP_11.2_120M	**East**	394763.562	**North**	6946116.732	**Elevation**	687.363	**Code**	180SBP RUN11
Point	180BP_11.2_160M	**East**	394735.475	**North**	6946087.865	**Elevation**	688.124	**Code**	180SBP RUN11
Point	180BP_11.2_200M	**East**	394719.169	**North**	6946047.412	**Elevation**	688.547	**Code**	180SBP RUN11

Point	180BP_12.2_B32	**East**	394855.792	**North**	6946193.581	**Elevation**	684.437	**Code**	180SBP RUN12
Point	180BP_12.2_40M	**East**	394825.067	**North**	6946167.760	**Elevation**	685.519	**Code**	180SBP RUN12
Point	180BP_12.2_80M	**East**	394794.392	**North**	6946142.227	**Elevation**	686.329	**Code**	180SBP RUN12
Point	180BP_12.2_120M	**East**	394763.568	**North**	6946116.733	**Elevation**	687.361	**Code**	180SBP RUN12
Point	180BP_12.2_160M	**East**	394735.476	**North**	6946087.869	**Elevation**	688.126	**Code**	180SBP RUN12
Point	180BP_12.2_200M	**East**	394719.172	**North**	6946047.418	**Elevation**	688.539	**Code**	180SBP RUN12

Appendix C6: RTK Observations 14 Aug 2013 – Set 3

Survey Controller Reduced Points

Point	ANANGA1	**East**	394586.985	**North**	6946490.639	**Elevation**	718.427	**Code**	1
Point	180BP_21_B32	**East**	394855.808	**North**	6946193.594	**Elevation**	684.432	**Code**	180SBP RUN21
Point	180BP_21_2M	**East**	394854.009	**North**	6946192.503	**Elevation**	684.576	**Code**	180SBP RUN21
Point	180BP_21_5M	**East**	394852.087	**North**	6946190.347	**Elevation**	684.638	**Code**	180SBP RUN21
Point	180BP_21_10M	**East**	394848.682	**North**	6946186.514	**Elevation**	684.748	**Code**	180SBP RUN21
Point	180BP_21_20M	**East**	394841.779	**North**	6946178.856	**Elevation**	684.915	**Code**	180SBP RUN21
Point	180BP_22_B32	**East**	394855.806	**North**	6946193.593	**Elevation**	684.437	**Code**	180SBP RUN22
Point	180BP_22_2M	**East**	394854.015	**North**	6946192.503	**Elevation**	684.575	**Code**	180SBP RUN22
Point	180BP_22_5M	**East**	394852.097	**North**	6946190.351	**Elevation**	684.642	**Code**	180SBP RUN22
Point	180BP_22_10M	**East**	394848.688	**North**	6946186.516	**Elevation**	684.749	**Code**	180SBP RUN22
Point	180BP_23_20M	**East**	394841.783	**North**	6946178.864	**Elevation**	684.914	**Code**	180SBP RUN22_ACT_22_20M
Point	180BP_24_B32	**East**	394855.805	**North**	6946193.595	**Elevation**	684.434	**Code**	180SBP RUN24_ACT_23_B32
Point	180BP_23_2M	**East**	394854.009	**North**	6946192.503	**Elevation**	684.576	**Code**	180SBP RUN23
Point	180BP_23_5M	**East**	394852.088	**North**	6946190.340	**Elevation**	684.644	**Code**	180SBP RUN23
Point	180BP_23_10M	**East**	394848.682	**North**	6946186.503	**Elevation**	684.745	**Code**	180SBP RUN23
Point	180BP_23_B32_2	**East**	394855.806	**North**	6946193.597	**Elevation**	684.432	**Code**	180SBP RUN23
Point	180BP_23_20M_ACT	**East**	394841.785	**North**	6946178.847	**Elevation**	684.913	**Code**	180SBP RUN23
Point	180BP_24_B32_ACT	**East**	394855.806	**North**	6946193.593	**Elevation**	684.434	**Code**	180SBP RUN24
Point	180BP_24_2M	**East**	394854.010	**North**	6946192.502	**Elevation**	684.569	**Code**	180SBP RUN24
Point	180BP_24_5M	**East**	394852.093	**North**	6946190.345	**Elevation**	684.641	**Code**	180SBP RUN24
Point	180BP_24_10M	**East**	394848.683	**North**	6946186.502	**Elevation**	684.754	**Code**	180SBP RUN24
Point	180BP_24_20M	**East**	394841.784	**North**	6946178.852	**Elevation**	684.914	**Code**	180SBP RUN24
Point	180BP_25_B32	**East**	394855.812	**North**	6946193.593	**Elevation**	684.434	**Code**	180SBP RUN25
Point	180BP_25_2M	**East**	394854.011	**North**	6946192.499	**Elevation**	684.579	**Code**	180SBP RUN25
Point	180BP_25_5M	**East**	394852.095	**North**	6946190.341	**Elevation**	684.657	**Code**	180SBP RUN25

Point	180BP_25_10M	**East**	394848.690	**North**	6946186.511	**Elevation**	684.753	**Code**	180SBP RUN25
Point	180BP_25_20M	**East**	394841.780	**North**	6946178.841	**Elevation**	684.910	**Code**	180SBP RUN25
Point	180BP_26_B32	**East**	394855.808	**North**	6946193.596	**Elevation**	684.436	**Code**	180SBP RUN26
Point	180BP_26_2M	**East**	394854.015	**North**	6946192.507	**Elevation**	684.579	**Code**	180SBP RUN26
Point	180BP_26_5M	**East**	394852.096	**North**	6946190.348	**Elevation**	684.638	**Code**	180SBP RUN26
Point	180BP_26_10M	**East**	394848.686	**North**	6946186.513	**Elevation**	684.746	**Code**	180SBP RUN26
Point	180BP_26_20M	**East**	394841.784	**North**	6946178.855	**Elevation**	684.915	**Code**	180SBP RUN26
Point	180BP_27_B32	**East**	394855.809	**North**	6946193.595	**Elevation**	684.428	**Code**	180SBP RUN27
Point	180BP_27_2M	**East**	394854.008	**North**	6946192.502	**Elevation**	684.574	**Code**	180SBP RUN27
Point	180BP_27_5M	**East**	394852.087	**North**	6946190.350	**Elevation**	684.649	**Code**	180SBP RUN27
Point	180BP_27_10M	**East**	394848.682	**North**	6946186.506	**Elevation**	684.749	**Code**	180SBP RUN27
Point	180BP_27_20M	**East**	394841.781	**North**	6946178.851	**Elevation**	684.907	**Code**	180SBP RUN27
Point	180BP_28_B32	**East**	394855.805	**North**	6946193.599	**Elevation**	684.428	**Code**	180SBP RUN28
Point	180BP_28_2M	**East**	394854.013	**North**	6946192.502	**Elevation**	684.564	**Code**	180SBP RUN28
Point	180BP_28_5M	**East**	394852.099	**North**	6946190.344	**Elevation**	684.639	**Code**	180SBP RUN28
Point	180BP_28_10M	**East**	394848.681	**North**	6946186.509	**Elevation**	684.744	**Code**	180SBP RUN28
Point	180BP_28_20M	**East**	394841.779	**North**	6946178.855	**Elevation**	684.914	**Code**	180SBP RUN28
Point	180BP_29_B32	**East**	394855.804	**North**	6946193.599	**Elevation**	684.434	**Code**	180SBP RUN29
Point	180BP_29_2M	**East**	394854.011	**North**	6946192.496	**Elevation**	684.576	**Code**	180SBP RUN29
Point	180BP_29_5M	**East**	394852.094	**North**	6946190.344	**Elevation**	684.630	**Code**	180SBP RUN29
Point	180BP_29_10M	**East**	394848.688	**North**	6946186.512	**Elevation**	684.749	**Code**	180SBP RUN29
Point	180BP_29_20M	**East**	394841.783	**North**	6946178.859	**Elevation**	684.923	**Code**	180SBP RUN29
Point	180BP_30_B32	**East**	394855.805	**North**	6946193.598	**Elevation**	684.434	**Code**	180SBP RUN30
Point	180BP_30_2M	**East**	394854.011	**North**	6946192.502	**Elevation**	684.569	**Code**	180SBP RUN30
Point	180BP_30_5M	**East**	394852.086	**North**	6946190.347	**Elevation**	684.642	**Code**	180SBP RUN30
Point	180BP_30_10M	**East**	394848.681	**North**	6946186.504	**Elevation**	684.750	**Code**	180SBP RUN30

Point	180BP_30_20M	**East**	394841.781	**North**	6946178.864	**Elevation**	684.925	**Code**	180SBP RUN30
Point	180BP_21.2_B32	**East**	394855.810	**North**	6946193.594	**Elevation**	684.436	**Code**	180SBP RUN21
Point	180BP_21.2_40M	**East**	394825.082	**North**	6946167.766	**Elevation**	685.505	**Code**	180SBP RUN21
Point	180BP_21.2_80M	**East**	394794.389	**North**	6946142.250	**Elevation**	686.331	**Code**	180SBP RUN21
Point	180BP_21.2_120M	**East**	394763.571	**North**	6946116.745	**Elevation**	687.368	**Code**	180SBP RUN21
Point	180BP_21.2_160M	**East**	394735.482	**North**	6946087.884	**Elevation**	688.120	**Code**	180SBP RUN21
Point	180BP_21.2_200M	**East**	394719.172	**North**	6946047.428	**Elevation**	688.538	**Code**	180SBP RUN21
Point	180BP_22.2_B32	**East**	394855.802	**North**	6946193.604	**Elevation**	684.442	**Code**	180SBP RUN22
Point	180BP_22.2_40M	**East**	394825.132	**North**	6946167.754	**Elevation**	685.494	**Code**	180SBP RUN22
Point	180BP_22.2_80M	**East**	394794.405	**North**	6946142.254	**Elevation**	686.334	**Code**	180SBP RUN22
Point	180BP_22.2_120M	**East**	394763.575	**North**	6946116.742	**Elevation**	687.358	**Code**	180SBP RUN22
Point	180BP_22.2_160M	**East**	394735.481	**North**	6946087.888	**Elevation**	688.140	**Code**	180SBP RUN22
Point	180BP_22.2_200M	**East**	394719.176	**North**	6946047.428	**Elevation**	688.554	**Code**	180SBP RUN22

Appendix C7: RTK Observations 15 Aug 2013 – Set 1

Survey Controller Reduced Points

Point	ANANGA1	**East**	394586.985	**North**	6946490.639	**Elevation**	718.427	**Code**	1
Point	180BP_3.2_B32	**East**	394855.796	**North**	6946193.602	**Elevation**	684.436	**Code**	180SBP RUN3
Point	180BP_3.2_40M	**East**	394825.076	**North**	6946167.765	**Elevation**	685.513	**Code**	180SBP RUN3
Point	180BP_3.2_80M	**East**	394794.385	**North**	6946142.247	**Elevation**	686.338	**Code**	180SBP RUN3
Point	180BP_3.2_120M	**East**	394763.558	**North**	6946116.749	**Elevation**	687.365	**Code**	180SBP RUN3
Point	180BP_3.2_160M	**East**	394735.476	**North**	6946087.874	**Elevation**	688.130	**Code**	180SBP RUN3
Point	180BP_3.2_200M	**East**	394719.170	**North**	6946047.420	**Elevation**	688.550	**Code**	180SBP RUN3
Point	180BP_4.2_B32	**East**	394855.794	**North**	6946193.604	**Elevation**	684.430	**Code**	180SBP RUN4
Point	180BP_4.2_40M	**East**	394825.076	**North**	6946167.767	**Elevation**	685.509	**Code**	180SBP RUN4
Point	180BP_4.2_80M	**East**	394794.381	**North**	6946142.245	**Elevation**	686.343	**Code**	180SBP RUN4
Point	180BP_4.2_120M	**East**	394763.556	**North**	6946116.727	**Elevation**	687.379	**Code**	180SBP RUN4
Point	180BP_4.2_160M	**East**	394735.472	**North**	6946087.878	**Elevation**	688.127	**Code**	180SBP RUN4
Point	180BP_4.2_200M	**East**	394719.169	**North**	6946047.425	**Elevation**	688.546	**Code**	180SBP RUN4
Point	180BP_5.2_B32	**East**	394855.802	**North**	6946193.591	**Elevation**	684.433	**Code**	180SBP RUN5
Point	180BP_5.2_40M	**East**	394825.076	**North**	6946167.760	**Elevation**	685.509	**Code**	180SBP RUN5
Point	180BP_5.2_80M	**East**	394794.383	**North**	6946142.250	**Elevation**	686.343	**Code**	180SBP RUN5
Point	180BP_5.2_120M	**East**	394763.562	**North**	6946116.737	**Elevation**	687.371	**Code**	180SBP RUN5
Point	180BP_5.2_160M	**East**	394735.479	**North**	6946087.882	**Elevation**	688.122	**Code**	180SBP RUN5
Point	180BP_5.2_200M	**East**	394719.172	**North**	6946047.424	**Elevation**	688.549	**Code**	180SBP RUN5
Point	180BP_6.2_B32	**East**	394855.794	**North**	6946193.593	**Elevation**	684.436	**Code**	180SBP RUN6
Point	180BP_6.2_40M	**East**	394825.078	**North**	6946167.761	**Elevation**	685.507	**Code**	180SBP RUN6
Point	180BP_6.2_80M	**East**	394794.380	**North**	6946142.249	**Elevation**	686.335	**Code**	180SBP RUN6
Point	180BP_6.2_120M	**East**	394763.557	**North**	6946116.729	**Elevation**	687.368	**Code**	180SBP RUN6
Point	180BP_6.2_160M	**East**	394735.471	**North**	6946087.880	**Elevation**	688.126	**Code**	180SBP RUN6
Point	180BP_6.2_200M	**East**	394719.170	**North**	6946047.419	**Elevation**	688.542	**Code**	180SBP RUN6

Point	180BP_7.2_B32	**East**	394855.792	**North**	6946193.595	**Elevation**	684.438	**Code**	180SBP RUN7
Point	180BP_7.2_40M	**East**	394825.069	**North**	6946167.767	**Elevation**	685.502	**Code**	180SBP RUN7
Point	180BP_7.2_80M	**East**	394794.373	**North**	6946142.242	**Elevation**	686.340	**Code**	180SBP RUN7
Point	180BP_7.2_120M	**East**	394763.552	**North**	6946116.736	**Elevation**	687.368	**Code**	180SBP RUN7
Point	180BP_7.2_160M	**East**	394735.469	**North**	6946087.877	**Elevation**	688.115	**Code**	180SBP RUN7
Point	180BP_7.2_200M	**East**	394719.173	**North**	6946047.427	**Elevation**	688.540	**Code**	180SBP RUN7
Point	180BP_8.2_B32	**East**	394855.789	**North**	6946193.585	**Elevation**	684.428	**Code**	180SBP RUN8
Point	180BP_8.2_40M	**East**	394825.072	**North**	6946167.762	**Elevation**	685.509	**Code**	180SBP RUN8
Point	180BP_8.2_80M	**East**	394794.381	**North**	6946142.243	**Elevation**	686.338	**Code**	180SBP RUN8
Point	180BP_8.2_120M	**East**	394763.556	**North**	6946116.745	**Elevation**	687.376	**Code**	180SBP RUN8
Point	180BP_8.2_160M	**East**	394735.476	**North**	6946087.882	**Elevation**	688.119	**Code**	180SBP RUN8
Point	180BP_8.2_200M	**East**	394719.163	**North**	6946047.425	**Elevation**	688.541	**Code**	180SBP RUN8
Point	180BP_9.2_B32	**East**	394855.798	**North**	6946193.593	**Elevation**	684.435	**Code**	180SBP RUN9
Point	180BP_9.2_40M	**East**	394825.066	**North**	6946167.763	**Elevation**	685.507	**Code**	180SBP RUN9
Point	180BP_9.2_80M	**East**	394794.382	**North**	6946142.242	**Elevation**	686.334	**Code**	180SBP RUN9
Point	180BP_9.2_120M	**East**	394763.554	**North**	6946116.737	**Elevation**	687.366	**Code**	180SBP RUN9
Point	180BP_9.2_160M	**East**	394735.469	**North**	6946087.876	**Elevation**	688.120	**Code**	180SBP RUN9
Point	180BP_9.2_200M	**East**	394719.166	**North**	6946047.415	**Elevation**	688.550	**Code**	180SBP RUN9
Point	180BP_10.2_B32	**East**	394855.801	**North**	6946193.591	**Elevation**	684.430	**Code**	180SBP RUN10
Point	180BP_10.2_40M	**East**	394825.071	**North**	6946167.760	**Elevation**	685.500	**Code**	180SBP RUN10
Point	180BP_10.2_80M	**East**	394794.372	**North**	6946142.242	**Elevation**	686.332	**Code**	180SBP RUN10
Point	180BP_10.2_120M	**East**	394763.556	**North**	6946116.744	**Elevation**	687.363	**Code**	180SBP RUN10
Point	180BP_10.2_160M	**East**	394735.474	**North**	6946087.887	**Elevation**	688.117	**Code**	180SBP RUN10
Point	180BP_10.2_200M	**East**	394719.172	**North**	6946047.420	**Elevation**	688.541	**Code**	180SBP RUN10

Appendix C8: RTK Observations 15 Aug 2013 – Set 2

Survey Controller Reduced Points

Point	ANANGA1	**East**	394586.985	**North**	6946490.639	**Elevation**	718.427	**Code**	1
Point	180BP_13.2_B32	**East**	394855.790	**North**	6946193.595	**Elevation**	684.437	**Code**	180SBP RUN13
Point	180BP_13.2_40M	**East**	394825.067	**North**	6946167.758	**Elevation**	685.504	**Code**	180SBP RUN13
Point	180BP_13.2_80M	**East**	394794.365	**North**	6946142.240	**Elevation**	686.338	**Code**	180SBP RUN13
Point	180BP_13.2_120M	**East**	394763.551	**North**	6946116.733	**Elevation**	687.374	**Code**	180SBP RUN13
Point	180BP_13.2_160M	**East**	394735.468	**North**	6946087.870	**Elevation**	688.125	**Code**	180SBP RUN13
Point	180BP_13.2_200M	**East**	394719.157	**North**	6946047.417	**Elevation**	688.551	**Code**	180SBP RUN13
Point	180BP_14.2_B32	**East**	394855.787	**North**	6946193.584	**Elevation**	684.435	**Code**	180SBP RUN14
Point	180BP_14.2_40M	**East**	394825.064	**North**	6946167.753	**Elevation**	685.505	**Code**	180SBP RUN14
Point	180BP_14.2_80M	**East**	394794.370	**North**	6946142.237	**Elevation**	686.337	**Code**	180SBP RUN14
Point	180BP_14.2_120M	**East**	394763.545	**North**	6946116.721	**Elevation**	687.378	**Code**	180SBP RUN14
Point	180BP_14.2_160M	**East**	394735.465	**North**	6946087.869	**Elevation**	688.122	**Code**	180SBP RUN14
Point	180BP_14.2_200M	**East**	394719.160	**North**	6946047.418	**Elevation**	688.545	**Code**	180SBP RUN14
Point	180BP_15.2_B32	**East**	394855.783	**North**	6946193.590	**Elevation**	684.435	**Code**	180SBP RUN15
Point	180BP_15.2_40M	**East**	394825.064	**North**	6946167.758	**Elevation**	685.508	**Code**	180SBP RUN15
Point	180BP_15.2_80M	**East**	394794.378	**North**	6946142.236	**Elevation**	686.337	**Code**	180SBP RUN15
Point	180BP_15.2_120M	**East**	394763.548	**North**	6946116.728	**Elevation**	687.363	**Code**	180SBP RUN15
Point	180BP_15.2_160M	**East**	394735.468	**North**	6946087.867	**Elevation**	688.122	**Code**	180SBP RUN15
Point	180BP_15.2_200M	**East**	394719.160	**North**	6946047.405	**Elevation**	688.540	**Code**	180SBP RUN15
Point	180BP_16.2_B32	**East**	394855.786	**North**	6946193.594	**Elevation**	684.429	**Code**	180SBP RUN16
Point	180BP_16.2_40M	**East**	394825.061	**North**	6946167.758	**Elevation**	685.510	**Code**	180SBP RUN16
Point	180BP_16.2_80M	**East**	394794.373	**North**	6946142.239	**Elevation**	686.333	**Code**	180SBP RUN16
Point	180BP_16.2_120M	**East**	394763.548	**North**	6946116.734	**Elevation**	687.364	**Code**	180SBP RUN16
Point	180BP_16.2_160M	**East**	394735.466	**North**	6946087.877	**Elevation**	688.122	**Code**	180SBP RUN16
Point	180BP_16.2_200M	**East**	394719.162	**North**	6946047.423	**Elevation**	688.551	**Code**	180SBP RUN16

Point	180BP_17.2_B32	**East**	394855.787	**North**	6946193.593	**Elevation**	684.425	**Code**	180SBP RUN17
Point	180BP_17.2_40M	**East**	394825.062	**North**	6946167.756	**Elevation**	685.508	**Code**	180SBP RUN17
Point	180BP_17.2_80M	**East**	394794.371	**North**	6946142.242	**Elevation**	686.339	**Code**	180SBP RUN17
Point	180BP_17.2_120M	**East**	394763.549	**North**	6946116.732	**Elevation**	687.369	**Code**	180SBP RUN17
Point	180BP_17.2_160M	**East**	394735.472	**North**	6946087.880	**Elevation**	688.120	**Code**	180SBP RUN17
Point	180BP_17.2_200M	**East**	394719.160	**North**	6946047.413	**Elevation**	688.544	**Code**	180SBP RUN17
Point	180BP_18.2_B32	**East**	394855.784	**North**	6946193.590	**Elevation**	684.431	**Code**	180SBP RUN18
Point	180BP_18.2_40M	**East**	394825.061	**North**	6946167.762	**Elevation**	685.511	**Code**	180SBP RUN18
Point	180BP_18.2_80M	**East**	394794.370	**North**	6946142.244	**Elevation**	686.343	**Code**	180SBP RUN18
Point	180BP_18.2_120M	**East**	394763.552	**North**	6946116.741	**Elevation**	687.364	**Code**	180SBP RUN18
Point	180BP_18.2_160M	**East**	394735.465	**North**	6946087.878	**Elevation**	688.119	**Code**	180SBP RUN18
Point	180BP_18.2_200M	**East**	394719.160	**North**	6946047.412	**Elevation**	688.546	**Code**	180SBP RUN18
Point	180BP_19.2_B32	**East**	394855.788	**North**	6946193.601	**Elevation**	684.430	**Code**	180SBP RUN19
Point	180BP_19.2_40M	**East**	394825.068	**North**	6946167.762	**Elevation**	685.505	**Code**	180SBP RUN19
Point	180BP_19.2_80M	**East**	394794.379	**North**	6946142.241	**Elevation**	686.332	**Code**	180SBP RUN19
Point	180BP_19.2_120M	**East**	394763.555	**North**	6946116.733	**Elevation**	687.361	**Code**	180SBP RUN19
Point	180BP_19.2_200M	**East**	394735.469	**North**	6946087.875	**Elevation**	688.118	**Code**	180SBP RUN19_ACT_160
Point	180BP_20.2_B32	**East**	394855.788	**North**	6946193.598	**Elevation**	684.427	**Code**	180SBP RUN20
Point	180BP_20.2_40M	**East**	394825.071	**North**	6946167.766	**Elevation**	685.500	**Code**	180SBP RUN20
Point	180BP_20.2_80M	**East**	394794.373	**North**	6946142.245	**Elevation**	686.330	**Code**	180SBP RUN20
Point	180BP_20.2_120M	**East**	394763.550	**North**	6946116.742	**Elevation**	687.356	**Code**	180SBP RUN20
Point	180BP_20.2_160M	**East**	394735.465	**North**	6946087.882	**Elevation**	688.122	**Code**	180SBP RUN20
Point	180BP_20.2_200M	**East**	394719.157	**North**	6946047.422	**Elevation**	688.546	**Code**	180SBP RUN20
Point	60BP_1_B32	**East**	394855.787	**North**	6946193.596	**Elevation**	684.434	**Code**	60SBP RUN1
Point	60BP_1_2M	**East**	394853.992	**North**	6946192.508	**Elevation**	684.571	**Code**	60SBP RUN1
Point	60BP_1_5M	**East**	394852.072	**North**	6946190.339	**Elevation**	684.642	**Code**	60SBP RUN1

Point	60BP_1_10M	**East**	394848.665	**North**	6946186.501	**Elevation**	684.751	**Code**	60SBP RUN1
Point	60BP_1_20M	**East**	394841.762	**North**	6946178.850	**Elevation**	684.913	**Code**	60SBP RUN1
Point	60BP_1_40M	**East**	394825.063	**North**	6946167.760	**Elevation**	685.498	**Code**	60SBP RUN1
Point	60BP_1_80M	**East**	394794.376	**North**	6946142.236	**Elevation**	686.347	**Code**	60SBP RUN1
Point	60BP_1_120M	**East**	394763.552	**North**	6946116.732	**Elevation**	687.373	**Code**	60SBP RUN1
Point	60BP_1_160M	**East**	394735.472	**North**	6946087.881	**Elevation**	688.128	**Code**	60SBP RUN1
Point	60BP_1_200M	**East**	394719.163	**North**	6946047.409	**Elevation**	688.562	**Code**	60SBP RUN1
Point	60BP_2_200M	**East**	394719.186	**North**	6946047.419	**Elevation**	688.561	**Code**	60SBP RUN2
Point	60BP_2_160M	**East**	394735.500	**North**	6946087.887	**Elevation**	688.128	**Code**	60SBP RUN2
Point	60BP_2_120M	**East**	394763.549	**North**	6946116.741	**Elevation**	687.383	**Code**	60SBP RUN2
Point	60BP_2_80M	**East**	394794.406	**North**	6946142.251	**Elevation**	686.351	**Code**	60SBP RUN2
Point	60BP_2_40M	**East**	394825.097	**North**	6946167.765	**Elevation**	685.511	**Code**	60SBP RUN2
Point	60BP_2_20M	**East**	394841.787	**North**	6946178.855	**Elevation**	684.919	**Code**	60SBP RUN2
Point	60BP_2_10M	**East**	394848.691	**North**	6946186.508	**Elevation**	684.746	**Code**	60SBP RUN2
Point	60BP_2_5M	**East**	394852.087	**North**	6946190.348	**Elevation**	684.637	**Code**	60SBP RUN2
Point	60BP_2_2M	**East**	394854.011	**North**	6946192.501	**Elevation**	684.576	**Code**	60SBP RUN2
Point	60BP_2_B32	**East**	394855.815	**North**	6946193.598	**Elevation**	684.433	**Code**	60SBP RUN2

Appendix C9: RTK Observations 15 Aug 2013 – Set 3

Survey Controller Reduced Points

Point	ANANGA1	**East**	394586.985	**North**	6946490.639	**Elevation**	718.427	**Code**	1
Point	180BP_23.2_B32	**East**	394855.804	**North**	6946193.594	**Elevation**	684.422	**Code**	180SBP RUN23
Point	180BP_23.2_40M	**East**	394825.081	**North**	6946167.760	**Elevation**	685.505	**Code**	180SBP RUN23
Point	180BP_23.2_80M	**East**	394794.392	**North**	6946142.242	**Elevation**	686.336	**Code**	180SBP RUN23
Point	180BP_23.2_120M	**East**	394763.567	**North**	6946116.736	**Elevation**	687.364	**Code**	180SBP RUN23
Point	180BP_23.2_160M	**East**	394735.484	**North**	6946087.881	**Elevation**	688.120	**Code**	180SBP RUN23
Point	180BP_23.2_200M	**East**	394719.181	**North**	6946047.425	**Elevation**	688.552	**Code**	180SBP RUN23
Point	180BP_24.2_B32	**East**	394855.807	**North**	6946193.589	**Elevation**	684.428	**Code**	180SBP RUN24
Point	180BP_24.2_40M	**East**	394825.087	**North**	6946167.761	**Elevation**	685.503	**Code**	180SBP RUN24
Point	180BP_24.2_80M	**East**	394794.389	**North**	6946142.245	**Elevation**	686.339	**Code**	180SBP RUN24
Point	180BP_24.2_160M	**East**	394763.561	**North**	6946116.733	**Elevation**	687.370	**Code**	180SBP RUN24_ACT120
Point	180BP_24.2_120M	**East**	394735.488	**North**	6946087.876	**Elevation**	688.121	**Code**	180SBP RUN24_ACT160
Point	180BP_24.2_200M	**East**	394719.180	**North**	6946047.432	**Elevation**	688.544	**Code**	180SBP RUN24
Point	180BP_25.2_B32	**East**	394855.806	**North**	6946193.594	**Elevation**	684.432	**Code**	180SBP RUN25
Point	180BP_25.2_40M	**East**	394825.091	**North**	6946167.762	**Elevation**	685.503	**Code**	180SBP RUN25
Point	180BP_25.2_80M	**East**	394794.396	**North**	6946142.248	**Elevation**	686.340	**Code**	180SBP RUN25
Point	180BP_25.2_120M	**East**	394763.567	**North**	6946116.737	**Elevation**	687.363	**Code**	180SBP RUN25
Point	180BP_25.2_160M	**East**	394735.486	**North**	6946087.876	**Elevation**	688.118	**Code**	180SBP RUN25
Point	180BP_25.2_200M	**East**	394719.177	**North**	6946047.424	**Elevation**	688.538	**Code**	180SBP RUN25
Point	180BP_26.2_B32	**East**	394855.807	**North**	6946193.594	**Elevation**	684.432	**Code**	180SBP RUN26
Point	180BP_26.2_40M	**East**	394825.090	**North**	6946167.757	**Elevation**	685.499	**Code**	180SBP RUN26
Point	180BP_26.2_80M	**East**	394794.390	**North**	6946142.243	**Elevation**	686.331	**Code**	180SBP RUN26
Point	180BP_26.2_160M	**East**	394763.575	**North**	6946116.736	**Elevation**	687.364	**Code**	180SBP RUN26_ACT120
Point	180BP_26.2_120M	**East**	394735.487	**North**	6946087.888	**Elevation**	688.115	**Code**	180SBP RUN26_ACT160
Point	180BP_26.2_200M	**East**	394719.183	**North**	6946047.428	**Elevation**	688.539	**Code**	180SBP RUN26

Point	180BP_27.2_B32	**East**	394855.808	**North**	6946193.598	**Elevation**	684.431	**Code**	180SBP RUN27
Point	180BP_27.2_40M	**East**	394825.082	**North**	6946167.765	**Elevation**	685.505	**Code**	180SBP RUN27
Point	180BP_27.2_80M	**East**	394794.393	**North**	6946142.246	**Elevation**	686.329	**Code**	180SBP RUN27
Point	180BP_27.2_120M	**East**	394763.574	**North**	6946116.743	**Elevation**	687.362	**Code**	180SBP RUN27
Point	180BP_27.2_160M	**East**	394735.490	**North**	6946087.885	**Elevation**	688.114	**Code**	180SBP RUN27
Point	180BP_27.2_200M	**East**	394719.181	**North**	6946047.432	**Elevation**	688.540	**Code**	180SBP RUN27
Point	180BP_28.2_B32	**East**	394855.808	**North**	6946193.603	**Elevation**	684.429	**Code**	180SBP RUN28
Point	180BP_28.2_40M	**East**	394825.085	**North**	6946167.767	**Elevation**	685.501	**Code**	180SBP RUN28
Point	180BP_28.2_80M	**East**	394794.395	**North**	6946142.252	**Elevation**	686.345	**Code**	180SBP RUN28
Point	180BP_28.2_120M	**East**	394763.574	**North**	6946116.745	**Elevation**	687.361	**Code**	180SBP RUN28
Point	180BP_28.2_160M	**East**	394735.488	**North**	6946087.885	**Elevation**	688.114	**Code**	180SBP RUN28
Point	180BP_28.2_200M	**East**	394719.177	**North**	6946047.430	**Elevation**	688.546	**Code**	180SBP RUN28
Point	180BP_29.2_B32	**East**	394855.806	**North**	6946193.595	**Elevation**	684.430	**Code**	180SBP RUN29
Point	180BP_29.2_40M	**East**	394825.089	**North**	6946167.763	**Elevation**	685.502	**Code**	180SBP RUN29
Point	180BP_29.2_80M	**East**	394794.392	**North**	6946142.248	**Elevation**	686.334	**Code**	180SBP RUN29
Point	180BP_29.2_120M	**East**	394763.572	**North**	6946116.742	**Elevation**	687.362	**Code**	180SBP RUN29
Point	180BP_29.2_160M	**East**	394735.488	**North**	6946087.883	**Elevation**	688.121	**Code**	180SBP RUN29
Point	180BP_29.2_200M	**East**	394719.180	**North**	6946047.428	**Elevation**	688.541	**Code**	180SBP RUN29
Point	180BP_30.2_B32	**East**	394855.806	**North**	6946193.596	**Elevation**	684.428	**Code**	180SBP RUN30
Point	180BP_30.2_40M	**East**	394825.087	**North**	6946167.763	**Elevation**	685.502	**Code**	180SBP RUN30
Point	180BP_30.2_80M	**East**	394794.392	**North**	6946142.242	**Elevation**	686.338	**Code**	180SBP RUN30
Point	180BP_30.2_120M	**East**	394763.572	**North**	6946116.749	**Elevation**	687.356	**Code**	180SBP RUN30
Point	180BP_30.2_160M	**East**	394735.485	**North**	6946087.887	**Elevation**	688.114	**Code**	180SBP RUN30
Point	180BP_30.2_200M	**East**	394719.172	**North**	6946047.434	**Elevation**	688.546	**Code**	180SBP RUN30
Point	60BP_15_B32	**East**	394855.809	**North**	6946193.600	**Elevation**	684.430	**Code**	60SBP RUN15
Point	60BP_15_2M	**East**	394854.013	**North**	6946192.500	**Elevation**	684.572	**Code**	60SBP RUN15

Point	60BP_15_5M	**East**	394852.100	**North**	6946190.344	**Elevation**	684.639	**Code**	60SBP RUN15
Point	60BP_15_10M	**East**	394848.688	**North**	6946186.510	**Elevation**	684.742	**Code**	60SBP RUN15
Point	60BP_15_20M	**East**	394841.784	**North**	6946178.858	**Elevation**	684.908	**Code**	60SBP RUN15
Point	60BP_15_40M	**East**	394825.083	**North**	6946167.766	**Elevation**	685.496	**Code**	60SBP RUN15
Point	60BP_15_80M	**East**	394794.400	**North**	6946142.252	**Elevation**	686.347	**Code**	60SBP RUN15
Point	60BP_15_120M	**East**	394763.572	**North**	6946116.747	**Elevation**	687.376	**Code**	60SBP RUN15
Point	60BP_15_160M	**East**	394735.483	**North**	6946087.891	**Elevation**	688.126	**Code**	60SBP RUN15
Point	60BP_15_200M	**East**	394719.162	**North**	6946047.439	**Elevation**	688.550	**Code**	60SBP RUN15
Point	60BP_16_200M	**East**	394719.163	**North**	6946047.425	**Elevation**	688.551	**Code**	60SBP RUN16
Point	60BP_16_160M	**East**	394735.470	**North**	6946087.877	**Elevation**	688.120	**Code**	60SBP RUN16
Point	60BP_16_120M	**East**	394763.555	**North**	6946116.741	**Elevation**	687.375	**Code**	60SBP RUN16
Point	60BP_16_80M	**East**	394794.385	**North**	6946142.241	**Elevation**	686.344	**Code**	60SBP RUN16
Point	60BP_16_40M	**East**	394825.065	**North**	6946167.764	**Elevation**	685.499	**Code**	60SBP RUN16
Point	60BP_16_20M	**East**	394841.765	**North**	6946178.856	**Elevation**	684.913	**Code**	60SBP RUN16
Point	60BP_16_10M	**East**	394848.672	**North**	6946186.502	**Elevation**	684.739	**Code**	60SBP RUN16
Point	60BP_16_5M	**East**	394852.079	**North**	6946190.334	**Elevation**	684.630	**Code**	60SBP RUN16
Point	60BP_16_2M	**East**	394853.994	**North**	6946192.496	**Elevation**	684.564	**Code**	60SBP RUN16
Point	60BP_16_B32	**East**	394855.784	**North**	6946193.593	**Elevation**	684.424	**Code**	60SBP RUN16

Appendix C10: RTK Observations 16 Aug 2013 – Set 1

Survey Controller Reduced Points

Point	ANANGA1	**East**	394586.985	**North**	6946490.639	**Elevation**	718.427	**Code**	1
Point	60BP_3_B32	**East**	394855.798	**North**	6946193.606	**Elevation**	684.439	**Code**	60SBP RUN3
Point	60BP_3_2M	**East**	394853.991	**North**	6946192.493	**Elevation**	684.581	**Code**	60SBP RUN3
Point	60BP_3_5M	**East**	394852.068	**North**	6946190.334	**Elevation**	684.649	**Code**	60SBP RUN3
Point	60BP_3_10M	**East**	394848.661	**North**	6946186.500	**Elevation**	684.760	**Code**	60SBP RUN3
Point	60BP_3_20M	**East**	394841.756	**North**	6946178.849	**Elevation**	684.917	**Code**	60SBP RUN3
Point	60BP_3_40M	**East**	394825.064	**North**	6946167.759	**Elevation**	685.511	**Code**	60SBP RUN3
Point	60BP_3_80M	**East**	394794.365	**North**	6946142.234	**Elevation**	686.347	**Code**	60SBP RUN3
Point	60BP_3_120M	**East**	394763.544	**North**	6946116.724	**Elevation**	687.376	**Code**	60SBP RUN3
Point	60BP_3_160M	**East**	394735.463	**North**	6946087.875	**Elevation**	688.123	**Code**	60SBP RUN3
Point	60BP_3_200M	**East**	394719.173	**North**	6946047.413	**Elevation**	688.562	**Code**	60SBP RUN3
Point	60BP_4_200M	**East**	394719.153	**North**	6946047.423	**Elevation**	688.559	**Code**	60SBP RUN4
Point	60BP_4_160M	**East**	394735.492	**North**	6946087.886	**Elevation**	688.129	**Code**	60SBP RUN4
Point	60BP_4_120M	**East**	394763.572	**North**	6946116.735	**Elevation**	687.382	**Code**	60SBP RUN4
Point	60BP_4_80M	**East**	394794.404	**North**	6946142.251	**Elevation**	686.355	**Code**	60SBP RUN4
Point	60BP_4_40M	**East**	394825.091	**North**	6946167.764	**Elevation**	685.507	**Code**	60SBP RUN4
Point	60BP_4_20M	**East**	394841.791	**North**	6946178.854	**Elevation**	684.921	**Code**	60SBP RUN4
Point	60BP_4_10M	**East**	394848.692	**North**	6946186.508	**Elevation**	684.748	**Code**	60SBP RUN4
Point	60BP_4_5M	**East**	394852.099	**North**	6946190.348	**Elevation**	684.640	**Code**	60SBP RUN4
Point	60BP_4_2M	**East**	394854.023	**North**	6946192.507	**Elevation**	684.572	**Code**	60SBP RUN4
Point	60BP_5_B32	**East**	394855.815	**North**	6946193.594	**Elevation**	684.432	**Code**	60SBP RUN5
Point	60BP_5_2M	**East**	394853.991	**North**	6946192.489	**Elevation**	684.581	**Code**	60SBP RUN5
Point	60BP_5_5M	**East**	394852.068	**North**	6946190.338	**Elevation**	684.646	**Code**	60SBP RUN5
Point	60BP_5_10M	**East**	394848.663	**North**	6946186.498	**Elevation**	684.749	**Code**	60SBP RUN5
Point	60BP_5_20M	**East**	394841.760	**North**	6946178.844	**Elevation**	684.911	**Code**	60SBP RUN5

Point	60BP_5_40M	**East**	394825.066	**North**	6946167.760	**Elevation**	685.502	**Code**	60SBP RUN5
Point	60BP_5_80M	**East**	394794.369	**North**	6946142.238	**Elevation**	686.337	**Code**	60SBP RUN5
Point	60BP_5_120M	**East**	394763.548	**North**	6946116.725	**Elevation**	687.376	**Code**	60SBP RUN5
Point	60BP_5_160M	**East**	394735.461	**North**	6946087.873	**Elevation**	688.123	**Code**	60SBP RUN5
Point	60BP_5_200M	**East**	394719.155	**North**	6946047.415	**Elevation**	688.540	**Code**	60SBP RUN5
Point	60BP_6_200M	**East**	394719.159	**North**	6946047.424	**Elevation**	688.550	**Code**	60SBP RUN6
Point	60BP_6_160M	**East**	394735.460	**North**	6946087.881	**Elevation**	688.125	**Code**	60SBP RUN6
Point	60BP_6_120M	**East**	394763.574	**North**	6946116.743	**Elevation**	687.362	**Code**	60SBP RUN6
Point	60BP_6_80M	**East**	394794.404	**North**	6946142.253	**Elevation**	686.341	**Code**	60SBP RUN6
Point	60BP_6_40M	**East**	394825.092	**North**	6946167.763	**Elevation**	685.505	**Code**	60SBP RUN6
Point	60BP_6_20M	**East**	394841.787	**North**	6946178.860	**Elevation**	684.913	**Code**	60SBP RUN6
Point	60BP_6_10M	**East**	394848.688	**North**	6946186.510	**Elevation**	684.745	**Code**	60SBP RUN6
Point	60BP_6_5M	**East**	394852.097	**North**	6946190.350	**Elevation**	684.648	**Code**	60SBP RUN6
Point	60BP_6_2M	**East**	394854.023	**North**	6946192.511	**Elevation**	684.577	**Code**	60SBP RUN6
Point	60BP_6_B32	**East**	394855.818	**North**	6946193.596	**Elevation**	684.430	**Code**	60SBP RUN6
Point	60BP_7_B32	**East**	394855.781	**North**	6946193.594	**Elevation**	684.443	**Code**	60SBP RUN7
Point	60BP_7_2M	**East**	394853.998	**North**	6946192.494	**Elevation**	684.582	**Code**	60SBP RUN7
Point	60BP_7_5M	**East**	394852.067	**North**	6946190.335	**Elevation**	684.655	**Code**	60SBP RUN7
Point	60BP_7_10M	**East**	394848.662	**North**	6946186.509	**Elevation**	684.751	**Code**	60SBP RUN7
Point	60BP_7_20M	**East**	394841.763	**North**	6946178.855	**Elevation**	684.914	**Code**	60SBP RUN7
Point	60BP_7_40M	**East**	394825.062	**North**	6946167.770	**Elevation**	685.512	**Code**	60SBP RUN7
Point	60BP_7_80M	**East**	394794.372	**North**	6946142.239	**Elevation**	686.335	**Code**	60SBP RUN7
Point	60BP_7_120M	**East**	394763.549	**North**	6946116.736	**Elevation**	687.375	**Code**	60SBP RUN7
Point	60BP_7_160M	**East**	394735.464	**North**	6946087.883	**Elevation**	688.133	**Code**	60SBP RUN7
Point	60BP_7_200M	**East**	394719.153	**North**	6946047.427	**Elevation**	688.545	**Code**	60SBP RUN7
Point	60BP_8_200M	**East**	394719.156	**North**	6946047.429	**Elevation**	688.537	**Code**	60SBP RUN8

