KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF ENGINEERING

DEPARTMENT OF GEOMATIC ENGINEERING

ASSESSING THE EFFICIENCIES OF USING GPS AND TOTAL STATION TECHNOLOGIES IN DISTRICT BOUNDARY DEMARCATION AND SURVEY IN GHANA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE OF GEOMATIC ENGINEERING, UNIVERSITY: KNUST, KUMASI-GHANA

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DECLARATION

I hereby declare that this submission is my own work towards the Masters of Science Degree and that, to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

Revenue mobilization is an important component of the socio-economic development of any country in general and at the district level in particular. Therefore, it is important that every district has its district boundaries clearly defined, set out (demarcated) on the ground and surveyed to avoid confusion, misunderstanding and open hostilities between adjoining districts as has been happening recently in Ghana. Hence the adoption of a good survey technique and data collection strategy that will show the exact location of district boundaries on the ground is a crucial factor in order to gather information accurately and efficiently at any given time in the district.

This thesis is aimed at assessing the suitability of GPS and Total Station technologies in the setting out and survey of district boundaries by comparing the parameters of accuracy, cost and time per the two survey methods.

Ga East and Ga West District boundaries having a rural setting and Ga South and Ga West, having urban settings were used for the experimental process. Thirteen boundary points selected in both rural and urban districts were observed with **Static** GPS measurements for thirty minutes and were processed using Topcon tools software. The results were adjusted using least squares methods. The results of the coordinates from this adjustment were held as reference. These same selected points were also surveyed using RTK GPS, Fast static GPS (5-, 10-, and 15-minutes) and a Total Station technique and their results also adjusted using least squares method. The coordinates of the boundary points from each of the methods were compared with the reference, which was the outcome of the 30-minutes Static GPS measurement. All the methods used satisfied the cadastral accuracy requirement. However, the 15-min Fast static GPS method achieved the best positional accuracy of 0.03m± 0.03m for Northings and 0.03m ±0.02m Eastings coordinates respectively. The RTK-GPS obtained the lowest Positional accuracy of 0.06m±0.01m for Northings and 0.05m ±0.02m Eastings coordinates respectively. The RTK-GPS spent shortest operational time.

The Total station method with a Positional accuracy of 0.05m±0.05m for Northings and 0.05m±0.05m Eastings coordinates respectively is the most expensive technique operationally with a cost of GH¢ 2500.00 for the rural district and GH¢2170.00 for the urban district respectively while the 5min-Fast static GPS technique was the least expensive for both the urban and rural district boundary survey. The most efficient technique in terms of accuracy, cost and time for setting out (demarcation) and subsequent survey of the district boundaries for both the rural and urban settings was the combination of the 10-minutes Fast static GPS Technique in conjunction with a high resolution satellite image. However, when boundary conditions vary a combination of the 10-minutes Fast Static GPS and the Total Station techniques together with the high resolution satellite imagery is the preferred option.

ACKNOWLEDGEMENT

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LIST OF ACRONYMS

2D Two Dimensional

C/A code Coarse Acquisition code

CORS Continuously operating reference system

ECEF Earth-Centered Earth Fixed

GLONASS Global Navigation Satellite System

GNSS	Global Navigation Satellite System
GPS	Global Positioning System
KNUST	Kwame Nkrumah University of Science and Technology
MATLAB	Matrix Laboratory
M-file	Matlab Function file
MINs	minutes
P-Code	Precise Code
RINEX	Receiver Independent Exchange Format
RMSE	Root Mean Square Error
SMD	Survey and Mapping Division
TM	Transverse Mercator
UTM	Universal Transverse Mercator
WGS 84	World Geodetic System 1984

CHAPTER 1
INTRODUCTION

1.1. BACKGROUND

Although GPS technology has been used for decades in geodesy and engineering works in Ghana, the use of GPS positioning techniques for cadastral survey of district boundaries is still in its early stage. In 2008, the Survey and Mapping Division of Lands Commission issued guidelines and standards for surveying and mapping in Ghana.

This guideline document however, covers the use of Static GPS Survey only. The use of GPS-RTK, Fast Static for cadastral surveys is still under consideration. (SMD, 2008)

Over the years the GNSS and, in particular, the Global Positioning System (GPS) technique for surveying has revolutionized survey practice.
The 24 satellite constellation arranged in 6 orbital planes each with 4 satellites, has offered surveyors (and others) uninterrupted, accurate three dimensional position measurement in all weather conditions.

The advent of Real Time Kinematic (RTK) GPS with occupation times reduced from a few minutes to only a few seconds has allowed land surveys to achieve reasonable accurate and instantaneous results in the field. Unlike conventional equipment which is hampered by its need for intervisibility between stations, a three-man team operation and the weather.

RTK and Fast Static GPS can dramatically decrease the time and manpower needed to complete a district boundary survey. This research is about assessing the various techniques/methods of boundary determination for district boundaries in Ghana. It involves the use of GNSS, Conventional Total station and high resolution satellite image.

1.2. THE RESEARCH PROBLEM

All the district administrative boundaries are ‘imaginary’ in that they are only shown on maps but not properly delineated on the ground with sign post (Bening, 1999). This means that most district assemblies do not know the exact location of their administrative boundaries on the ground. Lack of knowledge of these boundaries results in the overlapping of activities such as revenue collection, responsibilities, for the provision of social amenities, and disaster responses operations. In carrying out physical planning exercises and street naming, for example, knowledge of the exact boundaries of the districts are required.

1.3. RESEARCH AIM AND OBJECTIVES

The main objective of this study is to provide an appropriate procedure for determining District boundaries on the ground from a combination of existing survey methods and technologies.

Specific objectives include:

- The determination of the best ways of demarcating district administrative boundaries on the ground.
- The determination of the optimum survey procedure for the setting out and survey of the district boundary by comparing the selected methods of cadastral surveying both conventional and new, in terms of accuracy, cost and time.
- Setting cadastral accuracy thresholds for district boundary survey, in a rural/urban area.

1.4 RESEARCH QUESTIONS

From the problem statement above some important questions come to mind. Some of these questions include:

- Are the district boundaries of Ghana properly demarcated on ground with elaborate sign post for easy identification?
- Which of the conventional and new techniques of surveying is/are most appropriate for surveying district boundaries in terms of accuracy, cost and time?
- Are there laid down specifications for the survey and demarcation of district boundaries in Ghana?

1.5. JUSTIFICATION

The lack of knowledge of the exact location of district boundaries on the ground and infrequent update of maps result in some District Assemblies crossing boundaries to collect revenue. Applicants for building permits get confused as to which assembly will receive their application and subsequent grant of permits. However, with proper demarcation and marking of boundaries of the District Assemblies the above confusion will either be eliminated or minimized.

In order to maximize revenue volumes, some district assemblies deliberately shift their boundaries thereby trespassing into other administrative areas. According to a committee's report on district boundary disputes submitted to the Ministry of Local Government in 2010, the following cases were sited: Adentan and Ga East, Ga South and Awutu-Senya, and Ga West and the Akuapim South Municipal Assemblies.

Presently most administrative boundaries are identified by means of physical features, like rivers, hills, mountain ranges and valleys. However, in some instances, the boundaries do not follow natural features throughout their entire course. This again calls for a proper demarcation of the boundaries on ground with sign posts.

The Statistical Service Department (SSD) is unable to assign population figures to particular assemblies due largely to lack of physical presence of administrative boundaries on ground. This affects budgetary allocations and proper disbursement of "common funds" which are largely a function of the size and population of the assembly.

Establishing survey beacons along the boundaries in the presence of all the stakeholders from both district assemblies, and the subsequent survey of the boundary will help resolve these boundary problems.

This project is aimed at identifying the most convenient method of demarcating and surveying the district boundary which will further facilitate revenue generation.
It is the hope of the researcher that the findings of this research could contribute to the current discussion on the guidelines and standards for survey and mapping of district boundary by the Survey and Mapping division of the Lands Commission.

1.6. SCOPE OF RESEARCH

The thesis consists of both office work and field data collection. The methodology adopted included the following:

Literature review on boundaries, survey equipment, cadastral survey methods, Root Mean Square (RMS), Standard Deviation, Cost and Time estimation for the various survey procedures.

- Field measurements for both urban and rural districts, using GPS and Total station technologies.
- The processing of field data.
- The analysis of various methods used by computing accuracies of the results from the various methods, cost and time estimates for the project.
- The provision of time and cost estimates for the various techniques employed in the research.
- Conclusion and recommendation

1.7. OUTLINE OF THESIS

This thesis is organized into five chapters. In chapter one the problem statements, research significance, research objectives, scope of project and outline of the thesis were considered. Chapter two gives the background to Cadastral Survey, literature review on Boundary Systems, Boundary demarcation, Conventional survey methods, and concluded on the concept of root mean square error. The procedures for collecting field data, post-processing techniques and computations for both the rural and urban district boundaries are presented in chapter three. The study area and diagrams of survey are also described; materials, equipment and software used are listed. The methods of costing and efficiency of each of the surveying methods are also detailed in this chapter. In chapter four, the field data and the results obtained from the postprocessed data are presented. Analysis and discussions of these results via statistical comparisons are presented in chapter five. The chapter six, summarizes the thesis, draws the relevant conclusions, and makes some recommendation for future works (Figure1.1)

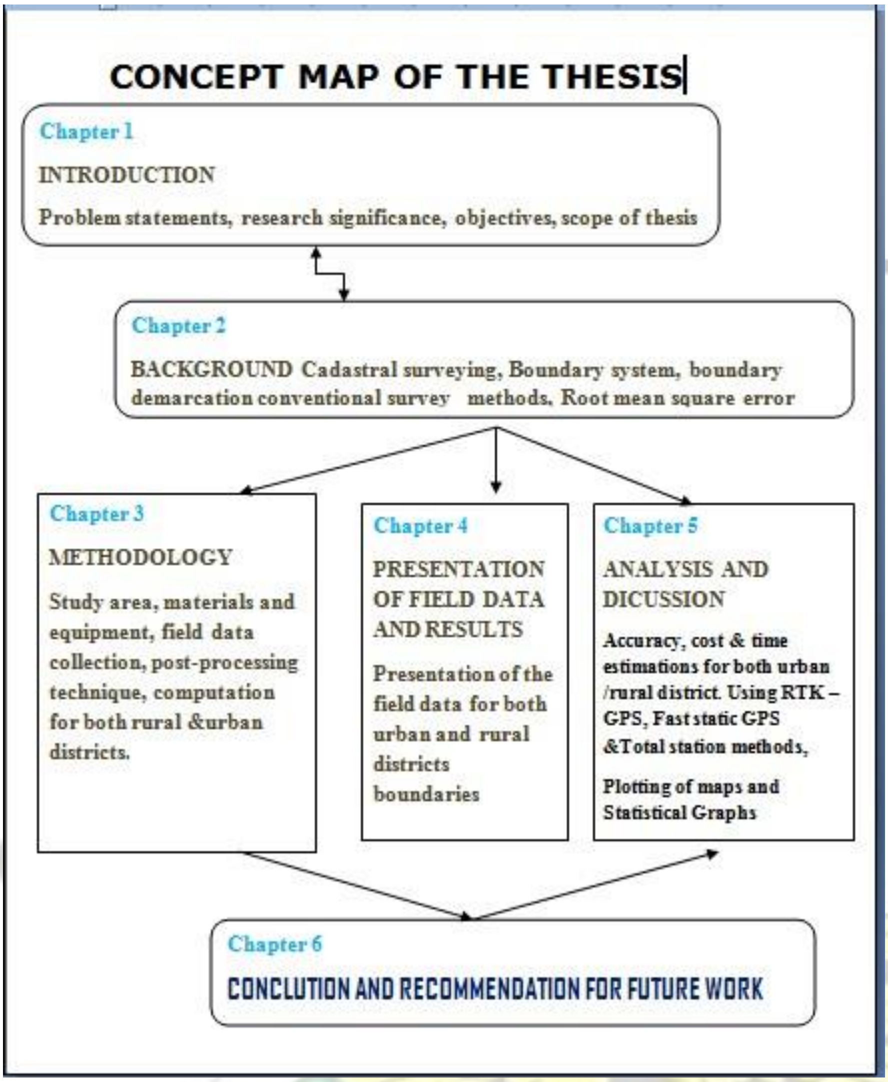

Figure 1.1: Concept Map of Study

CHAPTER 2
LITERATURE REVIEW

2.1. INTRODUCTION

This chapter reviews relevant literature related to the concepts of boundary, Conventional Survey methods, their efficiencies as well as the theorem of root mean square error, Global Navigation satellite system (GNSS), Global positioning methods, Fundamentals of GNSS Measurement, concept of costing survey work.

2.2. CONCEPTS OF BOUNDARY

The idea of boundary is to determine the legal extent of ownership of property and may be marked by natural features, survey pegs, or enclosed occupation such as fences, hedges or walls (Baalmann, 1979). This means that boundaries of properties are recognized in law and must be properly demarcated and marked on the ground to serve as limits or extent of economic properties. In common law where land is described as being bounded by a road for instance, ownership extents to the middle of the road unless a contrary definition is provided (The ad medium filum viae rule) It is important to note that features used as boundary marks have some order of priority (Hallmann,1994). Thus in the event of boundary disputes the nature of the boundary marks play an important role as the courts usually grant priorities of weight to these features. The order of priority is as follows:

- Natural boundaries such as rivers, streams, mountain chains, hedges, monumented lines
- Old occupations, which are long undisputed
- Abuttals
- Statement of length, bearing or direction (schedule)

There are several kinds of boundaries in cadastral surveying a few of which are discussed below.

2.2.1. Fixed Boundaries

Generally, boundaries of land are fixed and do not move despite that the interpretation of boundary location can be very difficult and professional judgments may vary in the interpretation of the evidence of the location. Whatever the case may be, fixed boundaries can be, marked on the ground in one place and do not change position over time (Gerden, 1991). The kinds of features used in marking fixed boundaries include survey beacons, concrete walls, traverse pickets etc.

2.2.2. General Boundaries

The kind of boundary features used in marking a given boundary may be natural such as the sea, lakes, rivers, to mention but a few. These boundaries are ambulatory and cannot be marked on the ground or fixed in one place because they may change position over time (Gerdan, 1991).

2.3 REGIONAL BOUNDARY

Regional boundaries delineate one region of a country from another and are therefore legal (Bening, 1999). Thus a legal survey, usually cadastral in nature, needs to be carried out to establish regional boundaries. They may be marked by natural or artificial features. Artificial features such as survey type 'A' beacons are used in marking regional boundaries (Bening, 1999). Typical natural features such as streams and ridges are used in marking regional boundaries. Regional boundaries are established through first class geodetic survey technology using National geodetic framework beacons. Regional boundaries have been entrenched in all the constitutions of Ghana and are established through legislature. Regional boundaries take precedence over district and constituency boundaries (Reindorf, 1966) as far as administrative boundaries are concerned.

2.3.1. District Boundary

District boundaries differentiate one district and constituency of a country from another and are therefore legal (Bening, 1999). Thus a legal survey has to be carried out to show their exact location on the ground for effective administrative planning. Most district boundaries in Ghana have not been physically demarcated on the ground. The boundaries of all districts in Ghana have been established by legislative instruments(LI) that show the description of district boundaries by means of natural and artificial features such as streams, cliffs, valleys, roads, railway lines, to mention but a few. This was done without sufficient consultation with the traditional authorities, opinion leaders, and other stakeholders.

As a result, most people cannot make a clear distinction between a traditional boundary and an administrative boundary. For cadastral purpose Type 'B' beacons are used in marking district boundaries (SMD, 2008).

2.3.2. The Ga West Municipal Assembly.

Ga West Municipal Assembly is one of the ten (10) districts in the Greater Accra Region of Ghana. Its capital is **Amasaman**. The Ga West Municipal Assembly was established by LI.1858 on November 2007 and it is the gateway to Accra on the Kumasi-Accra route. The Municipality lies within latitude 5°48' North, and 5°39' North, and longitude 0°12' West and 0°22' West. It shares boundaries with Ga East and Accra Metropolitan

Assembly to the East, Akuapim South to the North and Ga South to the south and West It occupies a land area of approximately 305.4 sq km with about 193 communities. Both Ga East and Ga South were created out of the then Ga District now Ga West Municipal Assembly (Ghana Districts.com 2010).

2.3.3. The Ga East Municipal Assembly.

The Ga East Municipal Assembly is located at the northern part of Greater Accra Region. The Administrative capital of the District is **Abokobi.** The municipality forms part of sixteen (16) Metropolis, municipalities and Districts in the Greater Accra Region. The Municipality shares boundaries with Akuapim South Municipal to the North, Ga West Municipal to the West, Adentan Municipal to the South and LaNkwantanang-Madina to the East.

2.3.4. The Ga South Municipal Assembly.

The Ga South (Weija) Municipal Assembly was carved from the Ga West District Assembly in November 2007. The Assembly was established by Legislative Instrument 1867 in 2007 with the capital at **Mallam**. The Ga South Municipal Assembly lies within latitude 5°48'North and 5°29'North and Longitudes 0° 8' East and 0° 3' West. It shares boundaries with Accra Metropolitan Assembly to the South East, Ga Central and Ga West to the East, Akwapim South to the North-East, West Akim Assembly to the North, Awutu Senya East Municipal Assembly to the West, Gomoa Assembly to the South-West and the Gulf of Guinea to the South. The estimated population of the Assembly according to the 2010 census is 485,643 (Ga Central inclusive). Fig 2.0 shows the district boundary map of Ga West.

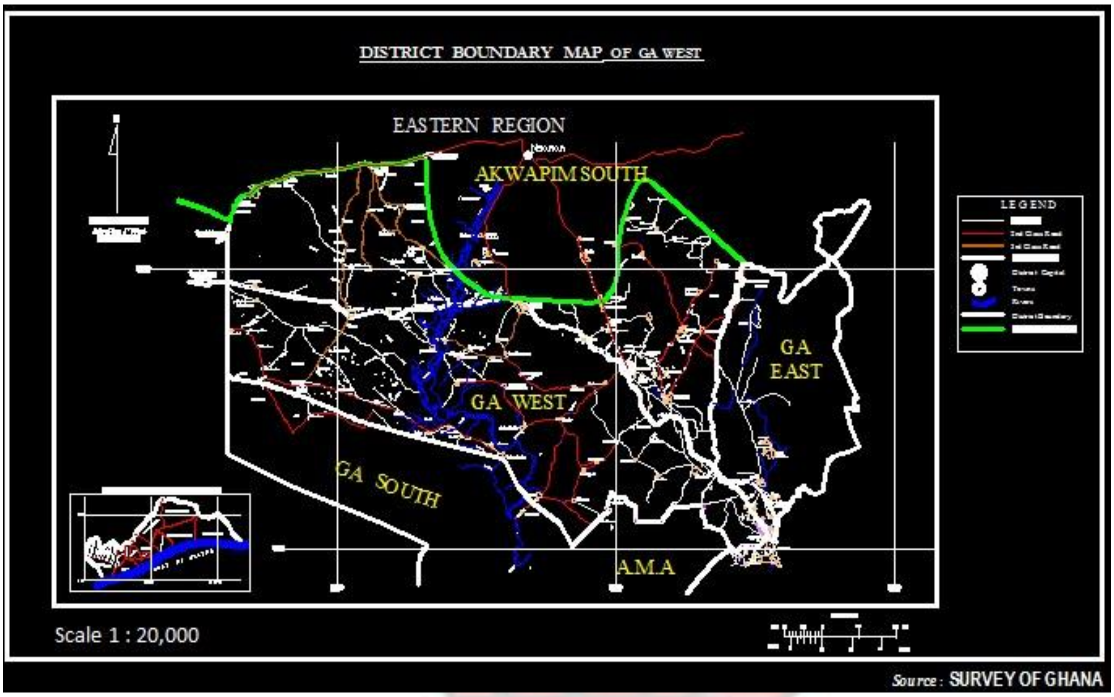

Figure.2.0: District boundary map of Ga West

2.4. PURPOSE OF BOUNDARY

Marked boundaries are the prima facie evidence of ownership of property (Hallmann, 1994). The idea of ownership of a property is meaningful only when boundaries of such properties are delineated properly and marked on the ground. The true nature of the boundaries needs to be determined and for this, the services of a Licensed Surveyor or Official Surveyor are required by law (Survey Act, 1962 and LI 1444).

2.5. MODERN SURVEY METHODS

2.5.1. Global Navigation Satellite System (GNSS)

Global Navigation Satellite Systems (GNSS) is a term used to describe all forms of satellite based navigation systems and encompasses all satellite radio-navigation systems that provide global coverage and signals that provide navigation, positioning, surveillance and timing information for ground, marine, aviation and space applications. GNSS is composed of two operational space satellite systems, the US Global Positioning System (NAVSTAR GPS), the Russian GLONASS and the upcoming European Global Satellite Navigation System – Galileo, which has been launched since 2010.

2.5.1.1. Global Positioning Methods

Global Positioning systems (GPS) is a satellite based navigation and positioning system providing 24-hour, all weather worldwide service, with appropriate 3D location information (providing latitude, longitude and altitude reading) and Precise timing services (Ovstedal, 2002). The GPS is the world leader component of the evolving Global Navigation Satellite Systems (GNSS) with 21+3 (24 operational plus 3 spares) space constellation (Figure 2.1).

With a worldwide common grid that is easily converted to any local grid Continuous real-time information, access to unlimited number of users, GPS is able to give better accuracies when compared to conventional techniques (Leick, 2004). The use of GPS in fixing ground position can be achieved using several measurements techniques. Some few of these techniques are discussed in subsection below.

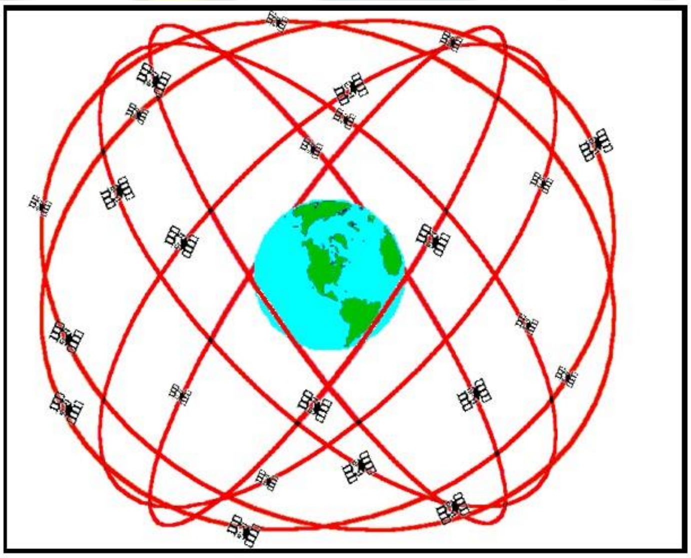

Figure 2.1: GPS Constellations

2.5.1.1.1. Absolute Positioning Using GNSS (GPS)

This positioning technique involves the use of a single passive receiver, with four satellite visibility for positioning, velocity and time (PVT) solutions (Wells, et-al 1986). Absolute DGPS result, in knowing the user's position with respect to an absolute coordinate system such as the one called the Earth-Centred Earth-Fixed (ECEF). This requires having a reference station whose position is accurately determined with respect to the absolute coordinate system ahead of time. Errors in GPS calculated position can be determined by a comparison between the known reference position and the GPS calculated position at the reference station. These errors are then broadcasted to surrounding receivers to update their positioning solutions. An example of absolute positioning is the handheld/standalone GPS (Ovstedal et al, 2002).

2.5.1.1.2. Handheld /Standalone GPS

Handheld GPS receivers are independent from all other receivers and uses only satellites to calculate positions by means of autonomous solutions. Handheld GPS with SBAS is able to produce 3m accuracy. They are used for navigational purpose.
Figure 2.2 shows GPS in Absolute positioning mode.