Point	60BP_8_160M	**East**	394735.463	**North**	6946087.882	**Elevation**	688.128	**Code**	60SBP RUN8
Point	60BP_8_120M	**East**	394763.581	**North**	6946116.742	**Elevation**	687.372	**Code**	60SBP RUN8
Point	60BP_8_80M	**East**	394794.401	**North**	6946142.247	**Elevation**	686.337	**Code**	60SBP RUN8
Point	60BP_8_40M	**East**	394825.089	**North**	6946167.764	**Elevation**	685.505	**Code**	60SBP RUN8
Point	60BP_8_20M	**East**	394841.788	**North**	6946178.857	**Elevation**	684.911	**Code**	60SBP RUN8
Point	60BP_8_10M	**East**	394848.684	**North**	6946186.506	**Elevation**	684.747	**Code**	60SBP RUN8
Point	60BP_8_5M	**East**	394852.100	**North**	6946190.346	**Elevation**	684.647	**Code**	60SBP RUN8
Point	60BP_8_2M	**East**	394854.014	**North**	6946192.507	**Elevation**	684.579	**Code**	60SBP RUN8
Point	60BP_8_B32	**East**	394855.806	**North**	6946193.593	**Elevation**	684.440	**Code**	60SBP RUN8
Point	60BP_9_B32	**East**	394855.783	**North**	6946193.595	**Elevation**	684.443	**Code**	60SBP RUN9
Point	60BP_9_2M	**East**	394853.987	**North**	6946192.503	**Elevation**	684.584	**Code**	60SBP RUN9
Point	60BP_9_5M	**East**	394852.068	**North**	6946190.346	**Elevation**	684.648	**Code**	60SBP RUN9
Point	60BP_9_10M	**East**	394848.657	**North**	6946186.510	**Elevation**	684.754	**Code**	60SBP RUN9
Point	60BP_9_20M	**East**	394841.758	**North**	6946178.854	**Elevation**	684.919	**Code**	60SBP RUN9
Point	60BP_9_40M	**East**	394825.061	**North**	6946167.766	**Elevation**	685.503	**Code**	60SBP RUN9
Point	60BP_9_80M	**East**	394794.367	**North**	6946142.247	**Elevation**	686.334	**Code**	60SBP RUN9
Point	60BP_9_120M	**East**	394763.547	**North**	6946116.747	**Elevation**	687.368	**Code**	60SBP RUN9
Point	60BP_9_160M	**East**	394735.463	**North**	6946087.882	**Elevation**	688.131	**Code**	60SBP RUN9
Point	60BP_9_200M	**East**	394719.153	**North**	6946047.412	**Elevation**	688.542	**Code**	60SBP RUN9
Point	60BP_10_200M	**East**	394719.156	**North**	6946047.412	**Elevation**	688.534	**Code**	60SBP RUN10
Point	60BP_10_160M	**East**	394735.493	**North**	6946087.879	**Elevation**	688.117	**Code**	60SBP RUN10
Point	60BP_10_120M	**East**	394763.575	**North**	6946116.747	**Elevation**	687.368	**Code**	60SBP RUN10
Point	60BP_10_80M	**East**	394794.398	**North**	6946142.249	**Elevation**	686.319	**Code**	60SBP RUN10
Point	60BP_10_40M	**East**	394825.088	**North**	6946167.757	**Elevation**	685.507	**Code**	60SBP RUN10
Point	60BP_10_20M	**East**	394841.781	**North**	6946178.854	**Elevation**	684.917	**Code**	60SBP RUN10
Point	60BP_10_10M	**East**	394848.684	**North**	6946186.504	**Elevation**	684.751	**Code**	60SBP RUN10

Point	60BP_10_5M	**East**	394852.092	**North**	6946190.348	**Elevation**	684.646	**Code**	60SBP RUN10
Point	60BP_10_2M	**East**	394854.015	**North**	6946192.506	**Elevation**	684.576	**Code**	60SBP RUN10
Point	60BP_10_B32	**East**	394855.809	**North**	6946193.593	**Elevation**	684.432	**Code**	60SBP RUN10
Point	60BP_11_B32	**East**	394855.783	**North**	6946193.599	**Elevation**	684.435	**Code**	60SBP RUN11
Point	60BP_11_2M	**East**	394853.989	**North**	6946192.508	**Elevation**	684.576	**Code**	60SBP RUN11
Point	60BP_11_5M	**East**	394852.068	**North**	6946190.342	**Elevation**	684.646	**Code**	60SBP RUN11
Point	60BP_11_10M	**East**	394848.663	**North**	6946186.503	**Elevation**	684.760	**Code**	60SBP RUN11
Point	60BP_11_20M	**East**	394841.760	**North**	6946178.859	**Elevation**	684.928	**Code**	60SBP RUN11
Point	60BP_11_40M	**East**	394825.064	**North**	6946167.766	**Elevation**	685.521	**Code**	60SBP RUN11
Point	60BP_11_80M	**East**	394794.371	**North**	6946142.248	**Elevation**	686.331	**Code**	60SBP RUN11
Point	60BP_11_120M	**East**	394763.544	**North**	6946116.740	**Elevation**	687.374	**Code**	60SBP RUN11
Point	60BP_11_160M	**East**	394735.460	**North**	6946087.881	**Elevation**	688.117	**Code**	60SBP RUN11
Point	60BP_11_200M	**East**	394719.157	**North**	6946047.424	**Elevation**	688.551	**Code**	60SBP RUN11
Point	60BP_12_200M	**East**	394719.154	**North**	6946047.422	**Elevation**	688.554	**Code**	60SBP RUN12
Point	60BP_12_160M	**East**	394735.489	**North**	6946087.881	**Elevation**	688.130	**Code**	60SBP RUN12
Point	60BP_12_120M	**East**	394763.577	**North**	6946116.739	**Elevation**	687.364	**Code**	60SBP RUN12
Point	60BP_12_80M	**East**	394794.398	**North**	6946142.241	**Elevation**	686.334	**Code**	60SBP RUN12
Point	60BP_12_40M	**East**	394825.088	**North**	6946167.764	**Elevation**	685.514	**Code**	60SBP RUN12
Point	60BP_12_20M	**East**	394841.782	**North**	6946178.851	**Elevation**	684.918	**Code**	60SBP RUN12
Point	60BP_12_10M	**East**	394848.682	**North**	6946186.512	**Elevation**	684.751	**Code**	60SBP RUN12
Point	60BP_12_5M	**East**	394852.093	**North**	6946190.344	**Elevation**	684.644	**Code**	60SBP RUN12
Point	60BP_12_2M	**East**	394854.011	**North**	6946192.502	**Elevation**	684.572	**Code**	60SBP RUN12
Point	60BP_12_B32	**East**	394855.812	**North**	6946193.591	**Elevation**	684.435	**Code**	60SBP RUN12
Point	60BP_13_B32	**East**	394855.792	**North**	6946193.589	**Elevation**	684.434	**Code**	60SBP RUN13
Point	60BP_13_2M	**East**	394853.992	**North**	6946192.495	**Elevation**	684.582	**Code**	60SBP RUN13
Point	60BP_13_5M	**East**	394852.071	**North**	6946190.337	**Elevation**	684.642	**Code**	60SBP RUN13

Point	60BP_13_10M	**East**	394848.666	**North**	6946186.497	**Elevation**	684.749	**Code**	60SBP RUN13
Point	60BP_13_20M	**East**	394841.759	**North**	6946178.850	**Elevation**	684.913	**Code**	60SBP RUN13
Point	60BP_13_40M	**East**	394825.064	**North**	6946167.763	**Elevation**	685.504	**Code**	60SBP RUN13
Point	60BP_13_80M	**East**	394794.372	**North**	6946142.245	**Elevation**	686.340	**Code**	60SBP RUN13
Point	60BP_13_120M	**East**	394763.547	**North**	6946116.740	**Elevation**	687.369	**Code**	60SBP RUN13
Point	60BP_13_160M	**East**	394735.465	**North**	6946087.876	**Elevation**	688.130	**Code**	60SBP RUN13
Point	60BP_13_200M	**East**	394719.154	**North**	6946047.421	**Elevation**	688.544	**Code**	60SBP RUN13
Point	60BP_14_200M	**East**	394719.157	**North**	6946047.422	**Elevation**	688.543	**Code**	60SBP RUN14
Point	60BP_14_160M	**East**	394735.501	**North**	6946087.875	**Elevation**	688.125	**Code**	60SBP RUN14
Point	60BP_14_120M	**East**	394763.582	**North**	6946116.739	**Elevation**	687.362	**Code**	60SBP RUN14
Point	60BP_14_180M	**East**	394794.404	**North**	6946142.246	**Elevation**	686.338	**Code**	60SBP RUN14_ACT80
Point	60BP_14_40M	**East**	394825.088	**North**	6946167.769	**Elevation**	685.510	**Code**	60SBP RUN14
Point	60BP_14_20M	**East**	394841.779	**North**	6946178.852	**Elevation**	684.921	**Code**	60SBP RUN14
Point	60BP_14_10M	**East**	394848.678	**North**	6946186.513	**Elevation**	684.746	**Code**	60SBP RUN14
Point	60BP_14_5M	**East**	394852.088	**North**	6946190.346	**Elevation**	684.638	**Code**	60SBP RUN14
Point	60BP_14_2M	**East**	394854.018	**North**	6946192.509	**Elevation**	684.568	**Code**	60SBP RUN14
Point	60BP_14_B32	**East**	394855.819	**North**	6946193.603	**Elevation**	684.419	**Code**	60SBP RUN14
Point	60BP_30_B32	**East**	394855.825	**North**	6946193.600	**Elevation**	684.420	**Code**	60SBP RUN30
Point	60BP_30_2M	**East**	394853.998	**North**	6946192.498	**Elevation**	684.564	**Code**	60SBP RUN30
Point	60BP_30_5M	**East**	394852.073	**North**	6946190.342	**Elevation**	684.635	**Code**	60SBP RUN30
Point	60BP_30_10M	**East**	394848.670	**North**	6946186.502	**Elevation**	684.748	**Code**	60SBP RUN30
Point	60BP_30_20M	**East**	394841.762	**North**	6946178.852	**Elevation**	684.915	**Code**	60SBP RUN30
Point	60BP_30_40M	**East**	394825.067	**North**	6946167.762	**Elevation**	685.508	**Code**	60SBP RUN30
Point	60BP_30_80M	**East**	394794.369	**North**	6946142.242	**Elevation**	686.351	**Code**	60SBP RUN30
Point	60BP_30_120M	**East**	394763.549	**North**	6946116.741	**Elevation**	687.365	**Code**	60SBP RUN30
Point	60BP_30_160M	**East**	394735.461	**North**	6946087.887	**Elevation**	688.118	**Code**	60SBP RUN30

Point	60BP_30_200M	**East**	394719.154	**North**	6946047.425	**Elevation**	688.539	**Code**	60SBP RUN30

Appendix C11: RTK Observations 16 Aug 2013 – Set 2

Survey Controller Reduced Points

Point	ANANGA1	**East**	394586.985	**North**	6946490.639	**Elevation**	718.427	**Code**	1
Point	60BP_17_B32	**East**	394855.801	**North**	6946193.593	**Elevation**	684.432	**Code**	60SBP RUN17
Point	60BP_17_2M	**East**	394854.011	**North**	6946192.494	**Elevation**	684.569	**Code**	60SBP RUN17
Point	60BP_17_5M	**East**	394852.092	**North**	6946190.338	**Elevation**	684.640	**Code**	60SBP RUN17
Point	60BP_17_10M	**East**	394848.684	**North**	6946186.503	**Elevation**	684.755	**Code**	60SBP RUN17
Point	60BP_17_20M	**East**	394841.778	**North**	6946178.846	**Elevation**	684.917	**Code**	60SBP RUN17
Point	60BP_17_40M	**East**	394825.085	**North**	6946167.760	**Elevation**	685.509	**Code**	60SBP RUN17
Point	60BP_17_80M	**East**	394794.396	**North**	6946142.243	**Elevation**	686.339	**Code**	60SBP RUN17
Point	60BP_17_120M	**East**	394763.563	**North**	6946116.742	**Elevation**	687.373	**Code**	60SBP RUN17
Point	60BP_17_160M	**East**	394735.487	**North**	6946087.885	**Elevation**	688.128	**Code**	60SBP RUN17
Point	60BP_17_200M	**East**	394719.173	**North**	6946047.432	**Elevation**	688.554	**Code**	60SBP RUN17
Point	60BP_18_200M	**East**	394719.177	**North**	6946047.435	**Elevation**	688.558	**Code**	60SBP RUN18
Point	60BP_18_160M	**East**	394735.469	**North**	6946087.875	**Elevation**	688.132	**Code**	60SBP RUN18
Point	60BP_18_120M	**East**	394763.549	**North**	6946116.730	**Elevation**	687.383	**Code**	60SBP RUN18
Point	60BP_18_80M	**East**	394794.385	**North**	6946142.240	**Elevation**	686.360	**Code**	60SBP RUN18
Point	60BP_18_40M	**East**	394825.073	**North**	6946167.765	**Elevation**	685.511	**Code**	60SBP RUN18
Point	60BP_18_20M	**East**	394841.768	**North**	6946178.851	**Elevation**	684.916	**Code**	60SBP RUN18
Point	60BP_18_10M	**East**	394848.670	**North**	6946186.506	**Elevation**	684.754	**Code**	60SBP RUN18
Point	60BP_18_5M	**East**	394852.072	**North**	6946190.343	**Elevation**	684.644	**Code**	60SBP RUN18
Point	60BP_18_2M	**East**	394853.998	**North**	6946192.498	**Elevation**	684.577	**Code**	60SBP RUN18
Point	60BP_18_B32	**East**	394855.791	**North**	6946193.598	**Elevation**	684.431	**Code**	60SBP RUN18
Point	60BP_19_B32	**East**	394855.802	**North**	6946193.594	**Elevation**	684.432	**Code**	60SBP RUN19
Point	60BP_19_2M	**East**	394854.007	**North**	6946192.500	**Elevation**	684.573	**Code**	60SBP RUN19
Point	60BP_19_5M	**East**	394852.092	**North**	6946190.346	**Elevation**	684.647	**Code**	60SBP RUN19
Point	60BP_19_10M	**East**	394848.682	**North**	6946186.511	**Elevation**	684.747	**Code**	60SBP RUN19

Point	60BP_19_20M	**East**	394841.781	**North**	6946178.854	**Elevation**	684.915	**Code**	60SBP RUN19
Point	60BP_19_40M	**East**	394825.083	**North**	6946167.765	**Elevation**	685.505	**Code**	60SBP RUN19
Point	60BP_19_80M	**East**	394794.394	**North**	6946142.243	**Elevation**	686.340	**Code**	60SBP RUN19
Point	60BP_19_120M	**East**	394763.568	**North**	6946116.734	**Elevation**	687.368	**Code**	60SBP RUN19
Point	60BP_19_160M	**East**	394735.487	**North**	6946087.879	**Elevation**	688.118	**Code**	60SBP RUN19
Point	60BP_19_200M	**East**	394719.179	**North**	6946047.429	**Elevation**	688.544	**Code**	60SBP RUN19
Point	60BP_20_200M	**East**	394719.179	**North**	6946047.429	**Elevation**	688.542	**Code**	60SBP RUN20
Point	60BP_20_160M	**East**	394735.490	**North**	6946087.883	**Elevation**	688.121	**Code**	60SBP RUN20
Point	60BP_20_120M	**East**	394763.553	**North**	6946116.735	**Elevation**	687.366	**Code**	60SBP RUN20
Point	60BP_20_80M	**East**	394794.382	**North**	6946142.245	**Elevation**	686.343	**Code**	60SBP RUN20
Point	60BP_20_40M	**East**	394825.074	**North**	6946167.764	**Elevation**	685.504	**Code**	60SBP RUN20
Point	60BP_20_20M	**East**	394841.764	**North**	6946178.851	**Elevation**	684.915	**Code**	60SBP RUN20
Point	60BP_20_10M	**East**	394848.667	**North**	6946186.507	**Elevation**	684.753	**Code**	60SBP RUN20
Point	60BP_20_5M	**East**	394852.085	**North**	6946190.341	**Elevation**	684.639	**Code**	60SBP RUN20
Point	60BP_20_2M	**East**	394854.001	**North**	6946192.493	**Elevation**	684.573	**Code**	60SBP RUN20
Point	60BP_20_B32	**East**	394855.795	**North**	6946193.597	**Elevation**	684.430	**Code**	60SBP RUN20
Point	60BP_21_B32	**East**	394855.810	**North**	6946193.593	**Elevation**	684.430	**Code**	60SBP RUN21
Point	60BP_21_2M	**East**	394854.013	**North**	6946192.507	**Elevation**	684.572	**Code**	60SBP RUN21
Point	60BP_21_5M	**East**	394852.091	**North**	6946190.347	**Elevation**	684.643	**Code**	60SBP RUN21
Point	60BP_21_10M	**East**	394848.679	**North**	6946186.503	**Elevation**	684.759	**Code**	60SBP RUN21
Point	60BP_21_20M	**East**	394841.776	**North**	6946178.851	**Elevation**	684.924	**Code**	60SBP RUN21
Point	60BP_21_40M	**East**	394825.079	**North**	6946167.763	**Elevation**	685.510	**Code**	60SBP RUN21
Point	60BP_21_80M	**East**	394794.391	**North**	6946142.239	**Elevation**	686.340	**Code**	60SBP RUN21
Point	60BP_21_120M	**East**	394763.572	**North**	6946116.735	**Elevation**	687.373	**Code**	60SBP RUN21
Point	60BP_21_160M	**East**	394735.483	**North**	6946087.892	**Elevation**	688.136	**Code**	60SBP RUN21
Point	60BP_21_200M	**East**	394719.171	**North**	6946047.425	**Elevation**	688.544	**Code**	60SBP RUN21

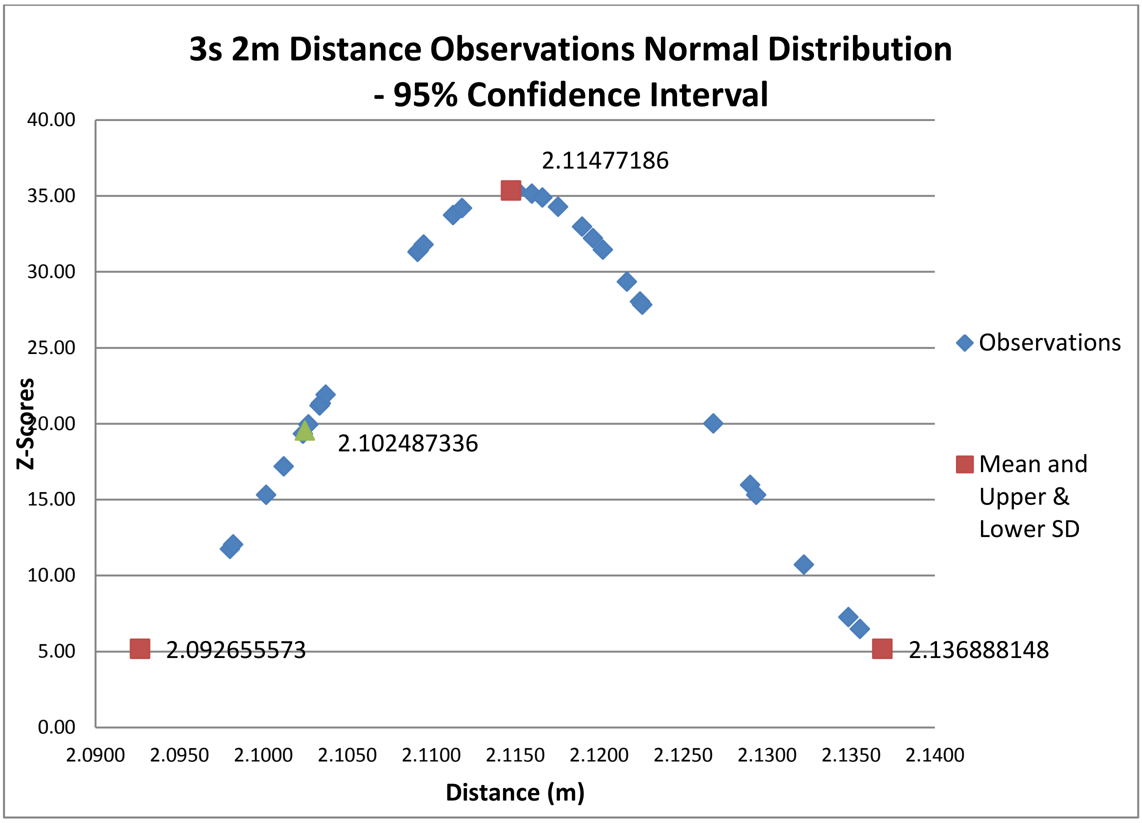
Point	60BP_22_200M	**East**	394719.180	**North**	6946047.431	**Elevation**	688.541	**Code**	60SBP RUN22
Point	60BP_22_160M	**East**	394735.482	**North**	6946087.886	**Elevation**	688.124	**Code**	60SBP RUN22
Point	60BP_22_120M	**East**	394763.556	**North**	6946116.734	**Elevation**	687.373	**Code**	60SBP RUN22
Point	60BP_22_80M	**East**	394794.384	**North**	6946142.249	**Elevation**	686.336	**Code**	60SBP RUN22
Point	60BP_22_40M	**East**	394825.068	**North**	6946167.771	**Elevation**	685.500	**Code**	60SBP RUN22
Point	60BP_22_20M	**East**	394841.767	**North**	6946178.853	**Elevation**	684.917	**Code**	60SBP RUN22
Point	60BP_22_10M	**East**	394848.670	**North**	6946186.507	**Elevation**	684.748	**Code**	60SBP RUN22
Point	60BP_22_5M	**East**	394852.079	**North**	6946190.337	**Elevation**	684.644	**Code**	60SBP RUN22
Point	60BP_22_2M	**East**	394853.999	**North**	6946192.498	**Elevation**	684.578	**Code**	60SBP RUN22
Point	60BP_22_B32	**East**	394855.792	**North**	6946193.594	**Elevation**	684.426	**Code**	60SBP RUN22
Point	60BP_23_B32	**East**	394855.792	**North**	6946193.598	**Elevation**	684.431	**Code**	60SBP RUN23
Point	60BP_23_2M	**East**	394854.009	**North**	6946192.499	**Elevation**	684.577	**Code**	60SBP RUN23
Point	60BP_23_5M	**East**	394852.091	**North**	6946190.348	**Elevation**	684.642	**Code**	60SBP RUN23
Point	60BP_23_10M	**East**	394848.682	**North**	6946186.509	**Elevation**	684.750	**Code**	60SBP RUN23
Point	60BP_23_20M	**East**	394841.777	**North**	6946178.849	**Elevation**	684.913	**Code**	60SBP RUN23
Point	60BP_23_40M	**East**	394825.082	**North**	6946167.766	**Elevation**	685.504	**Code**	60SBP RUN23
Point	60BP_23_80M	**East**	394794.387	**North**	6946142.246	**Elevation**	686.333	**Code**	60SBP RUN23
Point	60BP_23_120M	**East**	394763.565	**North**	6946116.742	**Elevation**	687.367	**Code**	60SBP RUN23
Point	60BP_23_160M	**East**	394735.483	**North**	6946087.887	**Elevation**	688.127	**Code**	60SBP RUN23
Point	60BP_23_200M	**East**	394719.176	**North**	6946047.426	**Elevation**	688.545	**Code**	60SBP RUN23
Point	60BP_24_200M	**East**	394719.187	**North**	6946047.430	**Elevation**	688.534	**Code**	60SBP RUN24
Point	60BP_24_160M	**East**	394735.470	**North**	6946087.875	**Elevation**	688.123	**Code**	60SBP RUN24
Point	60BP_24_120M	**East**	394763.552	**North**	6946116.740	**Elevation**	687.359	**Code**	60SBP RUN24
Point	60BP_24_80M	**East**	394794.370	**North**	6946142.245	**Elevation**	686.327	**Code**	60SBP RUN24
Point	60BP_24_40M	**East**	394825.068	**North**	6946167.761	**Elevation**	685.511	**Code**	60SBP RUN24
Point	60BP_24_20M	**East**	394841.764	**North**	6946178.850	**Elevation**	684.921	**Code**	60SBP RUN24

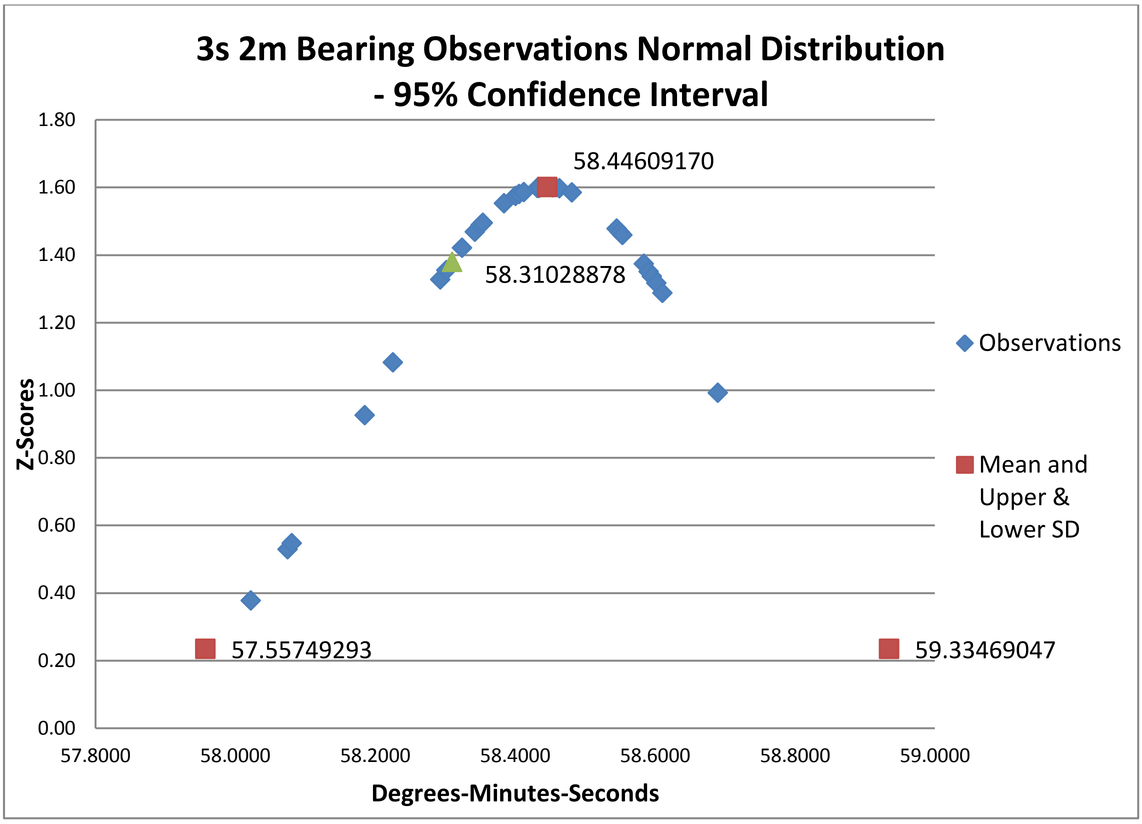
Point	60BP_24_10M	**East**	394848.667	**North**	6946186.507	**Elevation**	684.749	**Code**	60SBP RUN24
Point	60BP_24_5M	**East**	394852.076	**North**	6946190.336	**Elevation**	684.642	**Code**	60SBP RUN24
Point	60BP_24_2M	**East**	394854.002	**North**	6946192.502	**Elevation**	684.569	**Code**	60SBP RUN24
Point	60BP_24_B32	**East**	394855.788	**North**	6946193.599	**Elevation**	684.428	**Code**	60SBP RUN24
Point	60BP_25_B32	**East**	394855.786	**North**	6946193.602	**Elevation**	684.430	**Code**	60SBP RUN25
Point	60BP_25_2M	**East**	394854.006	**North**	6946192.504	**Elevation**	684.577	**Code**	60SBP RUN25
Point	60BP_25_5M	**East**	394852.093	**North**	6946190.344	**Elevation**	684.643	**Code**	60SBP RUN25
Point	60BP_25_10M	**East**	394848.686	**North**	6946186.506	**Elevation**	684.752	**Code**	60SBP RUN25
Point	60BP_25_20M	**East**	394841.780	**North**	6946178.854	**Elevation**	684.922	**Code**	60SBP RUN25
Point	60BP_25_40M	**East**	394825.087	**North**	6946167.769	**Elevation**	685.519	**Code**	60SBP RUN25
Point	60BP_25_80M	**East**	394794.392	**North**	6946142.246	**Elevation**	686.352	**Code**	60SBP RUN25
Point	60BP_25_120M	**East**	394763.568	**North**	6946116.736	**Elevation**	687.361	**Code**	60SBP RUN25
Point	60BP_25_160M	**East**	394735.487	**North**	6946087.877	**Elevation**	688.114	**Code**	60SBP RUN25
Point	60BP_25_200M	**East**	394719.177	**North**	6946047.424	**Elevation**	688.544	**Code**	60SBP RUN25
Point	60BP_26_200M	**East**	394719.178	**North**	6946047.428	**Elevation**	688.552	**Code**	60SBP RUN26
Point	60BP_26_160M	**East**	394735.466	**North**	6946087.883	**Elevation**	688.129	**Code**	60SBP RUN26
Point	60BP_26_120M	**East**	394763.562	**North**	6946116.743	**Elevation**	687.363	**Code**	60SBP RUN26
Point	60BP_26_40M	**East**	394825.063	**North**	6946167.764	**Elevation**	685.510	**Code**	60SBP RUN26
Point	60BP_26_20M	**East**	394841.760	**North**	6946178.855	**Elevation**	684.915	**Code**	60SBP RUN26
Point	60BP_26_10M	**East**	394848.667	**North**	6946186.506	**Elevation**	684.749	**Code**	60SBP RUN26
Point	60BP_26_5M	**East**	394852.071	**North**	6946190.339	**Elevation**	684.641	**Code**	60SBP RUN26
Point	60BP_26_2M	**East**	394853.993	**North**	6946192.490	**Elevation**	684.572	**Code**	60SBP RUN26
Point	60BP_26_B32	**East**	394855.789	**North**	6946193.592	**Elevation**	684.434	**Code**	60SBP RUN26
Point	60BP_27_B32	**East**	394855.789	**North**	6946193.593	**Elevation**	684.435	**Code**	60SBP RUN27
Point	60BP_27_2M	**East**	394854.016	**North**	6946192.508	**Elevation**	684.576	**Code**	60SBP RUN27
Point	60BP_27_5M	**East**	394852.096	**North**	6946190.340	**Elevation**	684.645	**Code**	60SBP RUN27

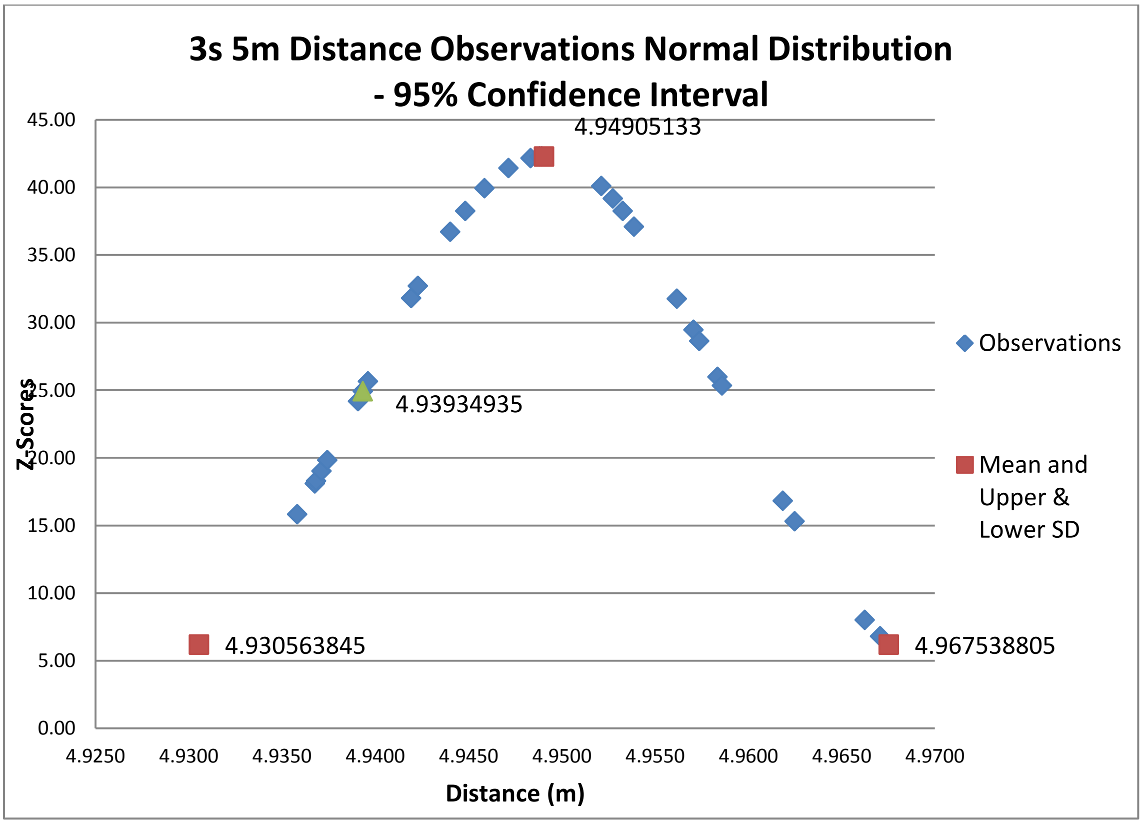
Point	60BP_27_10M	**East**	394848.687	**North**	6946186.507	**Elevation**	684.752	**Code**	60SBP RUN27
Point	60BP_27_20M	**East**	394841.782	**North**	6946178.849	**Elevation**	684.915	**Code**	60SBP RUN27
Point	60BP_27_40M	**East**	394825.082	**North**	6946167.763	**Elevation**	685.508	**Code**	60SBP RUN27
Point	60BP_27_80M	**East**	394794.390	**North**	6946142.241	**Elevation**	686.333	**Code**	60SBP RUN27
Point	60BP_27_120M	**East**	394763.567	**North**	6946116.744	**Elevation**	687.366	**Code**	60SBP RUN27
Point	60BP_27_160M	**East**	394735.482	**North**	6946087.884	**Elevation**	688.122	**Code**	60SBP RUN27
Point	60BP_27_200M	**East**	394719.177	**North**	6946047.428	**Elevation**	688.550	**Code**	60SBP RUN27
Point	60BP_28_200M	**East**	394719.178	**North**	6946047.426	**Elevation**	688.546	**Code**	60SBP RUN28
Point	60BP_28_160M	**East**	394735.479	**North**	6946087.877	**Elevation**	688.122	**Code**	60SBP RUN28
Point	60BP_28_120M	**East**	394763.556	**North**	6946116.742	**Elevation**	687.370	**Code**	60SBP RUN28
Point	60BP_28_80M	**East**	394794.375	**North**	6946142.244	**Elevation**	686.341	**Code**	60SBP RUN28
Point	60BP_28_40M	**East**	394825.066	**North**	6946167.770	**Elevation**	685.511	**Code**	60SBP RUN28
Point	60BP_28_20M	**East**	394841.754	**North**	6946178.856	**Elevation**	684.909	**Code**	60SBP RUN28
Point	60BP_28_10M	**East**	394848.661	**North**	6946186.505	**Elevation**	684.740	**Code**	60SBP RUN28
Point	60BP_28_5M	**East**	394852.079	**North**	6946190.341	**Elevation**	684.633	**Code**	60SBP RUN28
Point	60BP_28_2M	**East**	394853.994	**North**	6946192.494	**Elevation**	684.569	**Code**	60SBP RUN28
Point	60BP_28_B32	**East**	394855.819	**North**	6946193.599	**Elevation**	684.428	**Code**	60SBP RUN28
Point	60BP_29_B32	**East**	394855.819	**North**	6946193.600	**Elevation**	684.427	**Code**	60SBP RUN29
Point	60BP_29_2M	**East**	394854.012	**North**	6946192.500	**Elevation**	684.572	**Code**	60SBP RUN29
Point	60BP_29_5M	**East**	394852.093	**North**	6946190.350	**Elevation**	684.644	**Code**	60SBP RUN29
Point	60BP_29_10M	**East**	394848.681	**North**	6946186.505	**Elevation**	684.749	**Code**	60SBP RUN29
Point	60BP_29_20M	**East**	394841.779	**North**	6946178.858	**Elevation**	684.917	**Code**	60SBP RUN29
Point	60BP_29_40M	**East**	394825.077	**North**	6946167.777	**Elevation**	685.509	**Code**	60SBP RUN29
Point	60BP_29_80M	**East**	394794.389	**North**	6946142.255	**Elevation**	686.355	**Code**	60SBP RUN29
Point	60BP_29_120M	**East**	394763.569	**North**	6946116.752	**Elevation**	687.360	**Code**	60SBP RUN29
Point	60BP_29_160M	**East**	394735.473	**North**	6946087.899	**Elevation**	688.128	**Code**	60SBP RUN29

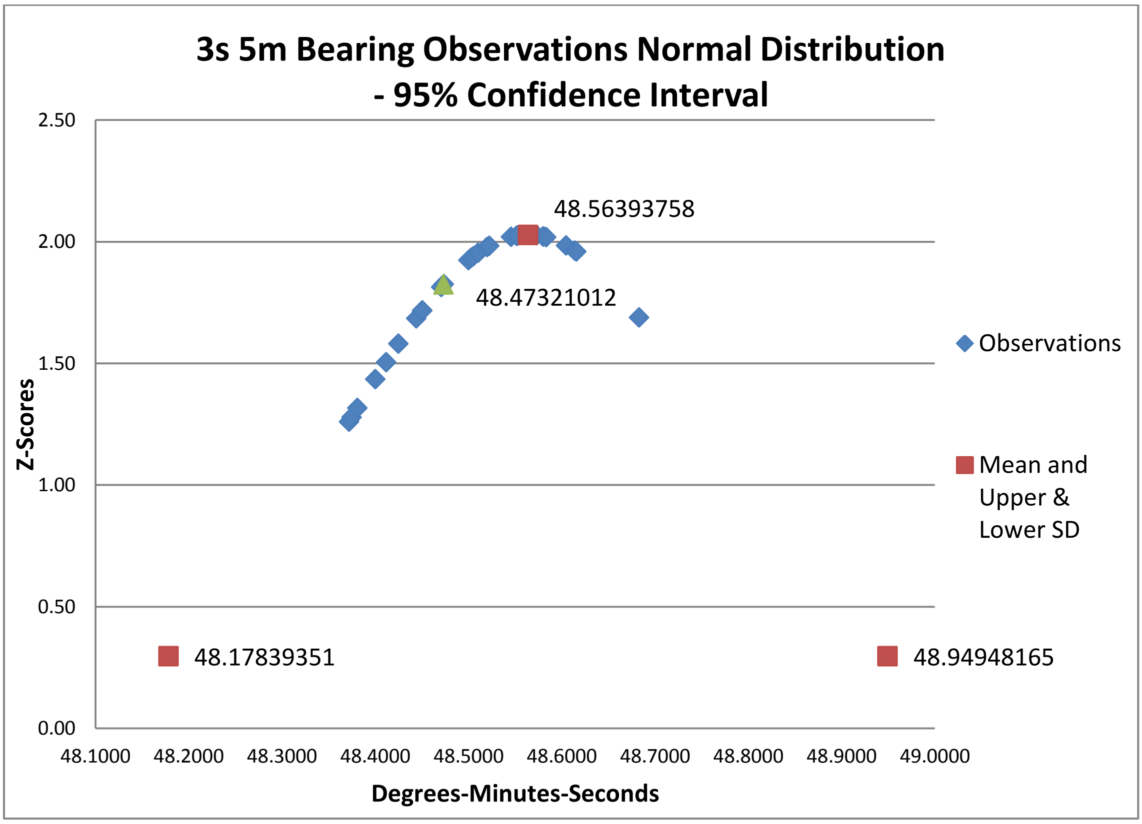
Point	60BP_29_200M	**East**	394719.179	**North**	6946047.438	**Elevation**	688.548	**Code**	60SBP RUN29

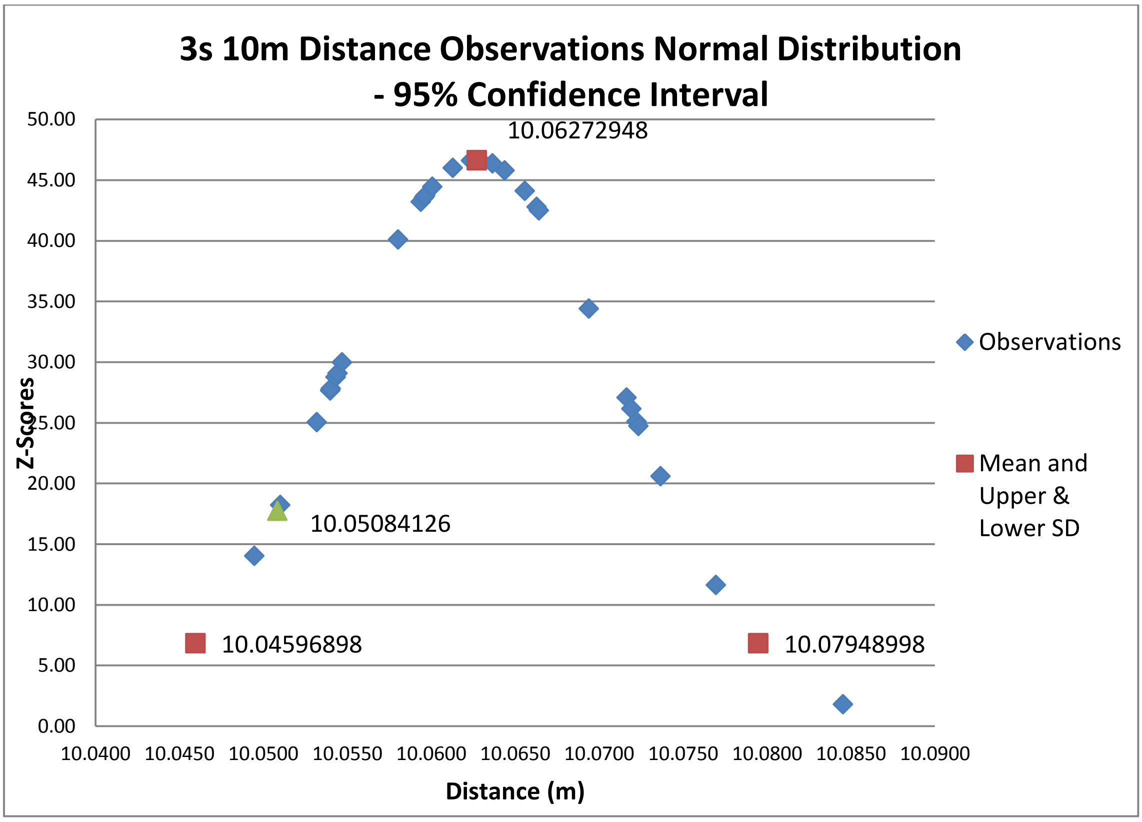
APPENDIX D: Normal Distribution of Bearing and Distances

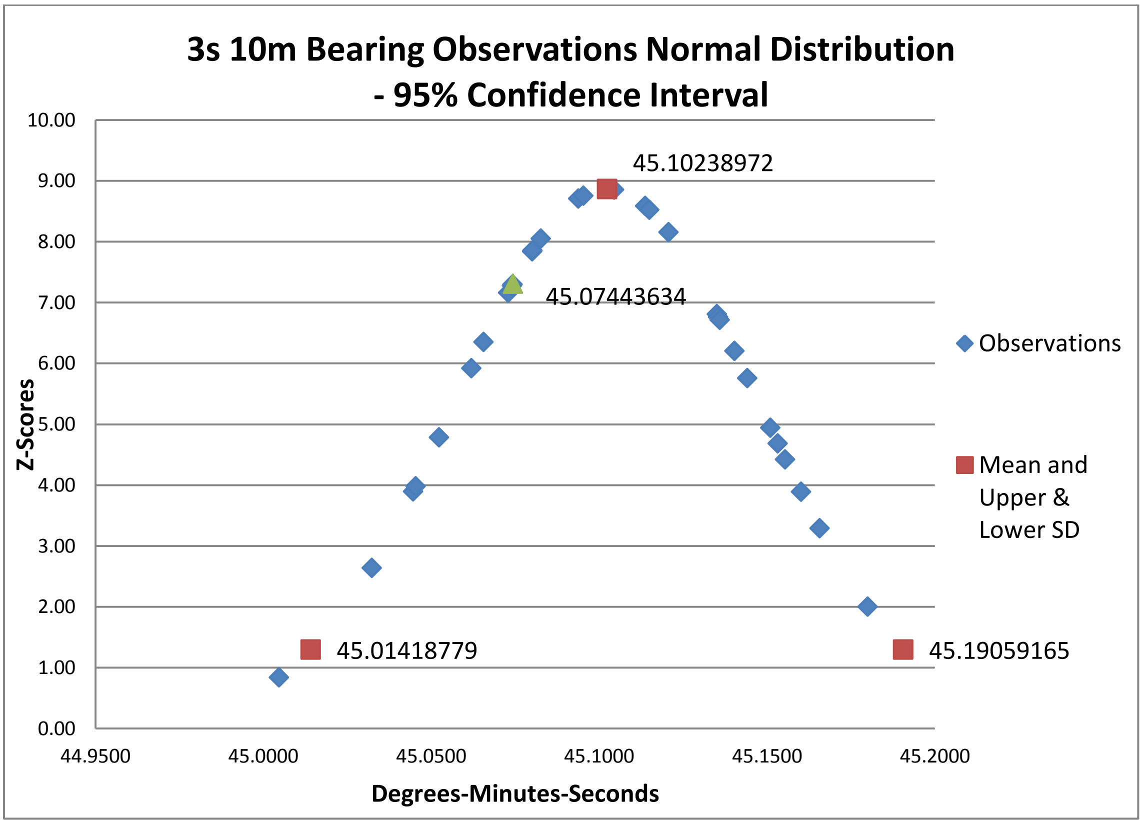


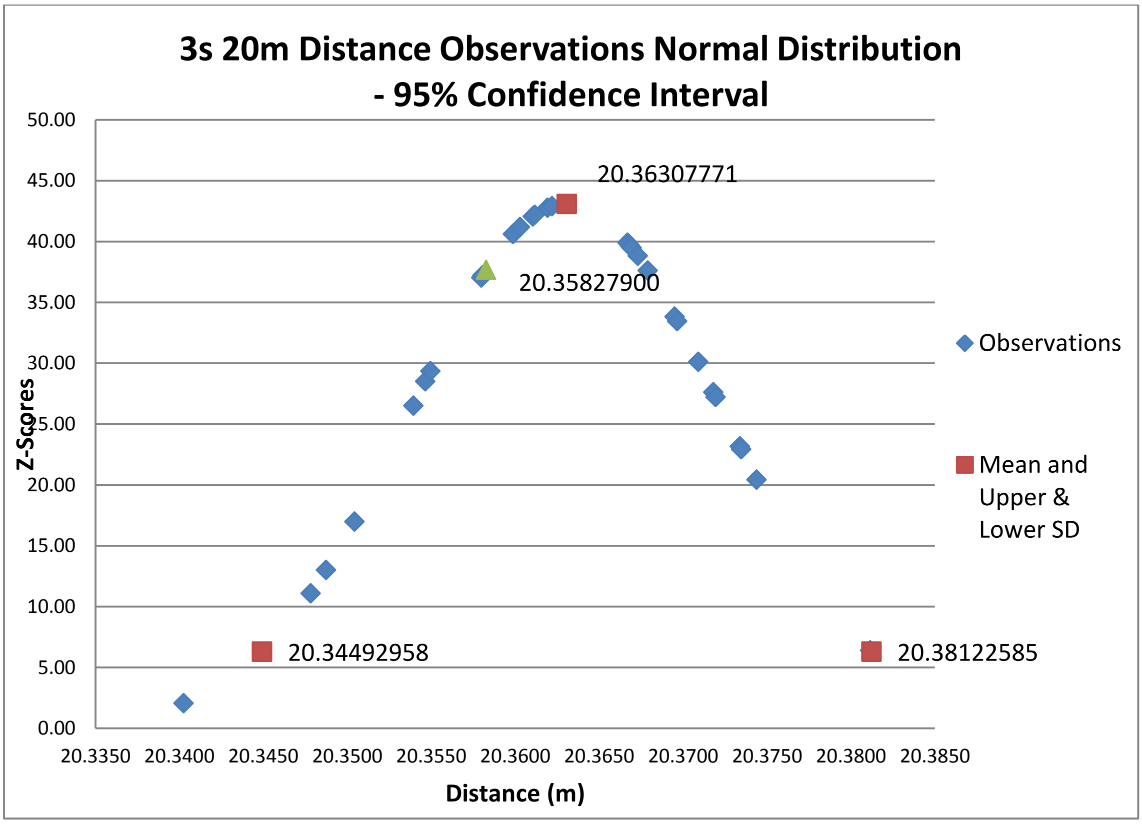


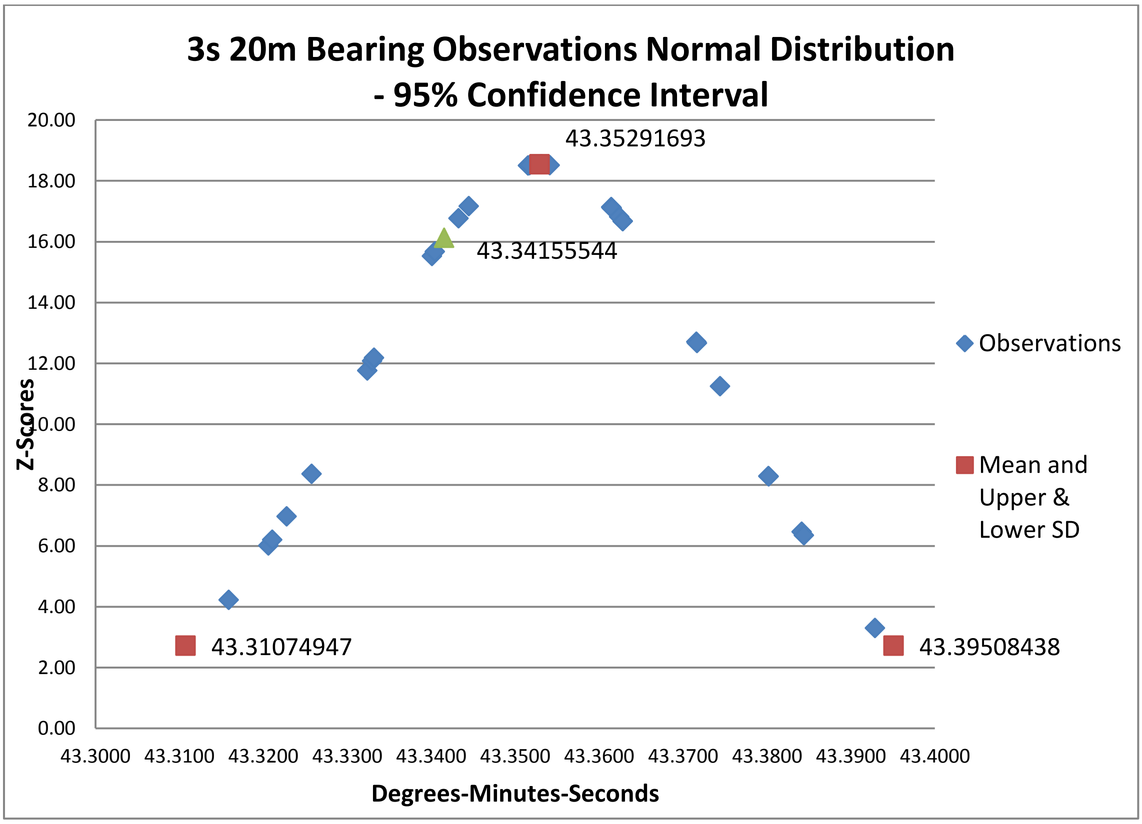

3s 5m Distance Observations Normal Distribution - 95% Confidence Interval
4.94905133
4.93934935
4.930563845
4.967538805
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Z-Scores
4.9250
4.9300
4.9350
4.9400
4.9450
4.9500
4.9550
4.9600
4.9650
4.9700
Distance (m)
Observations
Mean and Upper & Lower SD

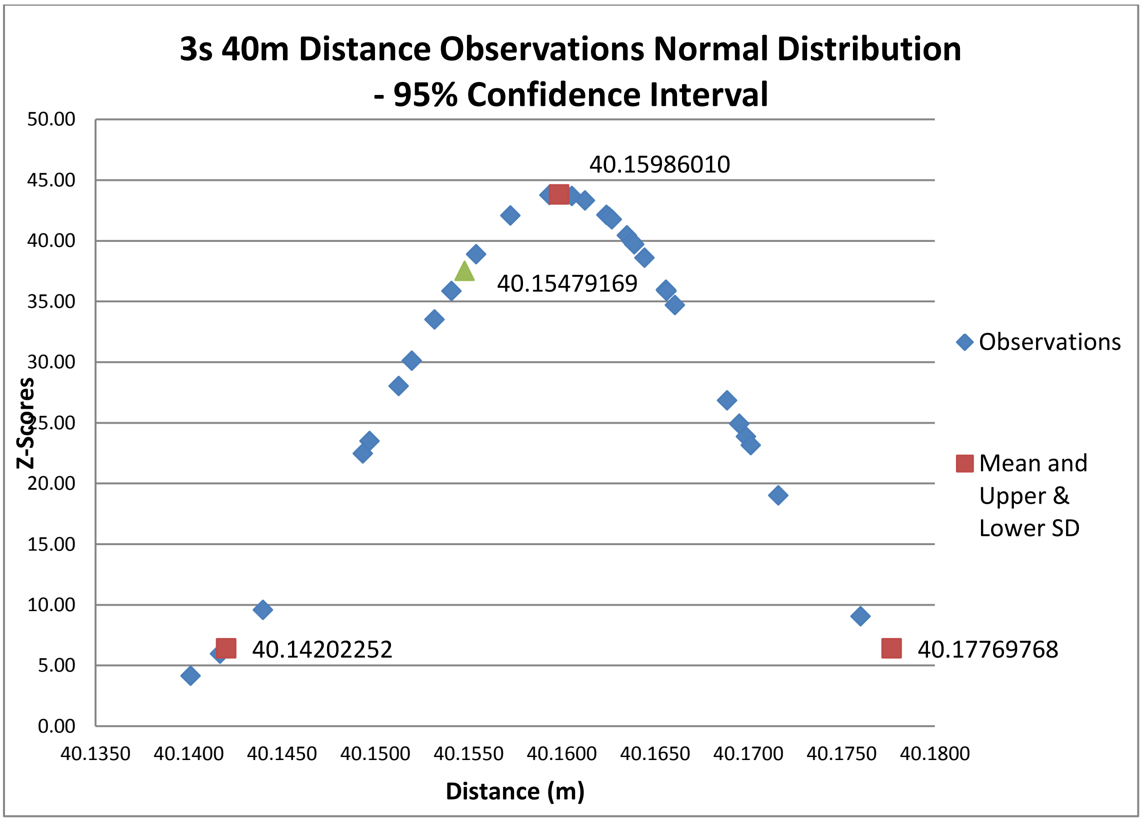

3s 5m Bearing Observations Normal Distribution - 95% Confidence Interval
48.56393758
48.47321012
48.17839351
48.94948165
2.50
2.00
1.50
1.00
0.50
0.00
Z-Scores
48.1000
48.2000
48.3000
48.4000
48.5000
48.6000
48.7000
48.8000
48.9000
49.0000
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD

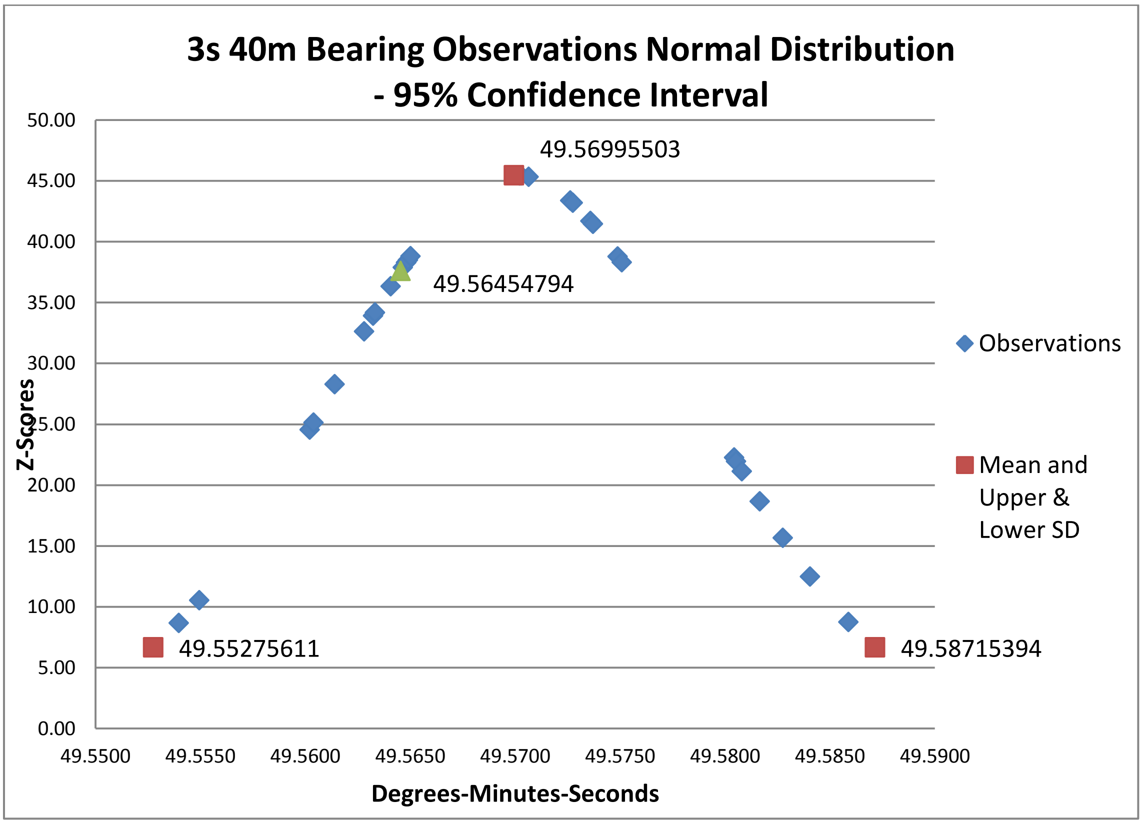

3s 10m Distance Observations Normal Distribution - 95% Confidence Interval
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Z-Scores
10.06272948
10.05084126
10.04596898
10.07948998
10.0400
10.0450
10.0500
10.0550
10.0600
10.0650
10.0700
10.0750
10.0800
10.0850
10.0900
Distance (m)
Observations
Mean and Upper & Lower SD


3s 10m Bearing Observations Normal Distribution - 95% Confidence Interval
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Z-Scores
45.10238972
45.07443634
45.01418779
45.19059165
44.9500
45.0000
45.0500
45.1000
45.1500
45.2000
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD


3s 20m Distance Observations Normal Distribution - 95% Confidence Interval
20.36307771
20.35827900
20.34492958
20.38122585
Z-Scores
Distance (m)
Observations
Mean and Upper & Lower SD
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
20.3350 20.3400 20.3450 20.3500 20.3550 20.3600 20.3650 20.3700 20.3750 20.3800 20.3850


3s 20m Bearing Observations Normal Distribution - 95% Confidence Interval
43.35291693
43.34155544
43.31074947
43.39508438
Z-Scores
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
43.3000 43.3100 43.3200 43.3300 43.3400 43.3500 43.3600 43.3700 43.3800 43.3900 43.4000


3s 40m Distance Observations Normal Distribution - 95% Confidence Interval
40.15986010
40.15479169
40.14202252
40.17769768
Observations
Mean and Upper & Lower SD
Z-Scores
Distance (m)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
40.1350
40.1400
40.1450
40.1500
40.1550
40.1600
40.1650
40.1700
40.1750
40.1800


3s 40m Bearing Observations Normal Distribution - 95% Confidence Interval
49.56995503
49.56454794
49.55275611
49.58715394
Observations
Mean and Upper & Lower SD
Z-Scores
Degrees-Minutes-Seconds
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
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49.5550
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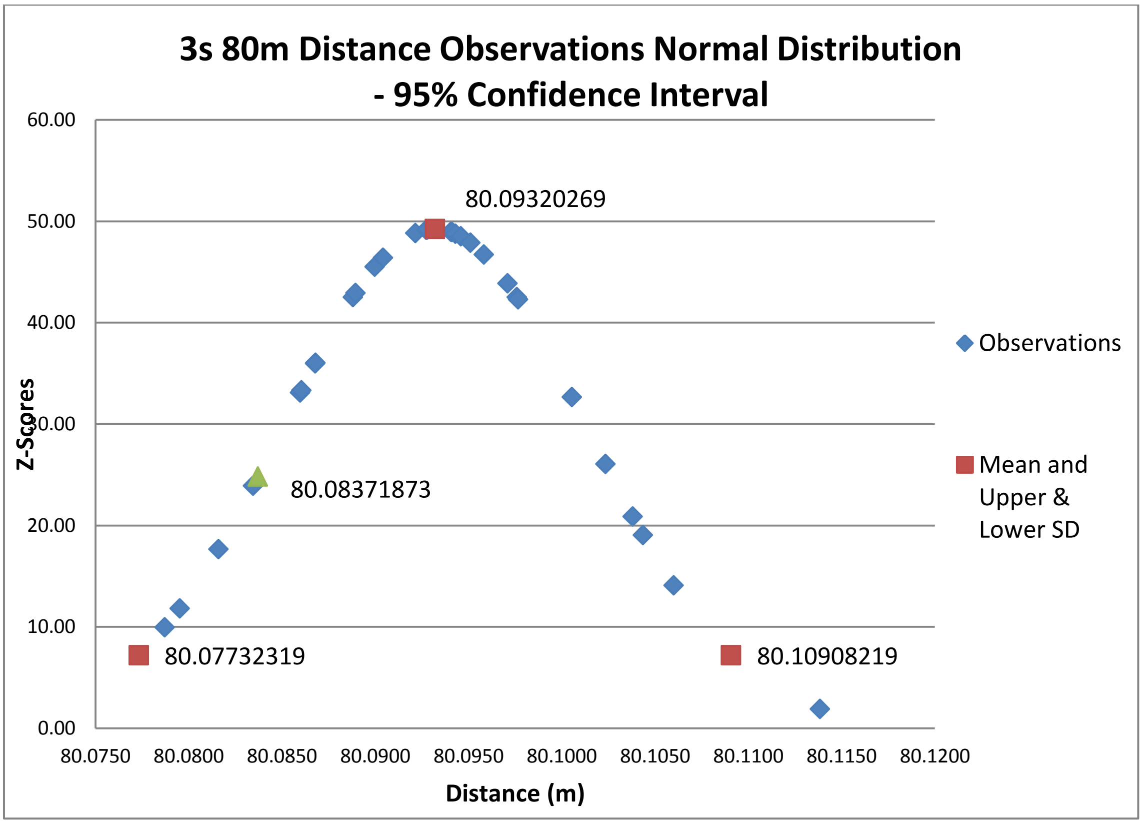
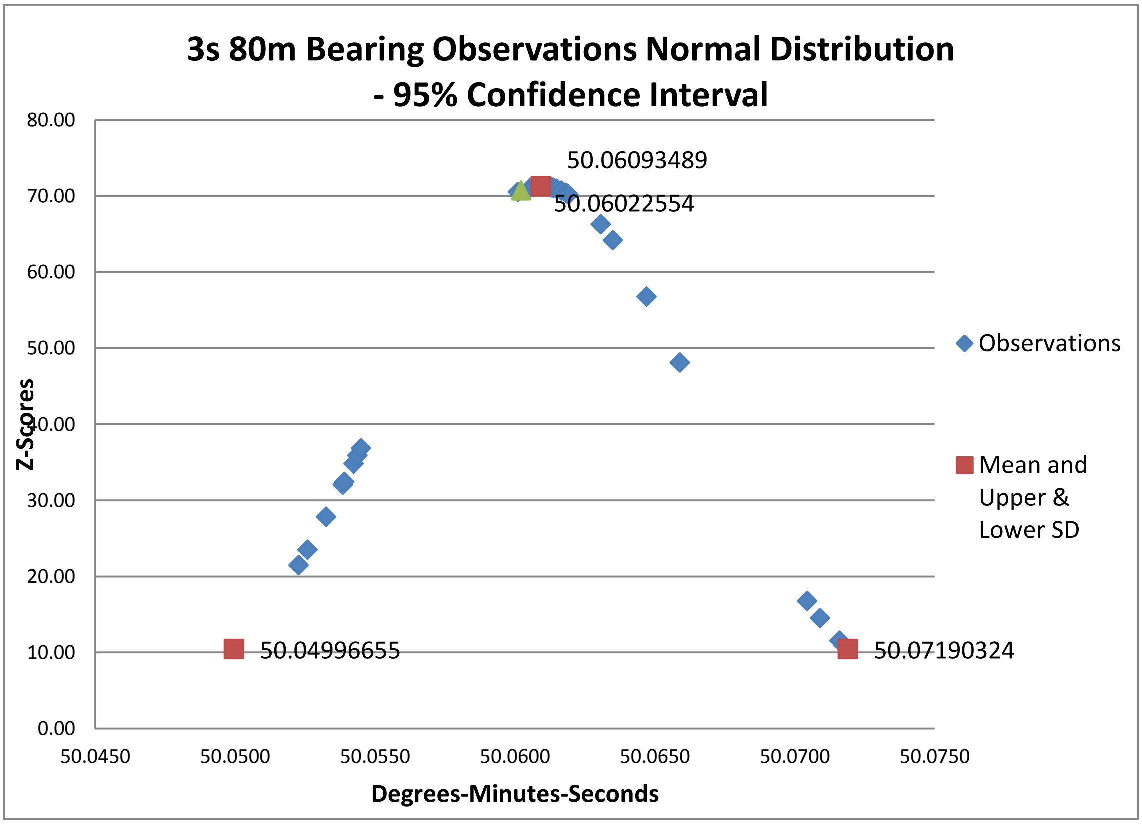
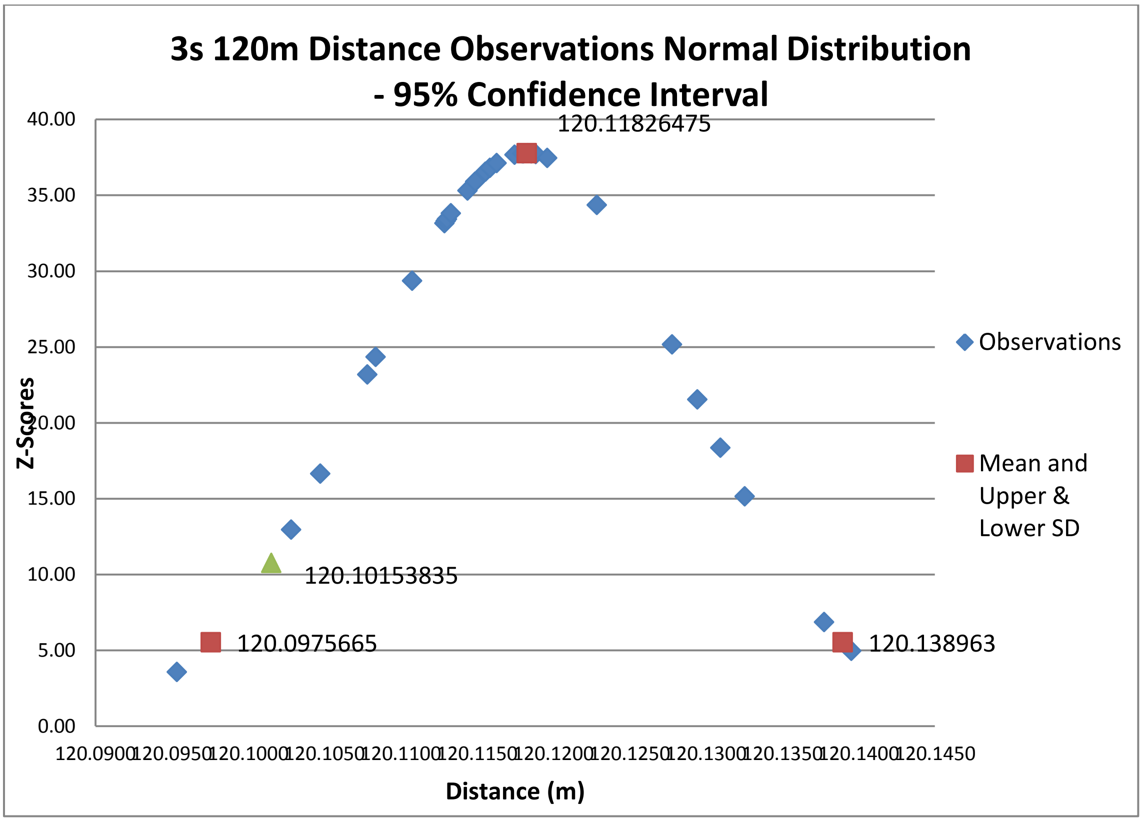
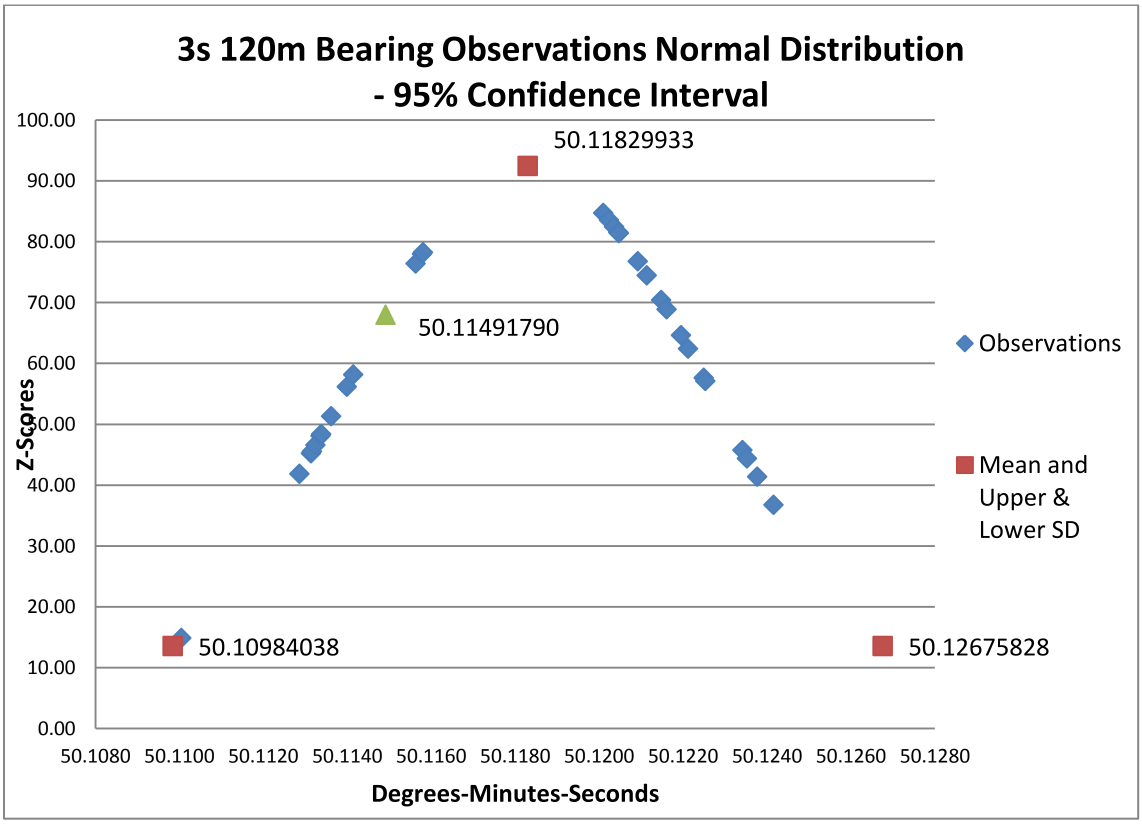
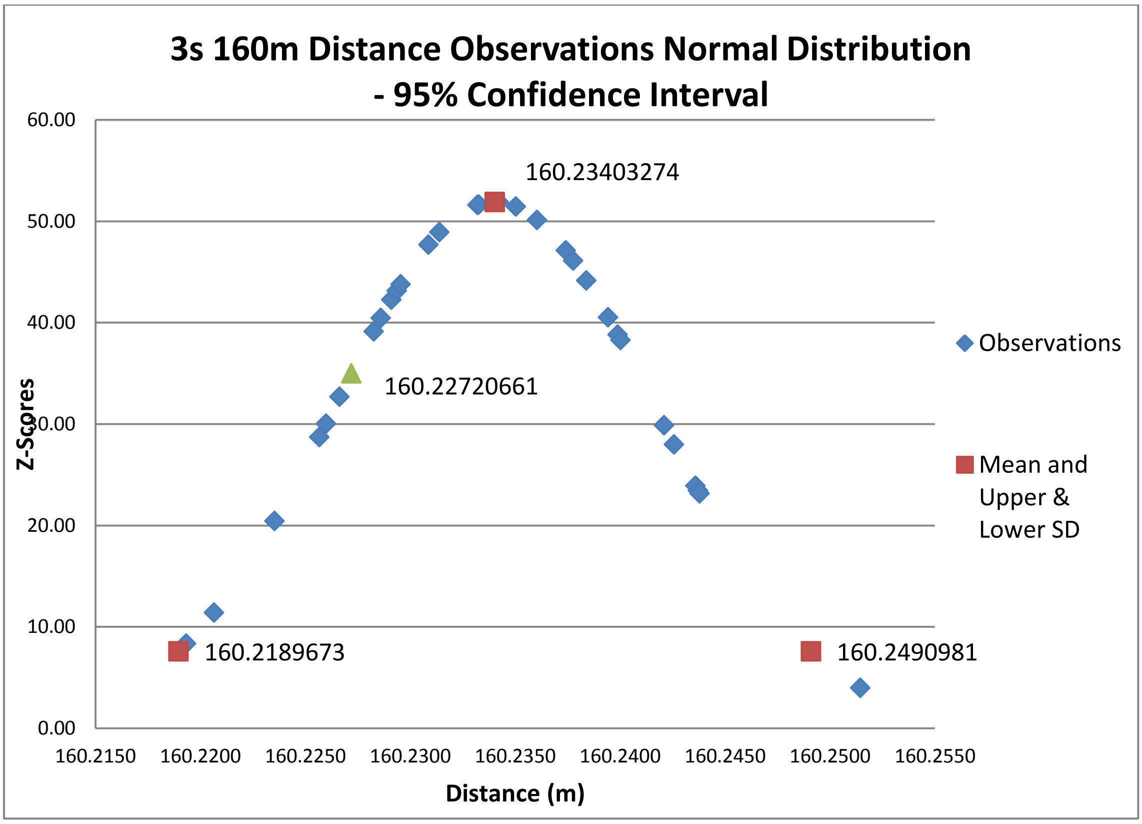
49.5800
49.5850
49.5900


3s 80m Distance Observations Normal Distribution - 95% Confidence Interval
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Z-Scores
80.09320269
80.08371873
80.07732319
80.10908219
80.0750
80.0800
80.0850
80.0900
80.0950
80.1000
80.1050
80.1100
80.1150
80.1200
Distance (m)
Observations
Mean and Upper & Lower SD

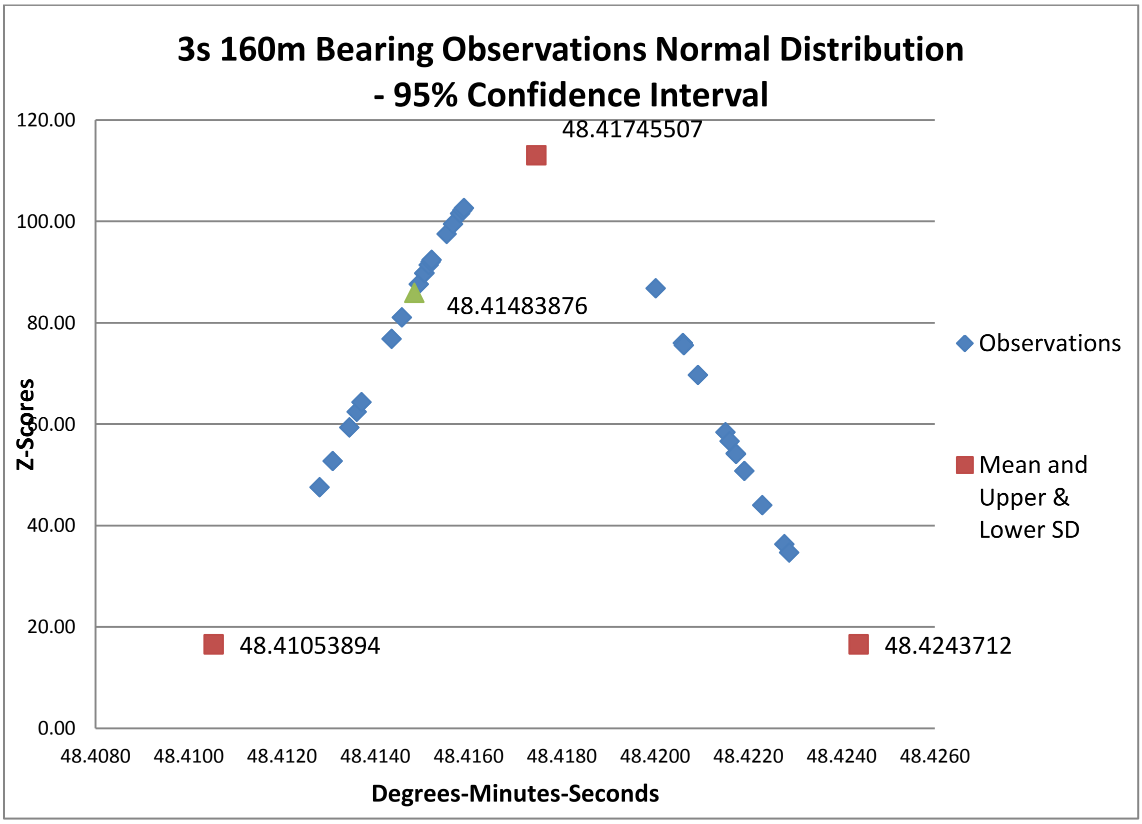

3s 80m Bearing Observations Normal Distribution - 95% Confidence Interval
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Z-Scores
50.06093489
50.06022554
50.04996655
50.07190324
50.0450
50.0500
50.0550
50.0600
50.0650
50.0700
50.0750
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD


3s 120m Distance Observations Normal Distribution - 95% Confidence Interval
120.11826475
120.10153835
120.0975665
120.138963
Z-Scores
Distance (m)
Observations
Mean and Upper & Lower SD
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
120.0900
120.0950
120.1000
120.1050
120.1100
120.1150
120.1200
120.1250
120.1300
120.1350
120.1400
120.1450

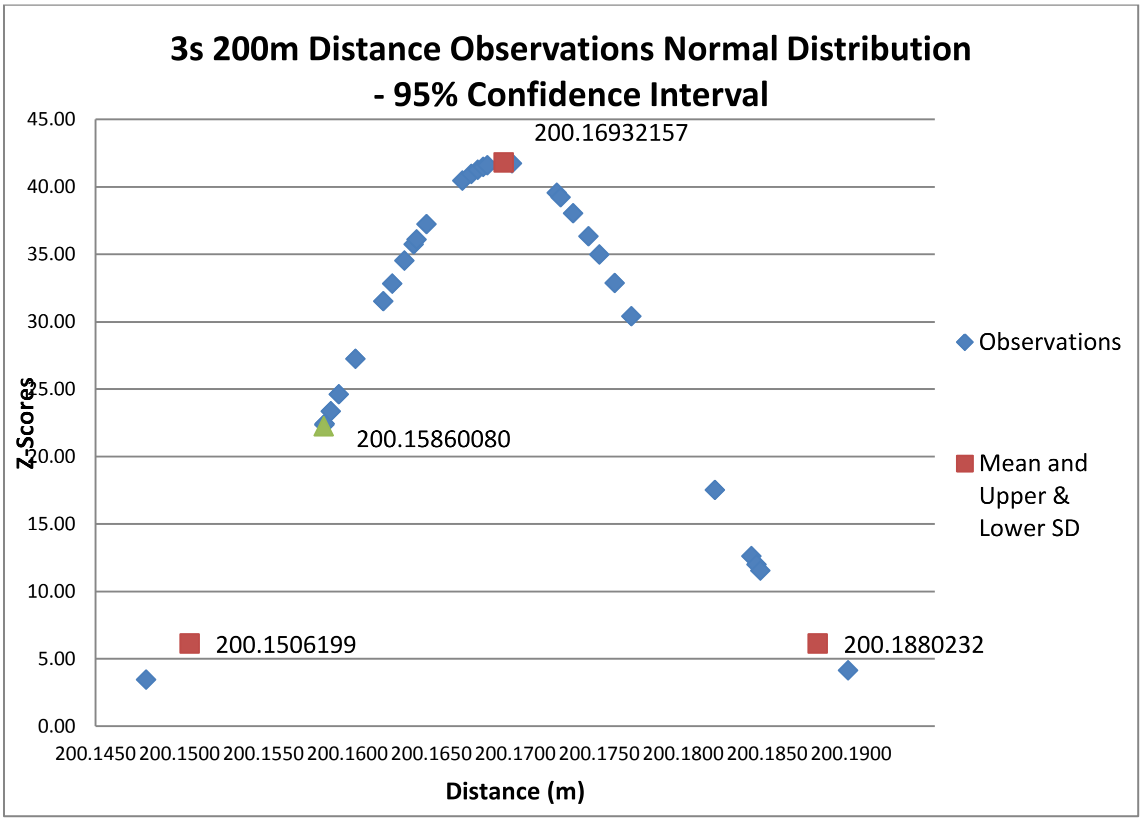

3s 120m Bearing Observations Normal Distribution - 95% Confidence Interval
50.11829933
50.11491790
50.10984038
50.12675828
Z-Scores
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
50.1080
50.1100
50.1120
50.1140
50.1160
50.1180
50.1200
50.1220
50.1240
50.1260
50.1280