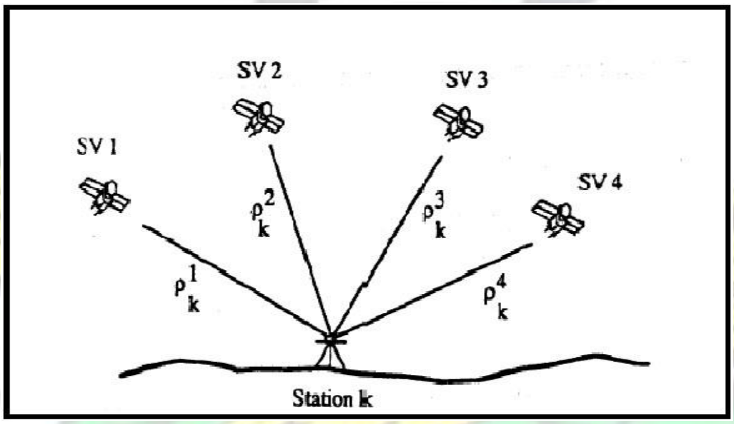

Figure 2.2: GPS Absolute Positioning Mode

2.5.1.1.3. Relative Positioning Using GNSS (GPS)

Relative DGPS results, in knowing the baseline vectors between different users. It requires having a reference station with known position. It is more challenging to implement as the receivers are all cooperating with each other to iteratively update and improve their positioning solution. Raw receiver data has to be shared with each member of the system. There is also a timing synchronization issue between each receiver of the system. Relative position techniques involve, Static, Fast static, Stopand-go kinematic and Real Time Kinematics (Wells, et-al.1987). Figure 2.3 shows GPS in Relative position mode.

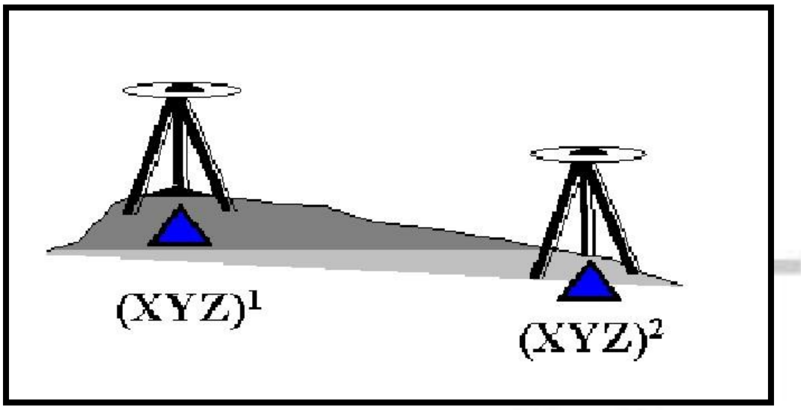

Figure 2.3: GPS Relative Positioning Mode

2.5.1.1.4. Static GPS technique.

Static GPS technique can either be relative or absolute. In static positioning, a receiver is mounted on the point whose position is to be determined. The receiver remains on the point from between a couple of minutes to sometimes hours in order to improve the accuracy of the position solution. This method is commonly adopted together with the relative position technique. In relative positioning technique a minimum of two receivers are required in which one receiver is set on a known ground position (master station) and the second receiver is mounted on the unknown point (Rover station).

Single or Dual frequency GPS receivers can be used in position fixing for a period of 30 minutes to 1hour minimum observation time. Static Satellite survey procedures allow various systematic errors to be resolved when high accuracy positioning is required. Static procedures are used to measure baselines between stationary GPS receivers by recording data over an extended period of time during which the satellite geometry changes (Hofmann-Wellenhof et al (2001).

2.5.1.1.5. Fast-static Surveys:

Fast-static surveys are similar to static GPS surveys, but with shorter observation periods. Fast-static GPS survey procedures require more advanced equipment and data reduction techniques than static GPS methods. Typically, the fast-static GPS method should not be used when horizontal accuracy requirements are greater than 1: 100,000 (SMD, 2008).

2.5.1.1.6. Real-Time Kinematic - GPS Surveys.

A base station is established by setting up a GPS receiver on a known survey beacon. The base station receiver broadcast data to one or more rovers. The processor of the rover combines the reference station data with that of the rover and computes the baseline. The RTK technique enables the rover to be positioned with accuracy better than a few centimeters relative to a reference station. The RTK technique is able to process and display results in real time. Real time kinematic surveys can either be continuous or “Stop and Go". “Stop and Go” station observation periods are of short duration, typically under two minutes. Kinematic surveys are employed where thirdorder or lower accuracy standards are applicable (Boey, 1996).

2.5.1.1.7. Continuously Operating Reference Station (CORS)

A system of GPS receiver which collects GPS data and broadcasts this signal in real time to rovers or stores the data for post-processing on data for differential positioning. Application is available online for all GPS users. The Accra GRN (CORS) station was used to accomplish this project.

2.5.2. Total Station Technology

A Total station instrument combines an EDM (electronic distance measurement) and electronic digital theodolite, and a micro-processor in one unit for measuring distances and angles for position fixing (Uren and Price, 2005). Similar to the GPS technology there are several techniques of fixing position by use of Total station, such as measuring angles and distances, bearings and distances and co-ordinates (COGO MENU). Horizontal and vertical angles as well as slope distances can be transmitted in real time to a built in micro-processor or can be displayed upon keyboard command.

Components used in Total station surveying are

- Total Station (and tripod)
- Field Note Book/Data Logger.
- Prism (and prism pole)
- Computer interface
- Batteries and communication gadgets.

2.5.3. Station marks

Station marks are established to be permanent, hence are usually constructed with cement, sand and stones using required ratios and the appropriate inscription written on them for future easy identification of the various boundaries.
Four types of station marks are used in Ghana namely International boundary pillars:

Type A. Regional boundary/acquisition/1st order surveys
Type B. District boundary/stool/skin boundary/2nd order surveys

Type C. Layout survey

2.6. BOUNDARY DEMARCATION

Demarcation is the marking of boundary using boundary post and the accurate surveys of the boundary post (Lin, 2003). There are two types of demarcation namely Paper and Ground demarcation.

2.6.1. Paper Demarcation

Office or paper demarcation involves identification and selection of both boundary and ground control points (GCP) (SMD, 2008).
These may either be natural and artificial features on an available map, topographical maps, town sheets, satellite image/Google map to aid in easy identification of the boundary and for accessibility analysis (Uren & Price, 2005). The coordinates of such points are obtained and prepared for the subsequent ground demarcation works.

2.6.2. Ground Demarcation

The ground demarcation work entails the identification of the boundary point, on the ground in the company of the surveyor together with either the prospective or the allodial owners, with the aid of simple Hand held devices. Appropriate boundary data obtained from the office demarcation analysis is fed into these devices either manually or digitally as the case may be and used for navigation which leads to the identification and marking of these boundary points.

2.6.3. The Use of High Resolution Satellite Imagery (Google Earth)

High Resolution Satellite Imagery is very useful in the identification of both boundary and Ground Control Points (GCP). This identification is done on a pan-sharpened image. These points may include natural and man-made details (building edges, wall corners, some anti-erosion rock string courses, small trees, and crossroads) and points that in general could guarantee univocal and easy identification both over the image and on the ground. **2.5M** resolution Goggle Earth imagery was used for this project.

2.7. ERROR ANALYSIS

Error is the difference between a measured or calculated and the established value of a quantity (Fan, 1997). In the case of this thesis the established value is the values determined through Static GPS observation by using Established control network for the survey.

2.7.1. Measurement Errors

There are three types of errors: systematic errors, gross errors and random errors. **Systematic errors** are those errors which follow certain physical or mathematical rules. These kinds of errors are: calibration errors, tension in analogue meters, ambient temperature, etc. These errors can be corrected by applying correction factors, calibrating instruments and selecting suitable instruments. In most cases **gross errors** can be caused by human mistakes such as carelessness. The instrument may be good and may not give any error but still the measurement may go wrong due to the operator. Those errors do not follow any physical or statistical rules. Examples of those kinds of errors are: taking wrong readings, wrong recording of instrument or target height, reading with parallax error, etc.

Random errors are most often errors in measurement that lead to measured values being inconsistent when repeated measurements are performed. Errors in measurements stem from three sources: personal, instrumental, and natural. Personal errors are caused by the physical limitations of the human senses of sight and touch. An example of a personal error is an error in the measured value of a horizontal angle, caused by the inability to hold a range pole perfectly in the direction of the plumb line. Instrumental errors are caused by imperfections in the design, construction, and adjustment of instruments and other equipment. Instruments can be calibrated to overcome these imperfections. Natural errors result from natural physical conditions such as atmospheric pressure, temperature, humidity, gravity, wind, and atmospheric refraction.

2.7.2. Theory of Standard Error

To evaluate the accuracy and precision of the various measurements, root mean square and standard deviation of the individual measurements were computed. **RMS** (root mean square error) is a measure of accuracy of the individual measurement. It can be computed from the deviations between true and measured values. True value of the measured quantity is the value which was determined with significantly higher precision. In this project the coordinates of the STATIC GPS observations were considered as 'true' which is determined in 1mm level. RMS was computed using the following formula:

$$RMS\ (\hat{l}) = \sqrt{\sum_{i=1}^{n} \frac{(\hat{l}-l_i)^2}{n}} \quad (2.5)$$

Where: $\hat{l}$ is the established value, l_i is individual measurement and n is the number of measurements.

Standard deviation is a measure of variations of the repeated measurement, i.e. of the precision of each individual observation. It can be computed from the mean values of the individual measurement and the individual measurement.

For a variable 'X' measured in 'n' times. The Standard deviation is computed according to the following formula

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad \text{……………………………………} (2.6)$$

$$\sigma_x = \pm\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(v_i\right)^2} = \pm\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2.7)$$

$$S_x = \pm\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \quad \text{i.e. } \sigma^2_\chi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.8)$$

$\bar{x}$ = Mean of the observations (MPV),

σ_χ = Standard Deviation

S_x=Standard Error

V_i = is a residual such as $V_i = (\chi_i - \bar{x})$

(n-1) is known as the number of degree of freedom which represents the number of extra measurement taken to determine the quantity. In cadastral survey practices better observations have smaller standard errors (SMD, 2008).

2.7.2.1. Positional Accuracy

The positional Accuracy of control points can be obtained from the formula,

Positional Accuracy , $f_{pi} = \sqrt{\Delta x_i^2 + \Delta y_i^2}$ …. ….. Eqn2.7

$$\Delta x(N) = x(N)_{RTK/F.S/T.S} - X(N)_S$$

$$\Delta Y(E) = Y(E)_{RTK/F.S/T.S} - Y(E)_S$$

Point Accuracy=Mean± σ (mm)

Max (N) = maximum 'X' coordinates in the Northings.

Max (E) = maximum 'Y' coordinates in the Eastings.

Min (N) = minimum 'X' coordinates in the Northings.

Min(Y) = minimum 'Y' coordinates in the Easting.

2.7.3. Sources of Errors in GNSS Measurement

The main sources of error that affect GPS measurement are, Satellite Geometry, Signal Multipath, atmospheric refraction (Chan, 2006).

Satellite Geometry errors arise due to orientation of the observable satellites which influence the achievable position accuracies usually described by dilution of precision (DOP) factors; GDOP expresses the confidence factor of the position solution.

Signal Multipath errors occur due to reflection of the GPS signals by objects surrounding the receiver antenna. Detail explanation of these biases can be read from many text books. See (Seeber, 1993, Leick, 2004).

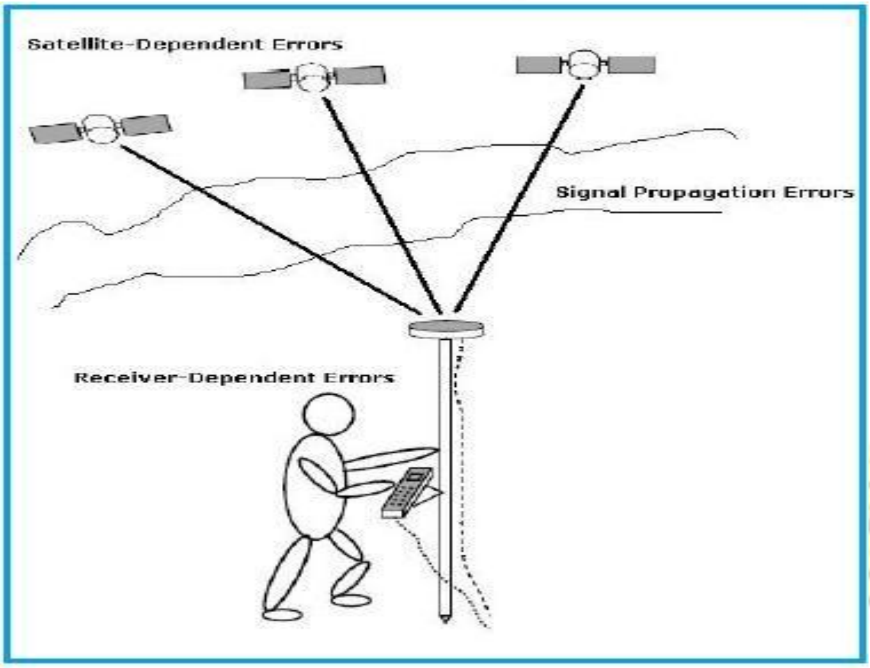

Figure 2.6: GNSS Error Sources

2.7.3.1. Prevention/Correction

The effect of the satellite geometry on GPS signals can be minimized by good mission planning whiles the siting of survey stations away from reflecting surfaces helps in reducing the multipath effect. Atmospheric refraction can be eliminated or minimized by relative or differential techniques.

2.7.4. Accuracy

Field observations and the resulting measurement are never exact. Any observation can contain various types of errors. Often some of these errors are known and can be eliminated or at least reduced by applying appropriate corrections. However, even after all known errors are eliminated, a measurement will still be in error by some unknown value. To minimize the effect of errors and maximize the accuracy of the final result, the surveyor has to adopt utmost care in making the observations. However, a measurement is never exact, regardless of the precision of the observations.

Accuracy is the degree of conformity with a standard or accepted value. Accuracy relates to the quality of the result. The standards used to determine accuracy can be:

- An exact known value, such as the sum of the three interior angles of a plane triangle is 180°.
- A value of a conventional unit as defined by a physical representation thereof, such as the international meter.
- A survey determined or established by superior methods and deemed sufficiently near the ideal or true value to be held constant for the control of detail survey.

The accuracy of a field survey depends directly upon the precision of the survey. Therefore, all measurements and results should be quoted in terms that are commensurate with the precision used to attain them (Alexander, 1992). Similarly, all surveys must be performed with a precision that ensures that the desired accuracy is attained. Although they are known to be not exact, established control points are deemed to have sufficient accuracy to be used as controls for all other detail surveys.

2.7.4.1. Precision

Precision is the ability to repeat the same measurement. It is a measure of the uniformity or reproducibility of the result. Precision is different from accuracy in that it relates to repeatability of the measurements made. In short, a set of measurements is precise if nearly similar results are obtained with repeated observations, while accuracy is the closeness to the established value.

2.7.4.2. Survey Accuracy

Accuracy of a field survey measurement can be expressed as the difference between observed and the true value (Boey & Hill, 1995). Accuracy of survey is mostly represented by the symbol sigma (ô). Table 2.1 shows the various standard deviation and their associated probability levels.

Table 2.1 standard deviations and their associated probability

	1-D	2-D	3-D
1-ô	68.0	39.3	19.9
2-ô	95.0	86.0	78.8
3-ô	99.7	98.9	97.1

(Source SMD 2008)

2.7.4.3. Accuracy Standards For Cadastral Surveys in Ghana

The horizontal accuracy requirement for a district boundary survey is of the third order accuracy (SMD, 2008). The third order horizontal measurement accuracies include the following:

(i) Plus/minus 0.05m, plus 0.01m per 100m, for each boundary point to each other boundary point.

(ii) Plus/minus 0.03m for each boundary point (other than an adopted point) to its witness mark or marks.

(iii) Plus/minus 0.03m. plus 0.01m per 100m, for each boundary point to each traverse or origin mark.

(iv) Plus/minus 0.02m, plus/minus 0.01 m per 100m, for each witness traverse or origin mark to each other witness traverse or origin mark.

For third order observation the instrument centering accuracy shall be to ±0.5 mm.
These requirements apply directly to cadastral surveying in general.

2.7.5. Total Station Surveys

The accuracy of the Topcon Total Station survey for cadastral works is dependent on the instrument type and the kind of cadastral work. Angle measurement accuracy (Horizontal or Vertical) can range from 2” to 5” (Bunce, 2012). Similarly distance measurement accuracy can range from: +/- (0.8 + 1 ppm x D) mm, to +/- (3 + 3 ppm x D) mm, where D represents the field distance measured.

2.7.6. Obtainable Accuracies with GPS Positioning Techniques in Ghana.

Table 2.2 showed accuracies obtainable with GPS positioning techniques

Table 2.2: Accuracies obtainable with GPS positioning techniques.

CONCEPT/ TECHNIQUES	MINIMUM REQUIREMET	APPLICATION	ACCURACY
STATIC	L1 OR L1/L2 GNSS(GPS) RECEIVER (30MIN)	Control Survey(High accuracy)	Sub-centimeter
FAST STATIC	L1/L2 GNSS (GPS) receiver. (5-20)min observation time	Control surveys- medium to high accuracy	Sub-centimeter
RTK	L1/L2 GNSS (GPS) (0-3) min observation time .RECEIVER DATA LINK REQUIRED. BASELINE should be 10km maintain satellite lock.	Photo control. Real-time topo. Construction stakeout	Centimeter +

(Source: Caltrans GPS survey specification 2012).

When GNSS techniques (especially GPS) are employed in general position determination, it is evident from table 2.2 that the technique selected for a particular survey project is directly a function of the accuracy requirement of the data to be determined.

2.8. GEOCENTRIC COORDINATE SYSTEM

The position of a point in space can be expressed in different coordinate systems. In this project three types of coordinate systems are considered, namely the World Geodetic System 1984 (WGS 84), Earth-Centered-Earth-Fixed (ECEF) Cartesian and ECEF

Geographical systems. These three main coordinate systems are described in detail in the following sub-sections. Coordinate transformations and map projections are also considered briefly in this section.

2.8.1. World Geodetic System 1984 (WGS 84)

The WGS84 Coordinate System is a Conventional Terrestrial Reference System (CTRS) or an earth-fixed Cartesian coordinate system. The Basic definitions of this coordinate system are as follows (McCarthy, 1996),

- Its origin is located at the earth's centre of mass, the geocentre,

It is geocentric, the center of mass being defined for the whole Earth including oceans and atmosphere. Its scale is that of the local Earth frame, in the meaning of a relativistic theory of gravitation.

- Its orientation was initially defined by the Bureau International de l'Heure (BIH) orientation of 1984.0.

- Its time of evolution in its orientation created no residual in global rotation with regard to the crust.

The WGS84 Coordinate System is a three-dimensional Cartesian right-handed, Earthfixed orthogonal coordinate system, shown in Figure 2.7.

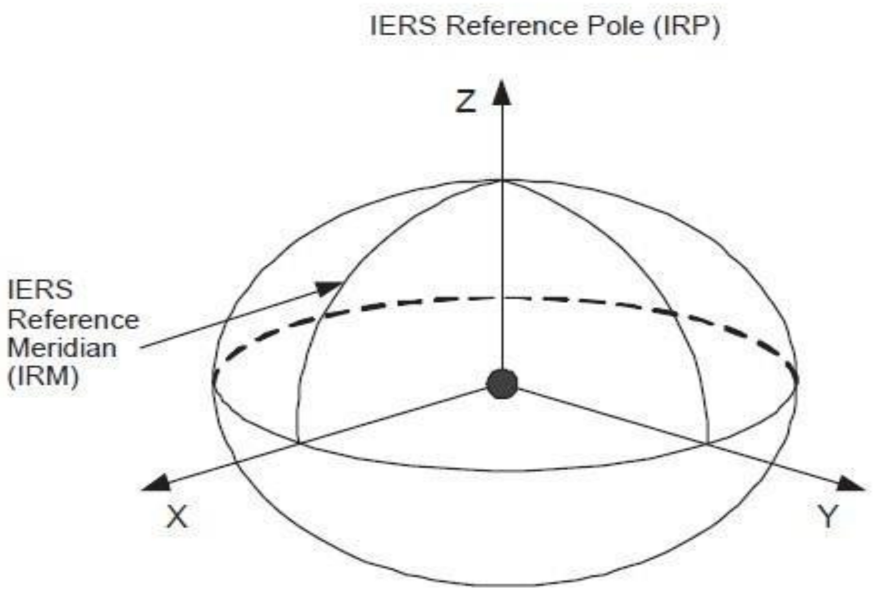

Figure 2.7: The WGS 84 Coordinate System Definition

The four defining parameters of the WGS84 ellipsoid with specified standard deviations are (Borre et al,1997):

- Semi-major axis (a) = 6378137m (σ_a = 2m).
- Ellipsoid flattening (f) = 1/298.257223563 (derived from the value of the normalised second degree zonal harmonic coefficient of the gravitational field: -484.16685x$^{10-6}$).
- The Earth's rotational rate or Angular velocity of the earth (ϖ_e):

  ϖe = 7292115.1467 x10^{-11} rad/sec; $\sigma_{\varpi e}$ = 15 x 10^{-11} rad/s

- The Speed of Light in vacuum c, c = 299792458 m/s; σc = 1.2m/s.
- The Earth's gravitational constant (including the mass of the Earth's atmosphere) (GM) = 3986005 x10^{-8}m^3/sec^2 (σ_{GM} = 0.6 x10^8 m^3/s^3.

In order to maintain consistency with GPS calculations within this project, it is reemphasized that only WGS 84 parameters are used. The WGS84 Coordinate System origin also serves as the geometric center of the WGS84 Ellipsoid and the Z-axis serves as the rotational axis of this ellipsoid (Bowring, 1985).

2.8.2. ECEF Cartesian Coordinate System

For the purpose of computing the position of a GPS receiver antenna, it is more convenient to use a coordinate system that rotates with the Earth, known as an EarthCentered Earth-Fixed (ECEF) system. In such a coordinate system, it is easier to compute the latitude, longitude, and height parameters that the receiver displays (Kaplan et al, 2006).

The ECEF coordinate system is defined by three right-handed orthogonal Cartesian system (x, y, z). the Earth spinning axis 'z-axis', the axis that cuts both the equatorial plane and Greenwich Meridian 'x-axis', and the axis that is perpendicular to the other two axes 'y-axis' (Chan, 2008). The position of a point (which can be either satellite or receiver) in ECEF Cartesian coordinate system is expressed as follows (Chan, 2008):

$$X_{ECEF} = \left[x_{ECEF} \quad y_{ECEF} \quad z_{ECEF}\right]^T$$

2.8.3. ECEF Geographical Coordinate System

The ECEF coordinate system can also be represented by an ellipsoidal or geodetic coordinate system. It is defined in terms of Latitude ‘ϕ ’, Longitude ‘λ’ and Ellipsoidal Height ‘h’ (perpendicular to ellipsoidal surface). The position of a point (which can be either satellite or receiver) in ECEF Geographical coordinate system is expressed as follows (Chan, 2008):

$$X_{ECEF,geo} = \left[\phi \quad \lambda \quad h\right]^T$$

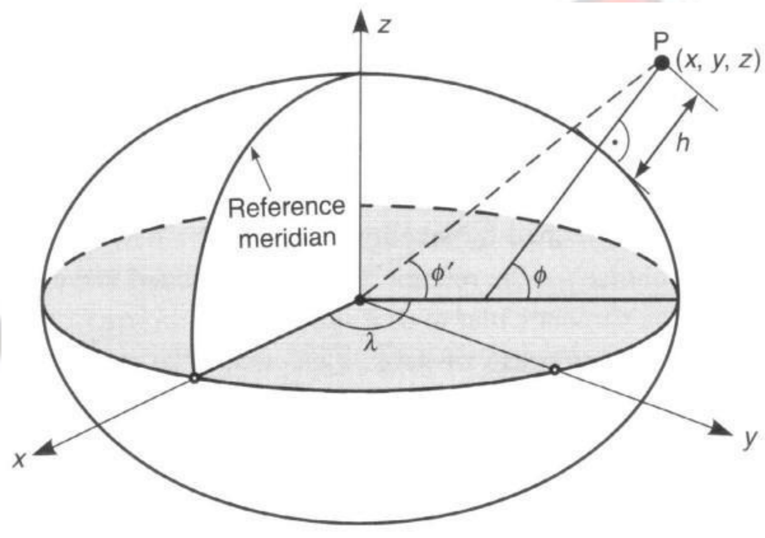

Figure 2.8: ECEF coordinate system

2.9. PROJECTED COORDINATES

In carrying out land surveying operations in Ghana, plane rectangular or grid coordinates are needed to produce a two-dimensional surface of a map. The objective is to map a point (ϕ, λ) on the ellipsoid into a point (x, y) in a plane. (Hofmann et al., 2008). Map coordinates use a 2D Cartesian system in which the two axes are known as northings and eastings. They are computed from the ellipsoidal latitude and longitude by a standard formula known as a map projection. The map projection used in Ghana is the Transverse Mercator projection (TM) and that which is used worldwide, especially by the GPS system is the Universal Transverse Mercator

(UTM) projection. Below in table 2.10 are the TM and UTM projection parameters on the War Office and the WGS84 ellipsoids respectively. The projection formulae for the two projections are given in appendix D

Table 2.3: Projection Parameters

ELLIPSOID: WAR OFFICE	*ELLIPSOID*: WGS 84
PARAMETERS	*PARAMETERS*
a □ 6378299.996*m* *Semi- major axis f*	*a* □ 6378137.0*m* *Semi- major axis f*
□1/ 296 *flattening*	□1/ 298.257223563 *flattening*
PROJECTION PARAMETERS	*PROJECTION PARAMETERS*
□$_0$ □ □4^o 40'□ Latitude of origin	□$_0$ □ 0 Latitude of origin
□$_0$ □1^o *w* Longitude of origin k_0	□$_0$ □ 3^o *w* Longitude of origin k_0
□ 0.99975 scale factor	□ 0.99960 scale factor
N_0 □ 0.0000 false Northing	N_0 □ 0.000*m* false Northing
E_0 □ 900000 *ft* false Easting	E_0 □ 500000*m* false Easting

2.10. GHANA NATIONAL GRID

The national Grid provides unique reference system based on the Transverse Mercator Projection which applies to all Ghana maps and plans at all scales. The main purpose of a grid is to provide a system for efficient location of points and referencing (Ayer and Fosu, 2008). The Ghana National Grid is based on the War Office spheroid whose general parameters are as follows; a = 20926201 ft. b = 20855505 ft.
f = 1/296

The units of measure are the feet. The true origin of latitude and meridian are:
Meridian of origin =1º00'West of Greenwich Latitude of origin = 4º40'North
Scale factor at origin = 0.99975. False origin of Ghana National coordinate system is 900,000ft Easting and 0.0000 ft Northing. Figure 2.9 Shows Ghana Map Grid under the Traverse Mercator projection

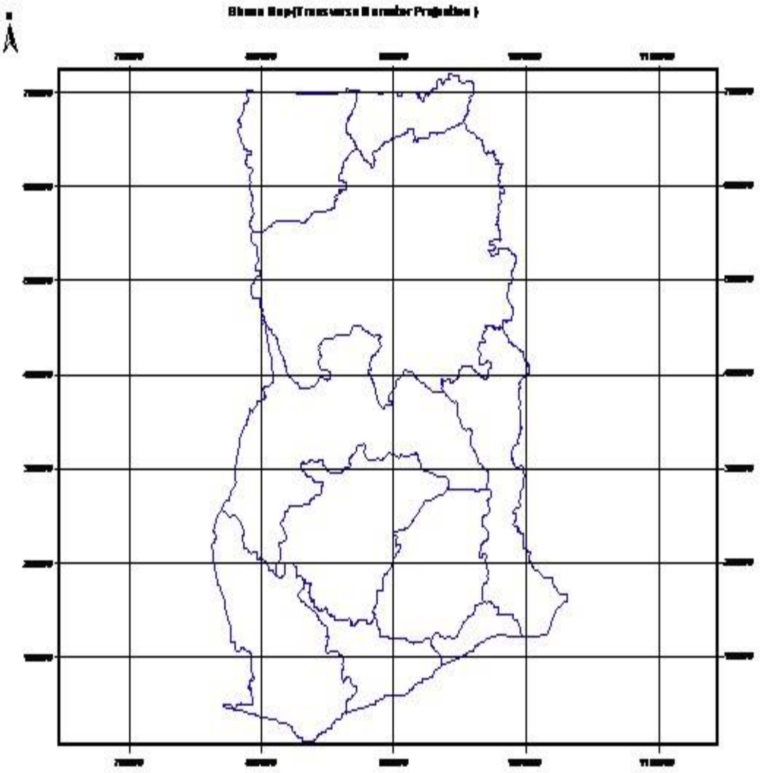

Figure. 2.9: The Ghana National Grid system

2.11. CO-ORDINATES TRANSFORMATION AND MAP PROJECTION

The 3D Cartesian coordinates can be used to transform geodetic coordinates (Latitude, Longitude and Height) or grid coordinates (Easting, Northing and Elevations) using the relevant software or subroutines included with the GPS data processing software (Ayer and Fosu, 2008). The delivered grid coordinates for the district boundary project was based on the Universal Transverse Mercator projection (Figure 2.10) for Zone 30 North (UTM-Z30N) as well as the geodetic coordinates for the control points.

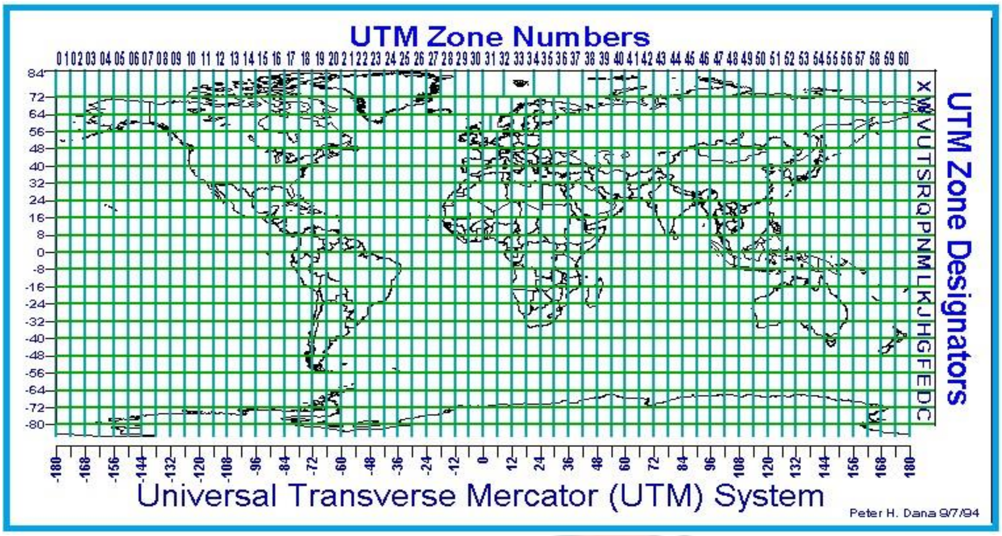

Figure 2.10: UTM projection Zones

2.12. COMMON DATA EXCHANGE FORMATS

RINEX is an acronym which stands for Receiver Independent Exchange Format, developed by the Astronomical Institute of the University of Berne allows the combination of data from different GPS receivers. RINEX version 3.00 format consist of three ASCII file types as indicated in table 2.3.

Table 2.3: Rinex File Types

File Type	**Containing Information**
Observation Data File (O-file)	GPS Measurements
GPS Navigation Message File (N-file)	Ephemeris (Orbit information)
Meteorological Data File	Pressure, Temperature, Relative Humidity, etc

Each file type consists of a header section and a data section. The header section contains global information for the entire file and is placed at the beginning of the file, and the data section contains the actual data. All satellite receiver data must be in RINEX format, the version of which is always determined by the Director of Surveys as far as measurements in Ghana are concerned.

2.13. SPECIFICATION OF DUAL FREQUENCY TOPCON HYPER LITE GPS

Survey Accuracy (1 sigma D: measuring distance in mm). Precision varies depending on number of satellites, satellite geometry, multi-path, ionosphere, and atmospheric conditions (Topcon manual, 2012).

Static, Fast Static Horizontal: 3mm + 0.5ppm (x baseline length);

Vertical: 5mm + 0.5ppm (x baseline length)

Kinematic, RTK Horizontal: 10mm + 1.0ppm (x baseline length);

Vertical: 15mm + 1.0ppm (x baseline length

2.14. QUALITY CONTROL

The term quality control (QC) refers to the efforts and procedures that researchers put in place to ensure the quality and accuracy of data being collected using the methodologies chosen for a particular study (FGCC, 1984). Quality control measure verifies the accuracy of the surveyed data by checking its compatibility with an independently surveyed data. In this thesis the coordinates obtained from the various techniques were compared with the independently Static GPS coordinates using Least Squares Adjustment. Thus, the Static GPS measurement serves as a standard set to check the quality of the various methods under investigation.

2.15. THE CONCEPT OF COST IN SURVEYING

2.15.1. Types of Cost

The idea of cost is to measure in economic terms the amount of resources expended in executing a project (Boardman, et al 1996). This means that before one can ascertain the cost of any land surveying project, the cost of resources used such as equipment, labour, materials (survey beacons, pickets, sigh post) must be considered. This kind of costing may sometimes be more of managerial than financial, since profits are not always the objective considered. However, when profits are added to the real cost then it becomes more of financial costing. Costing of most Land surveying projects is centered on what goes into the execution rather than the overheads.

There are various types of cost particularly in relation to contracting land surveying services (Boardman, et al 1996). This unit describes the various costing approaches and the components that constitute the total cost. Budgets of surveying projects have the characteristics of being either fixed, variable, direct or indirect.

2.15.2. Factors that affect costing

Cost estimation of land surveying projects depend on factors such as: accessibility, proximity of project site, site conditions, duration, season, and accuracy required (GhIS Manual, 2010). In addition, the purpose of the work must also be considered. This means that time is also a factor in determining the cost. The shorter the duration the greater the number of labourers required hence a greater quantum of remuneration. The accuracy of the work often stated in the specifications also plays an important role when costing. Thus the type of equipment used to yield the specified accuracy parameters comes with the corresponding appropriate rental rate.

Survey projects are often executed by conventional methods most of which have specific laid down operations procedures. Therefore, the selection of any survey method predetermines the operations involved, and hence a standard format of presenting cost of survey projects must be adopted, before the start of the survey project. The convention used for this project was based on managerial cost. This allows for a detailed description of the cost of execution and includes final drawings.
Profits are usually quoted as a percentage of the managerial cost.

2.16. SCHEDULE OF FEES FOR LAND SURVEY IN GHANA

Land Surveying areas are mainly fieldwork and are carried out by team (survey party) "The fees are arrived at, by considering the remuneration of the survey party allowance" in addition, overheads using the **time** taken by a survey party to carry out a piece of survey. Survey fees are mostly expressed in kilometers" (distance) or hectares (area) or per observation and are related to the topography and vegetation of the area. Salaries and wages used for the computations are those of the public services with the minimum wages of Gh¢1.9 per diem as of April 2007(GhIS). The Minimum Wage as at May 2014 is Gh¢ 6.00 per diem.

The Conversion used is

$$\text{New Fees} \square \frac{(\text{old fees} * 100 + 50\% \text{ increase in minimum wage})}{100}$$

2.16.1 Time Charges.

Local Grad	Man- Day Fee (Gh¢)	Man-Hour Fee (Gh¢)
1, Staff Surveyor	320	40
ii. Assistant Staff surveyor	280	35
iii. Survey technician	200	25
iv. Labourer	160	20

A Staff Surveyor is a corporate Member of Ghana Institution of Surveyors with not less than 5years post graduate experience, whiles an Assistant Staff Surveyor is a corporate member of Ghana Institution of Surveyors with a Bachelor degree in Geomatic Engineering (GhIS Manual, 2010). A skilled survey labourer is a person conversant with survey instruments their set ups and all operational procedures as far as field work is concerned. Building and Carrying of concrete beacons, clearing of survey lines and all manual survey duties are carried out by the survey labourer.

2.16.2. Time Expenditure

In order to compare the cost (time expenditure) of the methods applied, effective time has been recorded throughout the measurements. Effective time refers to the time needed to measure the required tasks without considering the delayed time due to some problems. The specified time is specific to this measurement because it depends on the operator engaged. For the convenience of comparison, time expenditure was classified in to time needed for total station traverse, fast static GPS survey and the Real Time Kinematic survey.

The required time does not include the time for transportation of instruments from store to the field and vice versa, and delayed time due to some problems such as: battery problem, incorrect reading, etc.

2.16.3. Total Station Traverse

The total station traverse consists of, 87 setups which were measured from the departure stations towards all 13 control point in both rural and urban districts. This was done using two faces with two rounds of measurements. The overall tasks were classified as field work and office lab work. But, here the time consumed was recorded only for the field measurement. Time allocated for every step of the measurement is presented in Tables 4.9 and 4.10. Time needed to setup the tripod of the instrument (Total Station) on one station was recorded and then multiplied by the number of instrument stations to determine the time expended on all instrument setups. In this project, the time expended for one setup of a tripod on one target is multiplied by13 to calculate the expended time on tripod setup, since 13 is the number of established control points in both, the rural and urban boundaries as indicated in table 4.9

2.16.4. Time expended for GPS RTK

Time expended for GPS RTK was recorded as time required for the reference base and for the rover. For the reference station, time was calculated as: time required for tripod setup plus to center it which was 8 min. For the rover measurement, time has been recorded as: time needed to center the rover plus time to record and to change to the next station and then multiplied by the number of control points (13) as indicated in tables 4.9.

2.16.5. Time expended for GPS Fast static

Time expended for GPS (5, 10, and 15) min-fast static was recorded as time required for the reference base and for the rover. For the reference station, time was calculated as time required for tripod setup plus to center it which was 8 min. For the rover measurement, time has been recorded as: time needed to center the rover plus (5-, 10-, 15-) min session time and to change to the next station and then multiplied by the number of control points (13) as indicated in tables 4.10.

CHAPTER 3
METHODOLOGY

3.1. INTRODUCTION

This chapter presents the methods and procedures adopted in order to achieve the set objectives. The equipment and materials used are also detailed. Because of time and cost constraint a portion of district boundaries located in the urban area (Ga South and Ga West) district and that district located in the Rural area (Ga West and Ga East) district both in the greater Accra Region was chosen as the study area. These sections were selected carefully making sure that they were representative of the characteristics of general conditions prevailing along the boundaries of both the rural and urban situations respectively.

The area was carefully selected so that the various survey methods under comparison could be employed to yield the needed results. Diagrams and flow chart of field measurement procedures are also presented in this unit. The GPS field data collected was post processed using Topcon Tools 8.23 version. Survey computation was performed using Least Square Adjustment for both the GPS and Total station traverse. This unit also presents the procedures for estimating the cost of using the survey methods under comparison. Finally, the time taken to execute the survey by each of the methods under comparison is also estimated. Prior to the start of the project a series of stakeholder meetings were organized to educate the chiefs, elders, and town development committee members living in the adjoining District assemblies. The work flow diagram in figure 3.1 shows the various field measurement procedures used to achieve the set objectives.

FLOW CHART OF THE STUDY

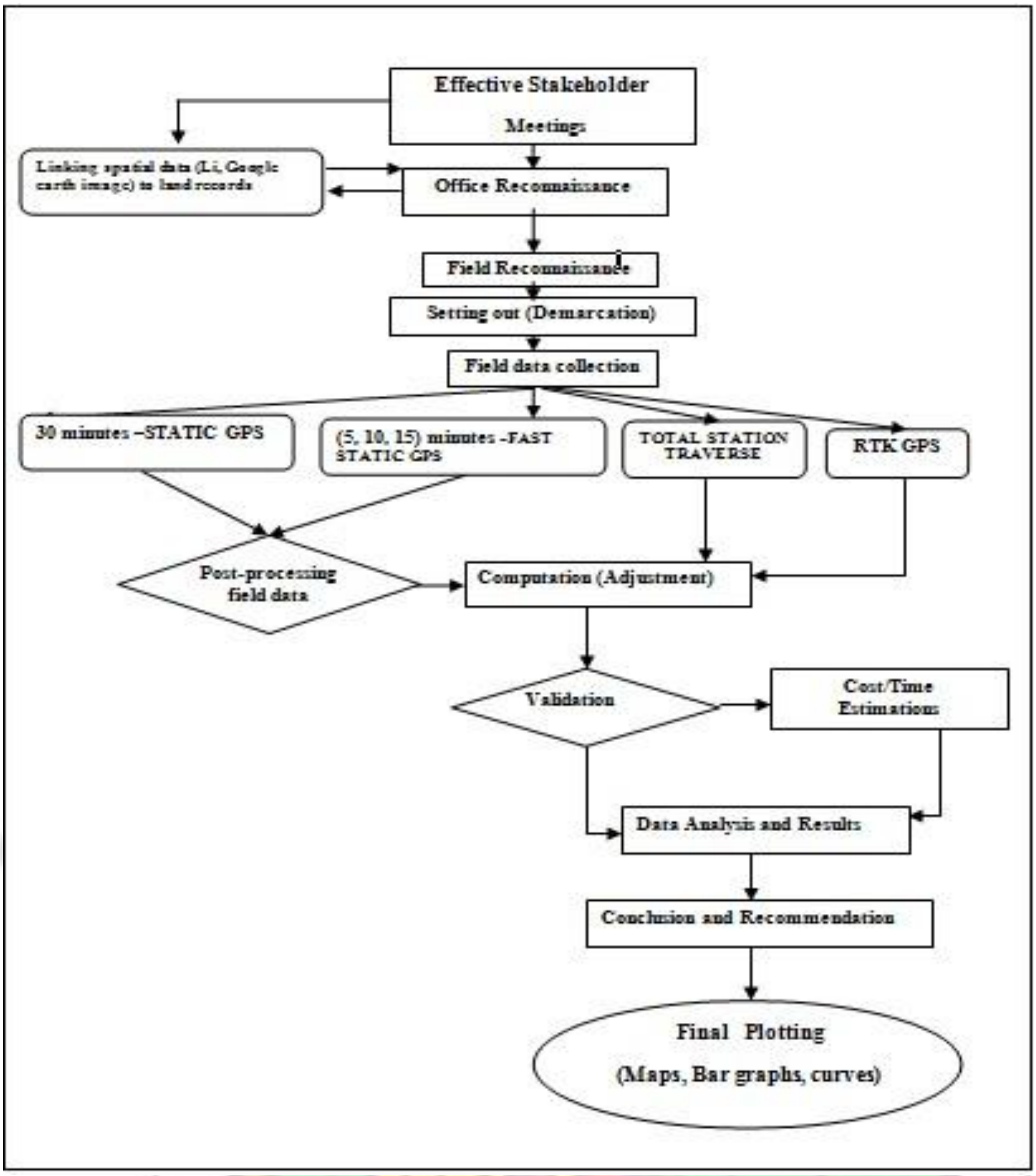

Figure 3.1: Work Flow Diagram

3.2. EFFECTIVE STAKEHOLDER MEETINGS

A series of meetings was organized at the district assembly to educate the people on specific objectives of the project. The present and future benefits of the project to the stakeholders in the assemblies were also presented.

3.3. EQUIPMENT AND MATERIALS

The research adopted the following methodology for the execution of the project.

- Review of relevant literature on boundaries and survey technical instructions.
- Use of Town sheet: Topographical map: High resolution satellite image (Google map) of the project area.

- The use of a Total Station, a handheld GPS device, Dual Frequency Topcon Hyper GPS with their accessories
- A personal laptop computer
- Topcon tools software was used to process the GPS data.
- Matlab 2012 software was used for the traverse adjustment
- All table and graphs were done in Microsoft Excel 2008 version.

3.4. STUDY AREA

The study area extends from latitude 5°37'N and longitude 0°14'W to 5°41'N and longitude 0°15'W for the rural district (Ga West and Ga East) in the Greater Accra Region. The urban district setting, extends from latitude 5°36'N and longitude 0°14'W to 5°40'N and longitude 0°16'W representing the Ga South and Ga West district boundary respectively. Figure 3.2 shows the extent of the selected boundaries for the project.

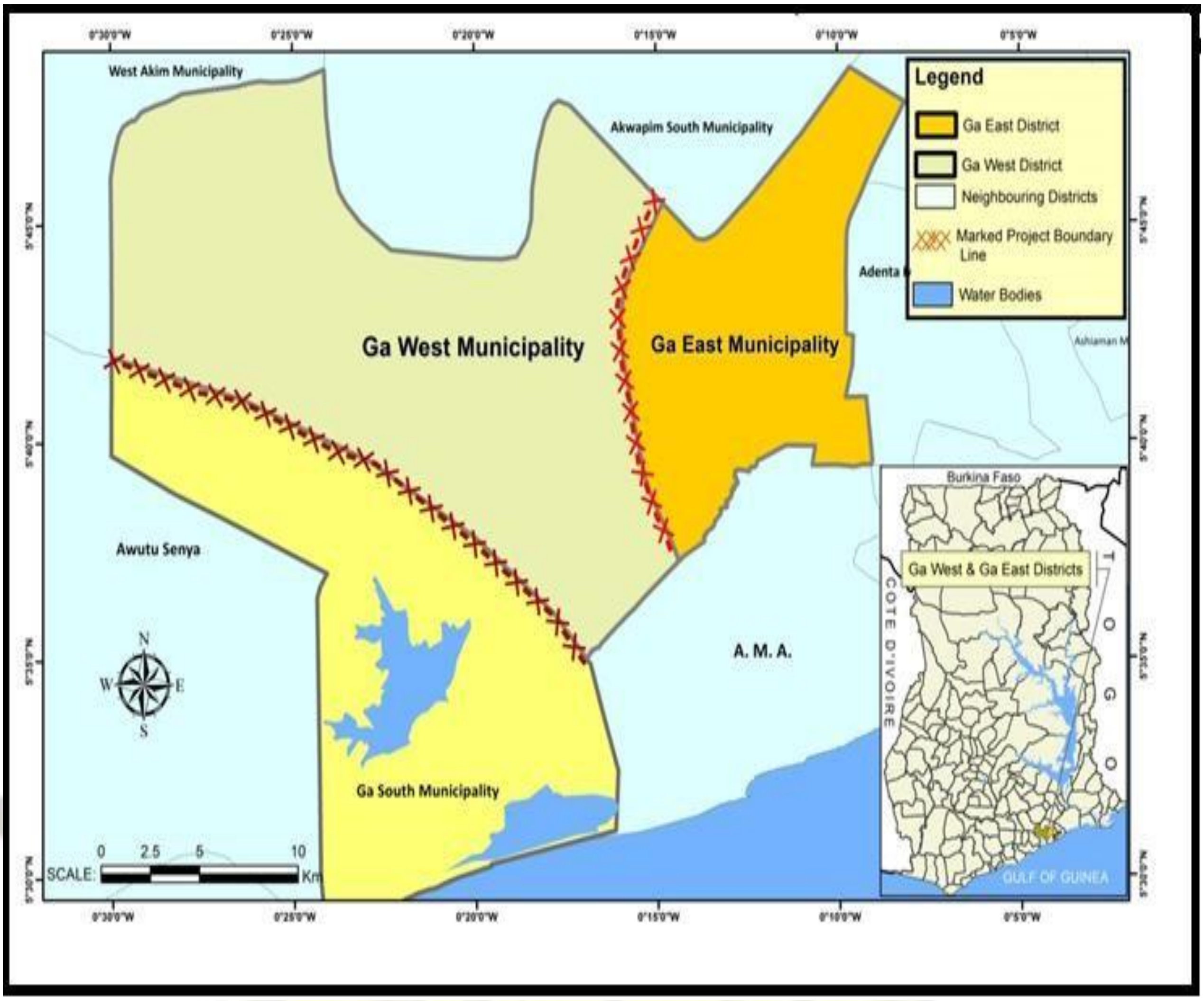

Figure 3.2: Map Showing the Selected Boundaries for the project.

3.5. FIELD WORK

3.5.1. Reconnaissance Survey

The Reconnaissance survey was broken down into two parts, namely the office and field works.