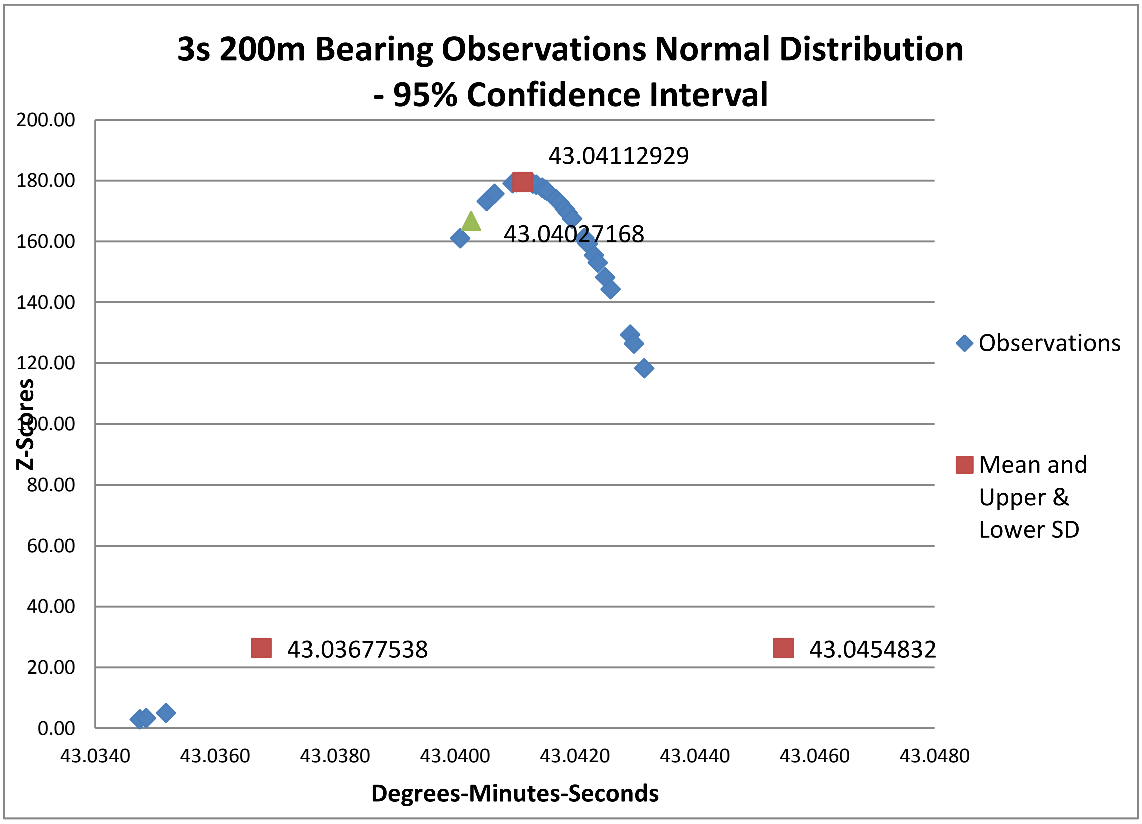


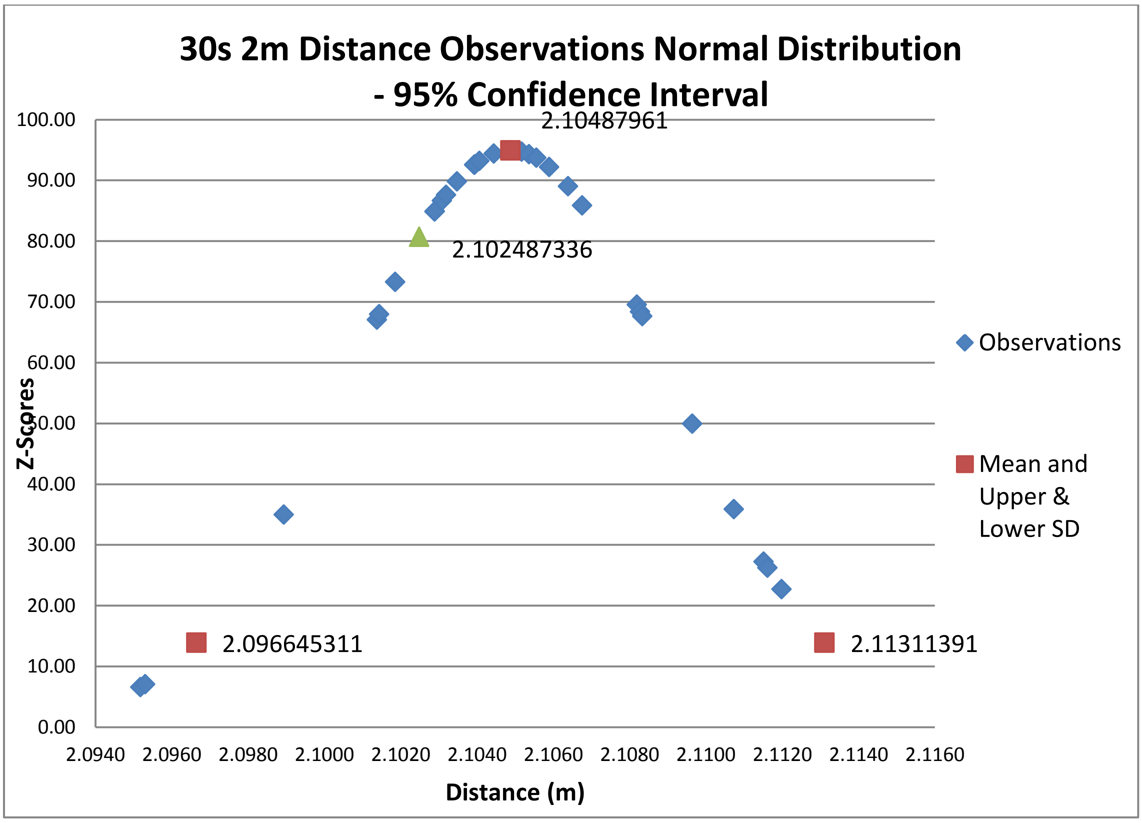
3s 160m Distance Observations Normal Distribution - 95% Confidence Interval
160.23403274
160.22720661
160.2189673
160.2490981
Observations
Mean and Upper & Lower SD
Z-Scores
60.00
50.00
40.00
30.00
20.00
10.00
0.00
160.2150
160.2200
160.2250
160.2300
160.2350
160.2400
160.2450
160.2500
160.2550
Distance (m)



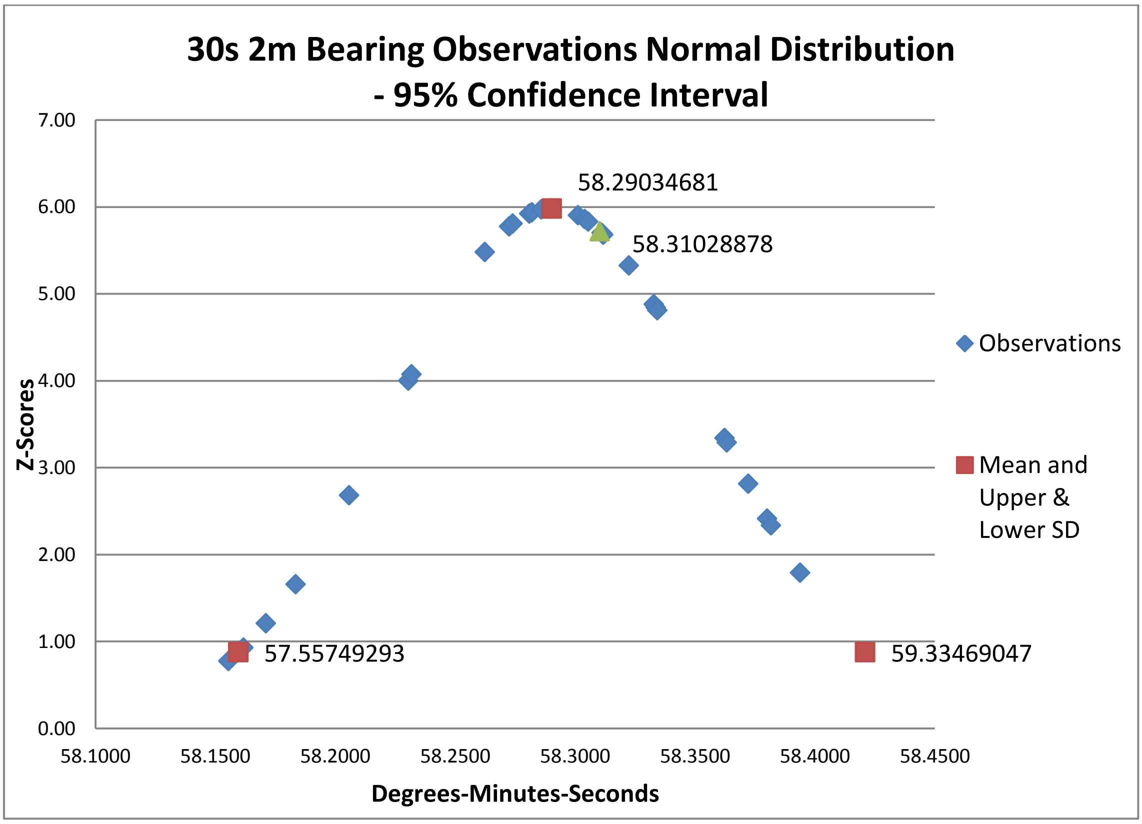
3s 160m Bearing Observations Normal Distribution - 95% Confidence Interval
48.41745507
48.41483876
48.41053894
48.4243712
Observations
Mean and Upper & Lower SD
Z-Scores
120.00
100.00
80.00
60.00
40.00
20.00
0.00
48.4080
48.4100
48.4120
48.4140
48.4160
48.4180
48.4200
48.4220
48.4240
48.4260
Degrees-Minutes-Seconds


3s 200m Distance Observations Normal Distribution - 95% Confidence Interval
200.16932157
200.15860080
200.1506199
200.1880232
Z-Scores
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
200.1450 200.1500 200.1550 200.1600 200.1650 200.1700 200.1750 200.1800 200.1850 200.1900
Distance (m)
Observations
Mean and Upper & Lower SD

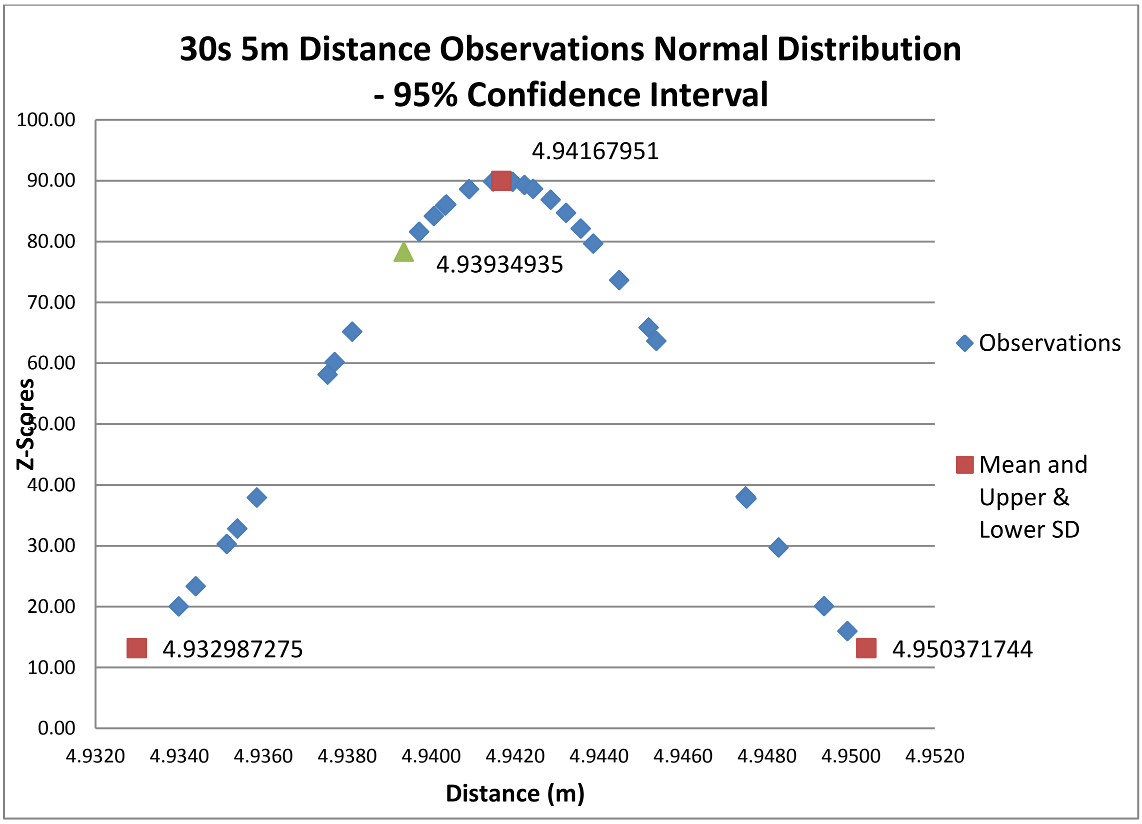

3s 200m Bearing Observations Normal Distribution - 95% Confidence Interval
43.04112929
43.04027168
43.03677538
43.0454832
Z-Scores
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
43.0340 43.0360 43.0380 43.0400 43.0420 43.0440 43.0460 43.0480
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD

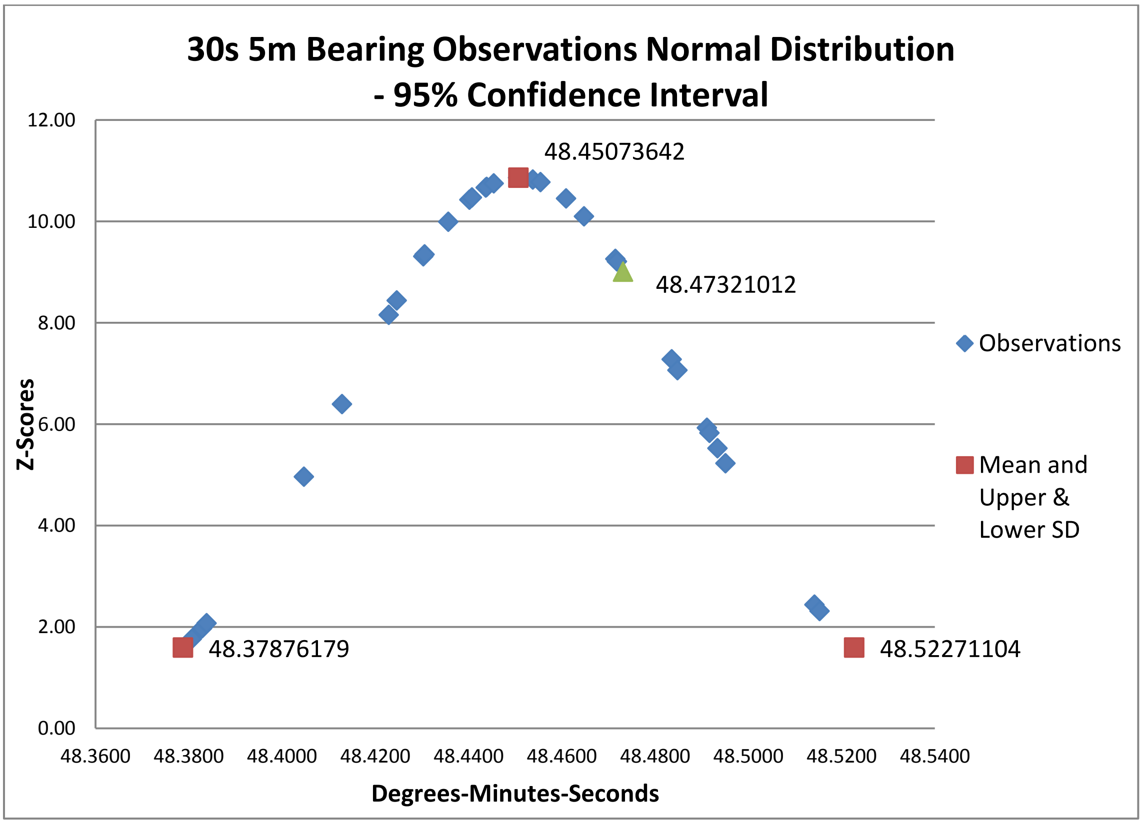


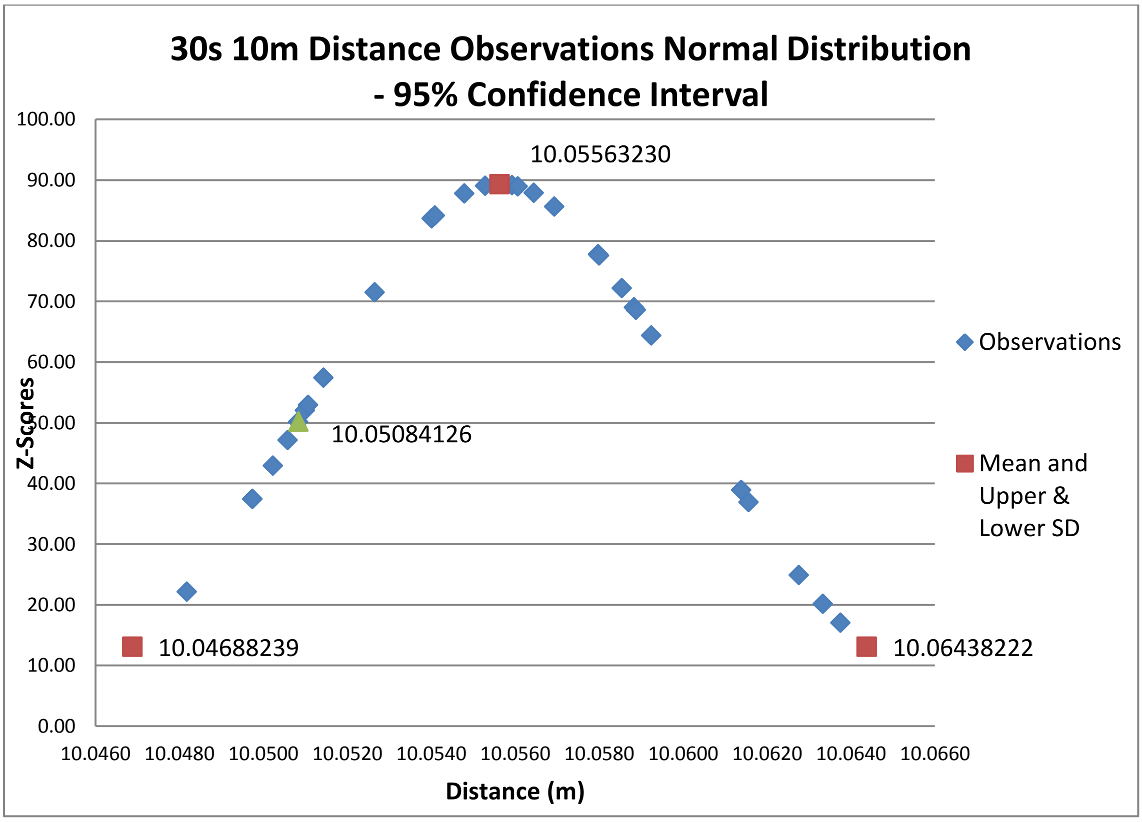
30s 2m Distance Observations Normal Distribution - 95% Confidence Interval
2.10487961
2.102487336
2.096645311
2.11311391
Z-Scores
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
2.0940
2.0960
2.0980
2.1000
2.1020
2.1040
2.1060
2.1080
2.1100
2.1120
2.1140
2.1160
Distance (m)
Observations
Mean and Upper & Lower SD

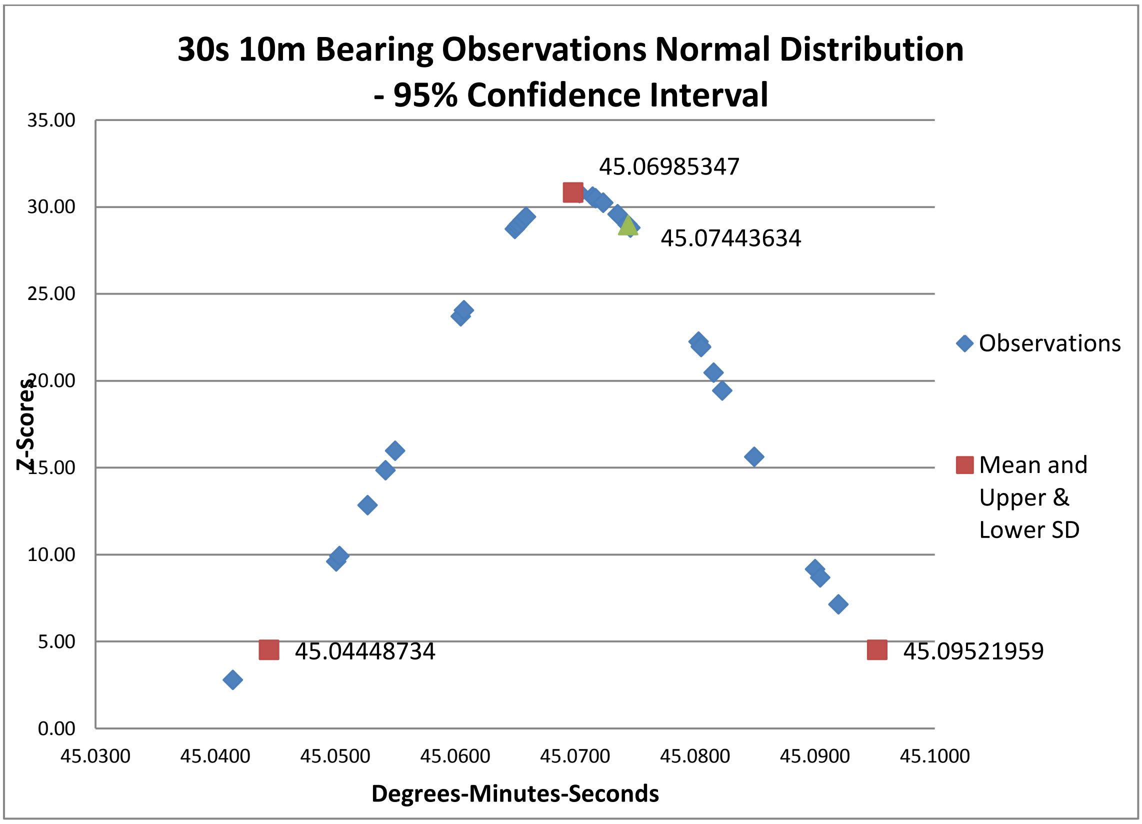


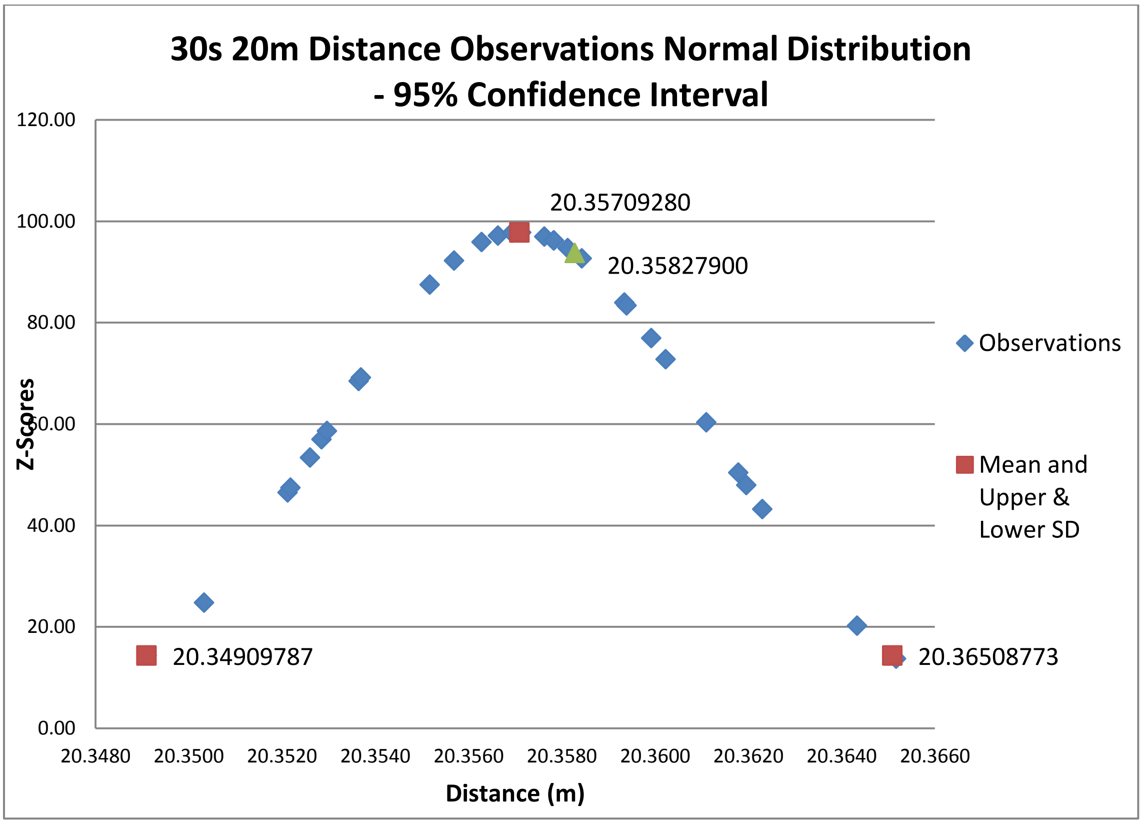
30s 2m Bearing Observations Normal Distribution - 95% Confidence Interval
58.29034681
58.31028878
57.55749293
59.33469047
Z-Scores
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
58.1000
58.1500
58.2000
58.2500
58.3000
58.3500
58.4000
58.4500
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD

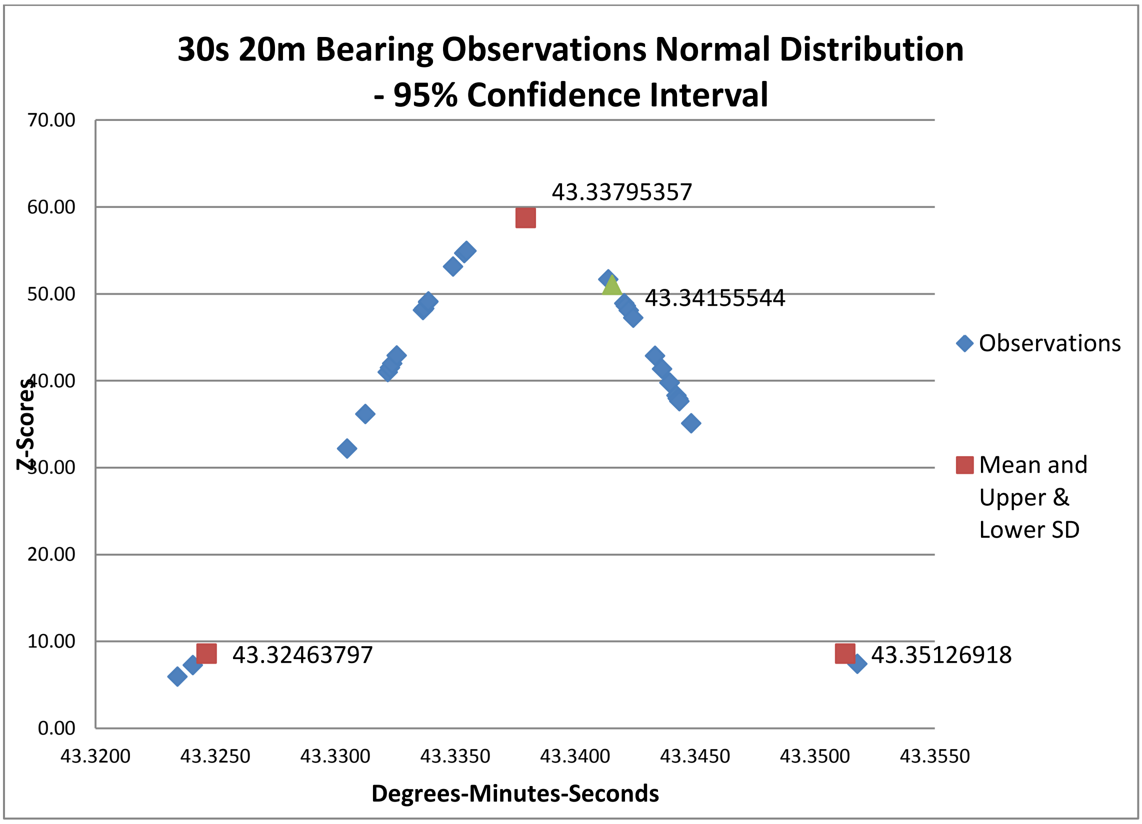

30s 5m Distance Observations Normal Distribution - 95% Confidence Interval
4.94167951
4.93934935
4.932987275
4.950371744
Observations
Mean and Upper & Lower SD
Z-Scores
Distance (m)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
4.9320
4.9340
4.9360
4.9380
4.9400
4.9420
4.9440
4.9460
4.9480
4.9500
4.9520

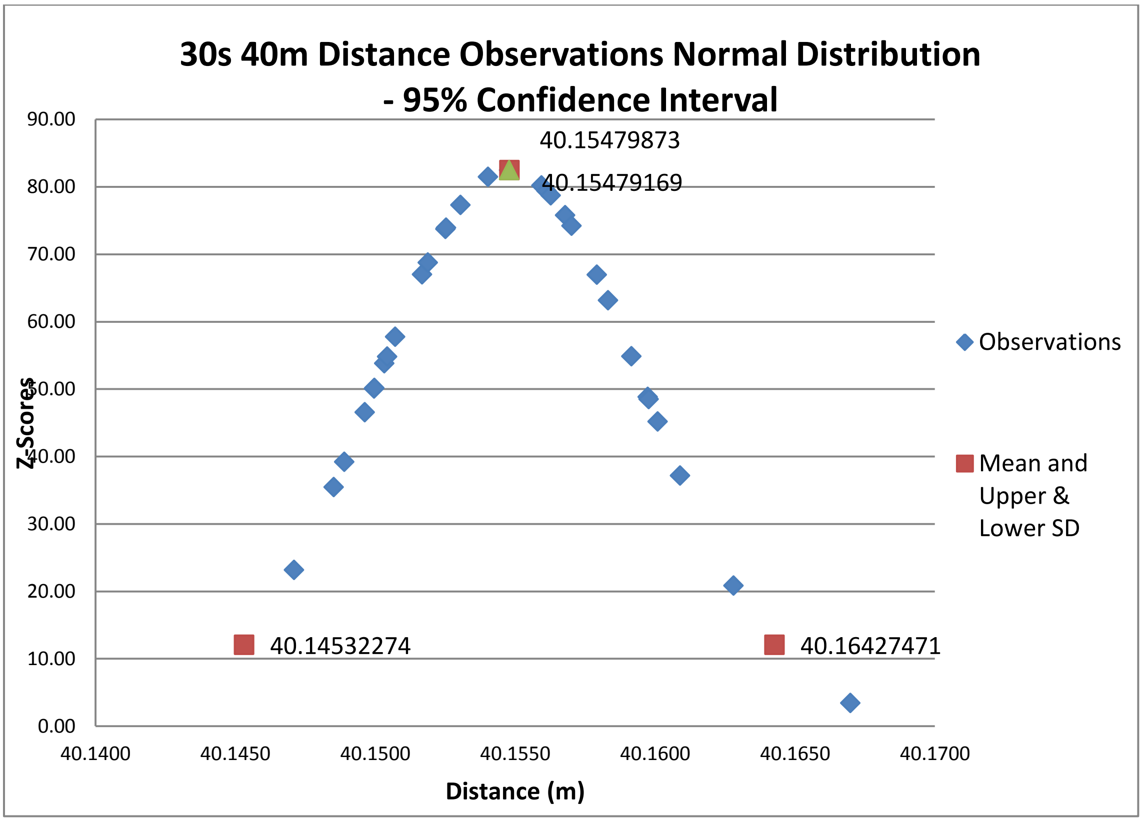

30s 5m Bearing Observations Normal Distribution - 95% Confidence Interval
48.45073642
48.47321012
48.37876179
48.52271104
Observations
Mean and Upper & Lower SD
Z-Scores
Degrees-Minutes-Seconds
0.00
2.00
4.00
6.00
8.00
10.00
12.00
48.3600
48.3800
48.4000
48.4200
48.4400
48.4600
48.4800
48.5000
48.5200
48.5400

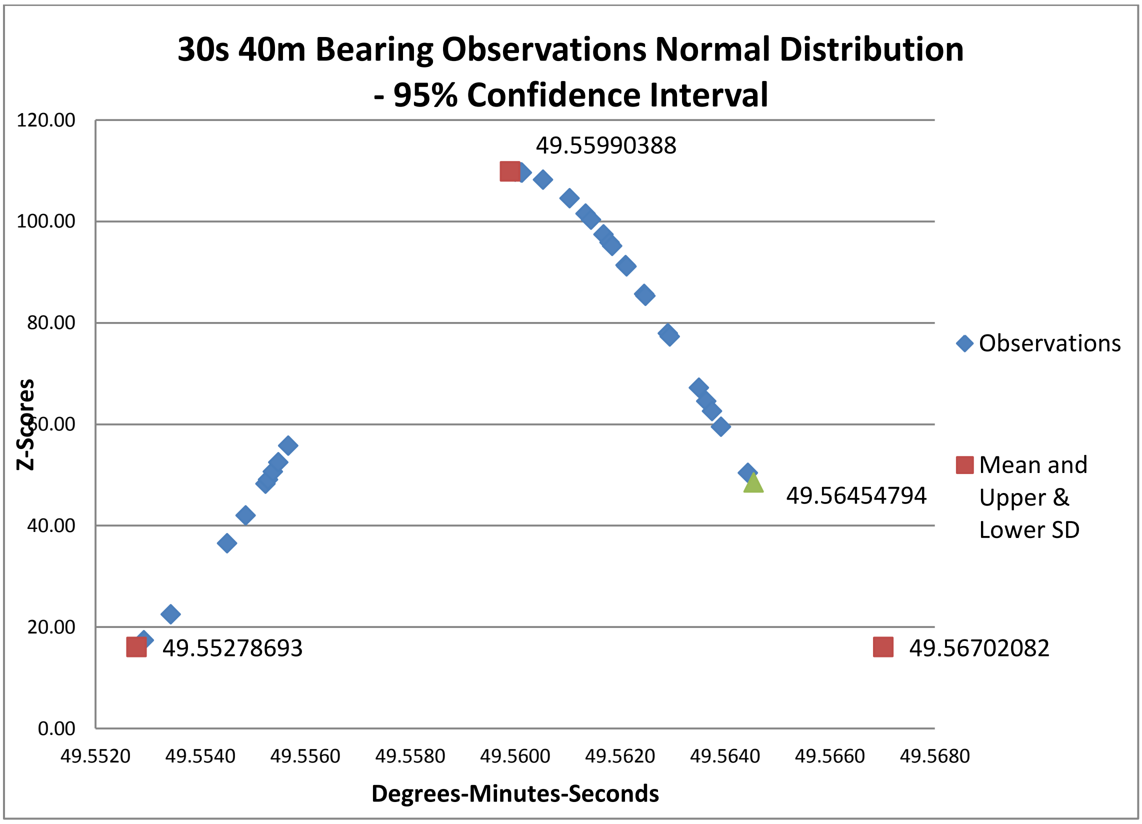

30s 10m Distance Observations Normal Distribution - 95% Confidence Interval
10.05563230
10.05084126
10.04688239
10.06438222
Z-Scores
Distance (m)
Observations
Mean and Upper & Lower SD
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
10.0460
10.0480
10.0500
10.0520
10.0540
10.0560
10.0580
10.0600
10.0620
10.0640
10.0660

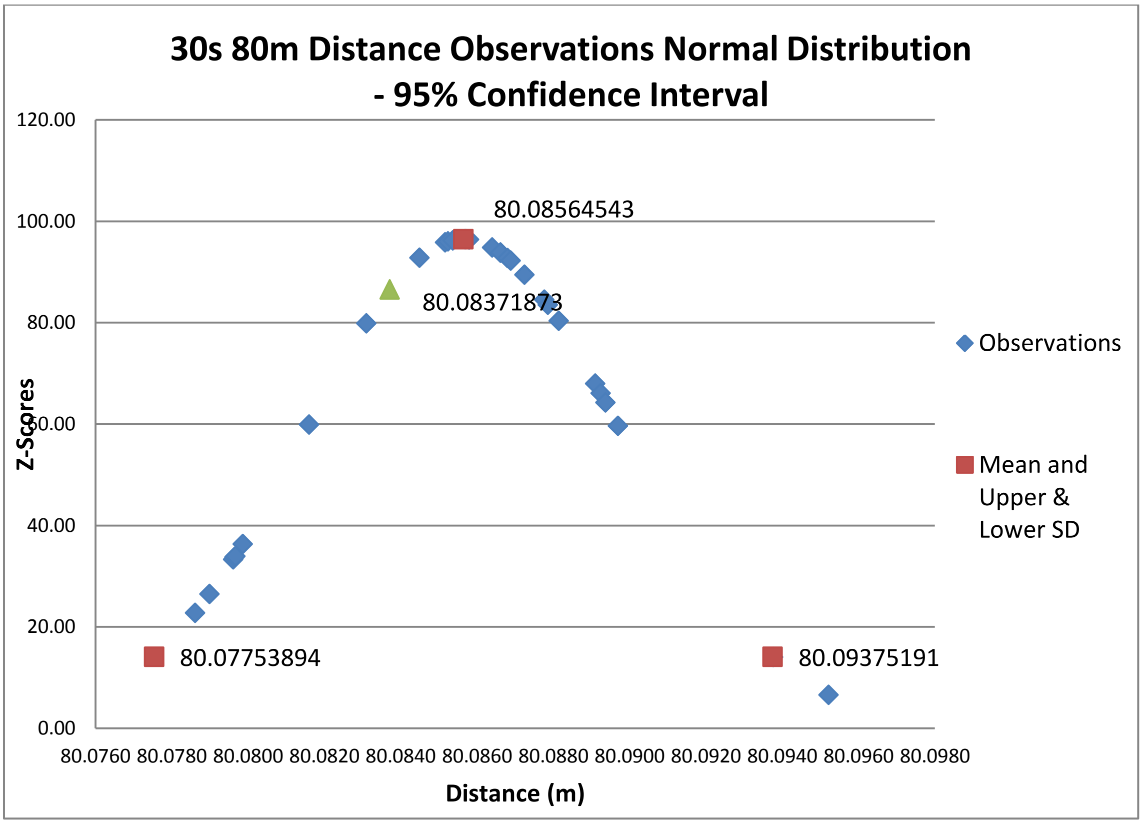

30s 10m Bearing Observations Normal Distribution - 95% Confidence Interval
45.06985347
45.07443634
45.04448734
45.09521959
Z-Scores
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
45.0300
45.0400
45.0500
45.0600
45.0700
45.0800
45.0900
45.1000

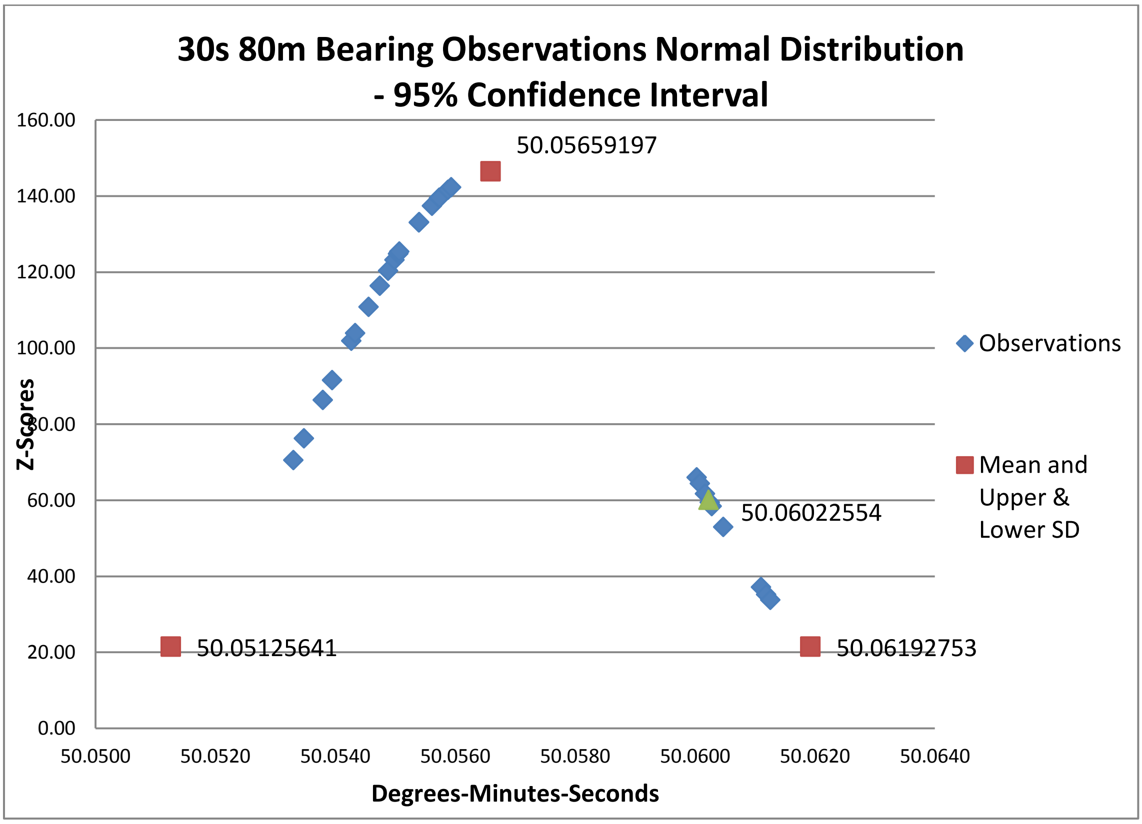

30s 20m Distance Observations Normal Distribution - 95% Confidence Interval
Z-Scores
Distance (m)
20.35709280
20.35827900
20.34909787
20.36508773
Observations
Mean and Upper & Lower SD
120.00
100.00
80.00
60.00
40.00
20.00
0.00
20.3480
20.3500
20.3520
20.3540
20.3560
20.3580
20.3600
20.3620
20.3640
20.3660