3.5.1.1. Office reconnaissance

The office reconnaissance involves the search and preparation of maps, town sheet, and high resolution satellite image (Google map) which were already available on the study area. It also entailed the identification of reliable ground control points (GCP), the extraction of coordinates of the boundary points and the importation of the relevant data into a handheld GPS device for subsequent navigation to the respective sites. The selected boundary lines (Figure 3.2) which were derived from various legislative instruments (LI) were compiled and superimposed on a high resolution geo referenced Google Earth Satellite image (Figure 3.3) of the study area. This aided in the selection of the relevant features identical with the boundary on the image and subsequently their coordinates were extracted and used for the navigation to the same on the ground. The satellite imagery also aided in the selection of the optimum routes to the various boundary points so selected. Office reconnaissance was done from 27th January to 10th February, 2014.

3.5.1.2. Field reconnaissance:

A field reconnaissance survey of the boundary was undertaken with the involvement of the chiefs, elders, and opinion leaders of the adjoining districts on the 20th and 21st February, 2014 for the rural district boundary and on 10th and 11th March 2014, for the urban boundary. A common boundary of the district was subsequently identified and agreed with the involvement of District coordinating directors, and staff surveyors from both the district assembles, opinion leaders and representatives of the traditional authorities. During this visit both the points of departure and new station points were confirmed.

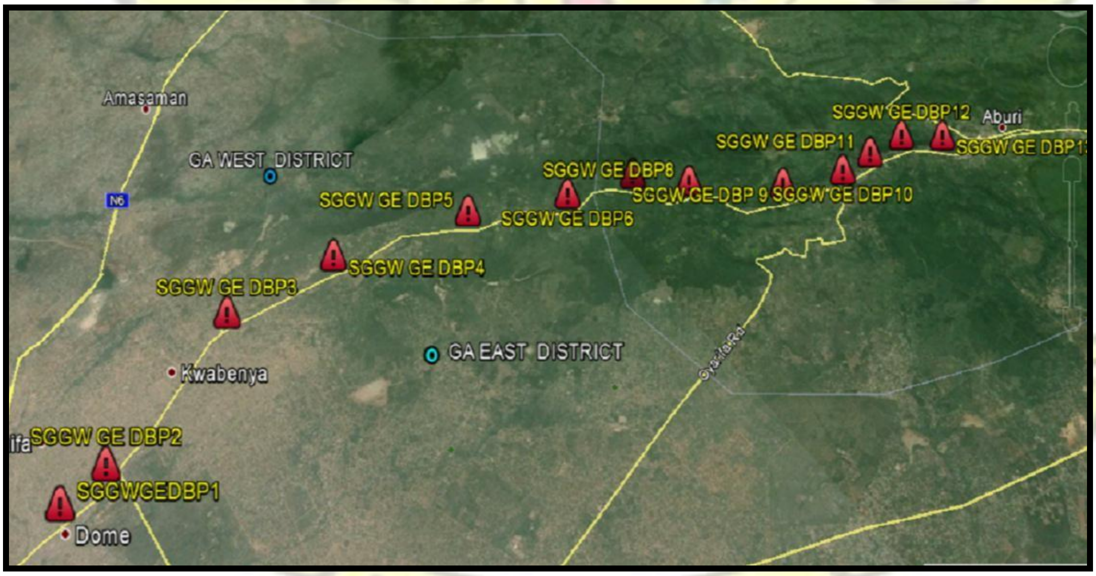

Figure3.3: Google Earth Image showing the distribution of the selected boundary points (Rural District boundary).

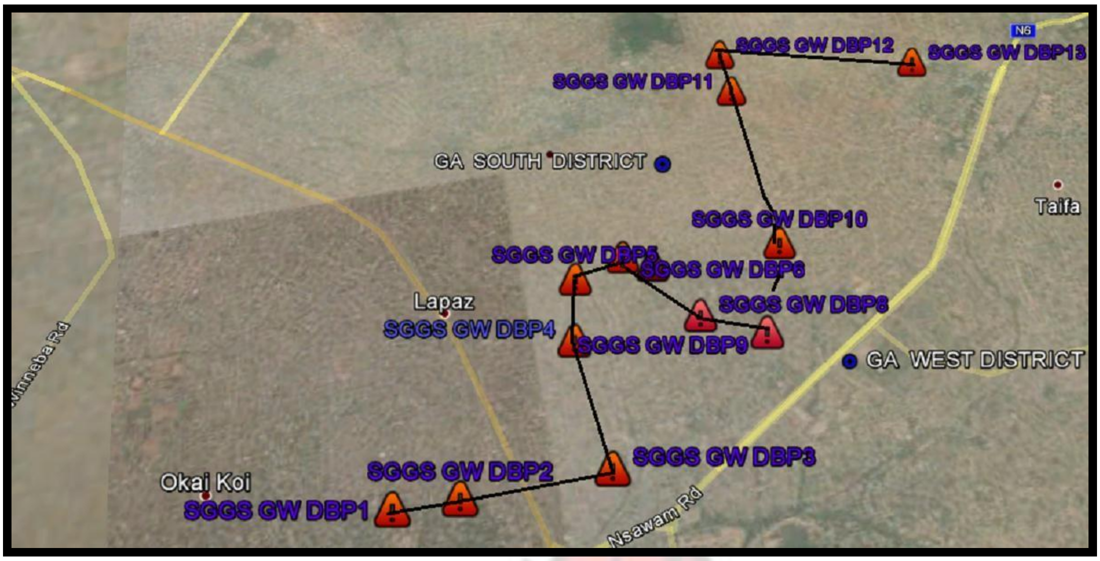

Figure3.4; Google Earth Image showing the distribution of the selected boundary points (Urban District boundary).

3.5.2. Boundary Identification

The method of identification by the two teams from both districts assemblies was aided by a GPS navigational device which helped in locating the exact position of points on the ground as indicated on the district map and the Google Earth image map of the area. This exercise was carried out on the 29th and 30th of March 2014.

3.5.2.1. Setting out

The final boundaries as agreed upon by the parties that went to the field from the districts were set out using a Hand held (standalone) GPS instrument with the coordinates generated from the district composite boundary map available. The coordinates are in tables 3.1 and 3.2 respectively. This method of setting out was applied for both the rural and urban boundary settings. Figure 3.1 is the work flow diagram. Tables 3.1 and 3.2 show the various geographic coordinates applied to the handheld (stand-alone) GPS instrument for the boundary identification and setting out.

Table 3.1: Stand-alone GPS Boundary points (Rural district)

Name	WGS84 Latitude	WGS84 Longitude
SGGW/GE/DBP1	5°37'N	0°14'W
SGGW/GE/DBP2	5°37'N	0°14'W
SGGW/GE/DBP3	5°37'N	0°14'W
SGGW/GE/DBP4	5°38'N	0°14'W
SGGW/GE/DBP5	5°38'N	0°14'W
SGGW/GE/DBP6	5°38'N	0°14'W
SGGW/GE/DBP7	5°38'N	0°15'W
SGGW/GE/DBP8	5°38'N	0°15'W
SGGW/GE/DBP9	5°38'N	0°15'W
SGGW/GE/DBP10	5°39'N	0°15'W
SGGW/GE/DBP11	5°39'N	0°15'W
SGGW/GE/DBP12	5°41'N	0°15'W
SGGW/GE/DBP13	5°41'N	0°15'W

Table 3.2: Stand-alone GPS Boundary points (urban district)

Name	WGS84 Latitude	WGS84 Longitude
SGGS.GW DBP1	5°36'N	0°14'W
SGGS.GW DBP 2	5°36'N	0°14'W
SGGS.GW DBP 3	5°36'N	0°14'W
SGGS.GW DBP 4	5°36'N	0°15'W
SGGS.GW DBP 5	5°37'N	0°15'W
SGGS.GW DBP 6	5°37'N	0°15'W
SGGS.GW DBP 7	5°37'N	0°15'W
SGGS.GW DBP 8	5°37'N	0°15'W
SGGS.GW DBP 9	5°37'N	0°15'W
SGGS.GW DBP 10	5°38'N	0°15'W
SGGS.GW DBP 11	5°38'N	0°16'W
SGGS.GW DBP 12	5°38'N	0°16'W
SGGS.GW DBP 13	5°39'N	0°16'W

3.5.2.2. Pillaring

Type 'B' beacons were planted along the boundaries as set out in the urban district boundary line with inscription SGGS/GW/DBP1-13 on the 7th and 8th April 2014, whiles type 'B' beacons with inscription SGGW/GE/DBP1-13, were used for the rural district boundary line on the 9th and 10th April 2014. At various points in-between the monuments teak trees were planted to help define the boundary so that it would be easily identified on a future aerial or satellite coverage. In selecting the pickets' positions the effects of surrounding features on the signals of the GPS equipment which would be used for the survey subsequently were considered.

3.5.3. Field observations

The survey team was composed of a representative of the chiefs from the adjoining lands, the district engineer, the surveyor and town planning officers from the two districts, two survey technicians trained to handle GPS and total station equipment. Two representatives each from the towns on either side of the boundary were used as an adjudicative party and were all present during the major part of the demarcation work to forestall any misunderstanding that may arise. Food and transportation was provided by the financial department of the districts involved.

3.5.3.1. Static GPS Survey

A Static differential GPS method was used to measure the boundary points with dual frequency Topcon hyper receivers. The base receiver was Accra (GRN) COR station. The rover occupied the boundary points individually for a session length of 30 minutes. The measurement was closed on the beacon SGGA.07/213/47, with SGGA.07/213/48 beacon as a check point as shown in the diagram of survey (Figure 3.5). At least four or more satellites were tracked during the observation period at each of the survey point. A slant antenna height measurement was taken at every station as indicated in Table 3.3. The same procedure was carried out for both rural and urban districts boundaries. The 30minutes static observation was taken as a Standard or reference and was assumed to be free from errors for the subsequent comparison with the other methods.

3.6. RURAL DISTRICT

The rural district boundary selected for this project forms portion of the boundary between the Ga East and Ga West districts, Figure 3.3, shows the diagram of survey for the Static GPS measurements for the rural district boundary line.

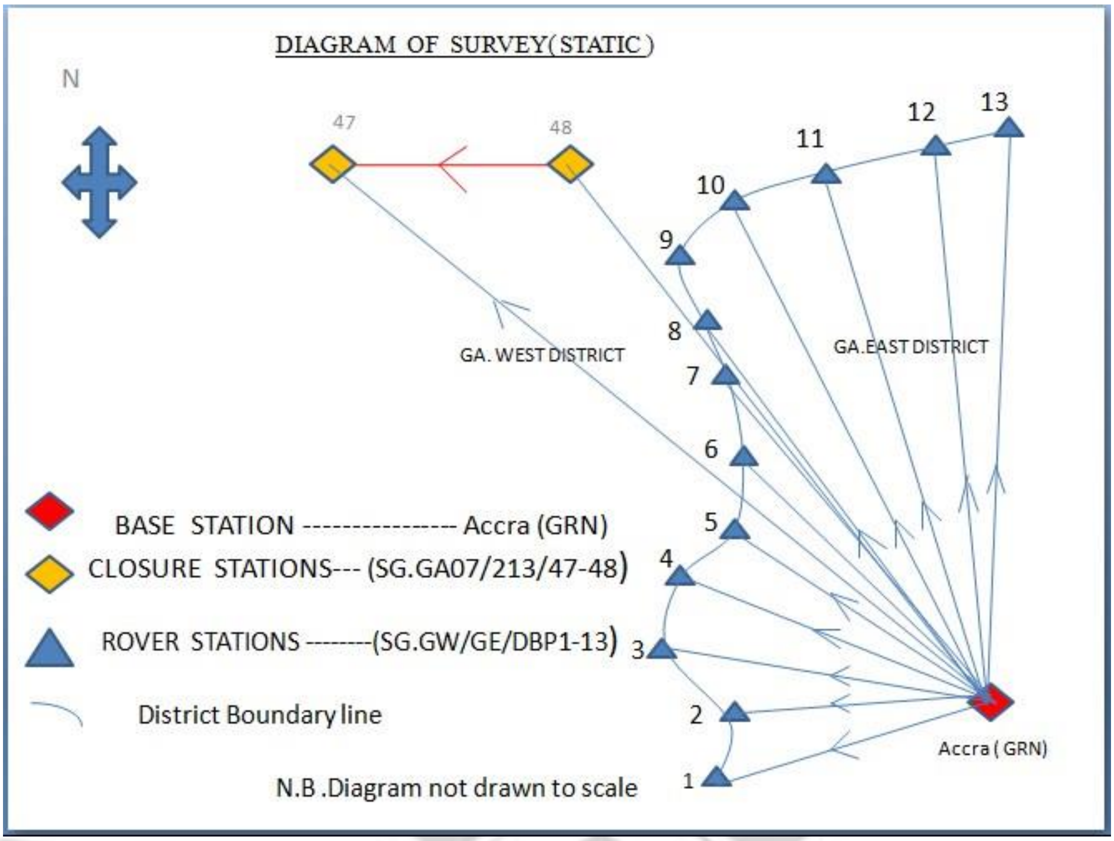

Figure 3.5: Diagram of Survey for the Static Method

Table 3.3 is an abstract of the GPS field records, showing the survey points, the antenna heights of the GPS and the time duration for each of the sessions during the measurements.

Table 3.3: GPS field records

Point Name	Ant Height(m)	Start Time	Stop Time	Duration
SGGA 07 213 48	1.37 (Base)	31-05-14 07:20	31-05-14 19:30	12:10:00
SGGW.GE/DBP/1	1.35	31-05-14 10:10	31-05-14 10:40	0:30:00
SGGW.GE/DBP/2	1.36	31-05-14 10:55	31-05-14 11:25	0:30:00
SGGW.GE/DBP/3	1.34	31-05-14 11:48	31-05-14 12:18	0:30:00
SGGW.GE/DBP/ 47	1.37	31-05-14 17:58	31-05-14 18:28	0:30:00

3.6.1. The Fast Static Survey:

Fast static differential GPS method was used with Accra (GRN) CORS as the Base station. Observation times of 5, 10, and 15 minutes were used as measurement times at all boundary points and the survey sessions were closed on pillar SGGA.07/213/48, with pillar SGGA.07/213/47 as a check station. The assistant surveyor ensured that at least four satellites had been tracked during the observation period. Antenna height was measured using a tripod vertical and was maintained during the field work. Figure 3.6 shows the diagram of survey for the fast static GPS surveys, for the rural district boundary line.

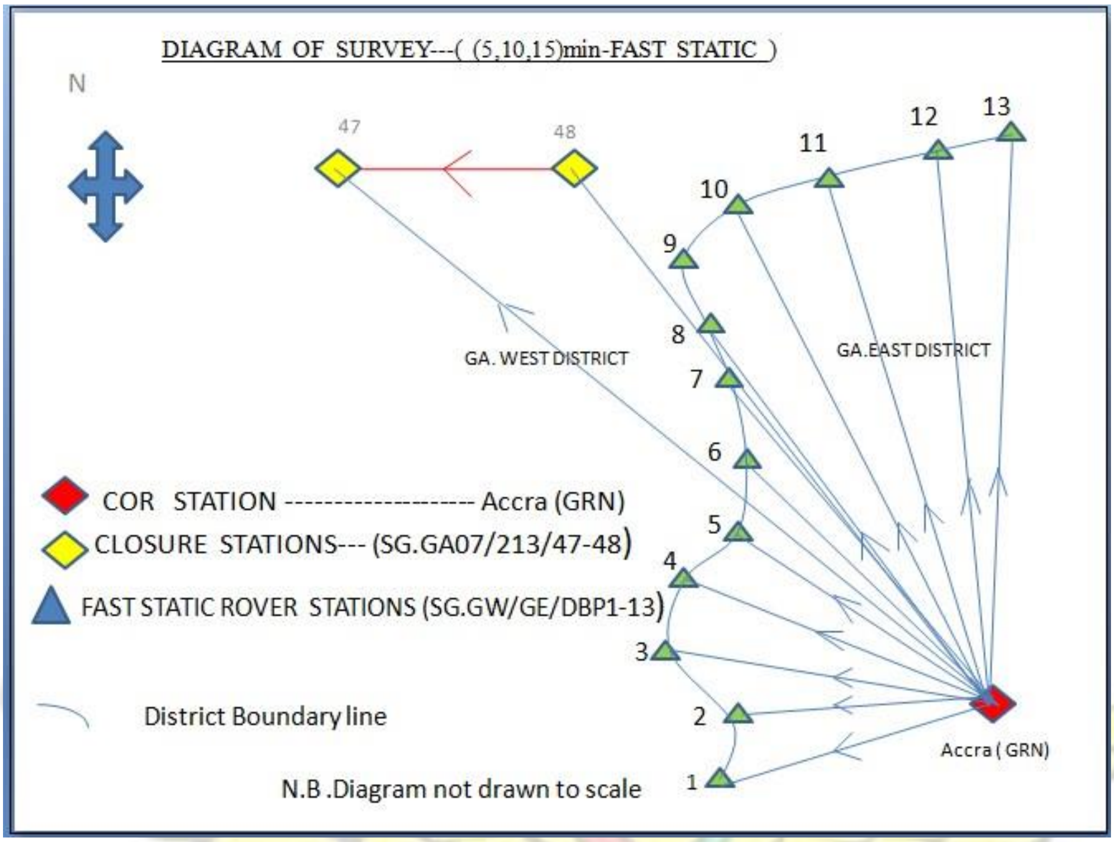

Figure 3.6: Diagram of Survey for the Fast Static Methods for the rural district boundary line.

Abstract of the GPS field observation for the Fast Static measurement, showing the antenna height, time duration for each session and the beacon used as far as the rural boundary line are concerned can be found in Table A6 of Appendix A.

3.6.2. The RTK Survey (Real Time Kinematic survey):

A stop and go real time kinematic survey was used to measure the same boundary points with dual frequency Topcon hyper receivers. The base receiver having an external radio device configured to cover a distance of approximately up to 10 kilometers was set at pillar SGGA 07/213/48 and the rover occupied the boundary points for a session length of between 1 to 2 minutes each. The session was closed on SGGA.07/213/47 with Accra (GRN) CORS serving as a check point as shown in the diagram of survey (Figure 3.7).

The same procedure was carried out for both the rural and urban districts settings.

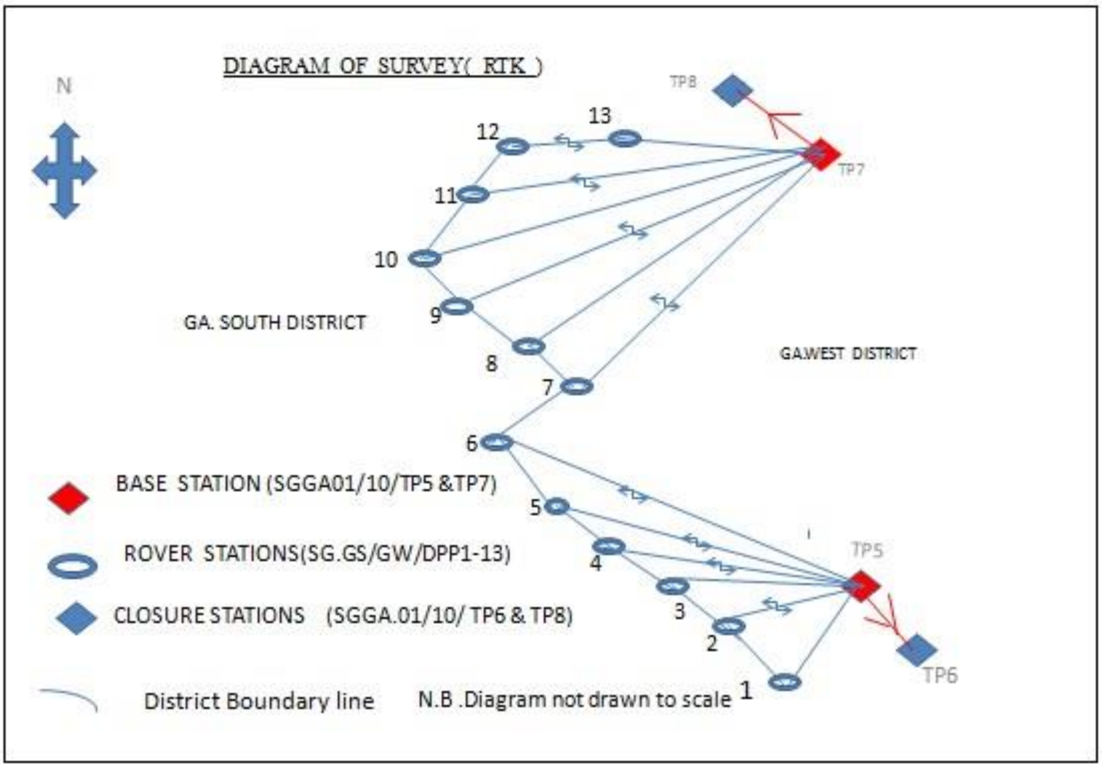

Figure 3.7: Diagram of Survey for the RTK Method

An abstract of the GPS field observation for the RTK measurement, showing the antenna height, time duration for each session and the beacon used as far as the rural boundary line are concerned can be found in Appendix A.

3.6.3. The Total Station Survey

A Total station traverse was carried out on 2nd and 3rd May 2014 along the boundary lines of the selected districts with Survey pillar SGGA.07/213/47, GGA.07/213/47/48 and SGGA.07/213/47/49 as points of departure. A closed traverse was carried out using Topcon GTS-220 series, 3prisms reflector that can measure distances up to 4,000m (13,200ft) and high accuracy of ± (2mm +2ppm x D) m.s.e where D is measuring distance (mm). Two face measurements with two rounds were taken on all boundary points to eliminate or reduce various systematic errors. To begin the points of departures were tested to check their reliability as shown in Table B11 of Appendix B. A Scale and Sea level correction factor of (0.99984) was applied to the measured distances to obtain the projected distances for the traverse computation. The survey was finally closed on pillar SGGA.07/213/47 as shown on the diagram of survey (Figure3.8). The

total distance covered was approximately 29km. An angular misclose of +01” per station and a Fractional Misclose of 1: 7000 were obtained.
Relevant field records can be found in Table 3.4 appendix A.

Traverse computations and Least Squares Adjustment was performed using the bearings and distances obtained from the total station traverse for both the rural and urban district boundary points to be able to be compared with the GPS techniques. Azimuth observation was performed on pillar SG.GWGE/DBP/1 and SG.GSGW/
DBP/1 to control the bearing of the traverse leg.

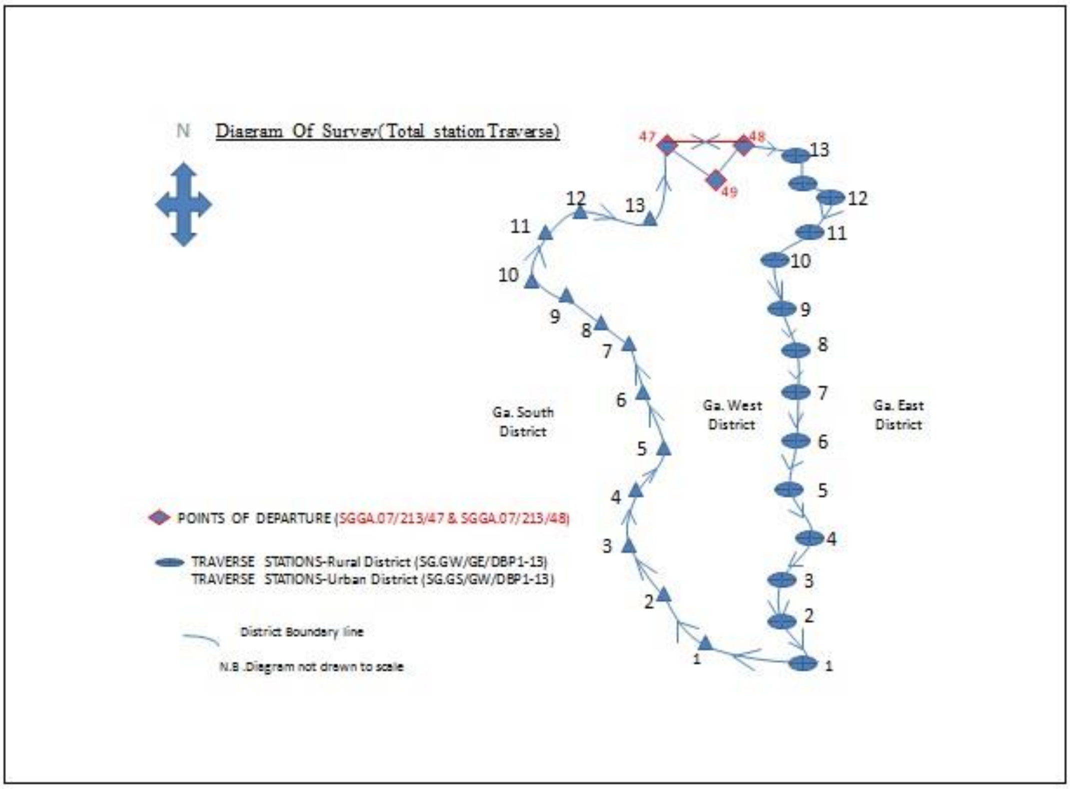

Figure 3.8: Diagram of Survey for the Total station Method for the Rural and Urban district boundary lines.

3.7. URBAN DISTRICT

A portion of the boundary between the Ga West District and the Ga South District boundaries was selected for the project.

3.7.1. Static GPS Observation

The procedure as was described in the case of the rural district was maintained for the urban district using the Accra (GRN) CORS and SGGA07/213/48 as Base stations and SGGA 07/213/47 as closure.

Position fixing was performed on all the 13 boundary points (Figure.3.9) with tripod slant heights and session duration times as indicated in Table 3.5 again the 30min static observation was set as the reference for the other survey methods.

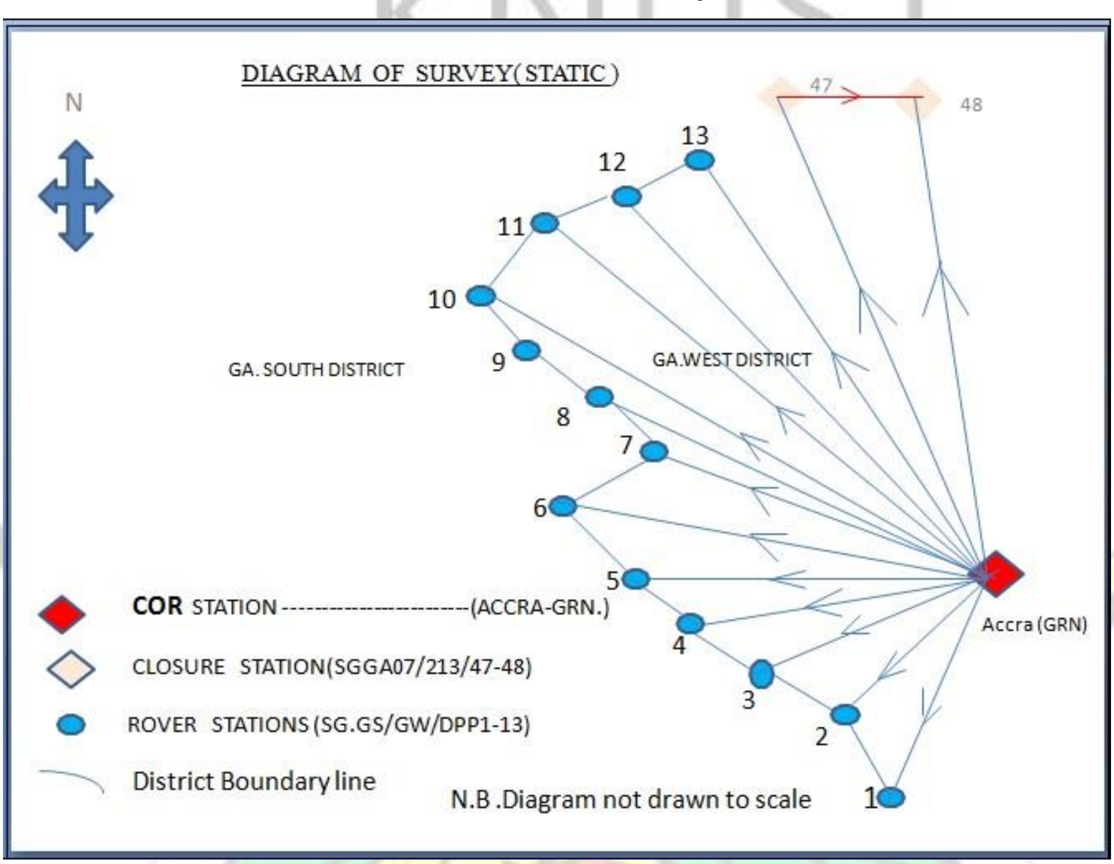

Figure 3.9: Diagram of Survey for the Static Method

Table 3.4 is an abstract of the GPS field records for the static survey, showing the antenna height, time duration for each session and the beacon used as far as the urban boundary line is concerned.

Table 3.4: An Abstract of the GPS field records

Point Name	Ant Height(m)	Start Time	Stop Time	Duration
SGGA 07 213 48	1.35	02-06-14 9:54	02-06-14 10:24	0:30:00
SG GS/GW /DBP 1	1.36	02-06-14 10:45	02-06-14 11:15	0:30:00
SG GS/GW /DBP 2	1.35	02-06-14 11:40	02-06-14 12:10	0:30:00
SG GS/GW/ DBP 3	1.35	02-06-14 12:29	02-06-14 12:59	0:30:00
SGGA 07 213 47	1.34	02-06-14 5:10	02-06-14 5:40	0:30:00

3.7.2. Fast static GPS method.

Fast static differential GPS method was used with Accra (GRN) CORS and pillar SGGA.07/213/48 as Base stations. An observation time of (5, 10, 15) minutes were used as measurement time at all boundary points and the survey session was closed on pillar SGGA.07/213/47. The team ensured that at least four satellites had been tracked during the observation period. Antenna height was measured using a tripod vertical and was maintained during the field work. The Figure 3.10 shows the diagram of survey for the fast static GPS survey, for the urban district boundary line.

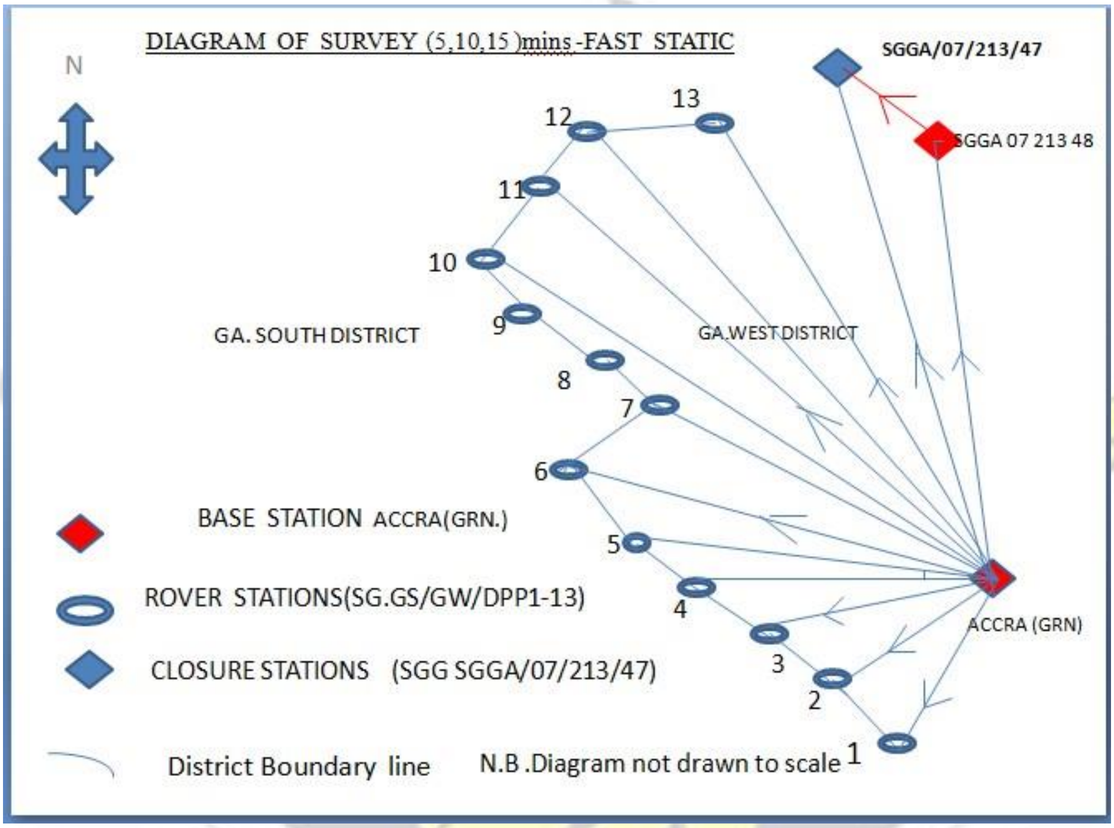

Figure 3.10: Diagram of Survey for the Fast Static GPS Method.

An abstract of the GPS field observation for the Fast Static measurement, showing the antenna height, time duration for each session and the beacon used as far as the urban boundary line is concerned can be found in appendix A.

3.7.3. RTK Survey Method.

A stop and go real time kinematic survey method similar to that described at section 3.6.2, was used to measure the boundary points with dual frequency Topcon hyper receivers. The base receiver having an external radio device configured to cover a distance of approximately up to 10 kilometers was set at pillar SGGA 07/213/48 and the rover set over the boundary points individually for a session length of between 1 to 2 minutes. The session was closed on point SGGA. 07/213/47 which is a reference `station as shown per the diagram of survey (figure 3.11).

The same procedure was carried out for both the rural and urban districts boundary lines.

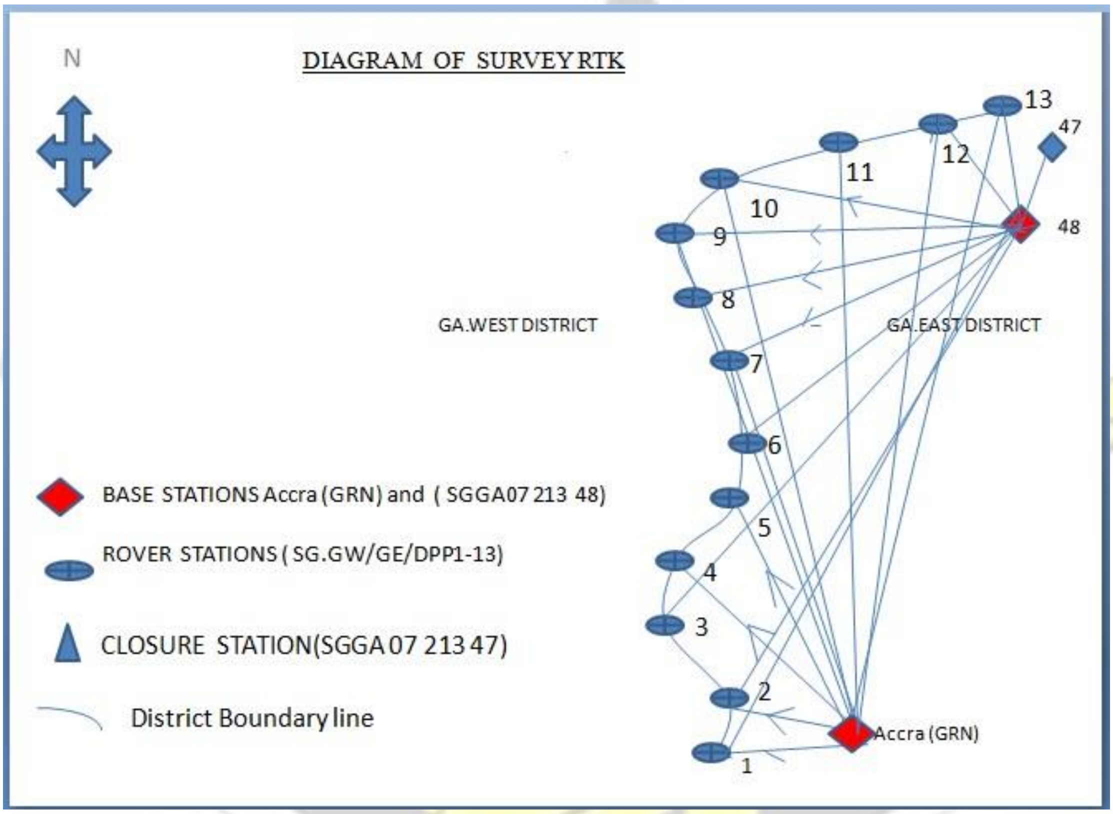

Figure 3.11: Diagram of Survey for the RTK Method for the urban district boundary line.

An abstract of the RTK field records showing the relevant field data can be found in Table A6 of Appendix A.

3.7.4. Total Station Survey of the urban boundary.

A total station traverse was carried out on the 6th and 7th May 2013. A Topcon total station was used to perform a closed traverse along the established boundary points starting from Survey pillar. SGGA.07/213/48 and closing on pillar SGGA.07/213/47. Figure 3.12 shows the diagram of survey for the total station traverse.

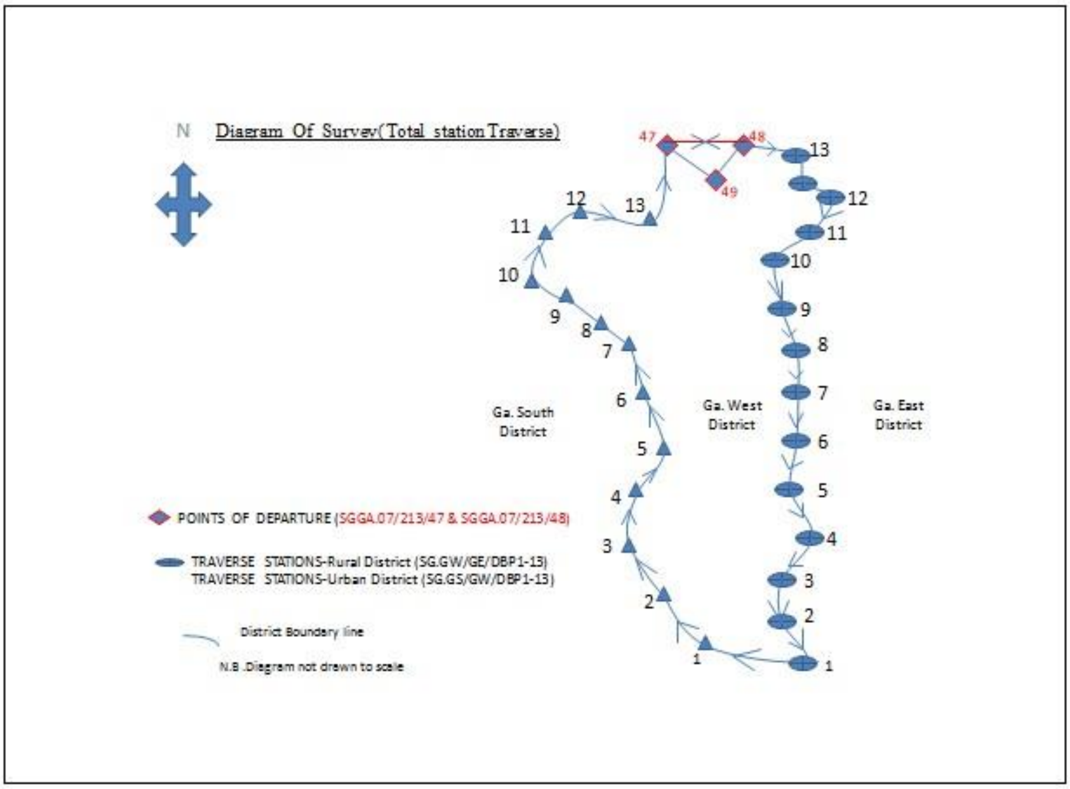

Figure3.12: Diagram of survey for the Total station method for both Rural and Urban district.

3.8. DATA PROCESSING

Data from the GPS was processed using the Topcon Tools 8.23 version software. As a matter of human limitations, imperfect instruments, unfavourable physical conditions and improper measurement routines, the results of most field measurements are likely to contain errors. To reduce the measurement errors on the final results one needs to improve the overall condition of the measurement using Least squares adjustment (Chan, 2008).

Adjustment of the network was performed using Topcon Tools software which uses method of least squares adjustment. Least squares adjustment is a method of estimating values from a set of observations by minimizing the sum of the squares of the difference between the observations and the values to be found.

Least squares method is a classical method which defines the optimal estimate of X(unknown) by minimizing the sum of the weighted observation residuals squared (Chan,2008).The results of the adjustment can be found in the Tables 4.1 and 4.2

3.9. ESTIMATING THE COST OF SURVEY PER THE VARIOUS SURVEY METHODS

Surveying of district boundaries is similar to any other project and comes with its budget and therefore cost parameters. The need to estimate the cost of survey by any method is very fundamental before any survey project starts. The computation in this thesis uses the Ghana Institution of Surveyors, (GhIS) rates for the 2014-2015 sessions.

The author adopted the managerial costing format in presenting the cost estimations. This is because profit factor does not really determine the suitability or otherwise of the methods used since it is just a percentage of the operational cost. The rest of this unit therefore presents the estimates for each of the survey methods under comparison. In other to have a fair assessment of the cost of survey by the various methods, there is a need to outline the cost components.

The method used in the thesis considered the following cost components in building up the cost, for the individual methods of survey: time; number of personnel involved, level of skill and the rental rates of equipment used. A GPS unit comprises Base station receiver and some rovers, whiles a Total station unit consists of the instrument, and two single reflectors for both forward and back station measurements.

3.9.1. Time Estimate

The method employed for the estimation of cost for time spent, put consideration on the average time required to complete the survey for the same length of boundary by the various survey methods using the appropriate minimum wage of GH¢6.00 as recommended by GhIS for 2014-2015. Estimation of time for the execution of the jobs is made on the basis of a working day made up of 8 hours. There is a significant difference in time required for the establishment and survey of one boundary point between the three survey methods. The survey using Fast static uses (5, 10, 15) minutes and 1-2 minutes for the stop and go kinematics (RTK) whiles the Total station needs (8-10) secs, according to the cadastral standards for the actual instrument measurement.

3.9.2. Number of personnel involved

The development of EDM technology saw the demise of the steel band; and therefore the personnel within a survey party or team has fallen considerably in the past 30 years. The rapid development of the Total station and data recorder technology has provided surveyors with a precise and efficient data capturing tool (Gerdan,1991). Undoubtedly, instruments for land surveying will continue to be developed and improved, which will lead to a higher and better work rate and profitability to surveyors, (Boey, et al 1996). The survey team for the boundary consists of 2 surveyors, skilled labourers and bush clearers as indicated in table (4.11), (4.12), (4.13), (4.14) and table 4.15. Surveyors are bound to adopt industry best practice at all times combined with the surveyor's code of ethics requirements and professional practice sustainability; this will ensure the interests of the community, respect for the individual, and the interests of the client which remains first and foremost the overall objectives of the profession.

3.9.3. Level of skill

The skilled personnel required to complete a total station survey are, an experienced qualified surveyor and two competent field hands. For the GPS methods, the level of skills required for this survey would be an experienced qualified surveyor or Registered/Licensed surveyor (Technical instruction 2008) and one or two competent field hands.

3.9.4. Rental rate of equipment

The Total station used for the project was hired from a reputable survey firm, at a charge out rate of GH¢ 100.00 per day. A Topcon Hyper RTK GPS with data logger was hired at a rate of GH¢**600**.00 and the Dual frequency Topcon Hyper GPS unit was hired at GH¢ **400.00** per day respectively.

CHAPTER 4
FIELD RESULTS

4.1. INTRODUCTION

This chapter presents all the field data as obtained from the ground measurements in accordance with the methodology outlined in chapter three. Thirteen boundary points selected in both rural and urban districts were observed with static GPS measurements for thirty minutes using the Accra (CORS) base station, and closure at SGGA 213/47. The baseline vectors were processed for both the rural and urban districts using Topcon tools 8.23. Least squares adjustment was used to compute for the variance - covariance matrices of the reference control points. The final field results are categorized into two main sets: Rural district boundary and Urban district boundary. Each of the surveying methods in comparison produced a set of results for the urban and rural boundary category. The Static GPS survey for both rural and urban district boundary was maintained as the standard set during the computations. Further computations of Root Mean Squares Errors (RMSE) were done from these results.

4.2. GPS BASELINE PROCESSING

Thirteen boundary points selected in both rural and urban districts were observed with static GPS measurement for thirty minutes using the Accra (CORS) base station. The data was processed for both the rural and urban district and least squares adjustment was performed on the base line vectors that form a network. The final adjusted coordinates of the 30-minutes static GPS results were used as a standard in the computation, of the RMS errors and standard deviations of the various survey methods. The final adjusted coordinates and their standard deviations of the reference stations are presented in Table 5.1.

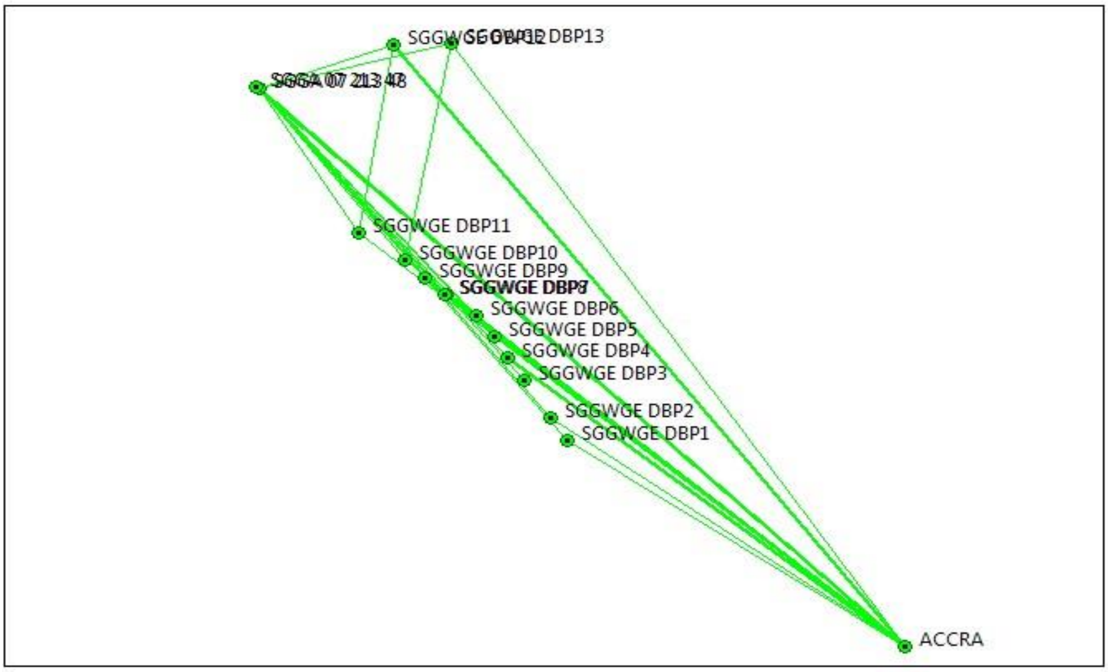

Figure 4.1: Graphical view of the reference network for Rural district boundary

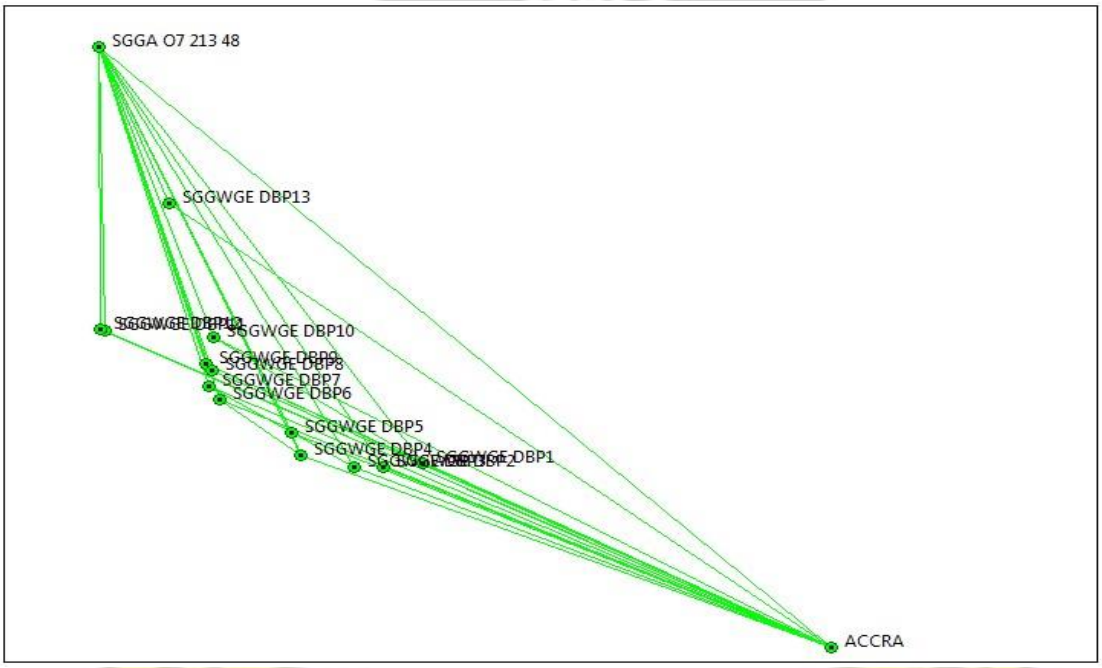

Figure 4.2: Graphical view of the reference network for Urban district boundary

4.3. THE LEAST SQUARES ADJUSTMENT

The 30 minutes Static GPS observation was used as a standard set for the other survey techniques under comparison for both the rural and urban district boundary, the coordinates must be adjusted to make all coordinate differences consistent with the other field measurements.