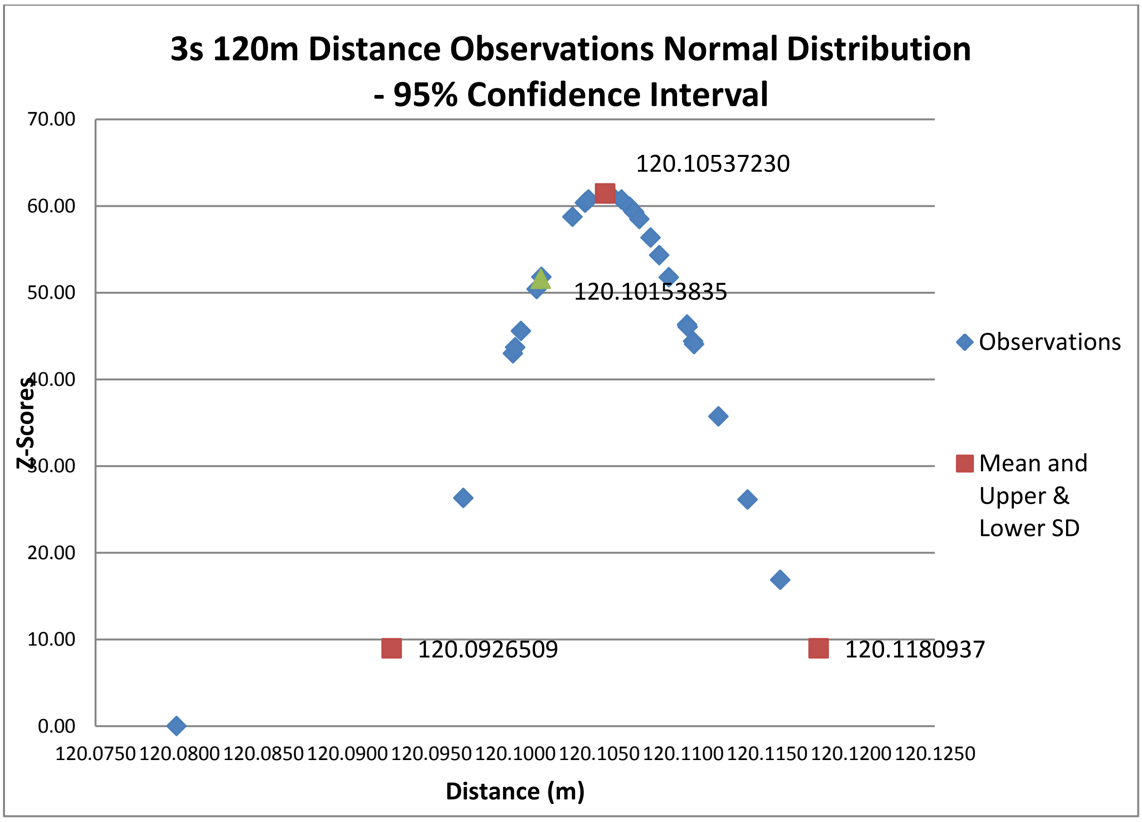

30s 20m Bearing Observations Normal Distribution - 95% Confidence Interval
Z-Scores
Degrees-Minutes-Seconds
43.33795357
43.34155544
43.32463797
43.35126918
Observations
Mean and Upper & Lower SD
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
43.3200
43.3250
43.3300
43.3350
43.3400
43.3450
43.3500
43.3550

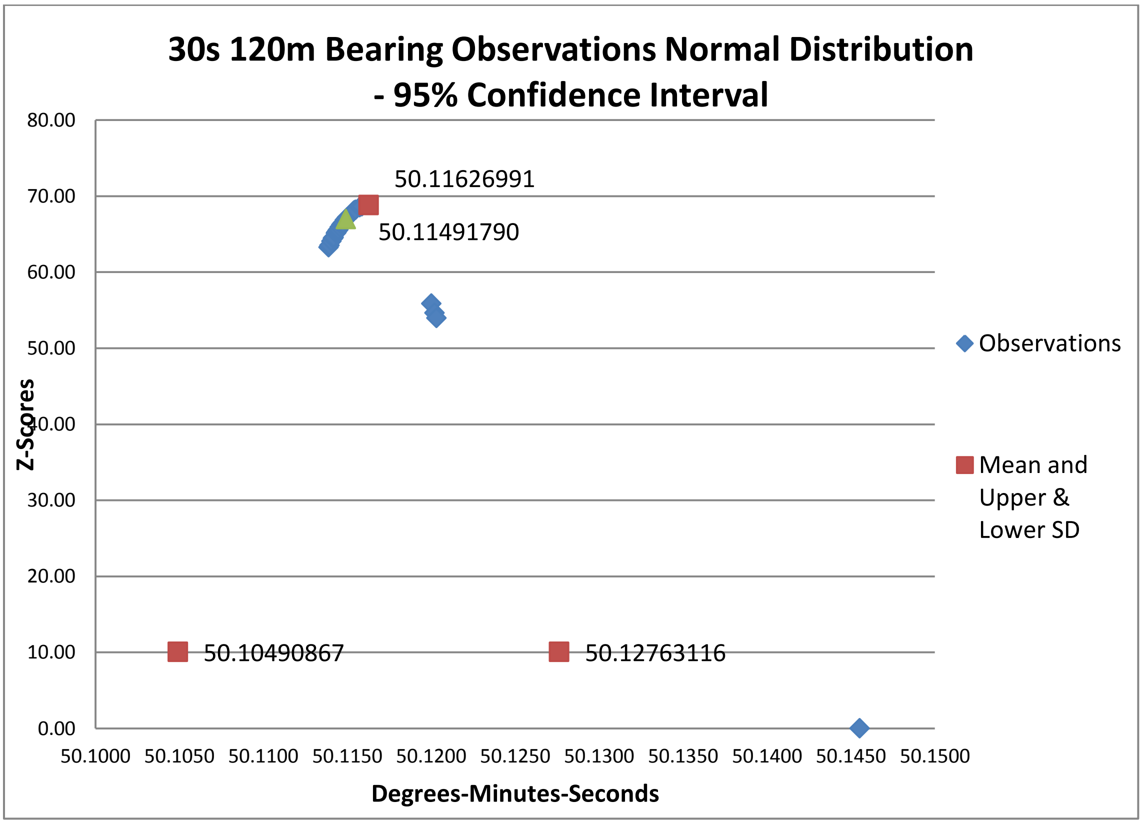

30s 40m Distance Observations Normal Distribution - 95% Confidence Interval
40.15479873
40.15479169
40.14532274
40.16427471
Z-Scores
Distance (m)
Observations
Mean and Upper & Lower SD

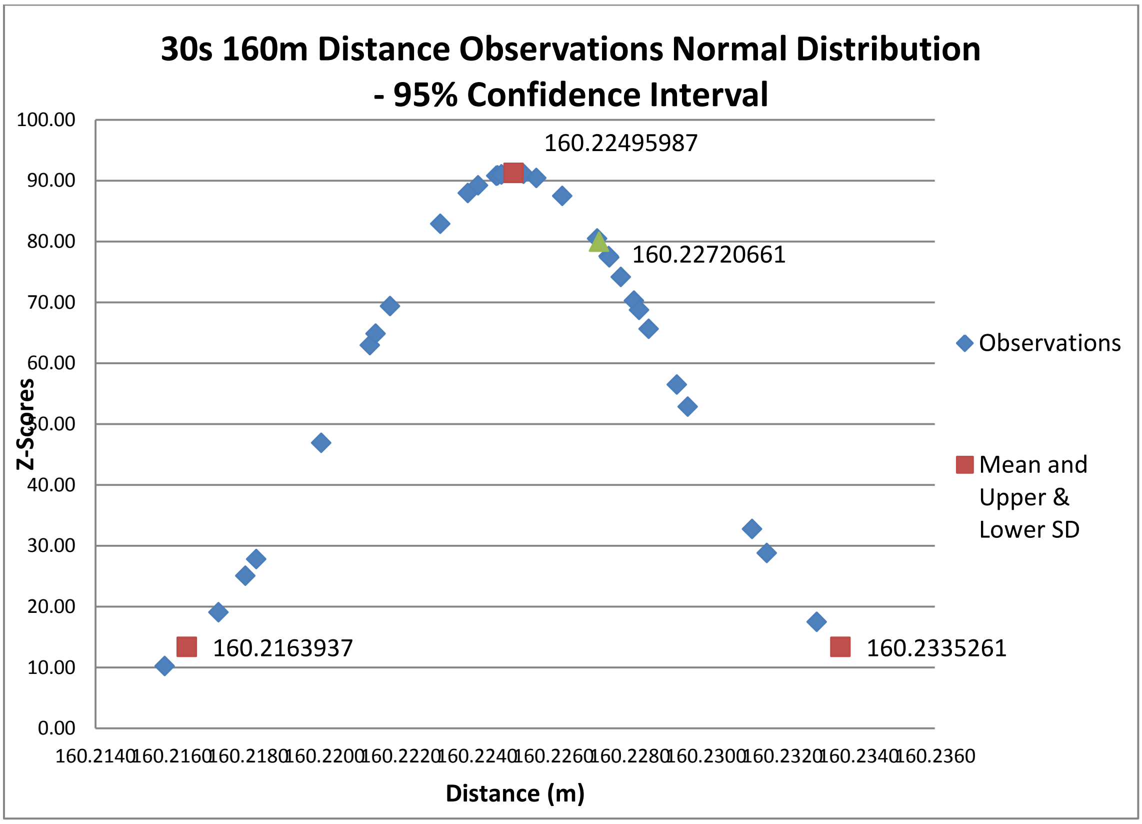

30s 40m Bearing Observations Normal Distribution - 95% Confidence Interval
49.55990388
49.56454794
49.55278693
49.56702082
Z-Scores
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD

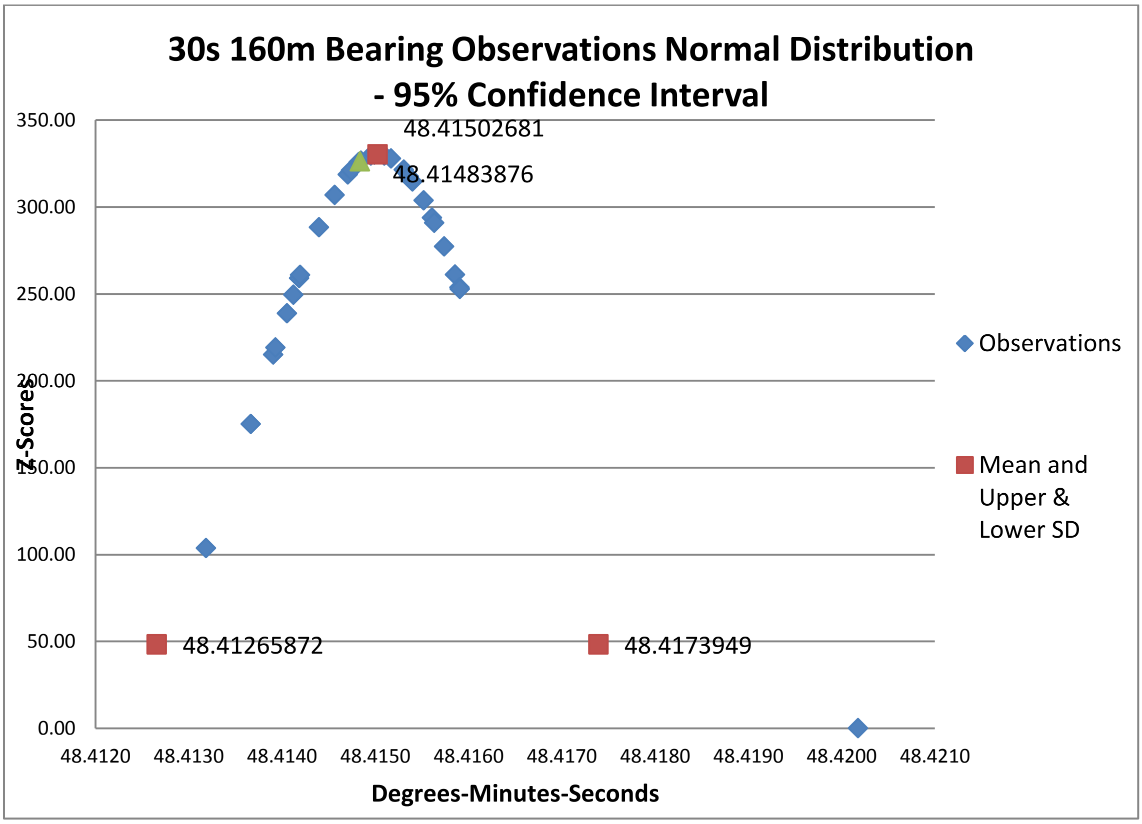

30s 80m Distance Observations Normal Distribution - 95% Confidence Interval
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Z-Scores
80.08564543
80.08371873
80.07753894
80.09375191
80.0760 80.0780 80.0800 80.0820 80.0840 80.0860 80.0880 80.0900 80.0920 80.0940 80.0960 80.0980
Distance (m)
Observations
Mean and Upper & Lower SD

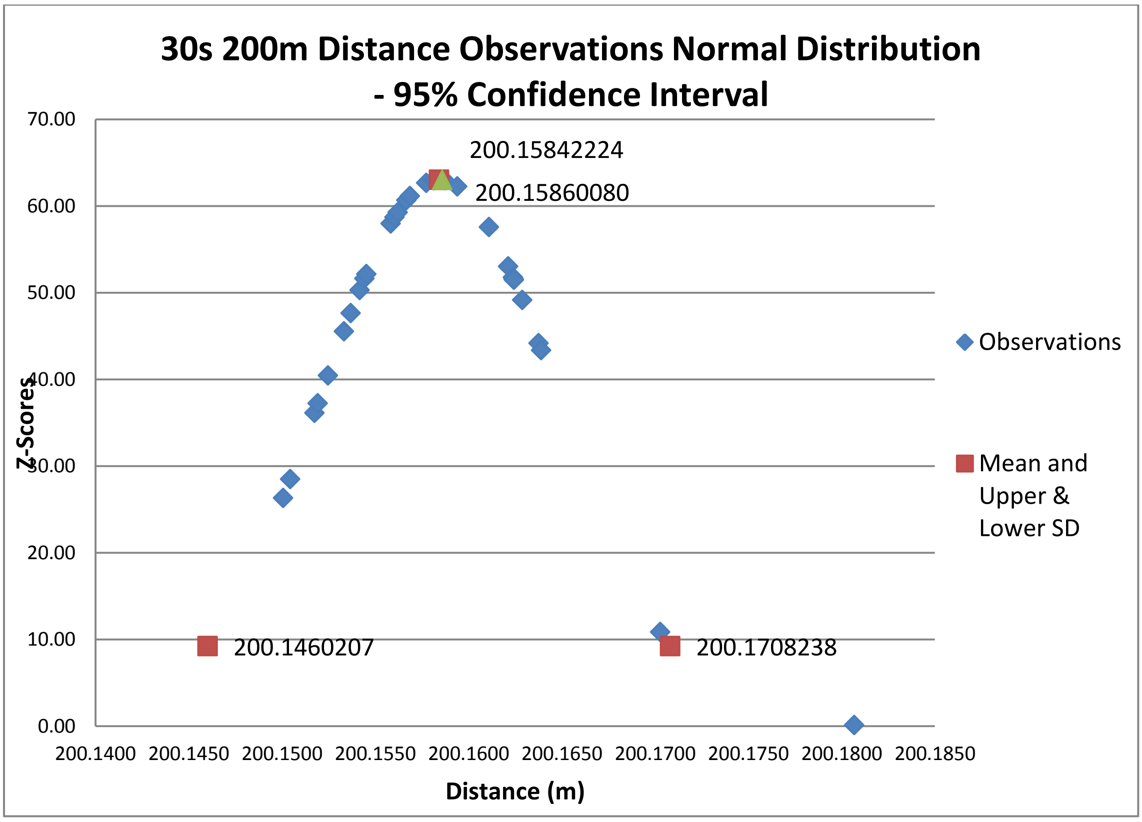

30s 80m Bearing Observations Normal Distribution - 95% Confidence Interval
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Z-Scores
50.05659197
50.06022554
50.05125641
50.06192753
50.0500 50.0520 50.0540 50.0560 50.0580 50.0600 50.0620 50.0640
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD

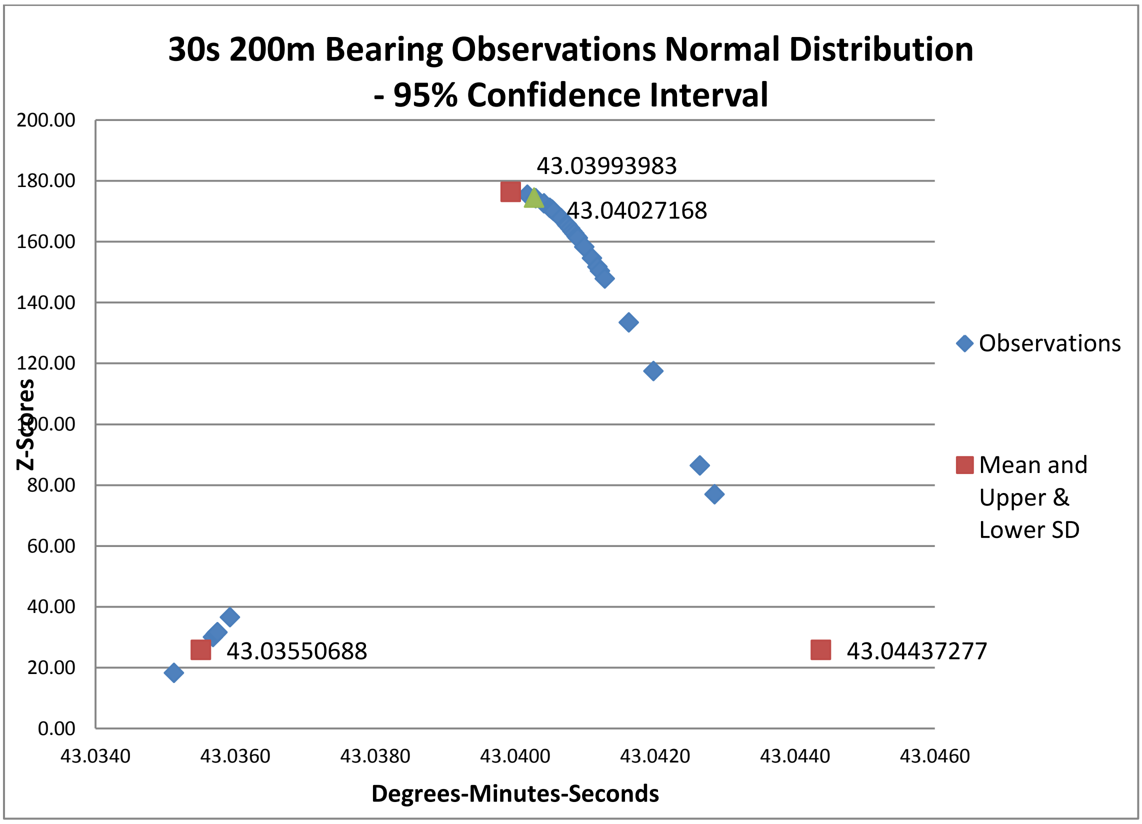

3s 120m Distance Observations Normal Distribution - 95% Confidence Interval
120.10537230
120.10153835
120.0926509
120.1180937
Z-Scores
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
120.0750 120.0800 120.0850 120.0900 120.0950 120.1000 120.1050 120.1100 120.1150 120.1200 120.1250
Distance (m)
Observations
Mean and Upper & Lower SD

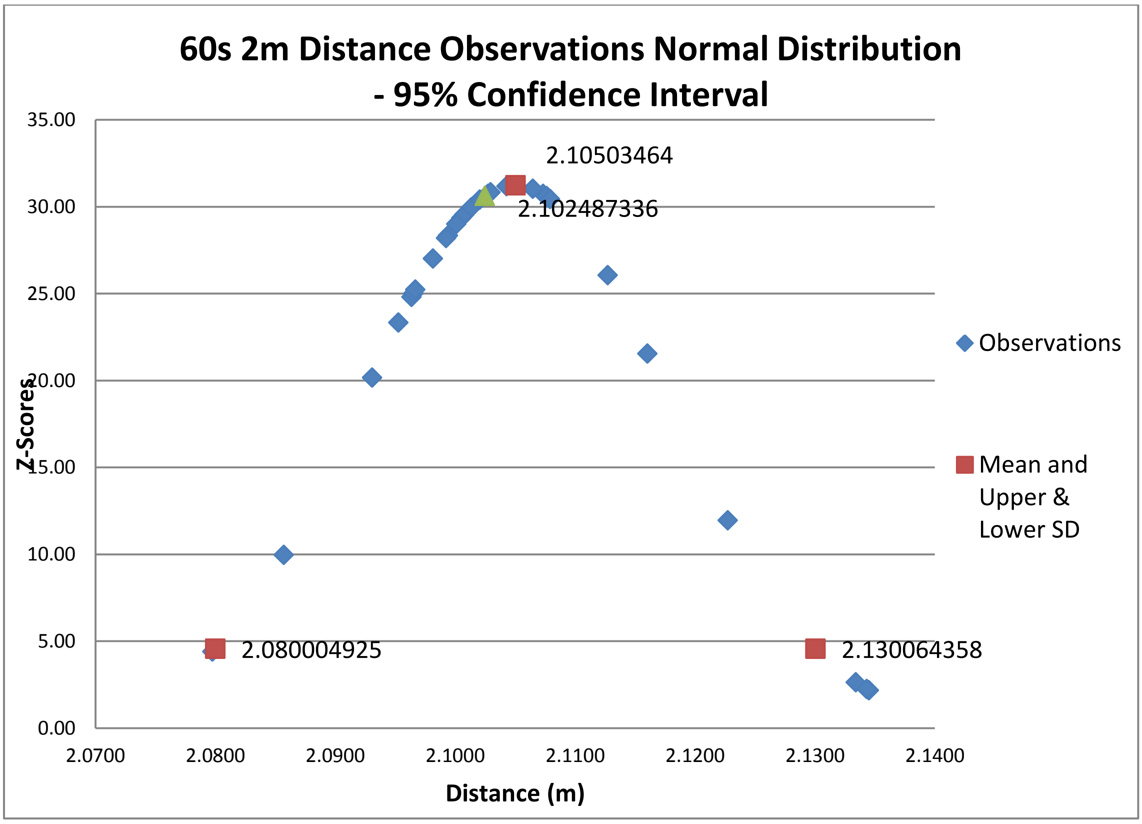

30s 120m Bearing Observations Normal Distribution - 95% Confidence Interval
50.11626991
50.11491790
50.10490867
50.12763116
Z-Scores
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
50.1000 50.1050 50.1100 50.1150 50.1200 50.1250 50.1300 50.1350 50.1400 50.1450 50.1500
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD

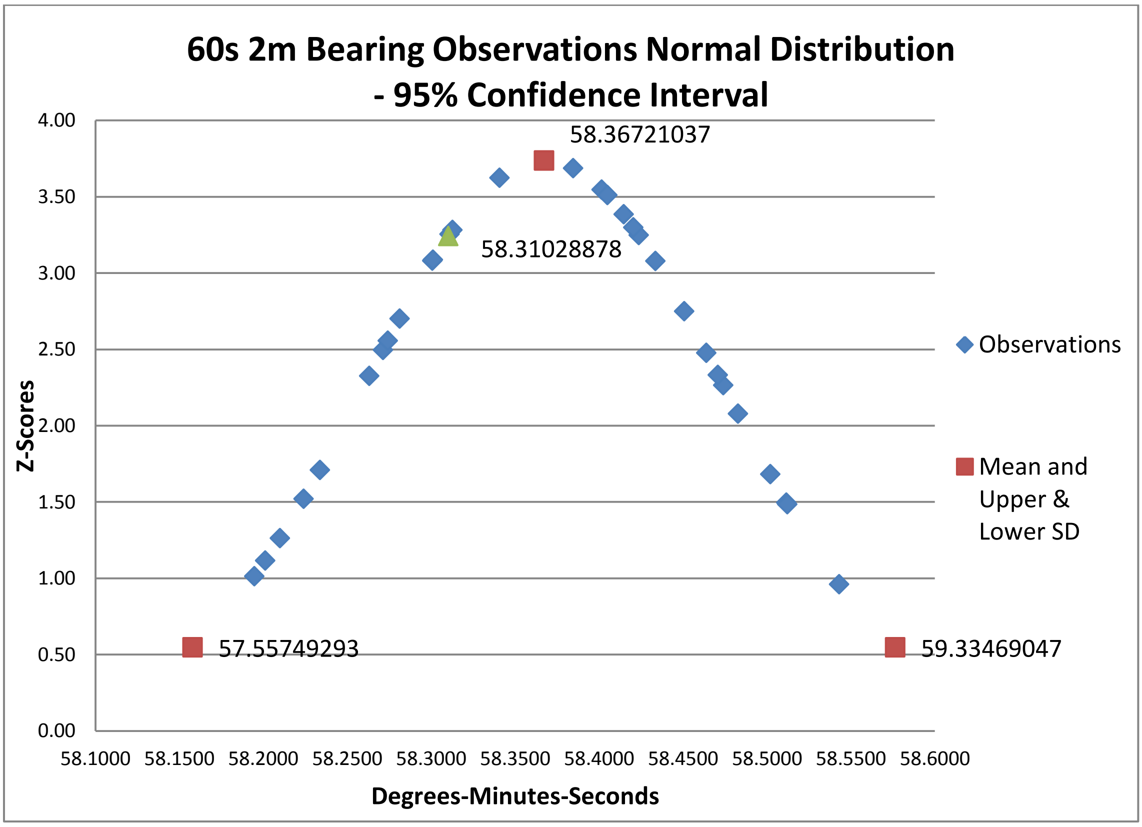

30s 160m Distance Observations Normal Distribution - 95% Confidence Interval
160.22495987
160.22720661
160.2163937
160.2335261
Observations
Mean and Upper & Lower SD
Z-Scores
Distance (m)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
160.2140 160.2160 160.2180 160.2200 160.2220 160.2240 160.2260 160.2280 160.2300 160.2320 160.2340 160.2360

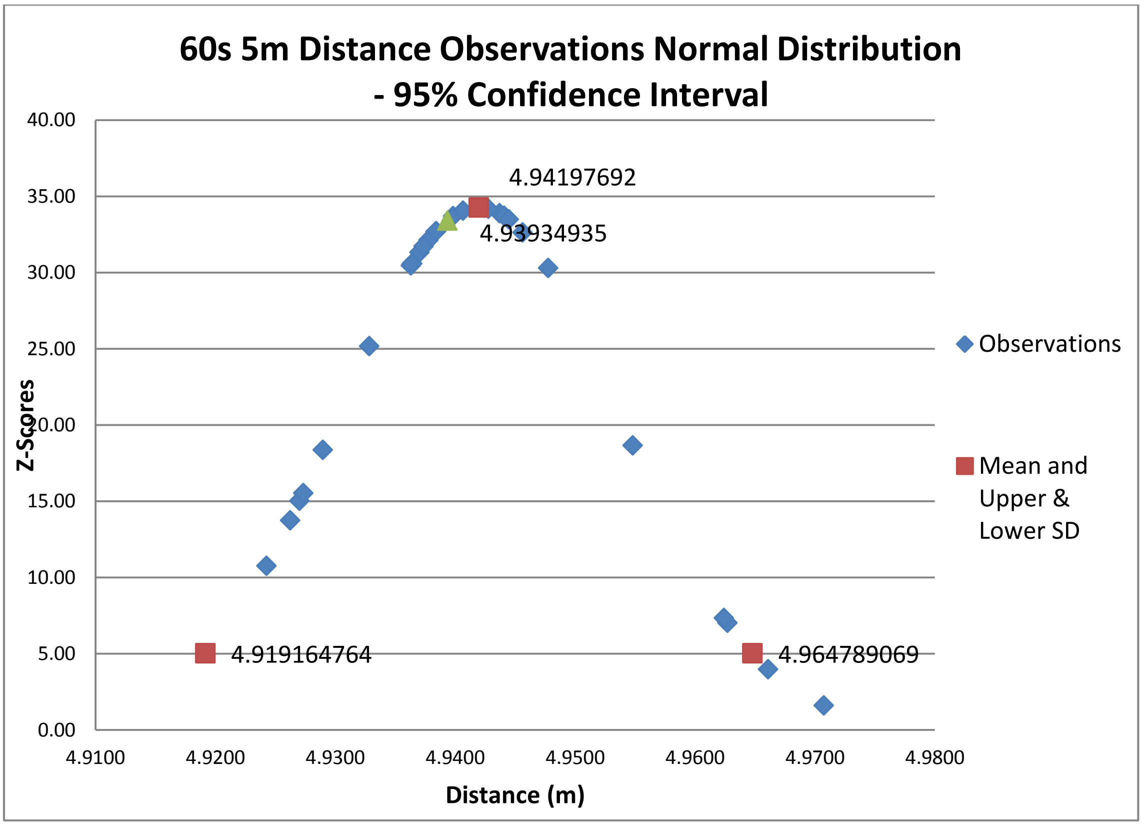

30s 160m Bearing Observations Normal Distribution - 95% Confidence Interval
48.41502681
48.41483876
48.41265872
48.4173949
Observations
Mean and Upper & Lower SD
Z-Scores
Degrees-Minutes-Seconds
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
48.4120 48.4130 48.4140 48.4150 48.4160 48.4170 48.4180 48.4190 48.4200 48.4210


30s 200m Distance Observations Normal Distribution - 95% Confidence Interval
200.15842224
200.15860080
200.1460207
200.1708238
Z-Scores
Distance (m)
Observations
Mean and Upper & Lower SD

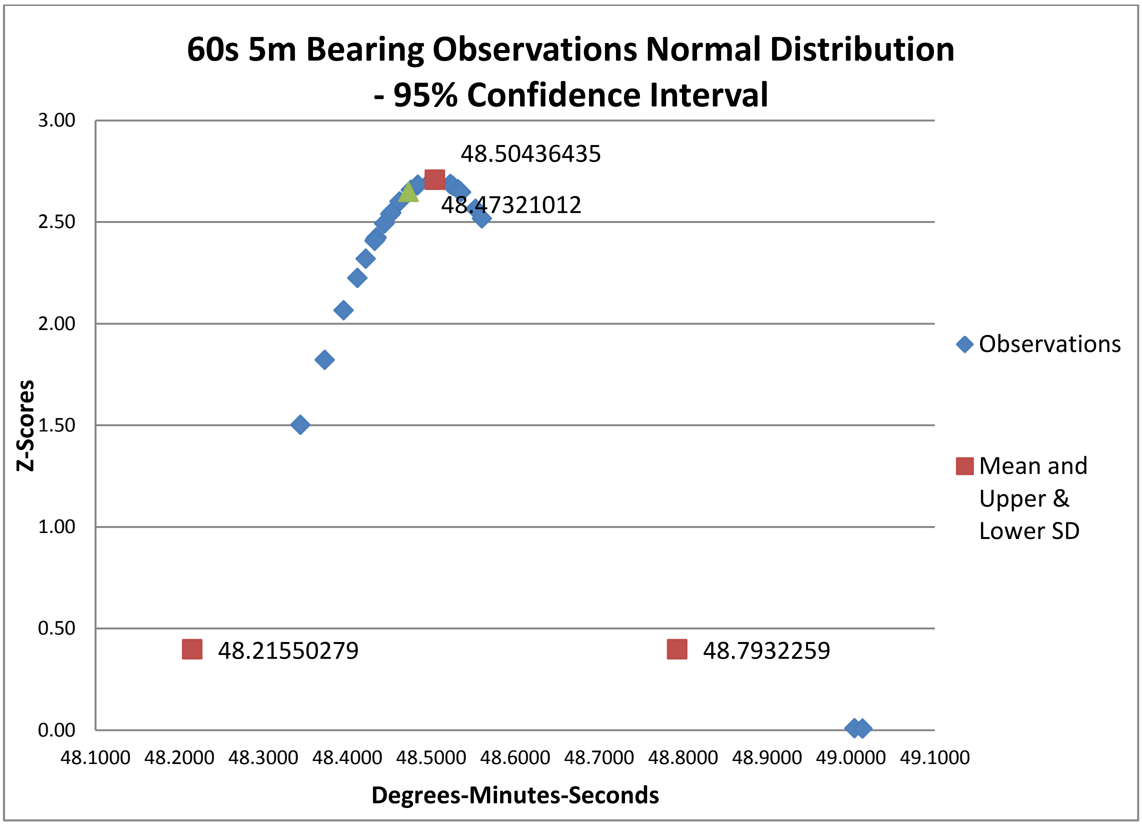

30s 200m Bearing Observations Normal Distribution - 95% Confidence Interval
43.03993983
43.04027168
43.03550688
43.04437277
Z-Scores
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD


60s 2m Distance Observations Normal Distribution - 95% Confidence Interval
2.10503464
2.102487336
2.080004925
2.130064358
Z-Scores
Distance (m)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
2.0700
2.0800
2.0900
2.1000
2.1100
2.1200
2.1300
2.1400
Observations
Mean and Upper & Lower SD

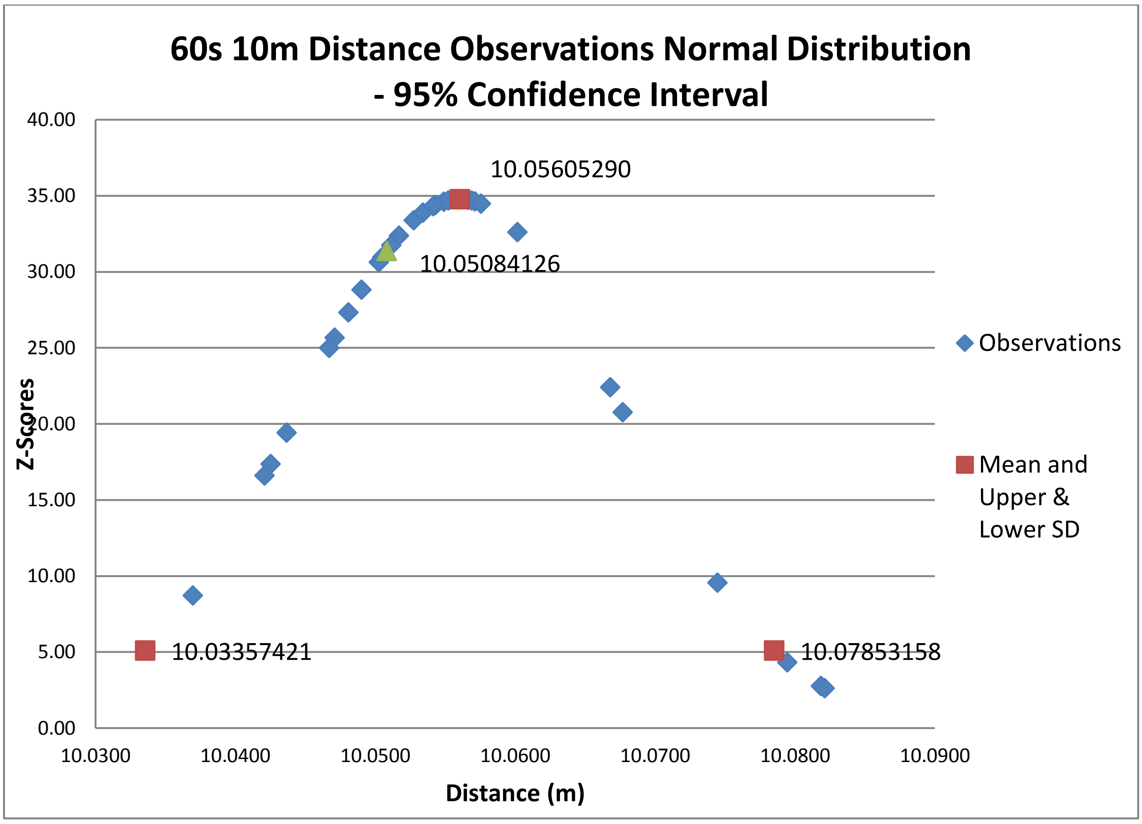

60s 2m Bearing Observations Normal Distribution - 95% Confidence Interval
58.36721037
58.31028878
57.55749293
59.33469047
Z-Scores
Degrees-Minutes-Seconds
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
58.1000
58.1500
58.2000
58.2500
58.3000
58.3500
58.4000
58.4500
58.5000
58.5500
58.6000
Observations
Mean and Upper & Lower SD

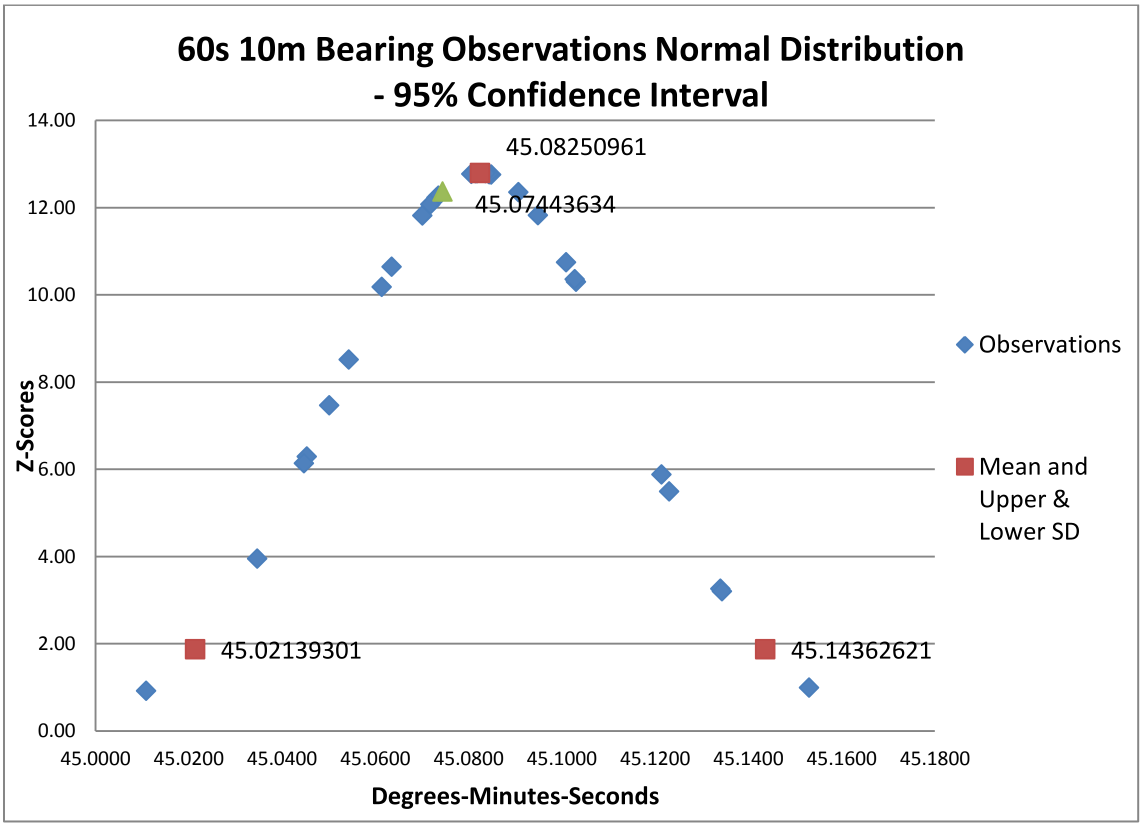


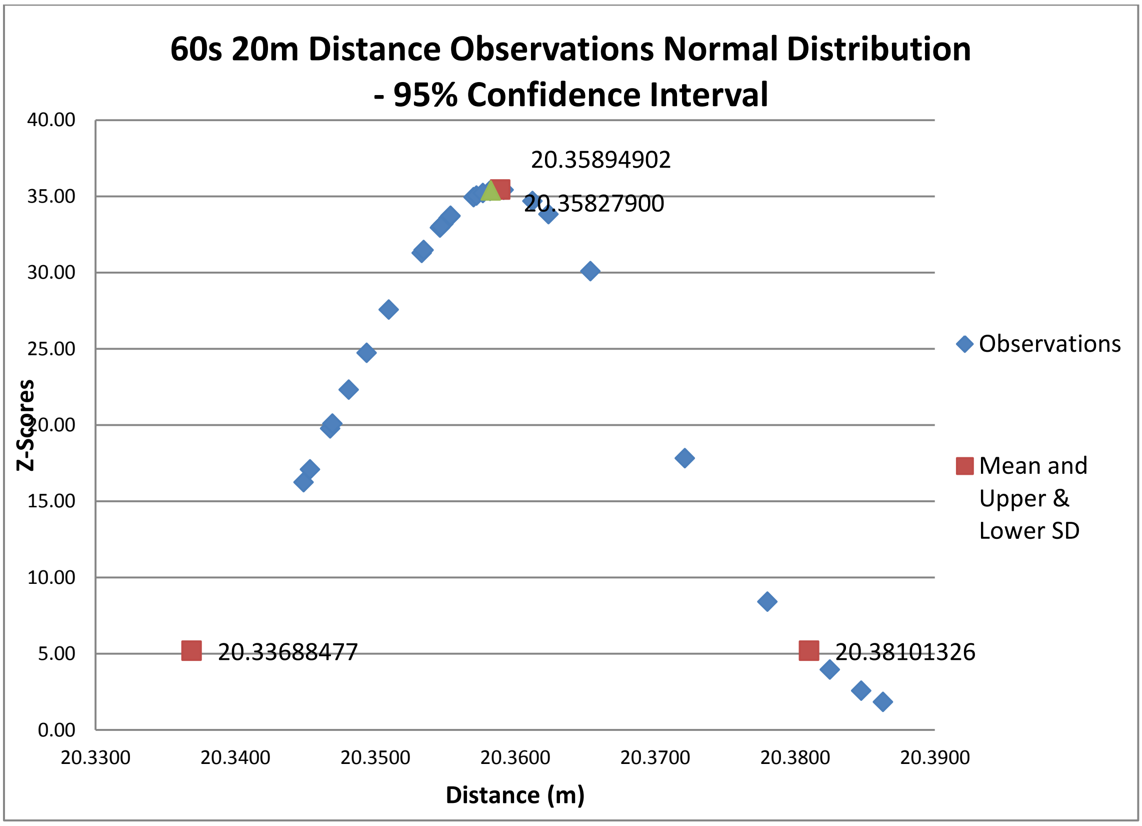
60s 5m Distance Observations Normal Distribution - 95% Confidence Interval
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Z-Scores
4.94197692
4.93934935
4.919164764
4.964789069
4.9100
4.9200
4.9300
4.9400
4.9500
4.9600
4.9700
4.9800
Distance (m)
Observations
Mean and Upper & Lower SD