In applying the method of least squares for the adjustment of baselines in GPS networks, observation equations are written that relate the control station coordinates to the coordinate differences observed and their corresponding residual errors (Blewitt, 1997). Observation equations for each of the measured baseline component are given below:

Observation equations

$\partial_{XA} = [X_A - X'_A]$--------- Eqtn.1

$\partial_{YA} = [Y_A - Y'_A]$----------- Eqtn.2

$\partial_{ZA} = [Z_A - Z'_A]$---------Eqtn.3

$\partial_{XB} - \partial_{XA} = [X_A + \Delta X_{AB} - X_B]$ -------- Eqtn.4

$\partial_{YB} - \partial_{YA} = [Y_A + \Delta Y_{AB} - Y_B]$ ---------Eqtn.5

$\partial_{ZB} - \partial_{ZA} = [Z_A + \Delta Z_{AB} - Z_B]$ ---------Eqtn.6

$\partial_{XC} - \partial_{XA} = [X_A + \Delta X_{AC} - X_C]$ -----------Eqtn.7

$\partial_{YC} - \partial_{YA} = [Y_A + \Delta Y_{AC} - Y_C]$ ---------- Eqtn. 8

$\partial_{ZC} - \partial_{ZA} = [Z_A + \Delta Z_{AC} - Z_C]$ ------------Eqtn. 9

The matrices obtained from the above observation equations can be expressed into a normal equation as shown below:

Normalize Equation (N) is

$A_x = L + V$ ----------------------------Eqtn. 10

----- $(A^TWA)_X = (A^TWL) + (A^TWV)$ ---------------- Eqtn. 11

But $(A^TWV) = 0$ -------------------------------------- Eqtn. 12

$X = (A^TWA)^{-1}.\ (A^TWL)$

------------------------------**Eqtn. 13**

Standard deviation (δ_0) = $\sqrt{\frac{V^TWV}{m-n}}$ **----------Eqtn. 14**

Where m = number of equations and n = number of unknowns. The

covariance matrix ($\sum$) = δ_0^2 $(A^TWA)^{-1}$

Standard deviation of adjusted field quantities (σ) = $\delta_0\sqrt{\sum}$

Table 4.1: Adjustment of unknown parameters of the observation.

Ref Unit variance)	=	0.005	m									
Ref Se(σo)	=	0.071	m									
STATIONS	PROVISIONAL XYZ COORD			PARAMETERS			ADJUSTED PARAMETERS			STANDARD ERRORS		
	X(m)	Y(m)	Z(m)	∂X(m)	∂Y(m)	∂Z(m)	ADJ X(m)	ADJ Y(m)	ADJ Z(m)	σx(m)	σy(m)	σz(m)
SGGA 07 213 48	6346999.119	-30968.523	627387.713	0.413962	-0.00683	-0.36734051	6346999.533	-30968.53	627387.346	0.051	0.051	0.051
SGGWGE DBP1	6347631.441	-25846.485	620984.247	0.457924	-0.00691	-0.40711651	6347631.899	-25846.492	620983.84	0.051	0.051	0.051
SGGWGE DBP2	6347597.715	-26127.965	621389.375	0.425605	-0.06168	-0.47558296	6347598.141	-26128.027	621388.899	0.051	0.051	0.051
SGGWGE DBP3	6347527.481	-26567.356	622076.25	0.580119	-0.00707	-0.51762966	6347528.061	-26567.363	622075.732	0.051	0.051	0.051
SGGWGE DBP4	6347490.876	-26836.461	622500.66	0.611479	-0.03331	-0.50072321	6347491.487	-26836.494	622500.159	0.036	0.036	0.036
SGGWGE DBP5	6347453.16	-27057.01	622882.217	0.655004	-0.06099	-0.50874314	6347453.815	-27057.071	622881.708	0.036	0.036	0.036
SGGWGE DBP6	6347426.914	-27357.676	623261.52	0.70088	-0.06756	-0.56366401	6347427.615	-27357.744	623260.956	0.036	0.036	0.036
SGGWGE DBP7	6347375.113	-27845.995	623641.637	0.718368	0.003294	-0.66175232	6347375.831	-27845.992	623640.975	0.027	0.027	0.027
SGGWGE DBP8	6347370.439	-27873.405	623651.383	0.740809	-0.0073	-0.66285626	6347371.18	-27873.412	623650.72	0.051	0.051	0.051
SGGWGE DBP9	6347338.603	-28229.345	623949.88	0.773059	-0.0987	-0.65688085	6347339.376	-28229.444	623949.223	0.037	0.037	0.037
SGGWGE DBP10	6347306.686	-28542.035	624277.747	0.830281	-0.00742	-0.74363581	6347307.516	-28542.042	624277.003	0.051	0.051	0.051
SGGWGE DBP11	6347260.262	-29324.959	624764.601	1.203501	-0.00801	-1.08183021	6347261.466	-29324.967	624763.519	0.051	0.051	0.051
SGGWGE DBP12	6346951.259	-28738.849	628173.453	1.191109	0.024875	-0.90380119	6346952.45	-28738.824	628172.549	0.037	0.037	0.037
SGGWGE DBP13	6346970.405	-27777.356	628214.774	1.116147	-0.01412	-0.99509902	6346971.521	-27777.37	628213.779	0.016	0.016	0.016

Table 4.2: Adjustment of the residuals (v)

BASELINES		OBSERVED VECTORS			RESIDUALS(v)			ADJUSTED VECTORS			STANDARD ERRORS		
FROM	TO	ΔX(m)	ΔY(m)	ΔZ(m)	VΔx(m)	VΔy(m)	VΔz(m)	ADJ Δz(m)	ADJ Δy(m)	ADJ Δz(m)	σΔX(m)	σΔY(m)	σΔZ(m)
Accra	SGGS.GW DBP 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.35	-7.949	0.016	0.016	0.016
SGGS.GW DBP 48	SGGS.GW DBP 1	-6424.659	5132.132	-24.433	-0.4174	0.0005	0.3774	-6425.076	5132.133	-24.056	0.051	0.051	0.051
Accra	SGGS.GW DBP 1	3753.506	-5639.095	-34.203	-0.7056	0.0010	0.6378	3752.8	-5639.094	-33.565	0.051	0.051	0.051
Accra	SGGS.GW DBP 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.35	-7.949	0.016	0.016	0.016
SGGS.GW DBP 48	SGGS.GW DBP 2	-6018.728	4850.033	-17.128	-0.4614	0.0006	0.4172	-6019.189	4850.034	-16.711	0.051	0.051	0.051
Accra	SGGS.GW DBP 2	4159.362	-5921.562	-26.772	-0.6617	0.0009	0.5981	4158.7	-5921.561	-26.174	0.051	0.051	0.051
Accra	SGGS.GW DBP 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.35	-7.949	0.016	0.016	0.016
SGGS.GW DBP 48	SGGS.GW DBP 3	-5329.148	4409.528	-17.804	-0.3208	0.1101	0.4854	-5329.469	4409.638	-17.319	0.051	0.051	0.051
Accra	SGGS.GW DBP 3	2682.933	-7455.271	-21.675	-0.5857	0.0008	0.5293	2682.347	-7455.27	-21.146	0.051	0.051	0.051
Accra	SGGS.GW DBP 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.35	-7.949	0.016	0.016	0.016
SGGS.GW DBP 48	SGGS.GW DBP 4	-4903.73	4139.765	-11.42	-0.5836	0.0008	0.5277	-4904.314	4139.766	-10.892	0.051	0.051	0.051
Accra	SGGS.GW DBP 4	5274.601	-6631.587	-20.173	-0.5395	0.0008	0.4875	5274.062	-6631.586	-19.685	0.051	0.051	0.051
Accra	SGGS.GW DBP 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.35	-7.949	0.016	0.016	0.016
SGGS.GW DBP 48	SGGS.GW DBP 5	-4605.299	3950.73	-11.972	-0.6172	-0.0023	0.5660	-4605.916	3950.728	-11.406	0.036	0.036	0.036
Accra	SGGS.GW DBP 5	5573.109	-6821.307	-21.583	-0.5059	0.0039	0.4493	5572.603	-6821.303	-21.134	0.038	0.038	0.038
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.35	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGS.GW DBP 6	-4151.661	3644.034	2.55	-0.6652	-0.0018	0.6024	-4152.326	3644.032	3.152	0.036	0.036	0.036
Accra	SGGS.GW DBP 6	6026.723	-7127.338	-6.231	-0.4579	0.0033	0.4128	6026.265	-7127.335	-5.818	0.038	0.038	0.038
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.35	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGS.GW DBP 7	-3748.769	3100.988	-13.827	-0.7106	0.0037	0.6421	-3749.48	3100.992	-13.185	0.036	0.036	0.036
Accra	SGGS.GW DBP 7	6429.527	-7670.535	-23.452	-0.4124	-0.0021	0.3732	6429.115	-7670.537	-23.079	0.038	0.038	0.038
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.35	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGS.GW DBP 8	-3688.177	3087.793	18.377	-0.7196	0.0042	0.6428	-3688.897	3087.797	19.02	0.027	0.027	0.027
Accra	SGGS.GW DBP 8	6514.143	-7702.432	-20.919	-0.4059	-0.0007	0.3754	6513.737	-7702.433	-20.544	0.029	0.029	0.029
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.35	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGS.GW DBP 9	-3449.208	2744.599	-14.385	-0.7443	0.0010	0.6729	-3449.952	2744.6	-13.712	0.051	0.051	0.051
Accra	SGGS.GW DBP 9	6729.318	-8026.663	-23.3	-0.3788	0.0005	0.3423	6728.939	-8026.662	-22.958	0.051	0.051	0.051

Tables 41 and 42 show the adjusted parameters of the observation, the adjusted vectors, as well as the adjusted residuals (v) for the 30 min static GPS observation, The Design Matrix (A). Matrix of absolute terms (L), adjusted observation (X) and the residuals (V) and all other viable information can be found in the appendix

Table 4.3: Final adjusted coordinates and their standard errors for rural district boundary session

STATIONS	GRID COORDINATES		STANDARD ERRORS			
	N(X)	E(Y)	σN(ft)	σE(ft)	σN(m)	σE(m)
SGGWGE DBP1	346690.288	1178515.684	0.509	0.509	0.155	0.155
SGGWGE DBP2	348022.047	1177590.173	0.509	0.509	0.155	0.155
SGGWGE DBP3	350284.075	1176145.208	0.509	0.509	0.155	0.155
SGGWGE DBP4	351680.05	1175260.223	0.365	0.365	0.111	0.111
SGGWGE DBP5	352659.347	1174639.867	0.365	0.365	0.111	0.111
SGGWGE DBP6	354147.656	1173633.636	0.365	0.365	0.111	0.111
SGGWGE DBP7	355469.487	1171851.972	0.267	0.267	0.081	0.081
SGGWGE DBP8	355781.38	1171656.464	0.509	0.509	0.155	0.155
SGGWGE DBP9	356452.297	1170682.684	0.371	0.371	0.113	0.113
SGGWGE DBP10	357531.422	1169655.255	0.509	0.509	0.155	0.155
SGGWGE DBP11	359130.834	1167084.349	0.509	0.509	0.155	0.155
SGGWGE DBP12	370361.425	1168987.95	0.371	0.371	0.113	0.113
SGGWGE DBP13	370495.923	1172141.906	0.156	0.156	0.048	0.048

The same procedure as used for the adjustment of the 30 minutes Static GPS observation at the rural district section was carried out for the urban boundary as well as the adjustment of the Total Station Traverse. The rest of the adjustment computation can be found in the appendix B. A soft copy has been attached to this project work that shows all the necessary results of the adjustment process. Table 4.4 show the standard errors obtained from the 30mins static GPS measurement and that of the Total station traverse.

Table 4.4: Results from the least square Adjustment for the 30 minutes- Static GPS observation and the Total Station traverse for rural and urban district boundary.

Survey Method	Unit Variance (m)	Standard Error(m)
30 mins –STATIC GPS (Rural district)	0.005	0.071
30 mins –STATIC GPS (Urban district)	0.0043	0.061
Total station Traverse(Rural district)	0.011	0.059
Total station Traverse(Urban district)	0.011	0.059

4.4. FIELD DATA

In table 4.5 and 4.6, the results from all the surveying methods under comparison are presented for the rural boundary category.

Table 4.5: Final Adjusted coordinates for the Rural Boundary points obtained from the various Survey Methods (Static,RTK and Total station).

	STATIC GPS CO-ORDS		RTK GPS CO-ORDS		TOTAL STATION	
PT ID	Northing [X] ft	Easting [Y] ft	Northing [X] ft	Easting [Y] ft	Northing [X] ft	Easting [Y] ft
SGGW/GE/DBP1	346690.288	1178515.684	346690.269	1178515.498	346690.188	1178515.584
SGGW/GE/DBP2	348022.047	1177590.173	348022.339	1177590.488	348022.243	1177590.293
SGGW/GE/DBP3	350284.075	1176145.208	350284.169	1176145.790.	350284.377	1176145.221
SGGW/GE/DBP4	351680.050.	1175260.223	351680.509	1175260.167	351680.259	1175260.233
SGGW/GE/DBP5	352659.347	1174639.867	352659.987	1174639.702	352659.356	1174639.765
SGGW/GE/DBP6	354147.656	1173633.636	354147.898	1173633.589	354147.521	1173633.507
SGGW/GE/DBP7	355469.487	1171851.972	355469.822	1171851.999	355469.373	1171851.894
SGGW/GE/DBP8	355781.380.	1171656.464	355781.012	1171656.156	355781.577	1171656.782
SGGW/GE/DBP9	356452.297	1170682.684	356452.466	1170682.768	356452.354	1170682.106
SGGW/GE/DBP10	357531.422	1169655.255	357531.402	1169654.932	357531.950.	1169655.415
SGGW/GE/DBP11	359130.834	1167084.349	359130.996	1167084.875	359130.632	1167084.410.
SGGW/GE/DBP12	370361.425	1168987.950.	370361.603	1168987.736	370361.384	1168987.998
SGGW/GE/DBP13	370495.923	1172141.906	370495.549	1172142.271	370495.852	1172141.753

Table 4.6: Final Adjusted coordinates for the Rural Boundary points obtained from the various Survey Methods (5.10.15)mins- Fast static GPS.

	5-MIN FAST STATIC CO-ORD		10-MIN FAST STATIC CO-ORD		15-MIN FAST STATIC CO-ORD	
PT ID	Northing [X] ft	Easting [Y] ft	Northing [X] ft	Easting [Y] ft	Northing [X] ft	Easting [Y] ft
SGGW/GE/DBP1	346690.167	1178515.987	346690.368	1178515.867	346690.312	1178515.544
SGGW/GE/DBP2	348022.340.	1177590.081	348022.070.	1177590.221	348022.037	1177590.255
SGGW/GE/DBP3	350284.226	1176145.165	350284.178	1176145.368	350284.329	1176145.172
SGGW/GE/DBP4	351679.511	1175260.225	351679.599	1175260.652	351680.064	1175260.209
SGGW/GE/DBP5	352659.739	1174639.721	352659.746	1174639.663	352659.253	1174639.899
SGGW/GE/DBP6	354147.509	1173633.989	354147.721	1173633.697	354147.666	1173633.635
SGGW/GE/DBP7	355469.463	1171851.961	355469.319	1171852.154	355469.489	1171851.950.
SGGW/GE/DBP8	355781.538	1171656.564	355781.105	1171656.296	355781.415	1171656.156
SGGW/GE/DBP9	356452.251	1170682.520.	356452.413	1170682.564	356452.272	1170682.669
SGGW/GE/DBP10	357531.610.	1169655.298	357531.592	1169655.167	357531.350.	1169655.236
SGGW/GE/DBP11	359130.871	1167084.430.	359130.793	1167084.311	359130.882	1167084.329
SGGW/GE/DBP12	370361.623	1168987.718	370361.527	1168988.346	370361.465	1168988.024
SGGW/GE/DBP13	370495.697	1172141.326	370495.775	1172141.984	370495.766	1172141.973

Similarly, in table 4.7 and 4.8 the results from all the surveying methods under comparison are presented for the urban boundary category.

Table 4.7: Final Adjusted coordinates for Urban Boundary points obtained from the Surveying Methods (Static ,RTK and Total station).

	STATIC GPS COORDS		RTK GPS COORDS		TOTAL STATION CO-ORD	
PT ID	Northing [X] ft	Easting [Y] ft	Northing [X]	Easting [Y]ft	Northing [X] ft	Easting [Y] ft
SGGS/GW/DBP1	344631.575	1177287.336	344631.493	1177287.459	344631.626	1177287.512
SGGS/GW/DBP2	344394.730.	1175390.933	344394.738	1175390.928	344394.173	1175390.975
SGGS/GW/DBP3	344410.549	1173992.439	344410.657	1173992.335	344410.498	1173992.479
SGGS/GW/DBP4	345121.313	1171401.771	345121.015	1171401.858	345121.213	1171401.267
SGGS/GW/DBP5	346357.835	1170924.121	346357.943	1170924.217	346357.735	1170924.024
SGGS/GW/DBP6	348206.677	1167453.437	348206.293	1167453.287	348206.767	1167453.553
SGGS/GW/DBP7	348919.504	1166997.070.	348919.493	1166997.013	348919.119	1166996.998
SGGS/GW/DBP8	351070.612	1168532.032	351070.514	1168532.116	351070.677	1168532.053
SGGS/GW/DBP9	350151.985	1166862.502	350151.742	1166863.035	350151.968	1166862.712
SGGS/GW/DBP10	351638.559	1167218.673	351638.605	1167218.603	351638.199	1167218.386
SGGS/GW/DBP11	352100.635	1161761.143	352100.624	1161761.315	352100.714	1161761.234
SGGS/GW/DBP12	352027.878	1161945.317	352027.156	1161945.483	352027.813	1161944.987
SGGS/GW/DBP13	359068.034	1165054.948	359068.329	1165055.600.	359068.134	1165054.876

Table4.8: Final Adjusted coordinates for Urban Boundary points obtained from the Surveying Methods (5.10.15)mins- Fast static GPS

	5-MINS FAST STATIC CO-ORDS		10MIN -FAST STATIC CO-ORD		15-MINS FAST STATIC CO-ORD	
PT ID	Northing [X] ft	Easting [Y] ft	Northing [X] f	Easting [Y] ft	Northing [X] ft	Easting [Y] ft
SGGS/GW/DBP1	344631.286	1177287.539	344631.646	1177287.182	344631.602	1177287.410.
SGGS/GW/DBP2	344394.677	1175390.624	344394.931	1175390.938	344394.713	1175390.858
SGGS/GW/DBP3	344410.431	1173992.402	344410.843	1173992.543	344410.484	1173992.442
SGGS/GW/DBP4	345121.268	1171401.965	345120.949	1171401.533	345121.446	1171401.674
SGGS/GW/DBP5	346357.973	1170924.336	346357.899	1170924.126	346357.814	1170924.103
SGGS/GW/DBP6	348206.271	1167453.409	348206.637	1167453.511	348206.635	1167453.502
SGGS/GW/DBP7	348920.005	1166996.709	348919.801	1166997.068	348919.492	1166997.112
SGGS/GW/DBP8	351070.453	1168532.476	351070.225	1168532.114	351070.593	1168532.162
SGGS/GW/DBP9	350151.790.	1166862.338	350151.761	1166862.490.	350151.883	1166862.822
SGGS/GW/DBP10	351638.566	1167218.964	351638.294	1167218.304	351638.749	1167218.585
SGGS/GW/DBP11	352100.618	1161761.150.	352100.618	1161761.150.	352100.723	1161761.209
SGGS/GW/DBP12	352028.099	1161945.288	352027.527	1161945.202	352027.930.	1161945.205
SGGS/GW/DBP13	359068.142	1165054.638	359068.152	1165054.599	359068.348	1165054.814

As stated in the introduction of this chapter the static GPS survey was taken as the standard set for the computation. The results of the Final adjusted coordinates per the various survey methods are presented in Tables 4.5, 4.6, 4.7 and 4.8.

4.5. COST ESTIMATION PER THE SURVEY METHODS

The methodology for costing in this research considered three main cost components: time; number of personnel; and rental rate of equipment. The costs of survey by the various survey methods were computed and tabulated as shown in tables 4.9, 4.10 and 4.7 for the rural district boundary category and tables 4.11, 4.12 and 4.13 for the urban category respectively.

4.5.1. Time Expenditure

In order to compare the cost (time expenditure) of the methods applied, effective time has been recorded throughout the measurements. Effective time refers to the time needed to measure the required tasks without considering the delayed time due to some problems. The specified time is specific to this measurement because it depends on the operator engaged. For the convenient of comparison, time expenditure was classified into time needed for total station traverse, fast static GPS survey and the Real Time Kinematic survey. The required time does not include the time for transportation of instruments from store to the field and vice versa, and delayed time due to some problems such as: battery problem, incorrect reading, etc.

4.5.1.1. Time Expended for Total Station Traverse

The total station traverse consists of 87 setups which were measured from the departure stations towards all the 13 control points in both the rural and urban districts. This was done on two faces and for two rounds of measurements. The overall tasks were classified as field and office work.

However, in the computations the time consumed was recorded only for the field measurement. Time allocated for every step of the measurement is presented in Table 4.15 and 4.16. Time needed to setup the tripod of the instrument (total station) on one station was recorded and then multiplied by the number of instrument stations to determine the time expended on all instrument setups. In this project, the time expended for one setup of a tripod on one target is multiplied by13 to calculate the expended time on the tripod setup, since 13 is the number of established control points in both, the rural and urban boundaries as indicated in table 4.9

4.5.1.2. Time Expended for GPS RTK

Time expended for GPS RTK was recorded as time required for the reference base and for the rover. For the reference station, time was calculated as: time required for the tripod setup plus the time used to center the instrument which was 8 min. For the rover measurement, time has been recorded as: time needed to center the rover plus time used to record and to change over to the next station. This is then multiplied by the number of control points (13) as indicated in tables 4.9 and 4.10 respectively.

4.5.1.3. Time expended for GPS Fast static

Time expended for GPS (5, 10, and15) min-fast static was recorded as time required for the reference base and for the rover. For the reference station, time was calculated as: time required for tripod setup plus the time used to center the instrument which was 8 min. For the rover measurement, time has been recorded as: time needed to center the rover plus (5, 10, 15) min session time and the time needed to change over to the next station this is then multiplied by the number of control points (13) as indicated in Table 4.10

Table 4.9: Time expenditure per survey methods.

Time expenditure in (min)				
Total station			RTK	
Measurement steps	Instrument	prism	Reference	Rover
Tripod Setup	4	4	5	1
Centering	5	3	3	1
Aiming	1	-	--	-
Recording	1	-	1	1
Travel time	-	180	-	180
Sum	11	(7x87)+180	9	(3x13)+180
	800=13hr33min= appt 2 days		**228=3hr 8min=approx. 1 day**	

Table 4.10: Time expenditure for fast static method.

Time expenditure in (min)			
	5 min-Fast static	**10 min-Fast static**	**15 min-Fast static**

Measurement steps	Reference	Rover	Reference	Rover	Reference	Rover
Tripod Setup	5	1	5	1	5	1
Centering	3	1	3	1	3	1
Session time	-	5	-	10	-	15
Recording	-	-	-	-	-	-
Travel time	-	180	-	180	-	180
Sum	8	(7x13) +180	8	(12x13)+180	8	(17x13)+180
	278=4hr65min= appt. a day		**344=5hr73min= appt. a day**		**409=6hrs 82min= appt. a day**	

4.5.2. Cost Estimate for Rural district boundary survey methods

Table 4.11: Cost of survey for the RTK method is presented.

RTK Survey	Unit	Time (hours)	Man- Hour fee(GH¢)	Man- Day fee(GH¢)	Total Cost (Hours) (GH¢)	Cost per day (GH¢)
Hiring fee for GPS (GH₵600 per day)	2	8hrs working day			600.00(fixed)	600.00
Actual measurement	-	4hrs≈1 day				
Surveyor	1	4hrs≈1 day	40	320	160.00	320.00
Asst .surveyor	1	4hrs≈1 day	35	280	140.00	280.00
Labourer (skilled)	1	4hr≈1 day	20	160	80.00	160.00
Spot Clearing	2	8hr≈1 day	6	48	96.00	96.00
Pillaring	2	8hrs≈1 day	6	48	96.00	96.00
Total Cost					GH¢**1,172.00**	GH¢**1,552.00**

Table 4.12: Cost of district boundary survey for the 5mins-Fast static method

Fast static Survey	Unit	Time (hours)	Man- Hour fee(GH¢)	Man- day fee(GH¢)	Total Cost (Hours) (GH¢) (GH¢)	Cost per day (GH¢)
Hiring fee for GPS (GH₵400 per day)	2	8hrs working day	-	-	400.00(fixed)	400.00
Actual measurement	-	5hrs≈1day	-	-	-	-
Surveyor	1	5hrs≈ 1day	40	320	200.00	320.00
Asst .surveyor	1	5hrs≈1 day	35	280	175.00	280.00

Labourer (skilled)	1	5hrs≈1 day	20	160	100.00	160.00
Spot Clearing	2	8hrs≈1 day	6	48	96.00	96.00
Pillaring	2	8hrs≈1 day	6	48	96.00	96.00
Total Cost					GH¢**1,067.00**	GH¢ **1,352.00**

Table 4.13: Cost of district boundary survey for the 10mins-Fast static method

Fast static Survey	**Unit**	**Time (hours)**	**Man- Hour fee(GH¢)**	**Man- day fee(GH¢)**	**Total Cost (Hours) (GH¢) (GH¢)**	**Cost per day (GH¢)**
Hiring fee for GPS (GH₵400 per day)	2	8hrs working day	-	-	400.00(fixed)	400.00
Actual measurement	-	6hrs≈1day	-	-	-	-
Surveyor	1	6hrs≈1day	40	320	240.00	320.00
Asst .surveyor	1	6hrs≈1 day	35	280	210.00	280.00
Labourer (skilled)	1	6hrs≈1 day	20	160	120.00	160.00
Spot Clearing	2	8hrs≈1 day	6	48	96.00	96.00
Pillaring	2	8hrs≈1 day	6	48	96.00	96.00
Total Cost					GH¢**1,162.00**	GH¢ **1,352.00**

Table 4.14: Cost of district boundary survey for the 15mins-Fast static method

Fast static Survey	**Unit**	**Time (hours)**	**Man- Hour fee(GH¢)**	**Man- day fee(GH¢)**	**Total Cost (Hours) (GH¢) (GH¢)**	**Cost per day (GH¢)**
Hiring fee for GPS (GH₵400 per day)	2	8hrs working day	-	-	400.00(fixed)	400.00
Actual measurement	-	7hrs≈1day	-	-	-	-
Surveyor	1	7hrs≈1day	40	320	280.00	320.00
Asst .surveyor	1	7hrs≈1 day	35	280	245.00	280.00
Labourer (skilled)	1	7hrs≈1 day	20	160	140.00	160.00
Spot Clearing	2	8hrs≈1 day	6	48	96.00	96.00
Pillaring	2	8hrs≈1 day	6	48	96.00	96.00
Total Cost					GH¢ **1,257.00**	GH¢ **1,352.00**

Table 4.15: Cost of district boundary survey for the Total station.

Total Station Survey	**Unit**	**Time (hours)**	**Man- Hour fee(GH¢)**	**Man- day fee(GH¢)**	**Total Cost (Hours) (GH¢)**	**Cost per day (GH¢)**
Hiring fee for Total station (GH₵100 per day)	2	8hrs working day			200.00(fixed)	200.00
Actual measurement	-	2 days				
Surveyor	1	14hrs≈2 day	40	320	560.00	640.00
Asst. surveyor	2	14hrs≈2 day	35	280	980.00	1120.00
Labourer	2	14hrs≈2 day	20	160	560.00	640.00
Spot Clearing	2	8hrs≈1 day	6	48	96.00	96.00
Pillaring	2	8hrs≈1 day	6	48	96.00	96.00
Total					GH¢ **2,492.00**	GH¢**2,792.00**

4.5.3. Cost estimate for the Urban district boundary survey methods

Table 4.16: Cost of survey for the RTK method is presented.

RTK Survey	Unit	Time (hours)	Man- Hour fee(GH¢)	Man- Day fee(GH¢)	**Total Cost (Hours)** (GH¢)	Cost per day (GH¢)
Hiring fee for GPS (GH₵600 per day)	2	8hrs working day			600.00(fixed)	600.00
Actual measurement	-	4hrs≈1 day				
Surveyor	1	4hrs≈1 day	40	320	160.00	320.00
Asst .surveyor	1	4hrs≈1 day	35	280	140.00	280.00
Labourer (skilled)	1	4hr≈1 day	20	160	80.00	160.00
Spot Clearing	1	8hr≈1 day	6	48	48.00	48.00
Pillaring	2	8hrs≈1 day	6	48	96.00	96.00
Total Cost					GH¢**1,124.00**	GH¢**1,504.00**

Table 4.17 : Cost of district boundary survey for the 5 min-fast static method

Fast static Survey	**Unit**	**Time (hours)**	**Man- Hour fee(GH¢)**	**Man- day fee(GH¢)**	**Total Cost (Hours) (GH¢)**	**Cost per day (GH¢)**
Hiring fee for GPS (GH₵400 per day)	2	8hrs working day	-	-	400.00(fixed)	400.00
Actual measurement	-	5hrs≈1day	-	-	-	-
Surveyor	1	5hrs≈1day	40	320	200.00	320.00
Asst .surveyor	1	5hrs≈1 day	35	280	175.00	280.00
Labourer (skilled)	1	5hrs≈1 day	20	160	100.00	160.00
Spot Clearing	1	8hrs≈1 day	6	48	48.00	48.00
Pillaring	2	8hrs≈1 day	6	48	96.00	96.00
Total Cost					GH¢ **1,019.00**	GH¢ **1,304.00**

Table 4.18: Cost of district boundary survey for the 10 min-fast static method

Fast static Survey	**Unit**	**Time (hours)**	**Man- Hour fee(GH¢)**	**Man- day fee(GH¢)**	**Total Cost (Hours) (GH¢)**	**Cost per day (GH¢)**
Hiring fee for GPS (GH₵400 per day)	2	8hrs working day	-	-	400.00(fixed)	400.00
Actual measurement	-	6hrs≈1day	-	-	-	-
Surveyor	1	6hrs≈1day	40	320	240.00	320.00
Asst .surveyor	1	6hrs≈1 day	35	280	210.00	280.00
Labourer (skilled)	1	6hrs≈1 day	20	160	120.00	160.00
Spot Clearing	1	8hrs≈1 day	6	48	48.00	48.00
Pillaring	2	8hrs≈1 day	6	48	96.00	96.00
Total Cost					GH¢ **1,114.00**	GH¢ **1,304.00**

Table 4.19: Cost of district boundary survey for the 15 min-fast static method.

Fast static Survey	Unit	Time (hours)	Man- Hour fee(GH¢)	Man- day fee(GH¢)	**Total Cost (Hours)** (GH¢)	Cost per day (GH¢)
Hiring fee for GPS (GH₵400 per day)	2	8hrs working day	-	-	400.00(fixed)	400.00

Table Cost of

Actual measurement	-	7hrs≈ 1day	-	-	-	-
Surveyor	1	7hrs≈1day	40	320	280.00	320.00
Asst .surveyor	1	7hrs≈1 day	35	280	245.00	280.00
Labourer (skilled)	1	7hrs≈1 day	20	160	140.00	160.00
Spot Clearing	1	8hrs≈1 day	6	48	48.00	48.00
Pillaring	2	8hrs≈1 day	6	48	96.00	96.00
Total Cost					GH¢ **1,209.00**	GH¢ **1,304.00**

4.20: district boundary survey for the Total station.

Total Station Survey	**Unit**	**Time (hours)**	Man- Hour fee(GH¢)	**Man- day fee(GH¢)**	**Total Cost (Hours) (GH¢)**	**Cost per day (GH¢)**
Hiring fee for Total station (GH₵100 per day)	2	8hrs working day			200.00(fixed)	200.00
Actual measurement	-	2 days				
Surveyor	1	14hrs≈2 day	40	320	560.00	640.00
Asst. surveyor	2	14hrs≈2 day	35	280	980.00	1120.00
Labourer	1	14hrs≈2 day	20	160	280.00	320.00
Spot Clearing	1	8hrs≈1 day	6	48	48.00	48.00
Pillaring	2	8hrs≈1 day	6	48	96.00	96.00
Total					GH¢ **2164.00**	GH¢**2,424.00**

4.5.4. Plotting of Final Results

The GPS data observed was processed using the Topcon tools software. The data was integrated into the new national Geodetic Reference Network (GRN) after which histogram graphs and line curves were generated in excel spread sheet. The data was imported into Auto Land Desktop. A scale of 1:20,000 was used for plotting a boundary map as shown in Figure 4.3. The positions of all the boundary markers of all kinds were noted in the field book as well as on the map.

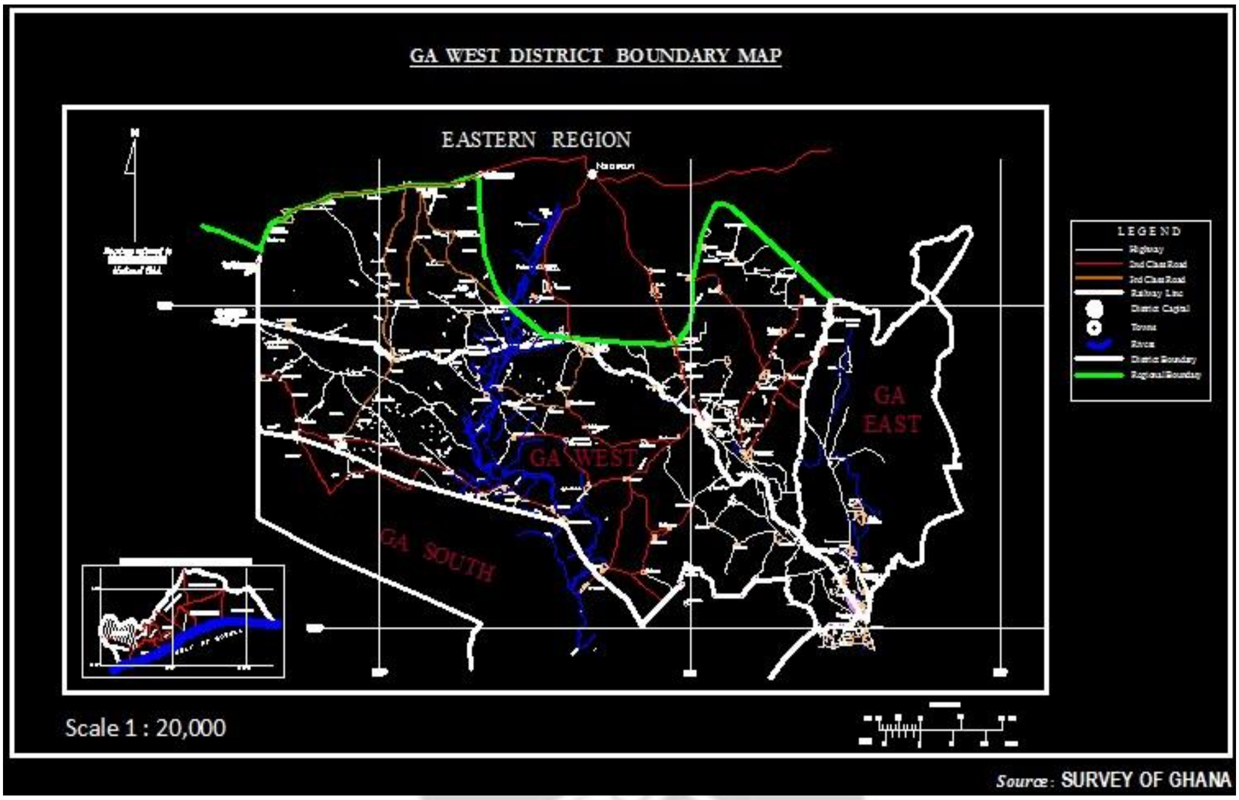

Figure 4.3: Final District Boundary Map

CHAPTER 5

ANALYSIS AND DISCUSSION OF RESULTS

5.1. INTRODUCTION

This chapter discusses the various results presented in chapter four. The discussions are categorized into two main sections. Section one compares the accuracies for the various methods and sections two compares their cost and execution time. This is to enable the researcher recommend the most efficient survey method or a combination of survey method(s) suitable for the district boundary survey in the urban and rural area in the country respectively.

5.2. RELEVANT STATISTICS FOR THE RURAL BOUNDARY

Tables 5.1, 5.2, 5.3 show the positional accuracies of each of the three techniques. Figure 5.1 to Figure 5.6 show the corresponding bar and line graphs of the positional accuracies. Tables 5.4 Shows the RMS errors for RTK-GPS, Fast Static GPS (5mins, 10mins, and 15mins) and Total Station Techniques. The final Accuracy in Northing and Easting co-ordinates of the RTK-GPS, Fast Static GPS (5mins, 10mins, and 15mins) and Total Station Techniques and their Cadastral Standards are presented in Table 5.11.and 5.12 respectively. Tables 5.13 and 5.14 show the performance comparison between the survey methods under investigation whiles Figure 5.17 and 5.18 show graphs of cost against the various survey methods

Table 5.1: Positional Accuracy of RTK, (5mins-Fast Static) and Total station for the various Rural Boundary Points.

PT ID	Fn CLOSURE ERROR(CE)						POSITIONAL ACCURACY(PA)		
	RTK		FAST STATIC		TOTAL STATION		RTK	F STATIC	T STATION
	ΔX(ΔN)	ΔY(ΔE)	ΔX(ΔN)	ΔY(ΔE)	ΔX(ΔN)	ΔY(ΔE)			
SGGW/GE/DBP1	-0.006	-0.057	-0.037	0.092	-0.030	-0.030	0.0570	0.0994	0.0431
SGGW/GE/DBP2	0.089	0.096	0.089	-0.028	0.060	0.037	0.1309	0.0936	0.0700
SGGW/GE/DBP3	0.029	0.177	0.046	-0.013	0.092	0.004	0.1797	0.0479	0.0921
SGGW/GE/DBP4	0.140	-0.017	-0.164	0.001	0.064	0.003	0.1409	0.1643	0.0638
SGGW/GE/DBP5	0.195	-0.050	0.119	-0.045	0.003	-0.031	0.2015	0.1275	0.0312
SGGW/GE/DBP6	0.074	-0.014	-0.045	0.108	-0.041	-0.039	0.0751	0.1166	0.0569
SGGW/GE/DBP7	0.102	0.008	-0.007	-0.003	-0.035	-0.024	0.1024	0.0080	0.0421
SGGW/GE/DBP8	-0.112	-0.094	0.048	0.030	0.060	0.097	0.1463	0.0570	0.1140
SGGW/GE/DBP9	0.052	0.026	-0.014	-0.050	0.017	-0.176	0.0575	0.0519	0.1770
SGGW/GE/DBP10	-0.006	-0.098	0.057	0.013	0.161	0.049	0.0986	0.0588	0.1682
SGGW/GE/DBP11	0.049	0.160	0.011	0.025	-0.062	0.019	0.1678	0.0271	0.0643
SGGW/GE/DBP12	0.054	-0.065	0.060	-0.071	-0.012	0.015	0.0848	0.0930	0.0192
SGGW/GE/DBP13	-0.114	0.111	-0.069	-0.177	-0.022	-0.047	0.1593	0.1897	0.0514

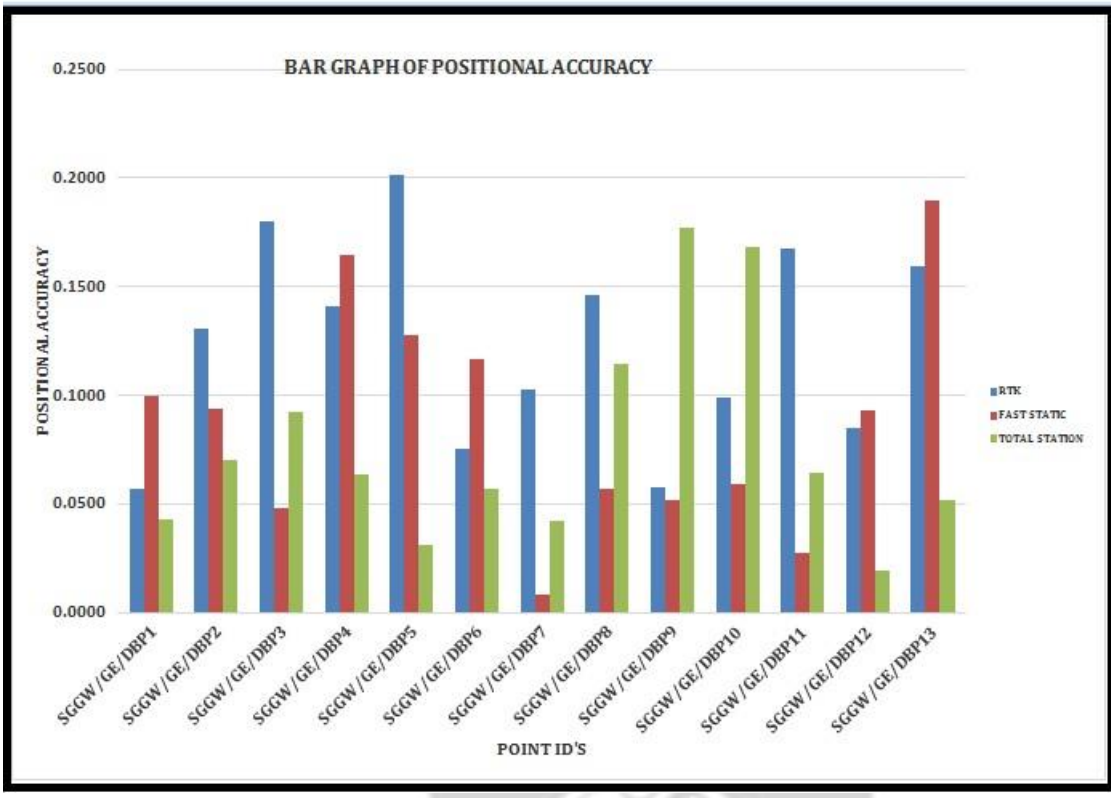

Figure 5.1: Bar Graph Showing the Positional Accuracy of RTK(5min-Fast static) and Total station methods for the Rural Boundary Points.

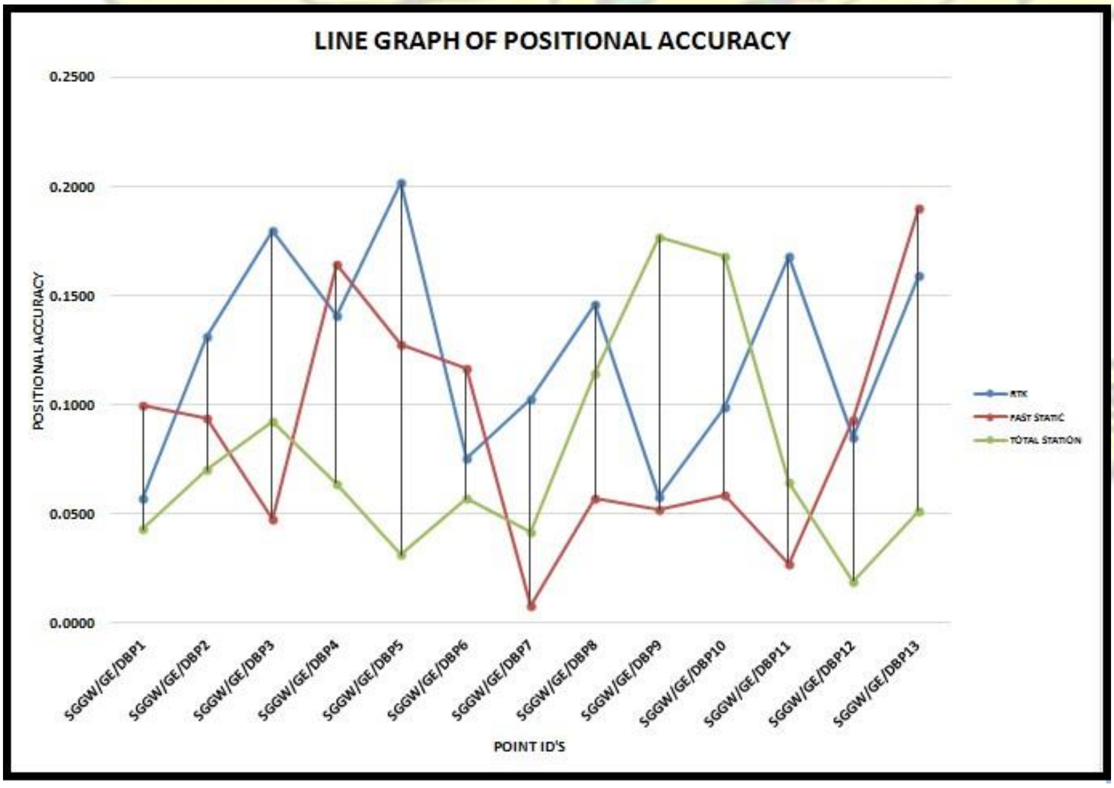

Figure 5.2: Line Graph Showing the Positional Accuracy of RTK(5min-Fast static) and Total station methods for the Rural Boundary Points.

Table 5.2: Positional Accuracy of RTK (10mins-Fast Static) and Total station for the various Rural Boundary Points.