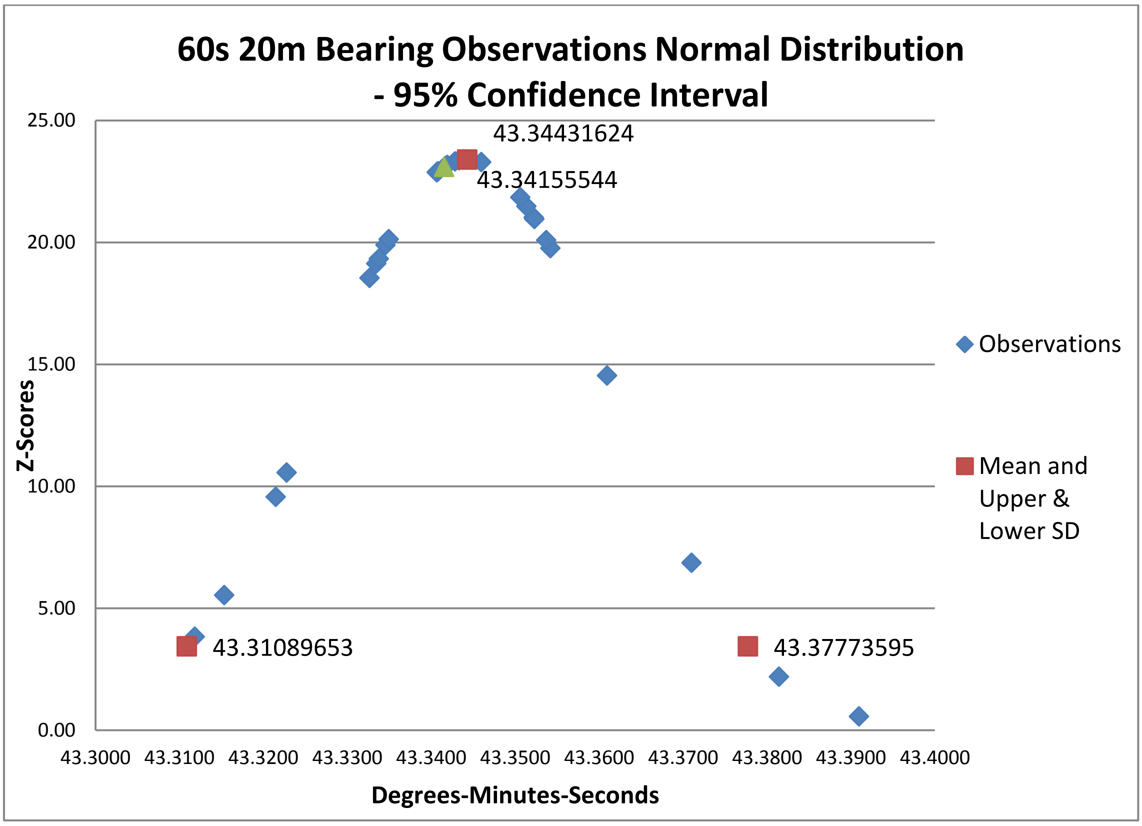


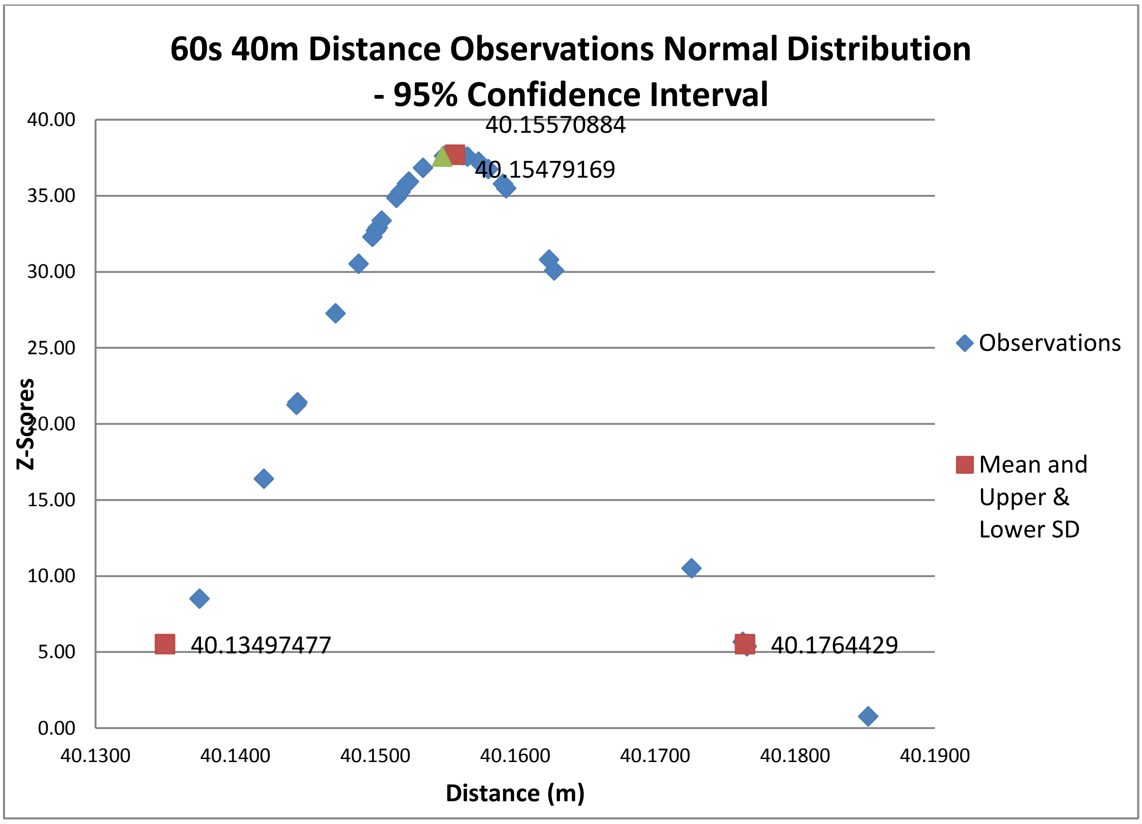
60s 5m Bearing Observations Normal Distribution - 95% Confidence Interval
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Z-Scores
48.50436435
48.47321012
48.21550279
48.7932259
48.1000
48.2000
48.3000
48.4000
48.5000
48.6000
48.7000
48.8000
48.9000
49.0000
49.1000
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD

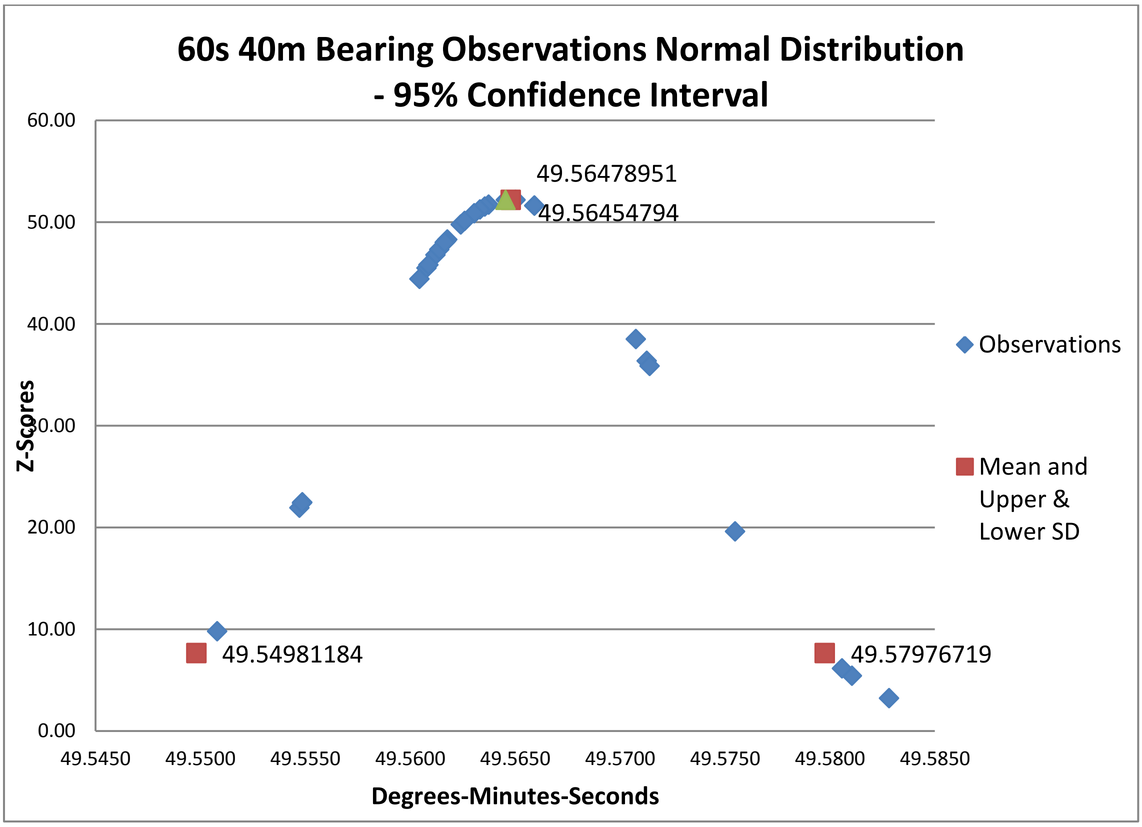

60s 10m Distance Observations Normal Distribution - 95% Confidence Interval
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Z-Scores
10.05605290
10.05084126
10.03357421
10.07853158
10.0300
10.0400
10.0500
10.0600
10.0700
10.0800
10.0900
Distance (m)
Observations
Mean and Upper & Lower SD

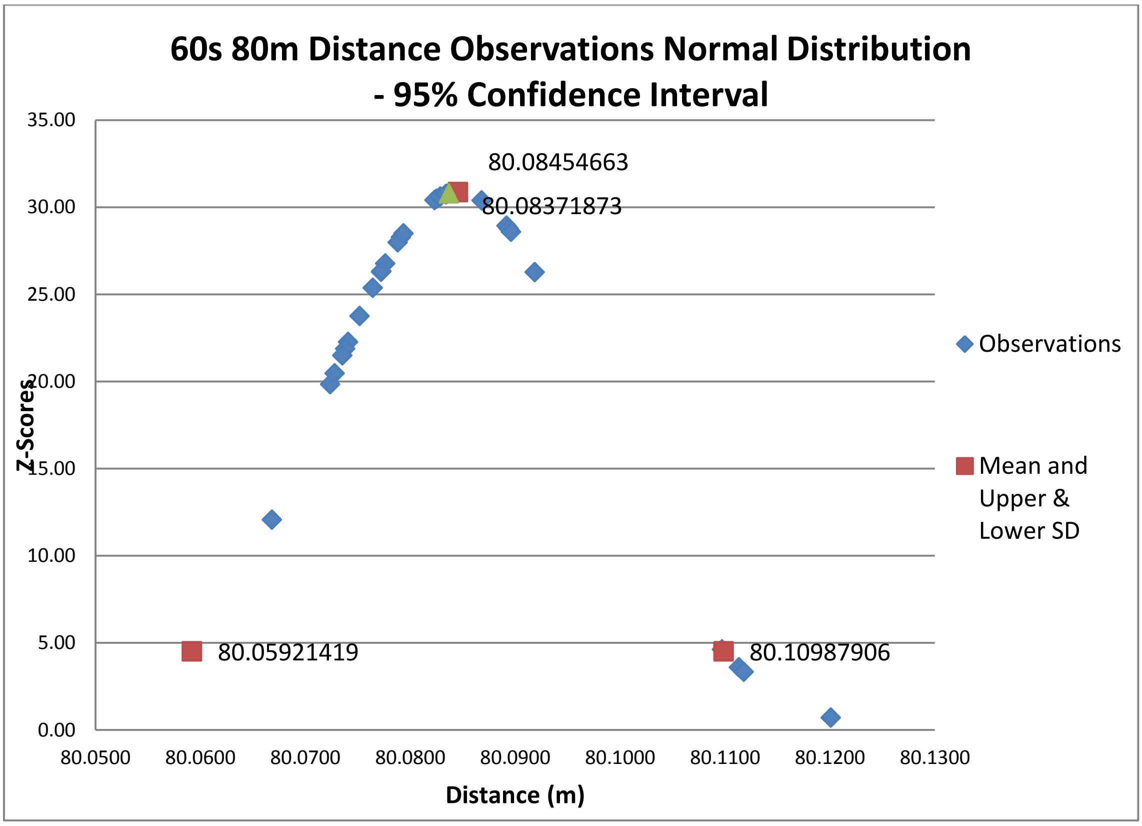

60s 10m Bearing Observations Normal Distribution - 95% Confidence Interval
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Z-Scores
45.08250961
45.07443634
45.02139301
45.14362621
45.0000
45.0200
45.0400
45.0600
45.0800
45.1000
45.1200
45.1400
45.1600
45.1800
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD

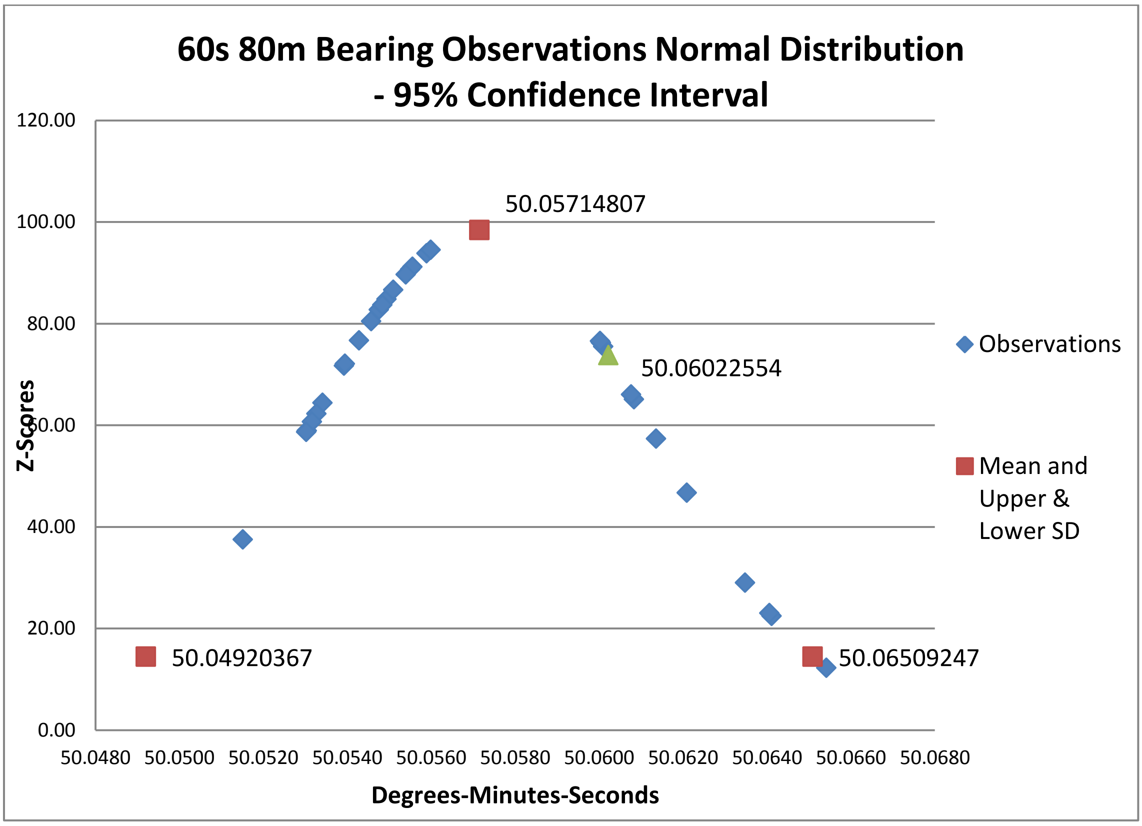

60s 20m Distance Observations Normal Distribution - 95% Confidence Interval
20.35894902
20.35827900
20.33688477
20.38101326
Observations
Mean and Upper & Lower SD
Z-Scores
Distance (m)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
20.3300
20.3400
20.3500
20.3600
20.3700
20.3800
20.3900

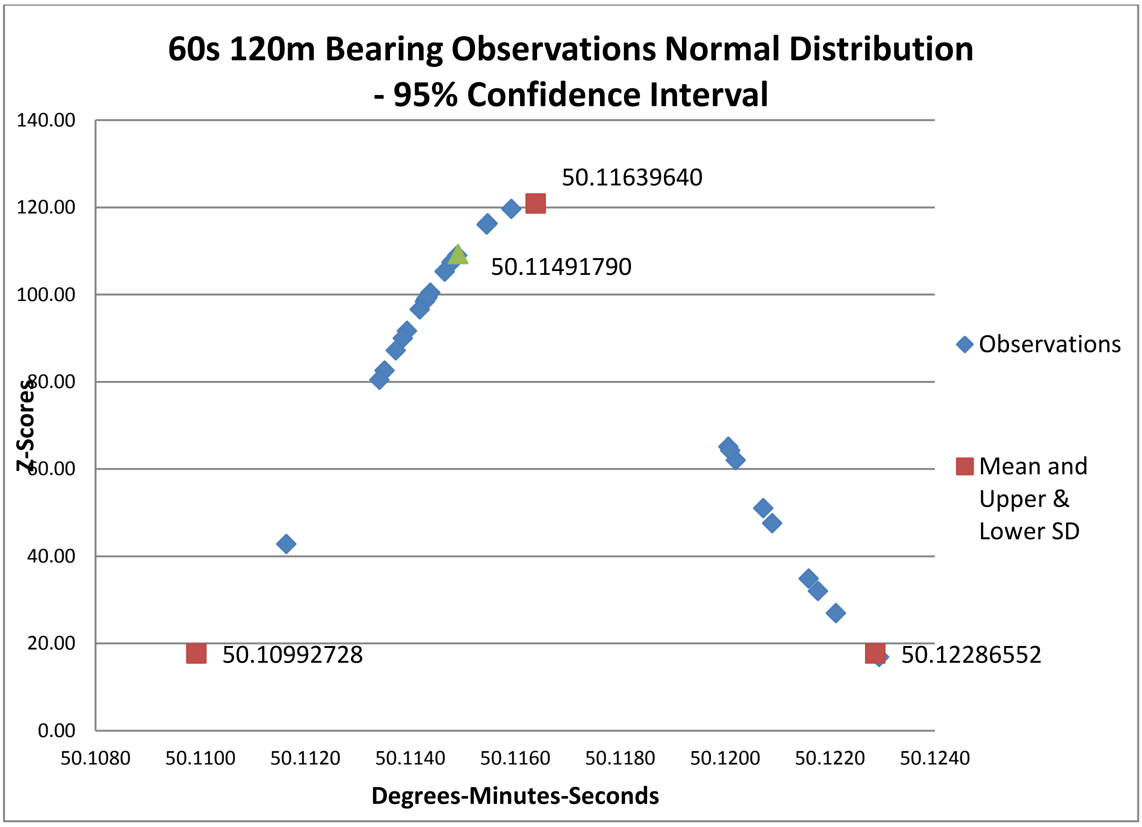

60s 20m Bearing Observations Normal Distribution - 95% Confidence Interval
43.34431624
43.34155544
43.31089653
43.37773595
Observations
Mean and Upper & Lower SD
Z-Scores
Degrees-Minutes-Seconds
25.00
20.00
15.00
10.00
5.00
0.00
43.3000
43.3100
43.3200
43.3300
43.3400
43.3500
43.3600
43.3700
43.3800
43.3900
43.4000


60s 40m Distance Observations Normal Distribution - 95% Confidence Interval
40.15570884
40.15479169
40.13497477
40.1764429
Z-Scores
Distance (m)
Observations
Mean and Upper & Lower SD

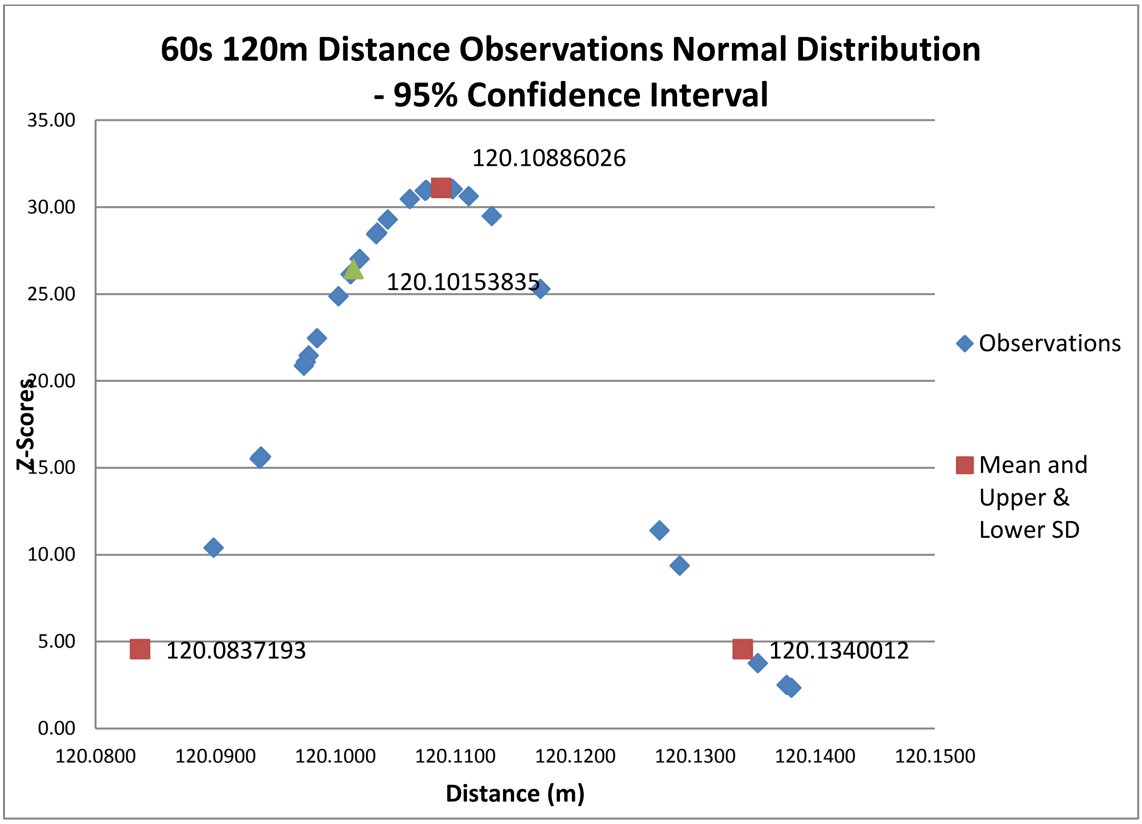

60s 40m Bearing Observations Normal Distribution - 95% Confidence Interval
49.56478951
49.56454794
49.54981184
49.57976719
Z-Scores
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD


60s 80m Distance Observations Normal Distribution - 95% Confidence Interval
80.08454663
80.08371873
80.05921419
80.10987906
Z-Scores
Distance (m)
Observations
Mean and Upper & Lower SD
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
80.0500
80.0600
80.0700
80.0800
80.0900
80.1000
80.1100
80.1200
80.1300

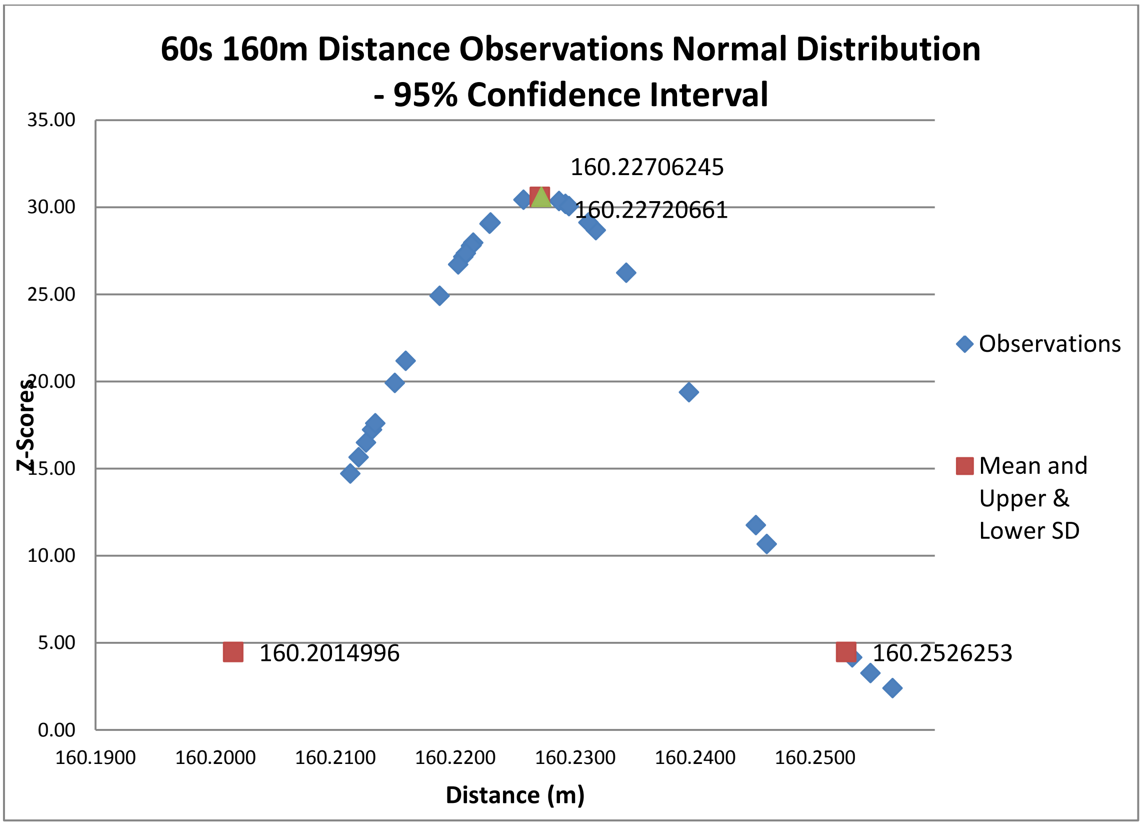

60s 80m Bearing Observations Normal Distribution - 95% Confidence Interval
50.05714807
50.06022554
50.04920367
50.06509247
Z-Scores
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD
120.00
100.00
80.00
60.00
40.00
20.00
0.00
50.0480
50.0500
50.0520
50.0540
50.0560
50.0580
50.0600
50.0620
50.0640
50.0660
50.0680

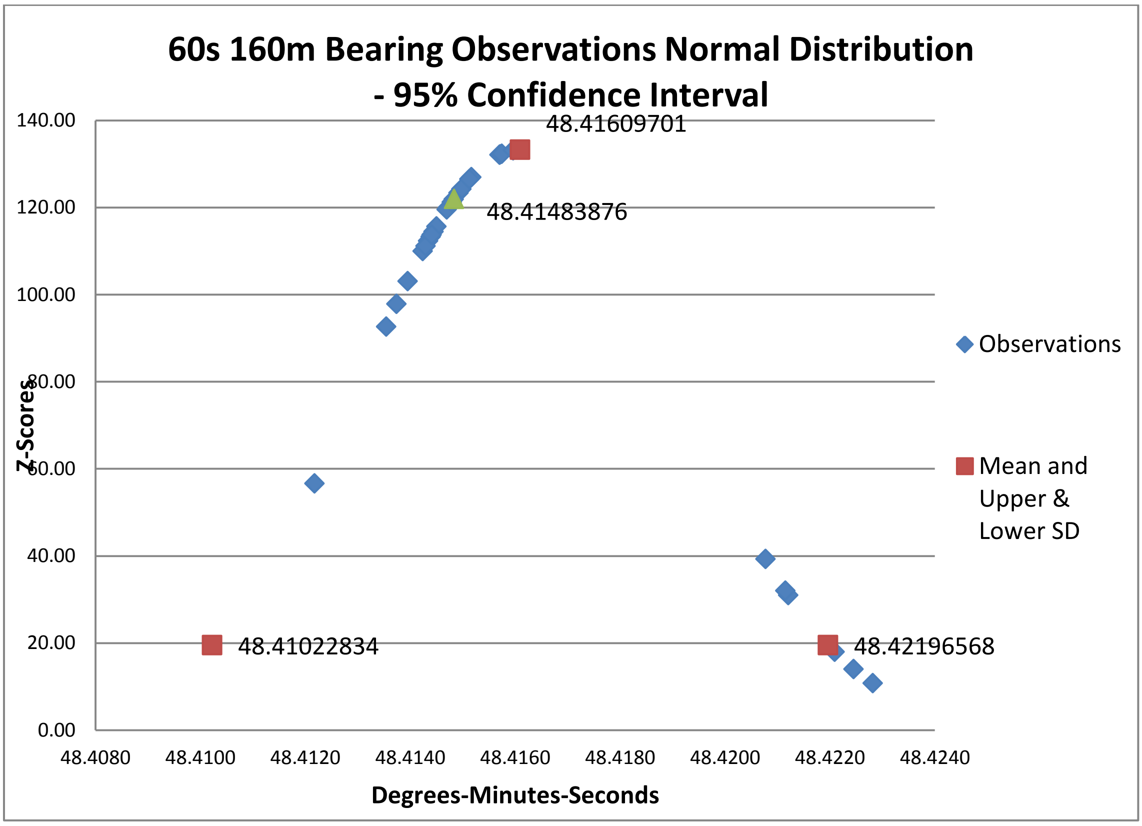


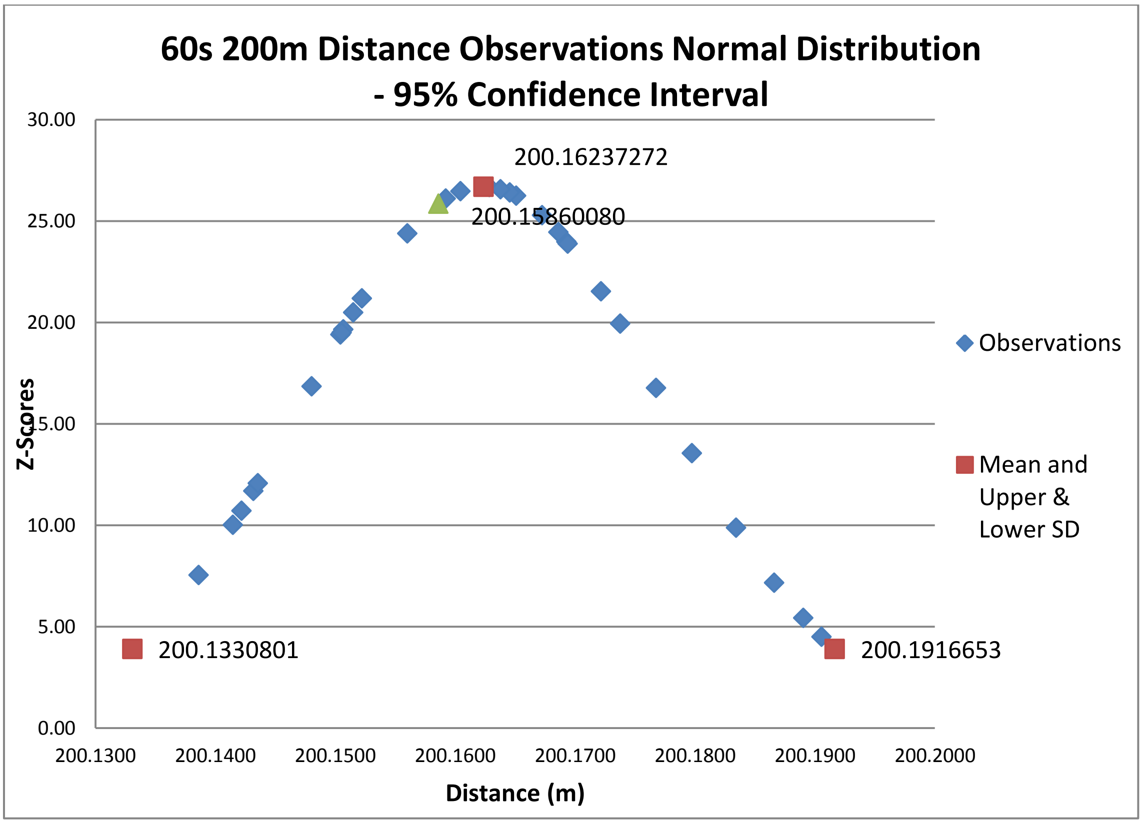
60s 120m Bearing Observations Normal Distribution - 95% Confidence Interval
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Z-Scores
50.11639640
50.11491790
50.10992728
50.12286552
50.1080
50.1100
50.1120
50.1140
50.1160
50.1180
50.1200
50.1220
50.1240
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD



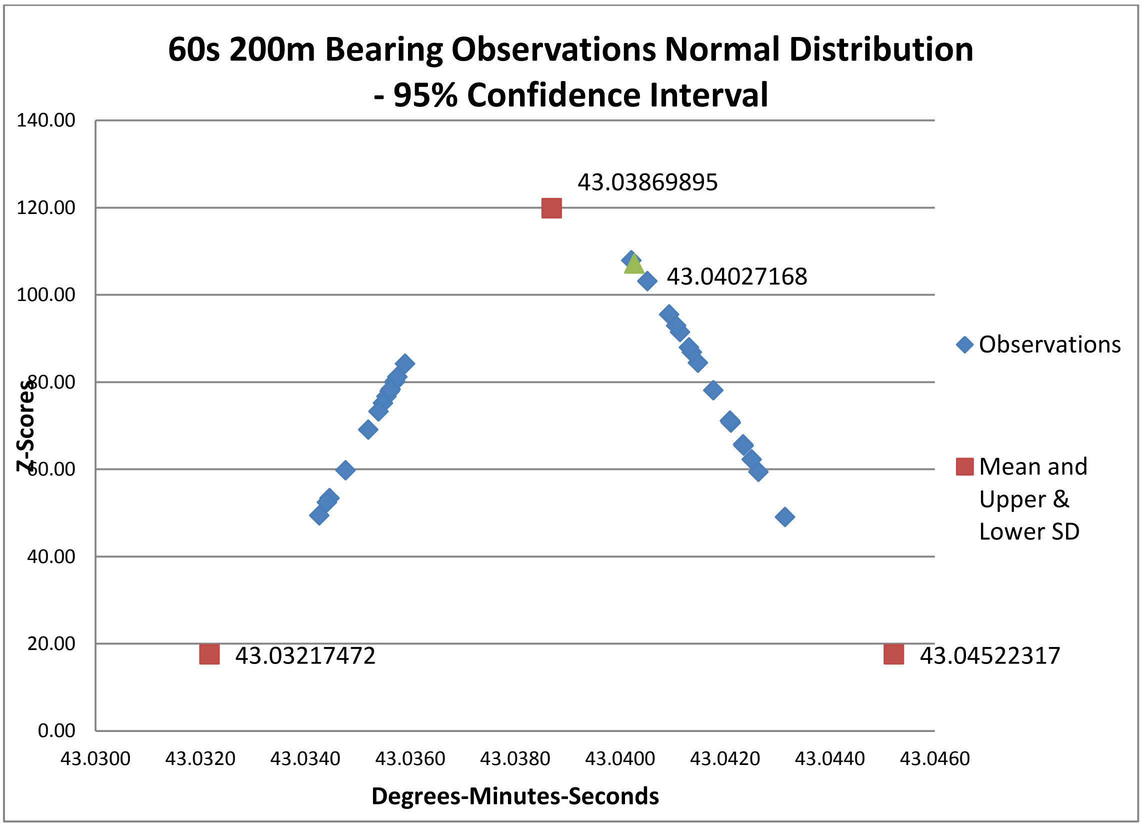
60s 120m Distance Observations Normal Distribution - 95% Confidence Interval
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Z-Scores
120.10886026
120.10153835
120.0837193
120.1340012
120.0800
120.0900
120.1000
120.1100
120.1200
120.1300
120.1400
120.1500
Distance (m)
Observations
Mean and Upper & Lower SD


60s 160m Distance Observations Normal Distribution - 95% Confidence Interval
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Z-Scores
160.1900
160.2000
160.2100
160.2200
160.2300
160.2400
160.2500
Distance (m)
160.22706245
160.22720661
160.2014996
160.2526253
Observations
Mean and Upper & Lower SD

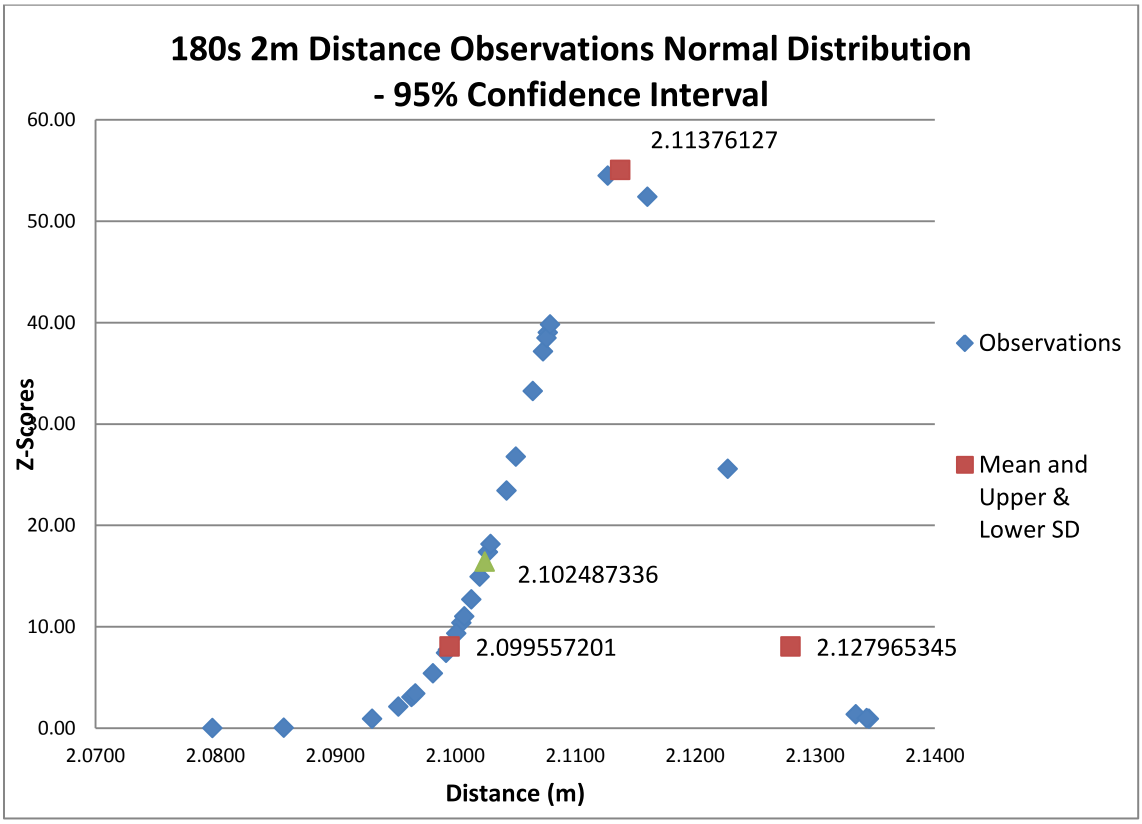

60s 160m Bearing Observations Normal Distribution - 95% Confidence Interval
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Z-Scores
48.4080
48.4100
48.4120
48.4140
48.4160
48.4180
48.4200
48.4220
48.4240
Degrees-Minutes-Seconds
48.41609701
48.41483876
48.41022834
48.42196568
Observations
Mean and Upper & Lower SD

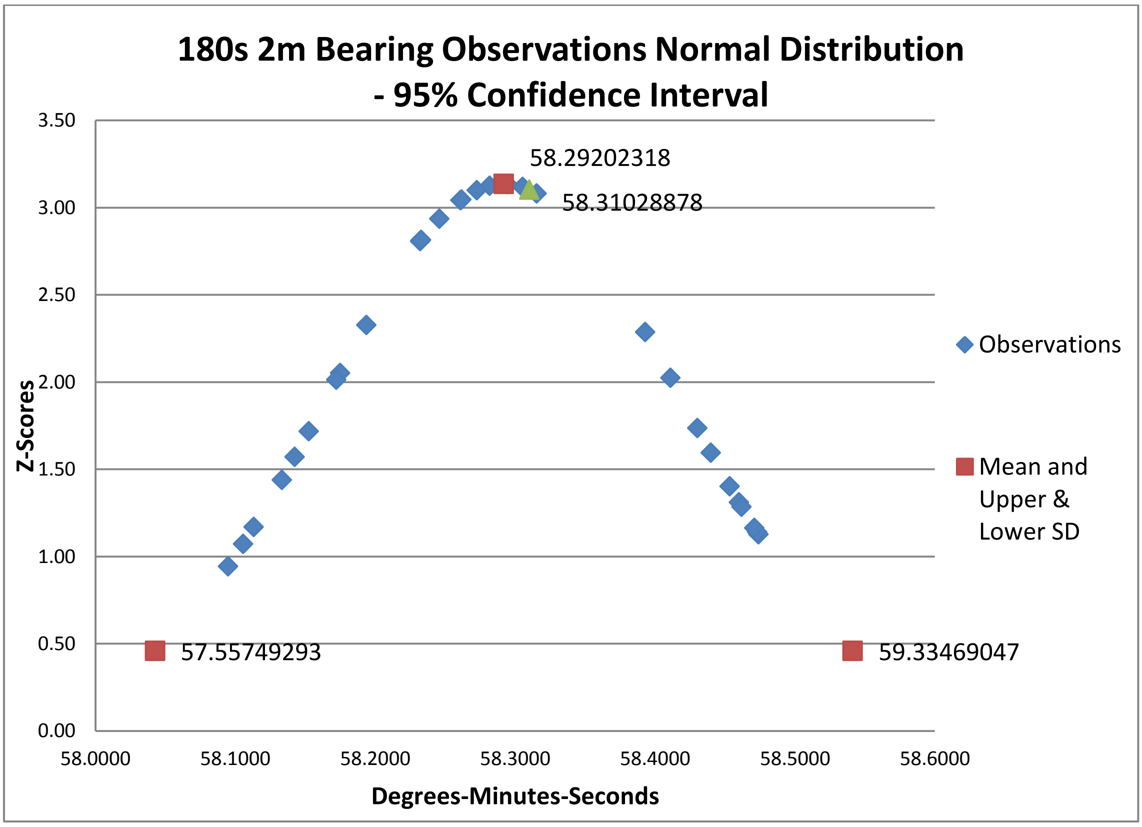


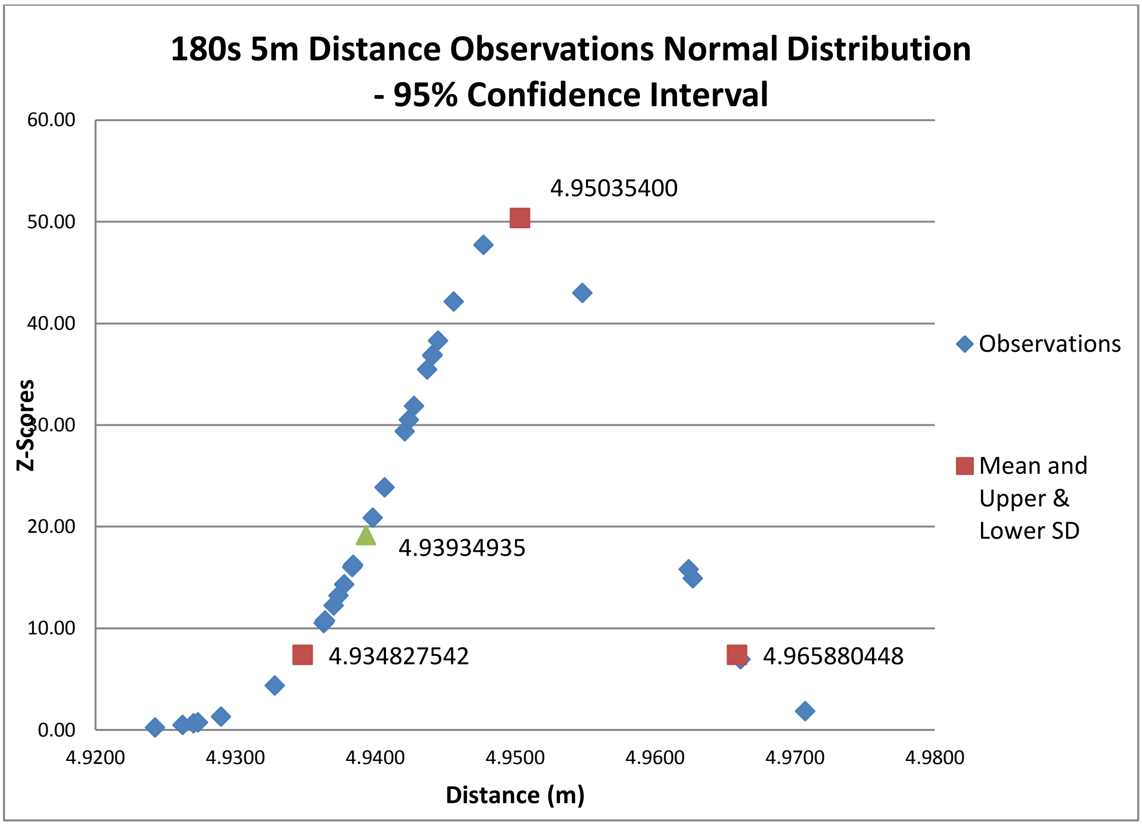
60s 200m Distance Observations Normal Distribution - 95% Confidence Interval
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Z-Scores
200.16237272
200.15860080
200.1330801
200.1916653
200.1300
200.1400
200.1500
200.1600
200.1700
200.1800
200.1900
200.2000
Distance (m)
Observations
Mean and Upper & Lower SD

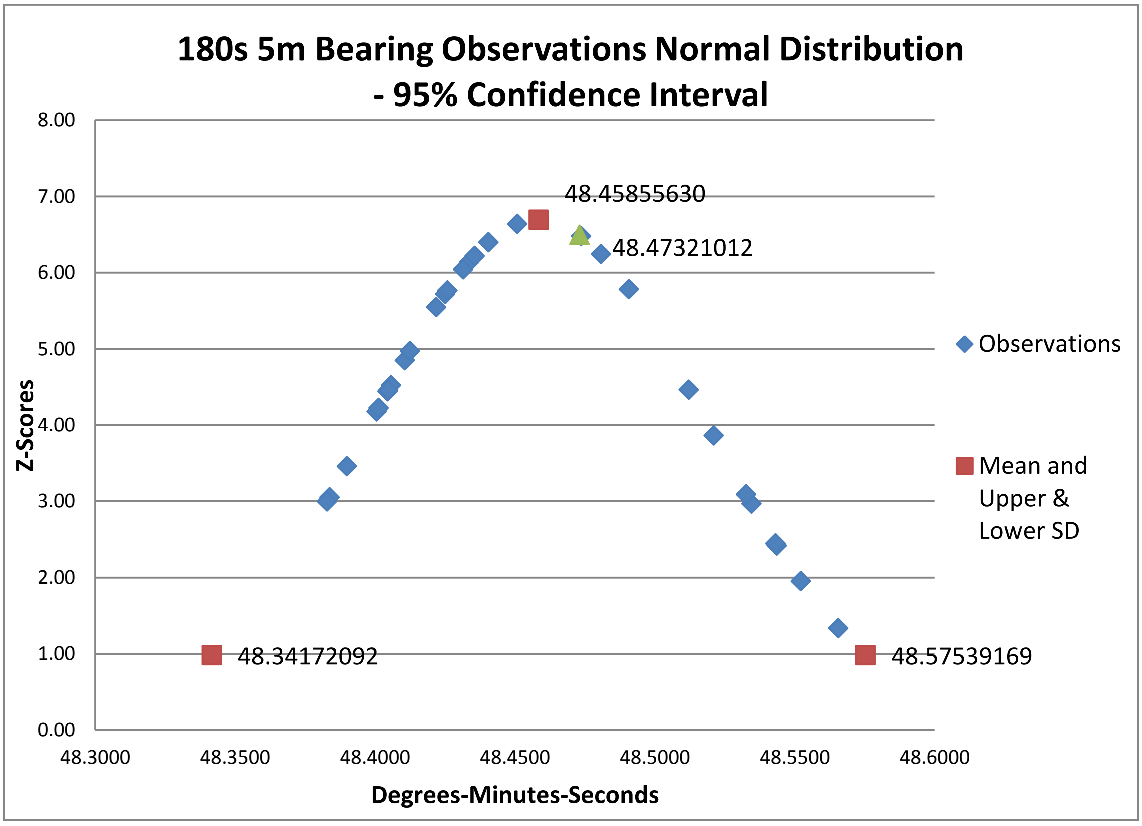


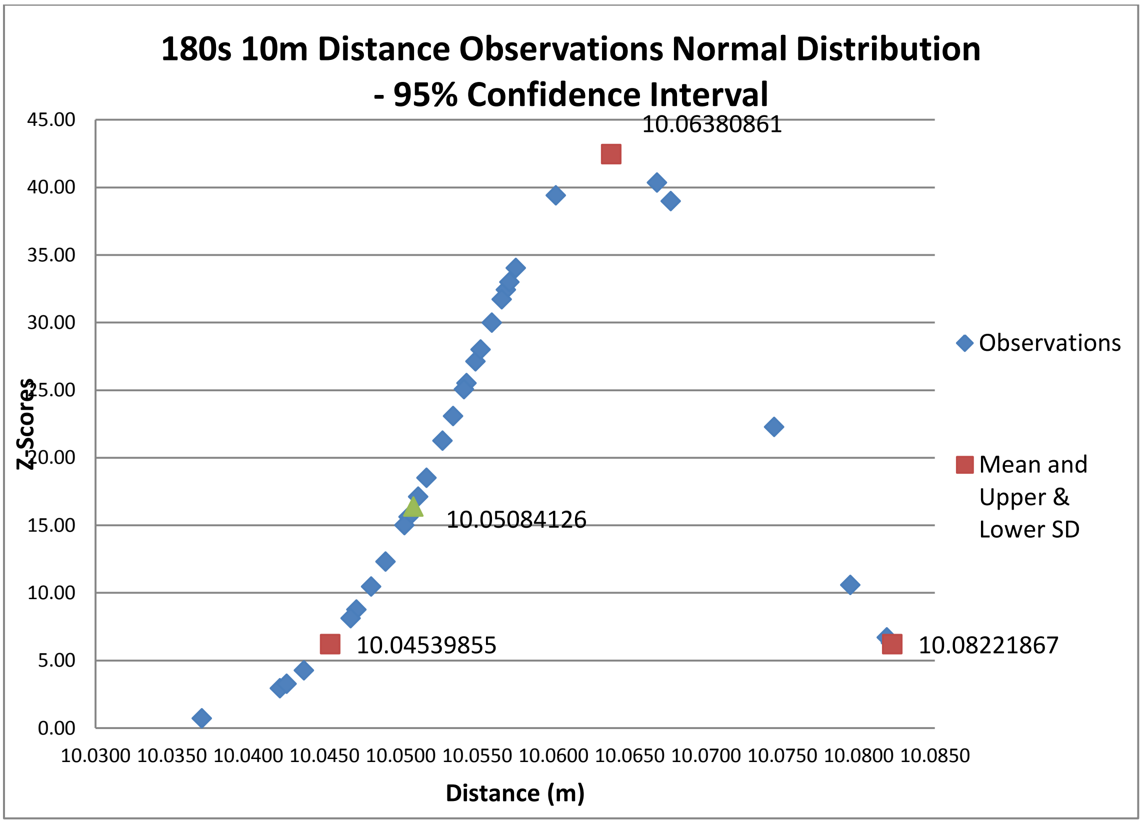
60s 200m Bearing Observations Normal Distribution - 95% Confidence Interval
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Z-Scores
43.03869895
43.04027168
43.03217472
43.04522317
43.0300
43.0320
43.0340
43.0360
43.0380
43.0400
43.0420
43.0440
43.0460
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD

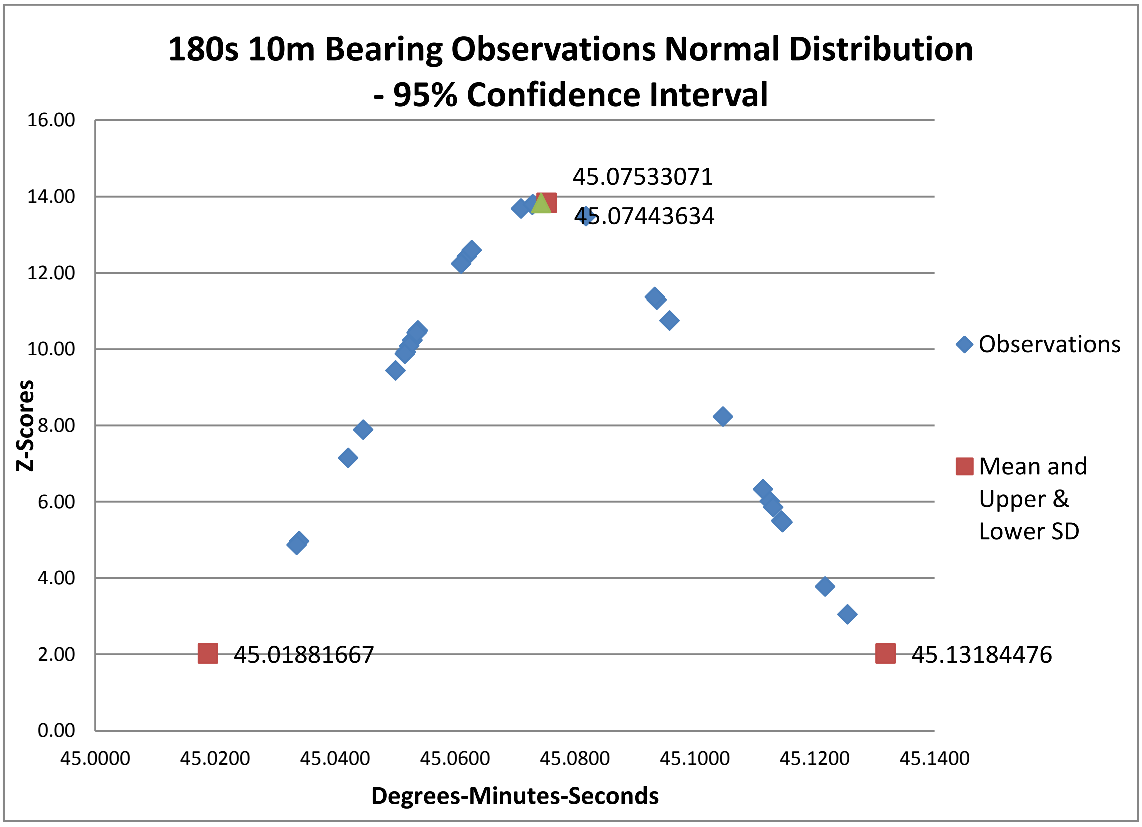

180s 2m Distance Observations Normal Distribution - 95% Confidence Interval
Z-Scores
Distance (m)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2.0700
2.0800
2.0900
2.1000
2.1100
2.1200
2.1300
2.1400
2.11376127
2.102487336
2.099557201
2.127965345
Observations
Mean and Upper & Lower SD

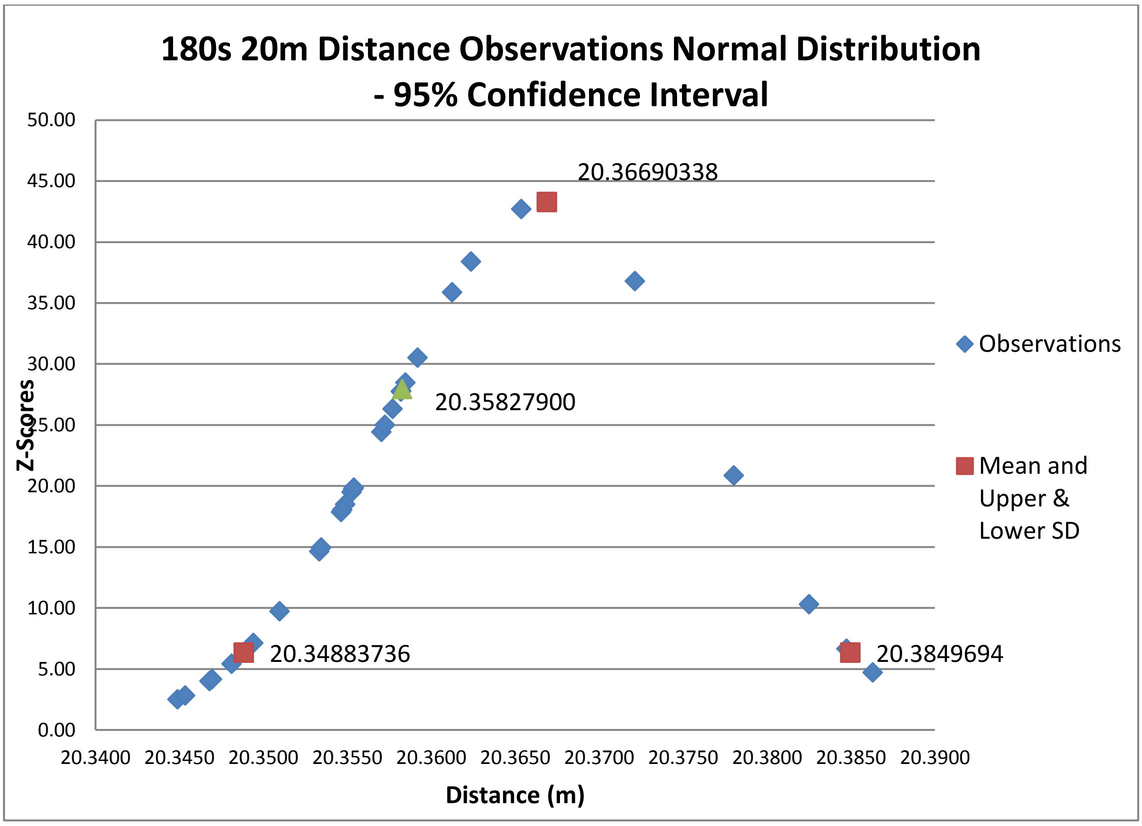

180s 2m Bearing Observations Normal Distribution - 95% Confidence Interval
Z-Scores
Degrees-Minutes-Seconds
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
58.0000
58.1000
58.2000
58.3000
58.4000
58.5000
58.6000
58.29202318
58.31028878
57.55749293
59.33469047
Observations
Mean and Upper & Lower SD

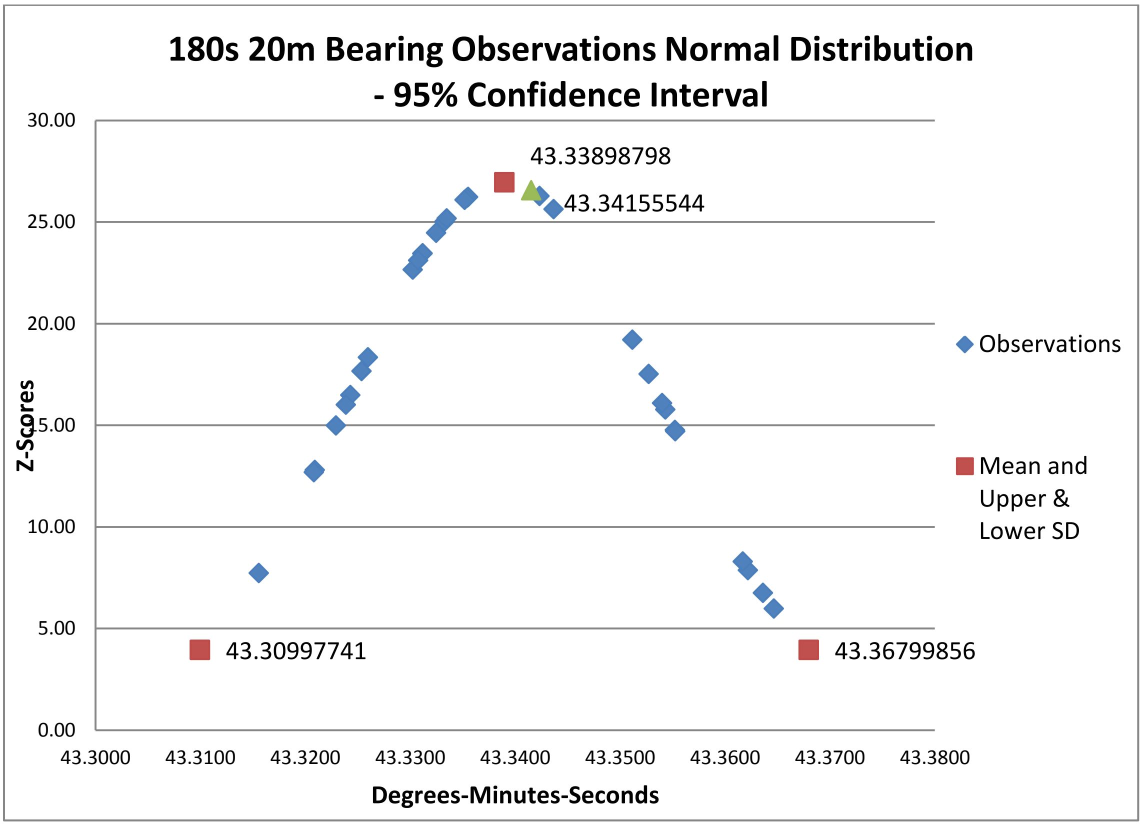

180s 5m Distance Observations Normal Distribution - 95% Confidence Interval
Z-Scores
Distance (m)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
4.9200
4.9300
4.9400
4.9500
4.9600
4.9700
4.9800
4.95035400
4.93934935
4.934827542
4.965880448
Observations
Mean and Upper & Lower SD

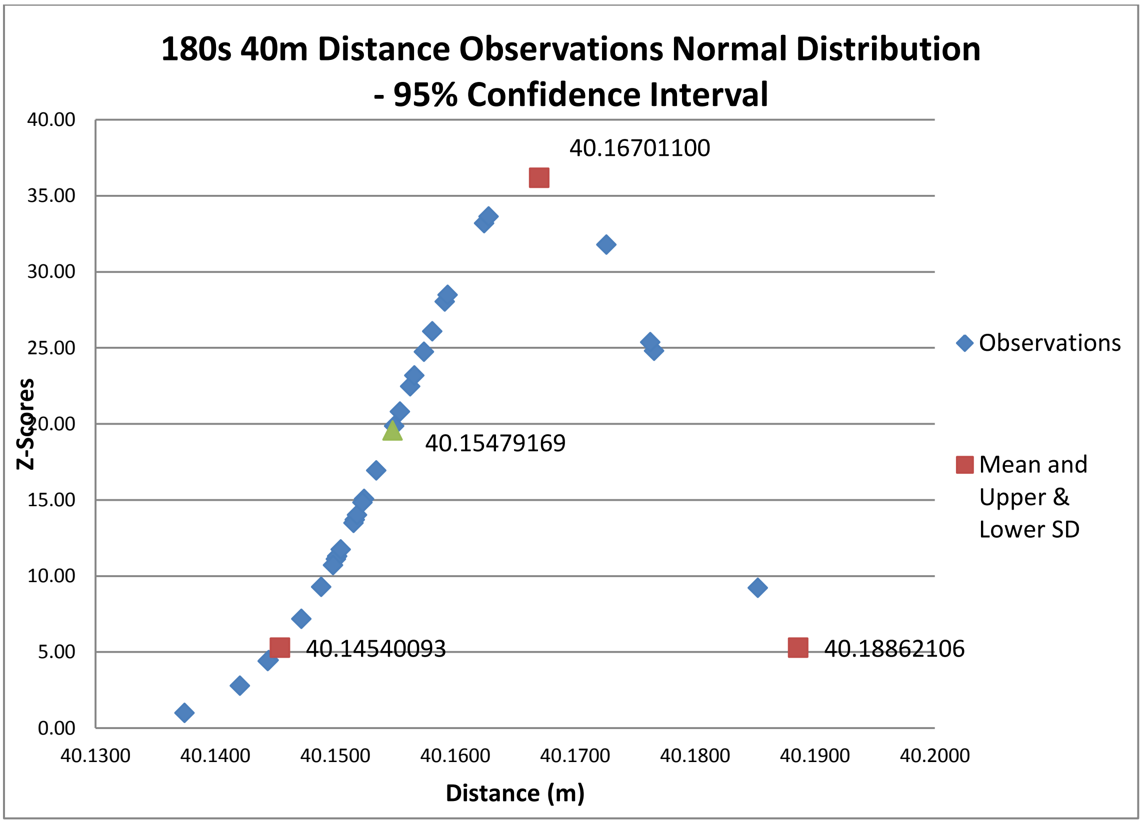

180s 5m Bearing Observations Normal Distribution - 95% Confidence Interval
Z-Scores
Degrees-Minutes-Seconds
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
48.3000
48.3500
48.4000
48.4500
48.5000
48.5500
48.6000
48.45855630
48.47321012
48.34172092
48.57539169
Observations
Mean and Upper & Lower SD

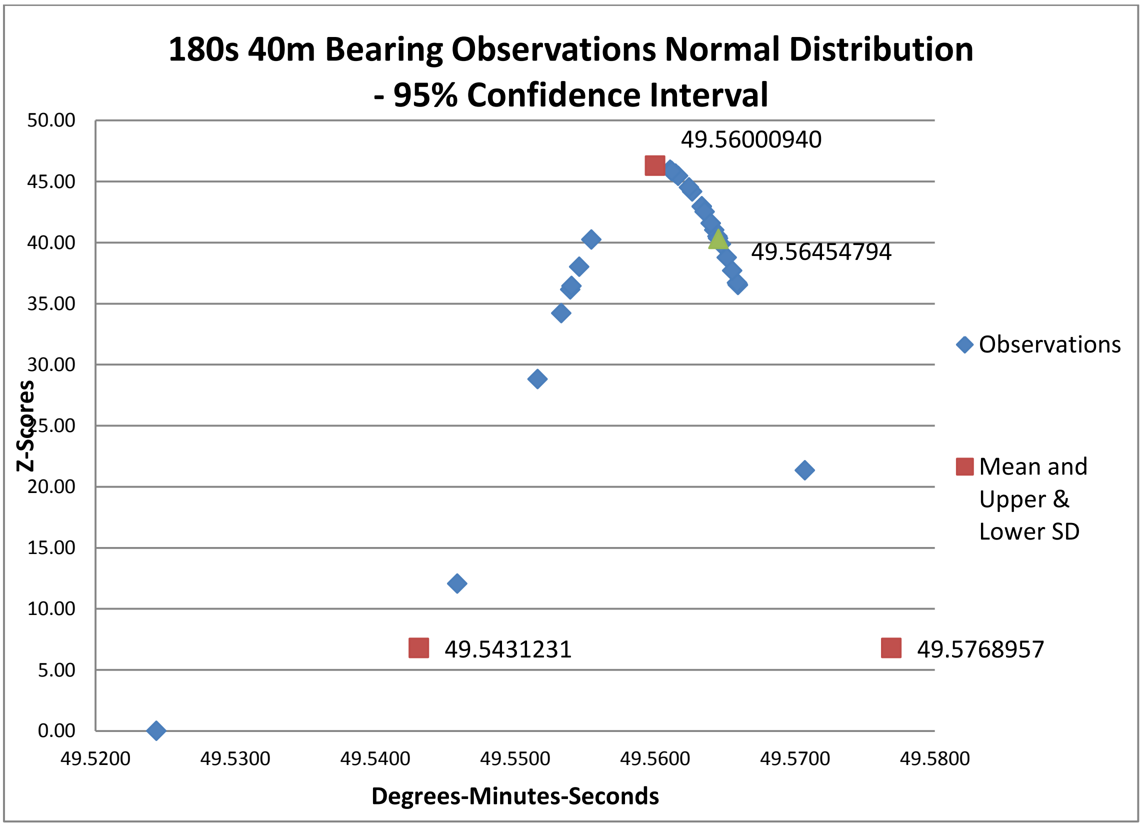

180s 10m Distance Observations Normal Distribution - 95% Confidence Interval
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Z-Scores
10.06380861
10.05084126
10.04539855
10.08221867
10.0300 10.0350 10.0400 10.0450 10.0500 10.0550 10.0600 10.0650 10.0700 10.0750 10.0800 10.0850
Distance (m)
Observations
Mean and Upper & Lower SD

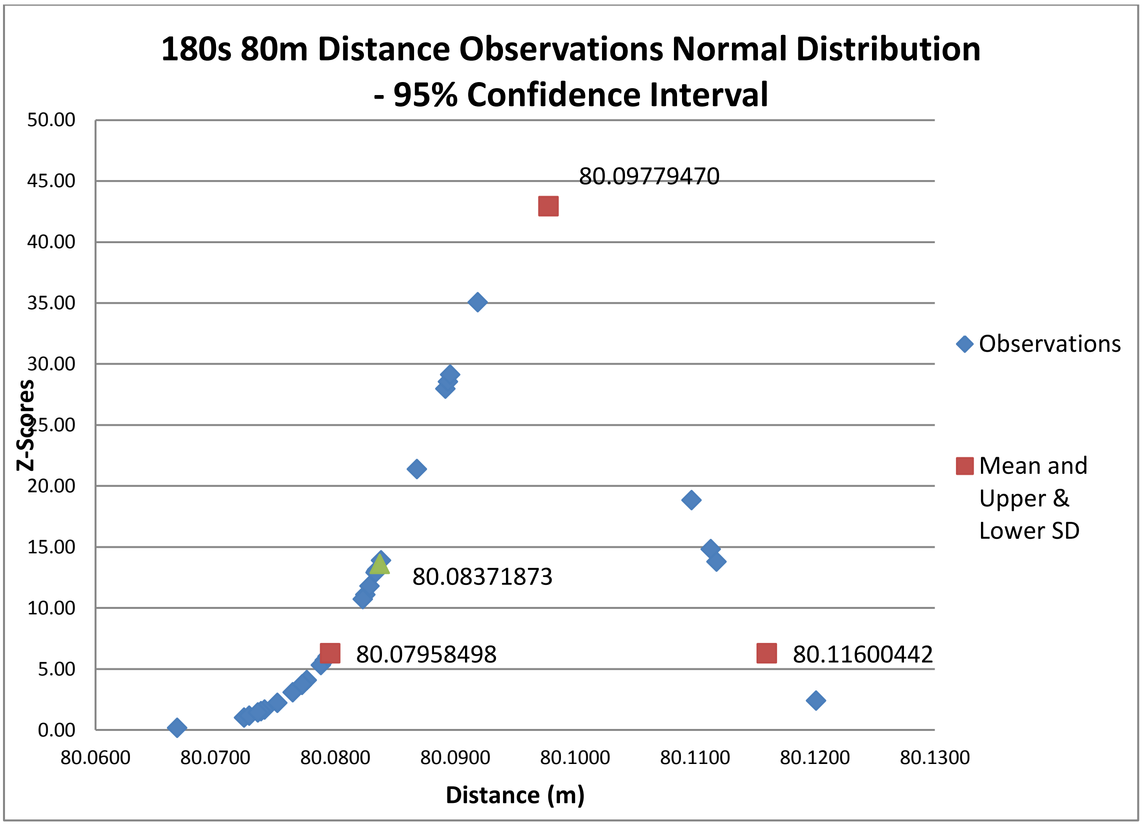

180s 10m Bearing Observations Normal Distribution - 95% Confidence Interval
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Z-Scores
45.07533071
45.07443634
45.01881667
45.13184476
45.0000
45.0200
45.0400
45.0600
45.0800
45.1000
45.1200
45.1400
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD

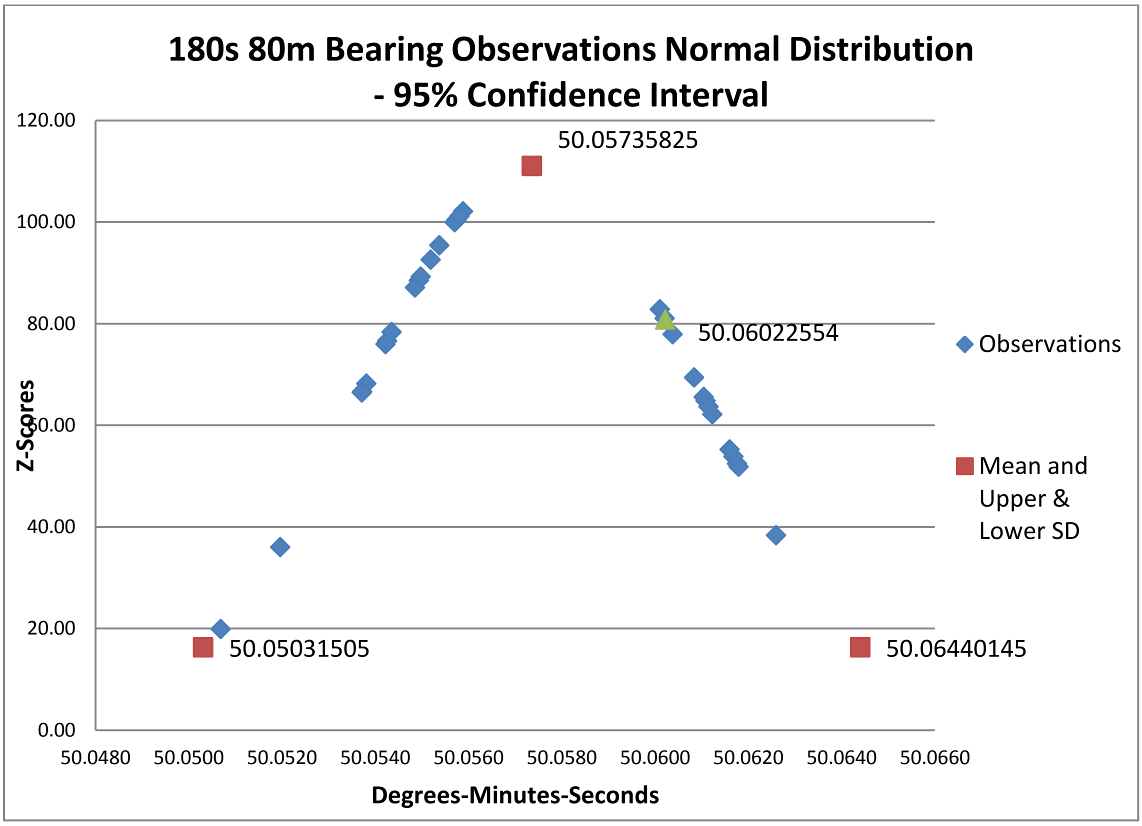

180s 20m Distance Observations Normal Distribution - 95% Confidence Interval
Z-Scores
Distance (m)
20.36690338
20.35827900
20.34883736
20.3849694
Observations
Mean and Upper & Lower SD
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
20.3400 20.3450 20.3500 20.3550 20.3600 20.3650 20.3700 20.3750 20.3800 20.3850 20.3900

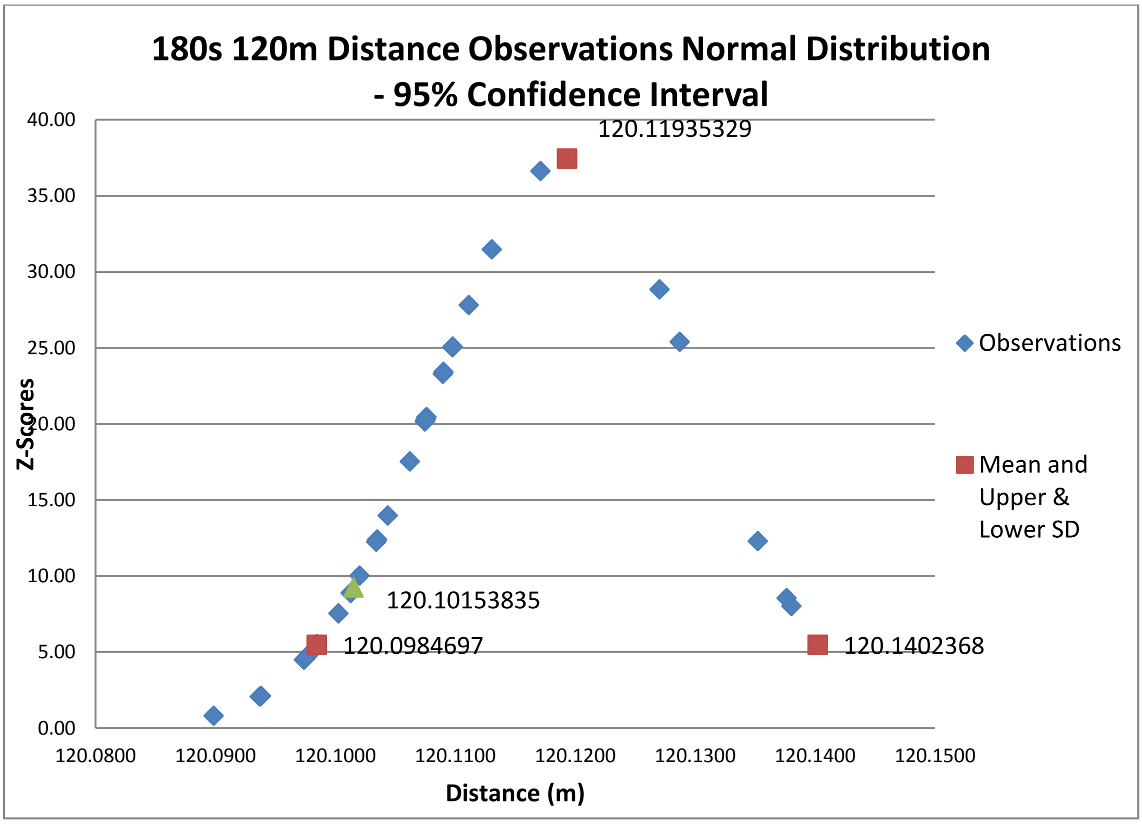

180s 20m Bearing Observations Normal Distribution - 95% Confidence Interval
Z-Scores
Degrees-Minutes-Seconds
43.33898798
43.34155544
43.30997741
43.36799856
Observations
Mean and Upper & Lower SD
30.00
25.00
20.00
15.00
10.00
5.00
0.00
43.3000 43.3100 43.3200 43.3300 43.3400 43.3500 43.3600 43.3700 43.3800

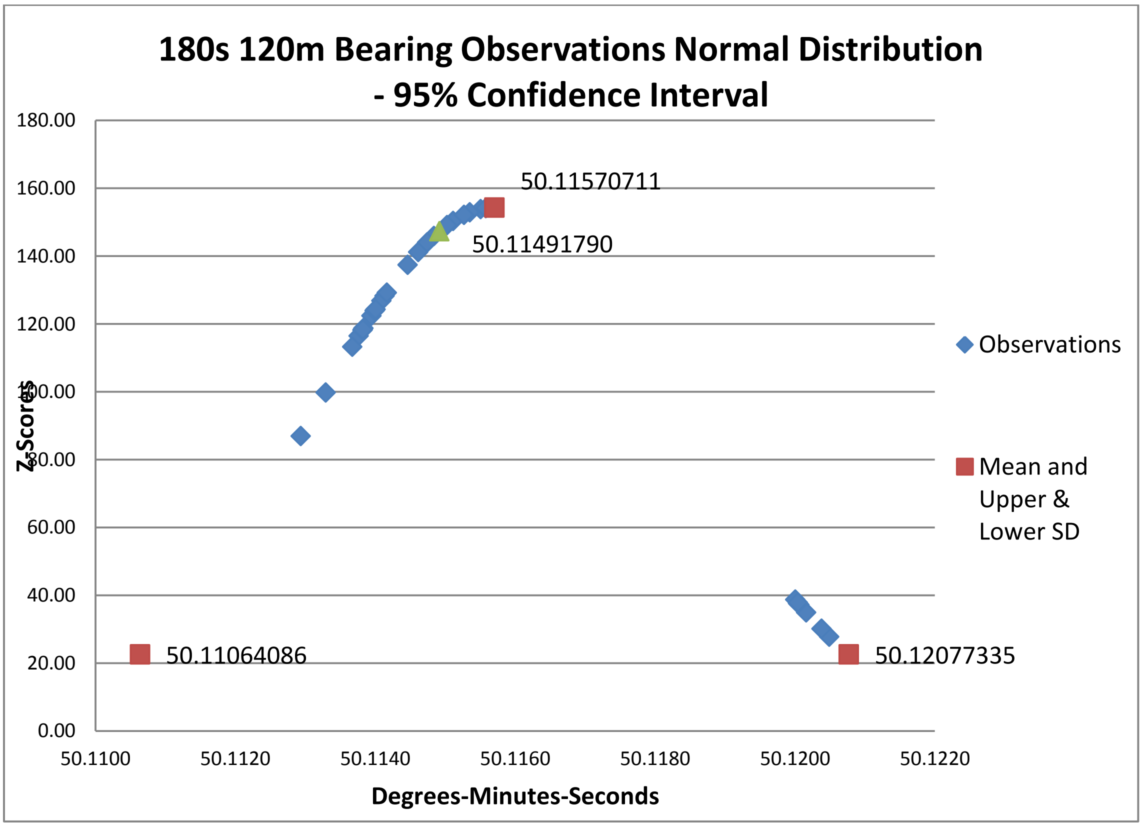

180s 40m Distance Observations Normal Distribution - 95% Confidence Interval
40.16701100
40.15479169
40.14540093
40.18862106
Observations
Mean and Upper & Lower SD
Z-Scores
Distance (m)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
40.1300
40.1400
40.1500
40.1600
40.1700
40.1800
40.1900
40.2000

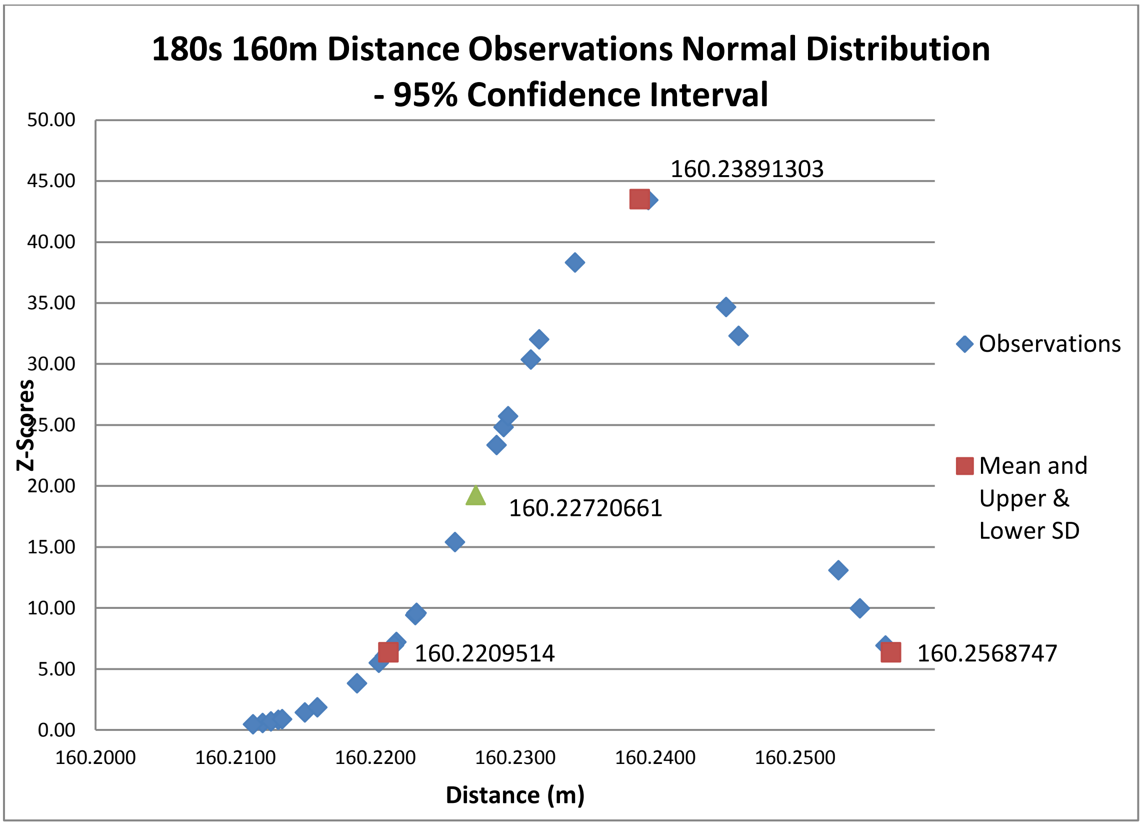

180s 40m Bearing Observations Normal Distribution - 95% Confidence Interval
49.56000940
49.56454794
49.5431231
49.5768957
Observations
Mean and Upper & Lower SD
Z-Scores
Degrees-Minutes-Seconds
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
49.5200
49.5300
49.5400
49.5500
49.5600
49.5700
49.5800

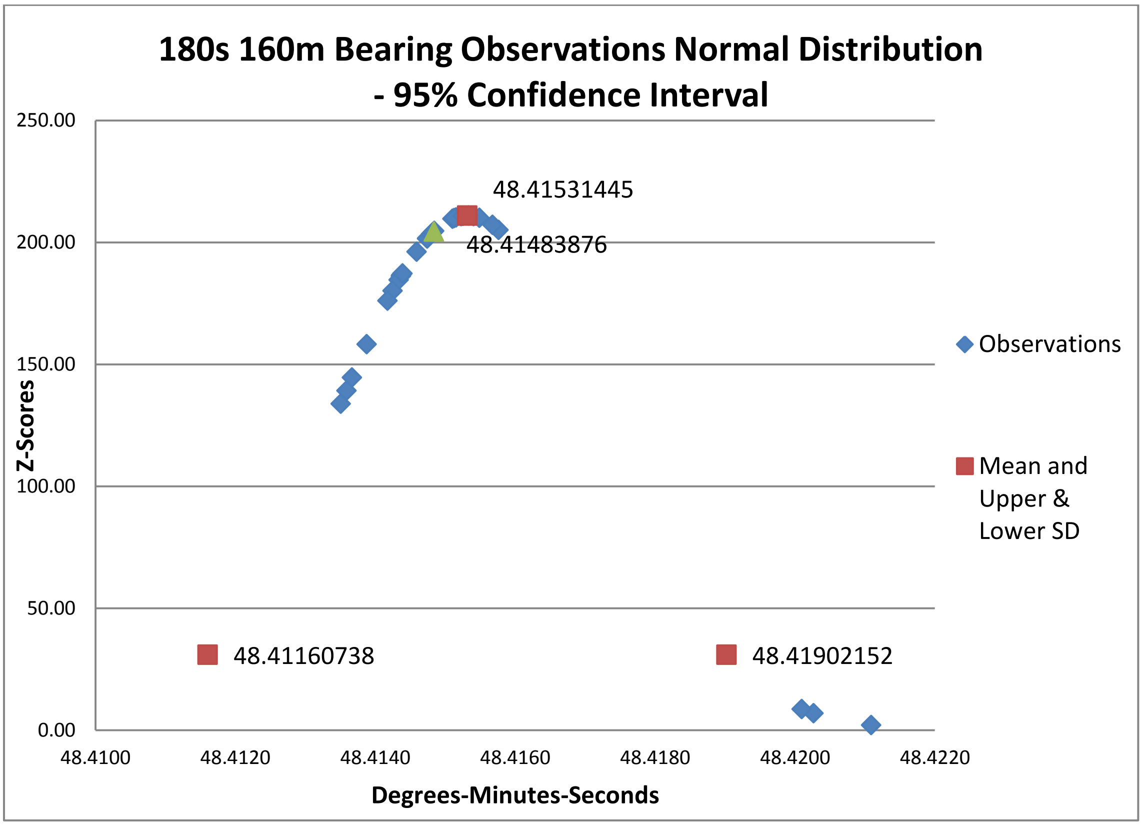

180s 80m Distance Observations Normal Distribution - 95% Confidence Interval
80.09779470
80.08371873
80.07958498
80.11600442
Observations
Mean and Upper & Lower SD
Z-Scores
Distance (m)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
80.0600
80.0700
80.0800
80.0900
80.1000
80.1100
80.1200
80.1300

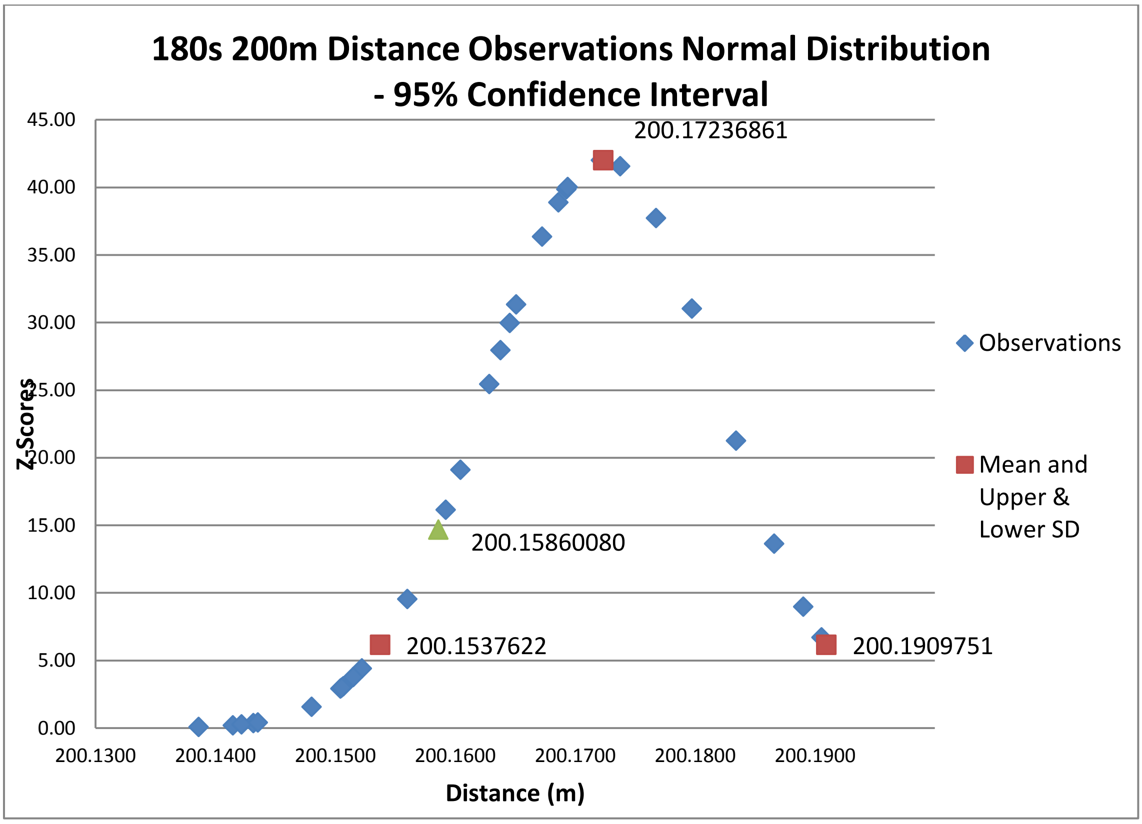

180s 80m Bearing Observations Normal Distribution - 95% Confidence Interval
50.05735825
50.06022554
50.05031505
50.06440145
Observations
Mean and Upper & Lower SD
Z-Scores
Degrees-Minutes-Seconds
0.00
20.00
40.00
60.00
80.00
100.00
120.00
50.0480
50.0500
50.0520
50.0540
50.0560
50.0580
50.0600
50.0620
50.0640
50.0660

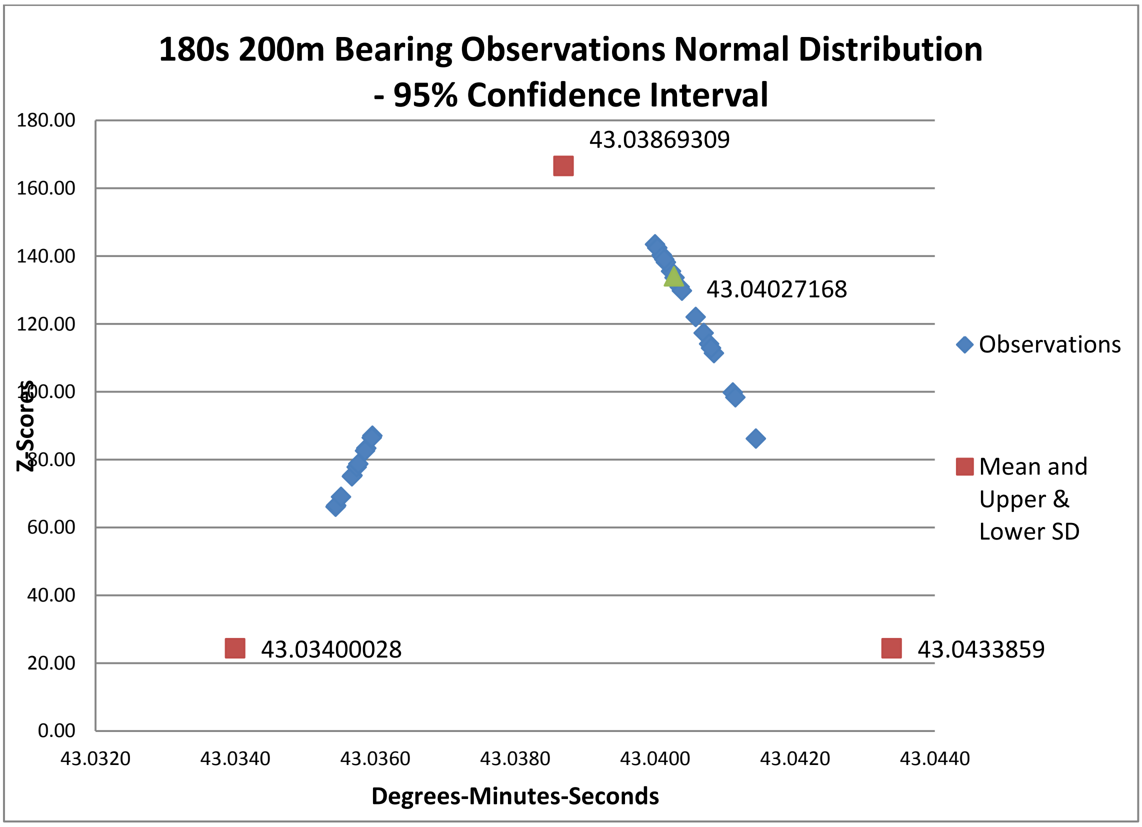

180s 120m Distance Observations Normal Distribution - 95% Confidence Interval
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Z-Scores
120.11935329
120.10153835
120.0984697
120.1402368
120.0800
120.0900
120.1000
120.1100
120.1200
120.1300
120.1400
120.1500
Distance (m)
Observations
Mean and Upper & Lower SD


180s 120m Bearing Observations Normal Distribution - 95% Confidence Interval
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Z-Scores
50.11570711
50.11491790
50.11064086
50.12077335
50.1100
50.1120
50.1140
50.1160
50.1180
50.1200
50.1220
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD


180s 160m Distance Observations Normal Distribution - 95% Confidence Interval
160.23891303
160.22720661
160.2209514
160.2568747
Z-Scores
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
160.2000
160.2100
160.2200
160.2300
160.2400
160.2500
Distance (m)
Observations
Mean and Upper & Lower SD


180s 160m Bearing Observations Normal Distribution - 95% Confidence Interval
48.41531445
48.41483876
48.41160738
48.41902152
Z-Scores
250.00
200.00
150.00
100.00
50.00
0.00
48.4100
48.4120
48.4140
48.4160
48.4180
48.4200
48.4220
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD


180s 200m Distance Observations Normal Distribution - 95% Confidence Interval
200.17236861
200.15860080
200.1537622
200.1909751
Z-Scores
Distance (m)
Observations
Mean and Upper & Lower SD


180s 200m Bearing Observations Normal Distribution - 95% Confidence Interval
43.03869309
43.04027168
43.03400028
43.0433859
Z-Scores
Degrees-Minutes-Seconds
Observations
Mean and Upper & Lower SD

APPENDIX E: Total Station Calibration Certificate

Ultimate Positioning

ULTIMATE POSITIONING GROUP PTY LTD
ABN 12 135 812 903
33 Allison St
Bowen Hills, QLD, 4006

07 3852 1245 Phone
07 3252 1275 Fax

www.ultimatepositioning.com

CALIBRATION CERTIFICATE

Date of Inspection:	**19.12.2012**
Client details:	**Minstaff Surveys**
Contact name:	**Survey Section**
Make/ Model:	**Trimble S8 DR Plus**
Serial number:	99310128

Ultimate Positioning confirms the instrument mentioned was inspected by ourselves and complies with **Trimble's Certificate of Calibration** that accompanies the said instrument.

Yours faithfully,

....
Julio Maldonado

Trimble is a Quality Assured Company and is registered as a supplier under SS-EN ISO 9001

Trimble. Authorised Dealer

Ultimate Positioning QLD
33 Allison Street
BOWEN HILLS QLD 4006
Ph: + 61 7 3852 1245
Fax: +61 7 3252 1275

Ultimate Positioning NSW
1-3 Nelson Street
THORNLEIGH NSW 2120
Ph: +61 2 9484 9293
Fax: +61 2 9875 3904

Ultimate Positioning VIC
Unit 1, 6 Garden Rd
CLAYTON 3168
Ph: +61 3 9518 7400
Fax: +61 3 9518 7401

Ultimate Positioning SA
92 Carrington Street
ADELAIDE SA 5000
Ph: +61 8 8223 7338
Fax: +61 8 8223 7345

APPENDIX F: EDM Calibration

CALIBRATION OF EDME

THIS PROGRAMME CARRIES OUT AN EVALUATION OF THE PERFORMANCE OF EDME OVER APPROVED BASELINES. INFORMATION MAY BE PROVIDED FULLY OR PARTIALLY REDUCED OR AS RAW DATA. CALCULATIONS ARE BASED ON FORMULAE AND PROGRAMS PROVIDED BY DR J M RUEGER OF UNIVERSITY OF NEW SOUTH WALES AS MODIFIED BY J M GAUDENS AND A SPENCE OF DNRM. QLD, TO INCLUDE LINEAR REGRESSION CAPABILITIES AND USE HISTORY FILES.

IN INSTANCES WHERE A BLANK APPEARS IN THE SPACE PROVIDED FOR A Y/N ANSWER,THE INFORMATION MAY NOT HAVE BEEN SUPPLIED AND IS ASSUMED TO BE NEGATIVE, OR ELSE THE INFORMATION IS NOT REQUIRED FOR CALCULATION AND REPORT.

DATA INPUT

INSTRUMENT S8 High Pres   BASELINE USED CABOOLTURE   DATE OF OBSERVATIONS 26/3/2013

SERIAL NO 99310128   OPERATOR/OWNER MINSTAFF   DATE OF COMPUTATION 8/4/2013

OCCUPIED STATIONS 0 1 2 3 4 5 6   UNOCCUPIED STATIONS   NUMBER OF OBSERVATIONS 21

TYPE OF PRISMS USED TRIMBLE   INDEX -0.035   WAS INDEX APPLIED TO DATA PROVIDED ? Y

WHAT CORRECTIONS HAVE TO BE APPLIED TO THE MEASURED DISTANCES ? :
ATMOSPHERICS ? Y REL HUM ? Y SLOPE ? Y OFFSET ? Y DATUM ? N CHORD-ARC ? N (BASES OVER 5 KM ONLY)
UNITS OF TEMPERATURE C UNITS OF PRESSURE MB

MET OBSERVATIONS (where applicable)

SEQ NO	DRY TEMP	REL HUM	PRESSURE
1	31.40	63.00	1014.40
2	31.40	63.00	1014.40
3	31.20	63.00	1014.40
4	31.30	63.00	1014.30
5	31.40	63.00	1014.30
6	31.40	63.00	1014.30
7	30.00	63.00	1014.10
8	29.50	63.00	1013.90
9	29.30	63.00	1013.80
10	29.10	63.00	1014.20
11	28.90	63.00	1014.00
12	28.80	63.00	1014.10
13	28.60	64.00	1014.20
14	28.50	64.00	1014.00
15	28.40	64.00	1014.30
16	28.10	64.00	1014.20
17	28.00	63.00	1014.40
18	27.80	63.00	1014.70
19	27.20	63.00	1014.80
20	26.90	63.00	1015.00
21	26.70	63.00	1015.10

INPUT						CORRECTIONS APPLIED					
SEQ NO	STN AT	HEIGHT INST	STN TO	HEIGHT INST	DISTANCE MEASURED	METS PPM	SLOPE M	OFFSET M	DATUM M	CHORD-ARC M	HORIZONTAL DISTANCE
1	0	0.000	1	0.000	64.8752	11.25	-0.0001	-0.0021	0.0000	0.0000	64.8738
2	0	0.000	2	0.000	181.1474	11.25	-0.0015	-0.0014	0.0000	0.0000	181.1465

3	0	0.000	3	0.000	398.7299	11.06	-0.0077	0.0000	0.0000	0.0000	398.7266
4	0	0.000	4	0.000	537.0483	11.18	-0.0073	-0.0001	0.0000	0.0000	537.0468
5	0	0.000	5	0.000	714.8689	11.27	-0.0092	-0.0002	0.0000	0.0000	714.8676
6	0	0.000	6	0.000	1148.5272	11.27	-0.0102	0.0000	0.0000	0.0000	1148.5299
7	1	0.000	2	0.000	116.2737	10.01	-0.0032	-0.0002	0.0000	0.0000	116.2715
8	1	0.000	3	0.000	333.8563	9.59	-0.0100	-0.0002	0.0000	0.0000	333.8493
9	1	0.000	4	0.000	472.1762	9.43	-0.0090	0.0000	0.0000	0.0000	472.1716
10	1	0.000	5	0.000	649.9972	9.13	-0.0107	-0.0008	0.0000	0.0000	649.9916
11	1	0.000	6	0.000	1083.6538	9.00	-0.0114	-0.0001	0.0000	0.0000	1083.6521
12	2	0.000	3	0.000	217.5841	8.87	-0.0069	-0.0007	0.0000	0.0000	217.5785
13	2	0.000	4	0.000	355.9015	8.67	-0.0060	-0.0002	0.0000	0.0000	355.8984
14	2	0.000	5	0.000	533.7241	8.63	-0.0078	-0.0015	0.0000	0.0000	533.7195
15	2	0.000	6	0.000	967.3809	8.46	-0.0087	-0.0003	0.0000	0.0000	967.3801
16	3	0.000	4	0.000	138.3202	8.20	-0.0004	-0.0001	0.0000	0.0000	138.3208
17	3	0.000	5	0.000	316.1418	8.03	-0.0021	-0.0008	0.0000	0.0000	316.1415
18	3	0.000	6	0.000	749.7988	7.76	-0.0038	0.0000	0.0000	0.0000	749.8008
19	4	0.000	5	0.000	177.8226	7.16	-0.0019	-0.0022	0.0000	0.0000	177.8198
20	4	0.000	6	0.000	611.4814	6.82	-0.0034	-0.0001	0.0000	0.0000	611.4821
21	5	0.000	6	0.000	433.6614	6.61	-0.0017	-0.0003	0.0000	0.0000	433.6622

COMMENTS:-

Delivery Instructions:-

EDM CALIBRATION - ANALYSIS OF RESULTS
****

STANDARD DEVIATION (A PRIORI) = 1 mm + 1 ppm

REDUCED OBSERVATIONS			CONSTRAINED ADJUSTMENT					FREE ADJUSTMENT		
LINE STN	OBSERVED TO STN	REDUCED DISTANCE (m)	ABSOLUTE DISTANCE (m)	REDUCED - ABS DIST (mm)	CORRECTED DISTANCE (m)	CORRECTED - ABS DIST (mm)	ALARM (NOTE 1)	ADJUSTED DIST (ADIST) (m)	ADIST - RED DIST (mm)	ALARM (NOTE 2)
0	1	64.8738	64.8740	-0.20	64.8742	0.19		64.8747	0.87	
0	2	181.1465	181.1470	-0.50	181.1466	-0.36		181.1469	0.39	
0	3	398.7266	398.7250	1.60	398.7263	1.27		398.7256	-0.99	
0	4	537.0468	537.0450	1.80	537.0462	1.16		537.0466	-0.21	
0	5	714.8676	714.8660	1.60	714.8666	0.58		714.8670	-0.56	
0	6	1148.5299	1148.5260	3.90	1148.5279	1.94		1148.5287	-1.20	
1	2	116.2715	116.2730	-1.50	116.2718	-1.22		116.2716	0.06	
1	3	333.8493	333.8510	-1.70	333.8491	-1.89		333.8503	0.98	
1	4	472.1716	472.1710	0.60	472.1711	0.11		472.1713	-0.34	
1	5	649.9916	649.9920	-0.40	649.9907	-1.28		649.9917	0.11	
1	6	1083.6521	1083.6520	0.10	1083.6503	-1.72		1083.6534	1.27	
2	3	217.5785	217.5780	0.50	217.5786	0.56		217.5781	-0.44	
2	4	355.8984	355.8980	0.40	355.8982	0.16		355.8990	0.65	
2	5	533.7195	533.7190	0.50	533.7189	-0.13		533.7195	-0.01	
2	6	967.3801	967.3790	1.10	967.3785	-0.47		967.3812	1.05	
3	4	138.3208	138.3200	0.80	138.3210	1.03		138.3203	-0.47	
3	5	316.1415	316.1410	0.50	316.1413	0.34		316.1408	-0.73	
3	6	749.8008	749.8010	-0.20	749.7997	-1.30		749.8024	1.63	
4	5	177.8198	177.8210	-1.20	177.8199	-1.05		177.8198	-0.01	
4	6	611.4821	611.4810	1.10	611.4813	0.30		611.4814	-0.65	
5	6	433.6622	433.6600	2.20	433.6618	1.79		433.6610	-1.20	

Constrained adjustment:

ADDITIVE CONSTANT 0.53 mm
STANDARD DEVIATION 0.47 mm

SCALE FACTOR 0.99999783 (-2.17 ppm)
STANDARD DEVIATION 0.813 ppm

Free adjustment:

ADDITIVE CONSTANT 0.66mm
STANDARD DEVIATION 0.38 mm

SCALE FACTOR 0.99999756

REDUCED DISTANCE - Observed Distance reduced to horizontal base linear

CORRECTED DISTANCE - Reduced Distance adjusted

NOTE 1: (TEST 3)
FAILURE OCCURS IF THE VALUE OF THE CORRECTED DISTANCE MINUS THE ABSOLUTE DISTANCE IS GREATER THAN TWICE THE SPECIFIED STANDARD DEVIATION

NOTE 2: (TEST 4)
FAILURE OCCURS IF THE ADJUSTED DIST. (VIA LEAST SQUARES) MINUS THE REDUCED DISTANCE IS GREATER THAN TWICE THE SPECIFIED STANDARD DEVIATION

for Scale and Additive Constant ADJUSTED DISTANCE - Most Probable Value minus Additive Constant	INDICATES A LACK OF ACCURACY	INDICATES A LACK OF PRECISION

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                              *****  REPORT ON  *****

                         CALIBRATION OF EDME - SUMMARY OF RESULTS

 Instrument:  S8 High Pres    ## Baseline Used:  CABOOLTURE  - QldBase.0.1.2030    Date of Observations:  26/3/2013

 Serial No :  58475021          Computed for:  MINSTAFF                            Date of Computation :   8/4/2013

 ## This Baseline holds a current Regulation 13 Certificate ( see Reg. 13 Base ID No. above ) under the
    National Measurement Regulations 1999 in Accordance with the National Measurement Act 1960

RESULTS OF CALIBRATIONS:-

   AGAINST ABSOLUTE VALUES (Linear Regression)                    USING LEAST SQUARES (Free Adjustment)

Previous Calibration (if available)        Baseline Used:                          Date of Observations:

                                  No Previous Calibration Data within 2 years Available !!!!

This Calibration ***

        Index   0.53 mm ** +/-   1.00 mm *                         Index    0.66 mm ** +/-   0.81 mm *
        Scale  0.9999978  ** +/-  1.74 ppm *                       Scale  0.9999976 **

Type of Prisms used:  TRIMBLE      Index:  -0.035      Has Prism Constant been Deducted ?:    Y

RESULTS OF TESTS :-
                  Test 1 : PASS              Test 2 : PASS              Test 3 : PASS              Test 4 : PASS

GENERAL COMMENTS:-

 The Instrument DOES / DOES NOT  appear to be performing within the Required Specifications.

THE FOLLOWING CORRECTIONS MAY BE USED FOR LOWER ORDER MEASUREMENTS:  **

Index                   Scale Factor                  or +/-              ppm.

CALCULATED AND ISSUED ON BEHALF OF THE QLD EDM CALIBRATION OFFICER, ISAAC STILLER, AS A DELEGATE OF THE DIRECTOR GENERAL,
DEPARTMENT OF NATURAL RESOURCES & WATER
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By: Date: 8/4/2013

********** NOTES **********

* The uncertainties quoted have been calculated at the 95% confidence level with a coverage factor (k) of 2

** Index and Scale should NOT be EXTRAPOLATED for Distances greater than TWICE THE LENGTH of the base.

*** The result and accuracy quoted herein are subject to the Information used being a true record of observations as conducted and using current recommended procedures and appropriate ancilliary equipment in accordance with ' Calibration of Electronic Distance Measuring Equipment ', NRW, 2009.

***** A CERTIFICATE of test can only be issued when an Accredited Representative of the EDM CALIBRATION OFFICER oversees or conducts the calibration.

########## TESTS ##########

TEST 1 : Checks that the difference between the additive constant via free and constrained methods is less than half the manufacturers (or applied) SD.

TEST 2 : Checks that the calculated SDs of both the additive constant and scale factor are not greater than the corresponding manufacturers (or applied) specifications.

TEST 3 : Constrained Adjustment Alarm

TEST 4 : Free Adjustment Alarm.

APPENDIX G: RISK ASSESSMENT

Replicated with permission from MinStaff Survey

SH&E Work Method Statement (SH&EWMS)

Project:	**RTK GNSS for Cadastral Surveying**	**Project No:**	**Undergraduate studies**
SH&EWMS No:	01	**Work Activity:**	Surveying Services
Revision No:	02		

ALL PERSONS INVOLVED IN THE WORKS MUST HAVE THE SH&EWMS EXPLAINED, COMMUNICATED TO THEM AND GIVEN AN OPPORTUNITY TO PROVIDE INPUT PRIOR TO START OF WORKS VIA A TOOLBOX TALK.

SH&EWMS DETAILS

Brief Description of Work Activity:	Establish control network, TS and RTK observations		
Location:	**Toowoomba, USQ Campus**	**Date:**	21/08/2013
Employer/Contractor: Trading Address:	**ABN:**	**Date to be Reviewed:**	
Personnel Responsible for Monitoring this Activity:	Michael Zahl		
Codes of Practice / Standards Consulted: These must be complied with.	Work Health and Safety Act 2011, Australian Standard 3012 & Risk Management Code of Practice 2007, Traffic Management for Construction or Maintenance Work Code of Practice 2008, MUTCD Part 3		
Plant and Equipment Required for this Activity:	S6/S8 Trimble Robotic Total Station & Accessories, Trimble R8 RTK GNSS & Accessories, 4WD L/Vehicle and mobile communications.		
Details of Maintenance Checks Required for this Activity:	Survey Equipment (S6 & R8) is Serviced and Calibrated annually.		
Materials Used:	Survey Stakes, Spray Paint, Pegs		

MSDS Required? (Yes / No)	Yes (Spray Paint) – Copy Attached
Personnel Qualifications Required for this Activity: Relevant WorkCover Ticket for task has been undertaken	

Review and Corrective Actions:
SH&EWMS will be reviewed to the Schedule of Task Observations using the Task Observation sheet to ensure the work is being carried out to the statement, corrective action will be noted which are passed to the Supervisor/Foreman to carry out remedial work for close out. If a failure is identified in the SH&EWMS, works will stop, the SH&EWMS will be amended and the changes communicated to the workforce.

Specific Training Required for this Activity: All personnel to have completed a Site Induction. Must be trained in this SH&EWMS and have all relevant certification for this task	Study of BSpSc (USQ), Generic Construction Industry Induction (Blue & White card), Minstaff Survey Induction, Internal training (appropriate use of Spray Paint)

Personnel consulted on development of SH&EWMS:

Name:	Title:	Signature:
Michael Zahl	Undergraduate	
Jake Laing	Operations Manager	

Minimum number of personnel required for this Activity:
This work can be carried out by a minimum of 1 staff member. In the event that work is undertaken in a remote area, and there is limited liaison/supervision with the principle client- then this work shall be completed by a minimum of 2 personnel.

APPROVED BY SENIOR MANAGEMENT

The hierarchy of controls needs to be considered when identifying control measures. The highest level of control should be implemented wherever reasonably practicable.

Name:		Title:		Signature:		Date:	

LIKELIHOOD 'Likelihood that the stated consequence will occur'

Almost certain	• Almost inevitable outcome, expected to occur in most circumstances.
Likely	• Not a certainty but there is a good chance of occurrence.
Possible	• Could occur.
Unlikely	• Could occur but not expected. Would require multiple failures of systems/controls.
Rare	• Little chance of occurrence. Would require a combination of factors to result.

EXPOSURE 'Consider the exposure (frequency) factor when determining the likelihood of the risk/hazard event occurring.'

Hazard event occurs	**Exposure factor**
Continuously	Many times daily
Frequently	Approximately once daily
Occasionally	Once a week to once a month
Infrequent	Once a month to once a year

• **CONSEQUENCE** 'The outcome of an event expressed qualitatively, being a loss, injury, disadvantage or gain.'

	• ***Health & Safety***	• ***Environment***
Catastrophic	• *Fatality or permanent disability (Class 1 incident)*	• *High severity which has or may have permanent and/or irreversible effects*
Major	• *Life threatening incident, Lost Time Injury or ongoing illness/health effects (Class 2 incident)*	• *Medium severity which has or may have persistent but reversible effects*
Moderate	• *Incident that requires medical treatment by a qualified medical practitioner (Class 2 incident)*	• *Low severity which has short term and reversible effects*
Minor	• *Incident that may require first aid treatment only (Class 3 incident)*	• *Impact confined to area impacted by work operations*
Insignificant	• *No injuries*	• *Very low environmental impact, not noticeable*

QUALITATIVE RISK ANALYSIS MATRIX: LEVEL OF RISK

	CONSEQUENCE				
LIKELIHOOD	**Insignificant 5**	**Minor 4**	**Moderate 3**	**Major 2**	**Catastrophic 1**
A - Almost Certain	H	H	E	E	E
B - Likely	M	H	H	E	E
C - Possible	L	M	H	E	E
D - Unlikely	L	L	M	H	E
E - Rare	L	L	M	H	H

RISK MATRIX

Extreme	Extreme risk, immediate action required, works must not proceed at this level.
High	High risk, acceptable to proceed only with strict controls.
Moderate	Moderate risk, acceptable to proceed with suitable controls
Low	Low risk, acceptable to proceed

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Highest Level of Control				Lowest Level of Control
Elimination	Substitution	Engineering	Administration	Personal Protective Equipment

L ACCEPTABLE M ACCEPTABLE WITH CONTROLS H ACCEPTABLE WITH STRICT CONTROL/SHORT DURATION E UNACCEPTABLE

Procedure Break the job down into steps	**Potential Safety and Environmental Hazards** What can go wrong	**Legislative References**	**Risk Rating** L X	C =	R	**Control Measures**	**Residual Risk Rating** L X	C =	R	**Person Responsible** To ensure management method applied	**Hierarchy control**
Field Prep • Loading/Unloading Vehicle	• Muscular Strain/Injury		D	3	M	• Lifting Equipment • Help from another team member	E	3	M	Project Surveyor	Admin
	• Slips, Trips and falls		C	3	H	• Personal Protective Equipment (PPE)	D	3	M	Project Surveyor	PPE
	• Traffic Interferences		D	1	E	• Ensure high visibility clothing, signage etc is loaded into vehicle. • High visibility clothing (including long sleeve short and long pants), awareness of all road users	E	1	H	Project Surveyor	Admin PPE
• Handling Survey Stakes	• Splinter/Cut		B	4	H	• Wear gloves	E	4	L	Project Surveyor	PPE

L ACCEPTABLE M ACCEPTABLE WITH CONTROLS H ACCEPTABLE WITH STRICT CONTROL/SHORT DURATION E UNACCEPTABLE

Procedure Break the job down into steps	Potential Safety and Environmental Hazards What can go wrong	Legislative References	Risk Rating			Control Measures	Residual Risk Rating			Person Responsible To ensure management method applied	Hierarchy control
			L X	C =	R		L X	C =	R		
Driving	• Fatigue		C	1	E	• Regular rest stops • Advise of estimated arrival time • Share driving • Meal breaks • Nil alcohol and drugs	E	1	H	Project Surveyor	Admin
	• Driver Error		C	1	E	• Defense Driving • Appropriate driver training	E	1	H	Operations Manager	Admin
	• Vehicle Failure		C	1	E	• Report defects, regularly check all tyres and fluid levels/servicing • Carry fire extinguisher • Maintain Service Schedule	E	1	H	Project Surveyor	Admin
	• Strike an Animal		C	2	E	• Avoid driving on rural roads at dawn, dusk & night	E	2	H	Project Surveyor	Admin
	• Fuel Leak		D	3	M	• Check caps daily • Driver is responsible for vehicle	E	3	M	Driver	Admin
Site traffic control	• Muscular Strain/Injury		D	3	M	• Lifting Equipment • Help from another team member	E	3	M	Project Surveyor	Admin
	• Traffic Interference		D	1	E	• Awareness of all road users • Erection of Signage; 'Surveyors Ahead'	E	1	H	Project Surveyor	Admin & PPE

L ACCEPTABLE M ACCEPTABLE WITH CONTROLS H ACCEPTABLE WITH STRICT CONTROL/SHORT DURATION E UNACCEPTABLE

Procedure Break the job down into steps	Potential Safety and Environmental Hazards What can go wrong	Legislative References	Risk Rating			Control Measures	Residual Risk Rating			Person Responsible To ensure management method applied	Hierarchy control
			L X	C =	R		L X	C =	R		
						• Cones around survey stations • Spotter utilisation • High visibility clothing (including long sleeve short and long pants) • Dual Flashing Beacons Under Traffic Control – As per approved TMP for works.					
Office Work • Calculations • Drafting • Writing Reports	• Occupational overuse syndrome		D	4	L	• Ergonomic office • Lighting • Breaks	E	4	L	Operations Manager	Eng. & Admin
Maintaining Equipment	• Muscular Strain/Injury		D	3	M	• Lifting Equipment • Help from another team member • Appropriate training	E	3	M	Project Surveyor	Admin
	• Plant & Equipment Failure		C	1	E	• Report defects, regularly check all tyres and fluid levels/servicing • Maintain Servicing & Calibration schedule • Carry fire extinguisher	E	1	H	Operations Manager	Admin
	• Slips, trips and falls		C	3	H	• Work on level ground • Clean and tidy workplace • PPE (including long sleeve short and long pants)	D	3	M	Project Surveyor	Admin & PPE

L ACCEPTABLE M ACCEPTABLE WITH CONTROLS H ACCEPTABLE WITH STRICT CONTROL/SHORT DURATION E UNACCEPTABLE

Procedure Break the job down into steps	**Potential Safety and Environmental Hazards** What can go wrong	**Legislative References**	**Risk Rating** L X	C =	R	**Control Measures**	**Residual Risk Rating** L X	C =	R	**Person Responsible** To ensure management method applied	**Hierarchy control**
Fieldwork • Locate survey marks • Carry equipment • Set up and remove instruments and targets • Clearing • Placing survey marks	• Muscular Strain/Injury		D	3	M	• Warm up exercises • Lifting Equipment • Help from another team member • Proper lifting techniques • Shovels, crowbars	E	3	M	Project Surveyor	Admin
	• Cuts/Abrasions/Splinters		B	4	H	• Wearing Gloves	E	4	L	Project Surveyor	PPE
	• Adverse Effects from the Weather – UV, cold & heat		B	2	E	• PPE, jacket. Long sleeved shirt and long pants, Wide-Brim hats. • Drinking water; >2L p/surveyor p/day • Sun Block 30 +	D	2	H	Project Surveyor	Admin & PPE
	• Hearing Damage		C	3	H	• Hearing Protection	E	3	M	Project Surveyor	PPE
	• Getting Lost		D	1	E	• Advise time of return • Mobile phones, two way radios etc	E	1	H	Project Surveyor	Admin
	• Ingestion/Inhalation/Skin and eye damage caused by working with Spray Paint		C	3	H	• Use Downwind • Appropriate Ventilation • Use spray paint as per manufacturers specs • Safety glasses • Hard Hats • Work gloves • Dispose of appropriately-as outlined on MSDS (EPA Standards) • Long sleeve shirt and long pants	D	3	M	Project Surveyor & Operations Manager	Eng/PPE/ Admin

L ACCEPTABLE M ACCEPTABLE WITH CONTROLS H ACCEPTABLE WITH STRICT CONTROL/SHORT DURATION E UNACCEPTABLE

Procedure Break the job down into steps	**Potential Safety and Environmental Hazards** What can go wrong	**Legislative References**	**Risk Rating** L X	C =	R	**Control Measures**	**Residual Risk Rating** L X	C =	R	**Person Responsible** To ensure management method applied	**Hierarchy control**
	• Piercing Underground Utilities/Services whilst penetrating the ground; survey pegs/star pickets/dumpies etc.		C	2	E	• Contact Principal Contractor/Client for a Ground Penetration Permit • U/G Survey Search (Dial before you Dig)	D	2	H	Project Surveyor	Admin
• Driving	• Collision		D	1	E	• Vehicle fitted with Mine Flag • Defensive Driving • Head lights on • Keep to left when driving over crests • Drive to conditions • Obey speed limits	E	1	H	Project Surveyor	Admin
	• Bogged Vehicle		C	3	H	• Assess Road Conditions • Drive to Conditions	E	3	M	Project Surveyor	Admin
	• Spread of weeds whilst driving between sites and properties		B	2	E	• Wash vehicle and attain Weed Inspection Certificate when travelling between sites/properties	D	2	H	Project Surveyor	Admin
• Work on or beside the road	• Being struck by a vehicle	Section 4.3 MUTCD Part 3	D	1	E	• Park the vehicle clear of traffic lanes • Personnel utilise verges • Personnel wear hi-viz clothing at all times (long sleeve and long pants) • Flashing light to be operable	E	1	H	Project Surveyor	Admin & PPE

REVIEWS

Review No:	1	2	3	4	5	6	7	8	9
Name & Initials									
Date:									

Review using the tool SH&EWMS Review Checklist and guidance from Knowledge Resource using the Prepare, Review and Accept SH&EWMS

SIGNOFF

We the undersigned, confirm that the SH&EWMS nominated above has been explained and its contents are clearly understood and accepted. We also confirm that our required qualifications to undertake this activity are current. We also clearly understand the controls in this SH&EWMS must be applied as documented; otherwise work is to cease immediately.

Name	Position	Qualification Required for this Activity	Signature	Date	Time	Employer
Michael Zahl	Surveyor	UG BSpSc, Construction induction, in-house training		15/08/2013	12 noon	N/A