PT ID	Fnl CLOSURE ERROR(CE)						POSITIONAL ACCURACY(PA)		
	RTK		FAST STATIC		TOTAL STATION		RTK	F STATIC	T STATION
	ΔX(ΔN)	ΔY(ΔE)	ΔX(ΔN)	ΔY(ΔE)	ΔX(ΔN)	ΔY(ΔE)			
SGGW/GE/DBP1	-0.006	-0.057	0.024	0.056	-0.030	-0.030	0.0570	0.0609	0.0431
SGGW/GE/DBP2	0.089	0.096	0.007	0.015	0.060	0.037	0.1309	0.0162	0.0700
SGGW/GE/DBP3	0.029	0.177	0.031	0.049	0.092	0.004	0.1797	0.0580	0.0921
SGGW/GE/DBP4	0.140	-0.017	-0.137	0.131	0.064	0.003	0.1409	0.1897	0.0638
SGGW/GE/DBP5	0.195	-0.050	0.122	-0.062	0.003	-0.031	0.2015	0.1366	0.0312
SGGW/GE/DBP6	0.074	-0.014	0.020	0.019	-0.041	-0.039	0.0751	0.0272	0.0569
SGGW/GE/DBP7	0.102	0.008	-0.051	0.055	-0.035	-0.024	0.1024	0.0755	0.0421
SGGW/GE/DBP8	-0.112	-0.094	-0.084	-0.051	0.060	0.097	0.1463	0.0982	0.1140
SGGW/GE/DBP9	0.052	0.026	0.035	-0.037	0.017	-0.176	0.0575	0.0509	0.1770
SGGW/GE/DBP10	-0.006	-0.098	0.052	-0.027	0.161	0.049	0.0986	0.0583	0.1682
SGGW/GE/DBP11	0.049	0.160	-0.012	-0.012	-0.062	0.019	0.1678	0.0170	0.0643
SGGW/GE/DBP12	0.054	-0.065	0.031	0.121	-0.012	0.015	0.0848	0.1246	0.0192
SGGW/GE/DBP13	-0.114	0.111	-0.045	0.024	-0.022	-0.047	0.1593	0.0510	0.0514

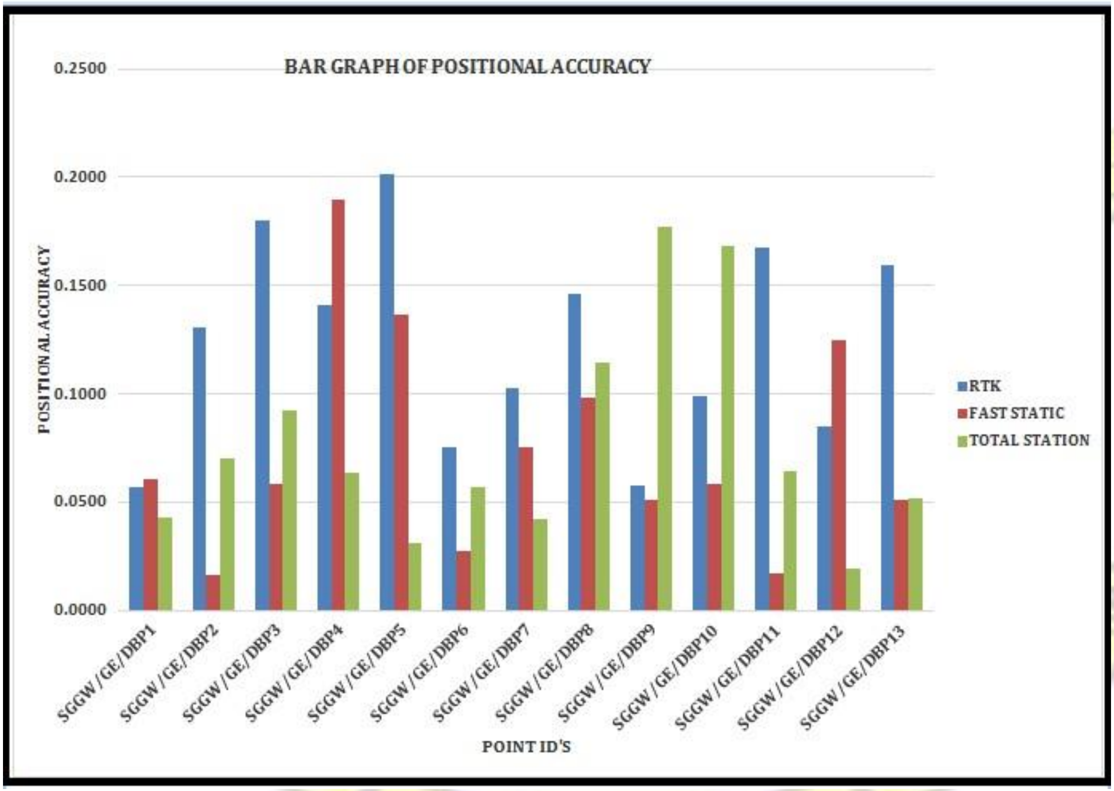

Figure 5.3: Bar Graph Showing the Positional Accuracy of RTK(10min-Fast static) and Total station method for the Rural Boundary Points.

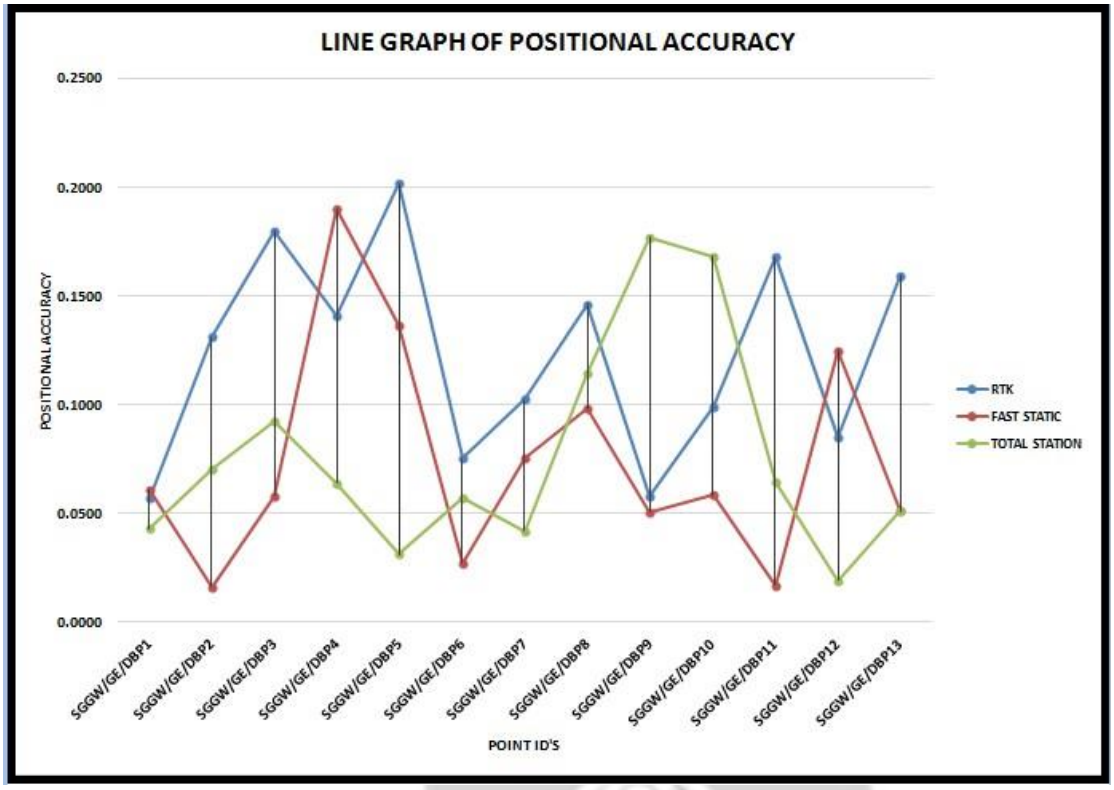

Figure 5.4: Line Graph Showing the Positional Accuracy for RTK(10min-Fast static)and Total station method for the Rural Boundary Points.

Table 5.3: Positional Accuracy of RTK(15mins-Fast Static) and Total station for the various Rural Boundary Points.

PT ID	FNL CLOSURE ERROR(CE)						POSITIONAL ACCURACY(PA)		
	RTK		FAST STATIC		TOTAL STATION		RTK	F STATIC	T STATION
	ΔX(ΔN)	ΔY(ΔE)	ΔX(ΔN)	ΔY(ΔE)	ΔX(ΔN)	ΔY(ΔE)			
SGGW/GE/DBP1	-0.006	-0.057	0.007	-0.043	-0.030	-0.030	0.0570	0.0433	0.0431
SGGW/GE/DBP2	0.089	0.096	-0.003	0.025	0.060	0.037	0.1309	0.0252	0.0700
SGGW/GE/DBP3	0.029	0.177	0.077	-0.011	0.092	0.004	0.1797	0.0782	0.0921
SGGW/GE/DBP4	0.140	-0.017	0.004	-0.004	0.064	0.003	0.1409	0.0060	0.0638
SGGW/GE/DBP5	0.195	-0.050	-0.029	0.010	0.003	-0.031	0.2015	0.0303	0.0312
SGGW/GE/DBP6	0.074	-0.014	0.003	0.000	-0.041	-0.039	0.0751	0.0031	0.0569
SGGW/GE/DBP7	0.102	0.008	0.001	-0.007	-0.035	-0.024	0.1024	0.0067	0.0421
SGGW/GE/DBP8	-0.112	-0.094	0.011	-0.094	0.060	0.097	0.1463	0.0945	0.1140
SGGW/GE/DBP9	0.052	0.026	-0.008	-0.005	0.017	-0.176	0.0575	0.0089	0.1770
SGGW/GE/DBP10	-0.006	-0.098	-0.022	-0.006	0.161	0.049	0.0986	0.0227	0.1682
SGGW/GE/DBP11	0.049	0.160	0.015	-0.006	-0.062	0.019	0.1678	0.0158	0.0643
SGGW/GE/DBP12	0.054	-0.065	0.012	0.023	-0.012	0.015	0.0848	0.0256	0.0192
SGGW/GE/DBP13	-0.114	0.111	-0.048	0.020	-0.022	-0.047	0.1593	0.0520	0.0514

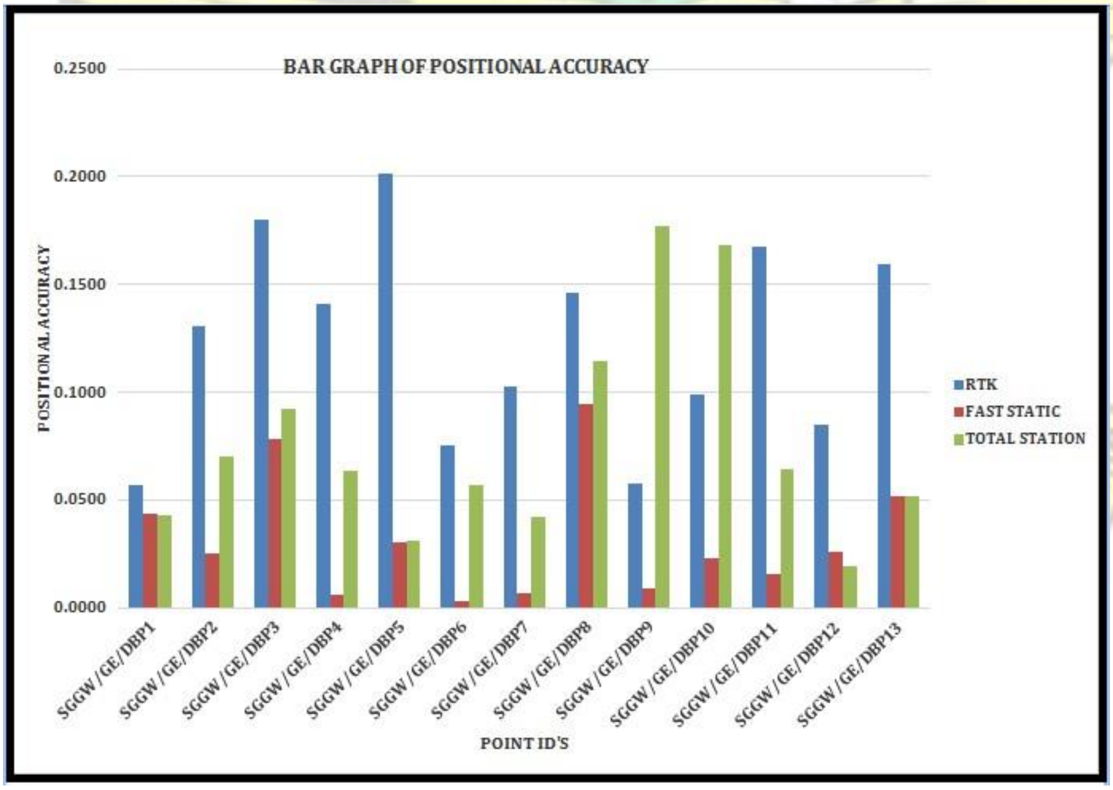

Figure 5.5: Bar Graph Showing the Positional Accuracy of RTK(15min-Fast static) and Total station method for the Rural Boundary Points.

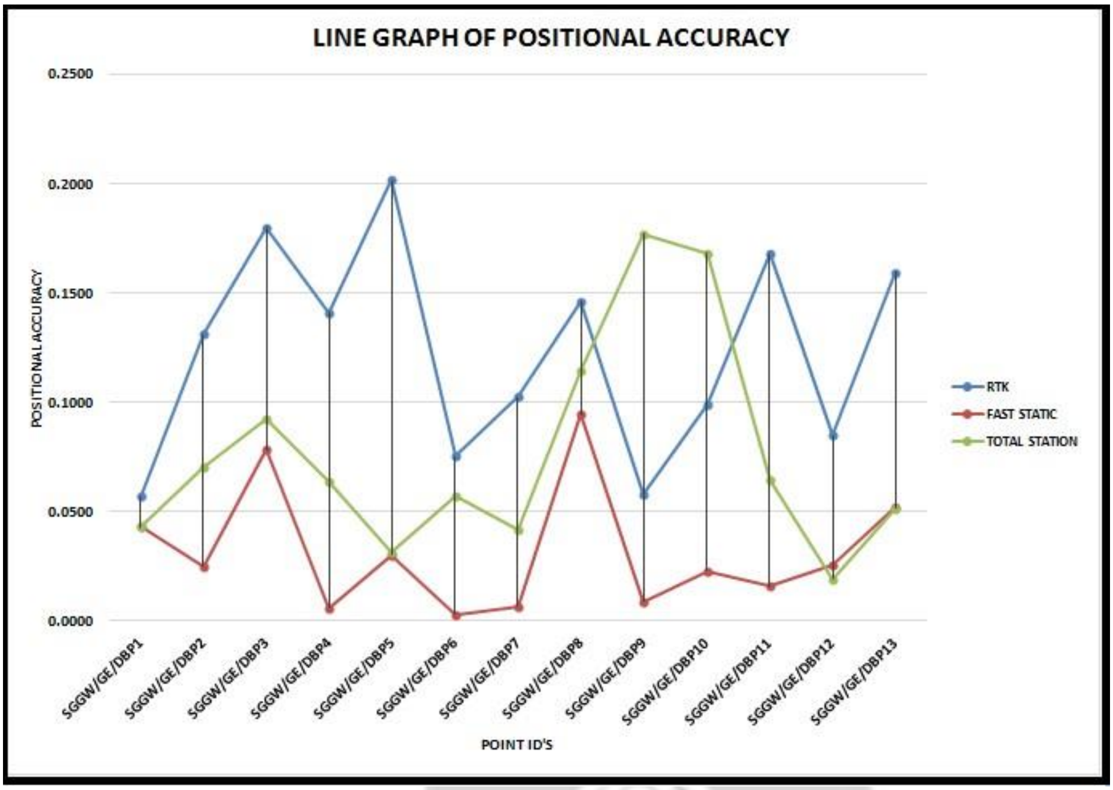

Figure 5.6: Line Graph Showing the Positional Accuracy for RTK(15min-Fast static)and Total station method for the Rural Boundary Point.

Table 5.4: RMS Error for the RTK(5,10,15) mins-fast static GPS method and the Total station method for the Rural Boundary Point

METHOD	RMS(m)	
	Northings(X)	Eastings(Y)
RTK	0.052	0.052
5 MINS-FAST STATIC	0.043	0.048
10 Min-FAST STATIC	0.039	0.036
15 Mins-FAST STATIC	0.021	0.024
TOTAL STATION	0.053	0.054

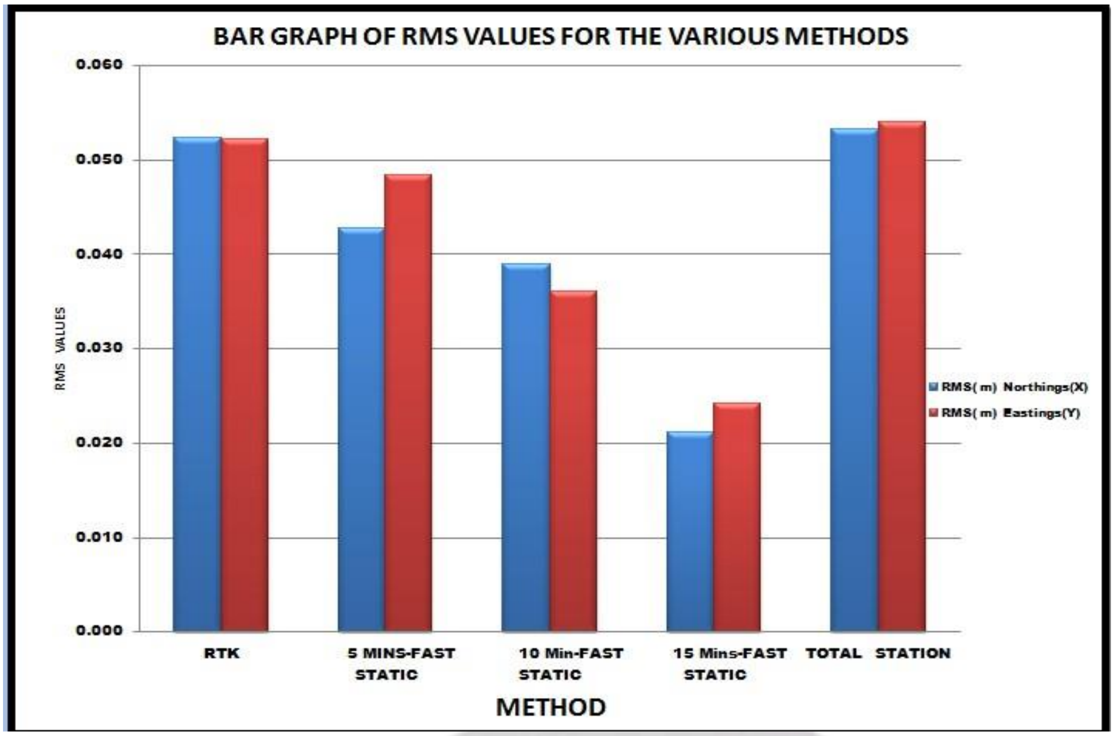

Figure 5.7: Line Graph showing RMS Error (m) of the RTK GPS(5, 10, 15) mins-Fast static and Total station method for the Rural Boundary Points.

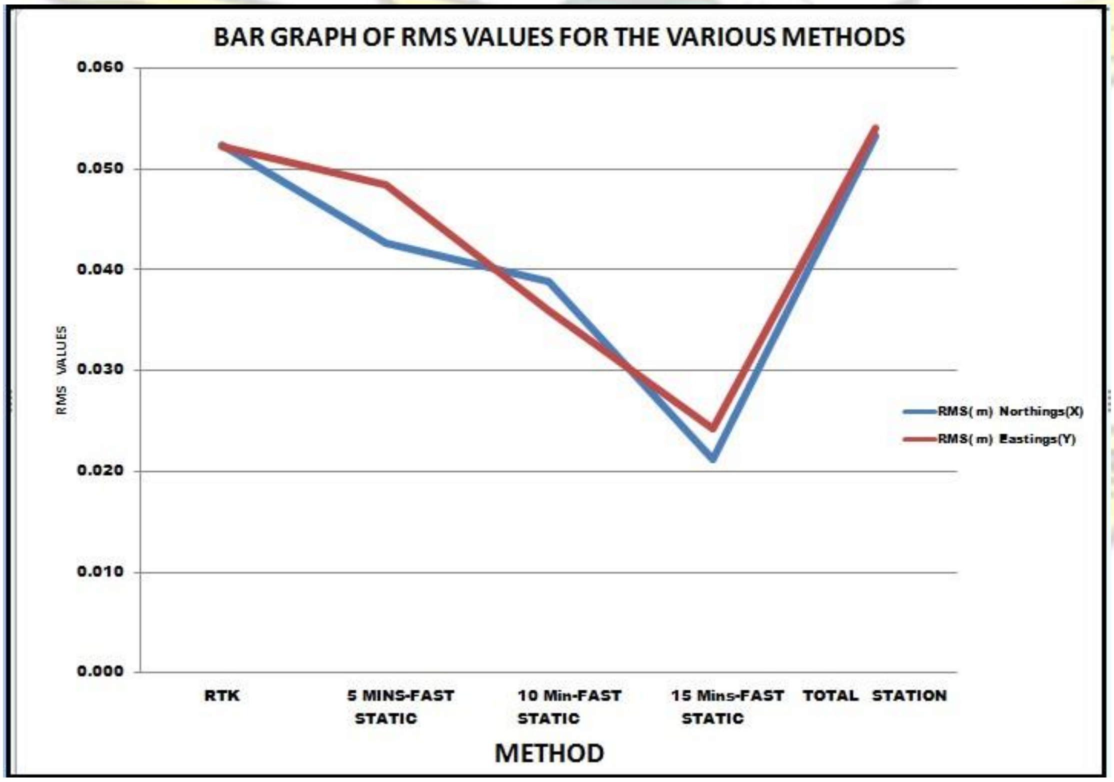

Figure 5.8: Line Graph showing RMS Error (m) of the RTK GPS (5, 10, 15) mins-Fast static and Total station method for the Rural Boundary Points.

5.2.1. Relevant Statistics for Urban Category:

Tables 5.5, 5.6 and 5.7 show the positional accuracies of each of the three techniques. Figure 5.9 to Figure 5.14 show their corresponding bar and line graphs. Table 5.8 shows the RMS errors of the RTK GPS, Fast static GPS (5mins, 10mins, 15mins) and the Total station method. Bar and line graphs of the RMS error are presented in Figures 5.15 and 5.16. The final Accuracy in Northing and Easting co-ordinates of the RTK-GPS, Fast Static GPS (5mins, 10mins, and 15mins) and Total Station Techniques and their cadastral accuracy standards are presented in Tables 5.9 and 5.10 respectively.

Table 5.5: Positional Accuracy of RTK,(5 mins-Fast Static) and Total station for the Urban Boundary Points.

PT ID	CLOSURE ERROR(CE)						POSITIONAL ACCURACY(PA)		
	RTK		FAST STATIC		TOTAL STATION		RTK	F STATIC	T STATION
	ΔX(ΔN)	ΔY(ΔE)	ΔX(ΔN)	ΔY(ΔE)	ΔX(ΔN)	ΔY(ΔE)			
SGGS/GW/DBP1	-0.025	0.037	-0.088	0.062	0.016	0.054	0.0451	0.1076	0.0559
SGGS/GW/DBP2	0.002	-0.002	-0.016	-0.094	-0.170	0.013	0.0029	0.0956	0.1703
SGGS/GW/DBP3	0.033	-0.032	-0.036	-0.011	-0.016	0.012	0.0457	0.0377	0.0198
SGGS/GW/DBP4	-0.091	0.027	-0.014	0.059	-0.030	-0.154	0.0946	0.0607	0.1566
SGGS/GW/DBP5	0.033	0.029	0.042	0.066	-0.030	-0.030	0.0440	0.0779	0.0425
SGGS/GW/DBP6	-0.117	-0.046	-0.124	-0.009	0.027	0.035	0.1257	0.1240	0.0448
SGGS/GW/DBP7	-0.003	-0.017	0.153	-0.110	-0.117	-0.022	0.0177	0.1882	0.1194
SGGS/GW/DBP8	-0.030	0.026	-0.048	0.135	0.020	0.006	0.0393	0.1437	0.0208
SGGS/GW/DBP9	-0.074	0.162	-0.059	-0.050	-0.005	0.064	0.1785	0.0777	0.0642
SGGS/GW/DBP10	0.014	-0.021	0.002	0.089	-0.110	-0.087	0.0255	0.0887	0.1403
SGGS/GW/DBP11	-0.003	0.052	-0.005	0.002	0.024	0.028	0.0525	0.0056	0.0367
SGGS/GW/DBP12	-0.220	0.051	0.067	-0.009	-0.020	-0.101	0.2258	0.0679	0.1025
SGGS/GW/DBP13	0.090	0.199	0.033	-0.094	0.030	-0.022	0.2181	0.1001	0.0376

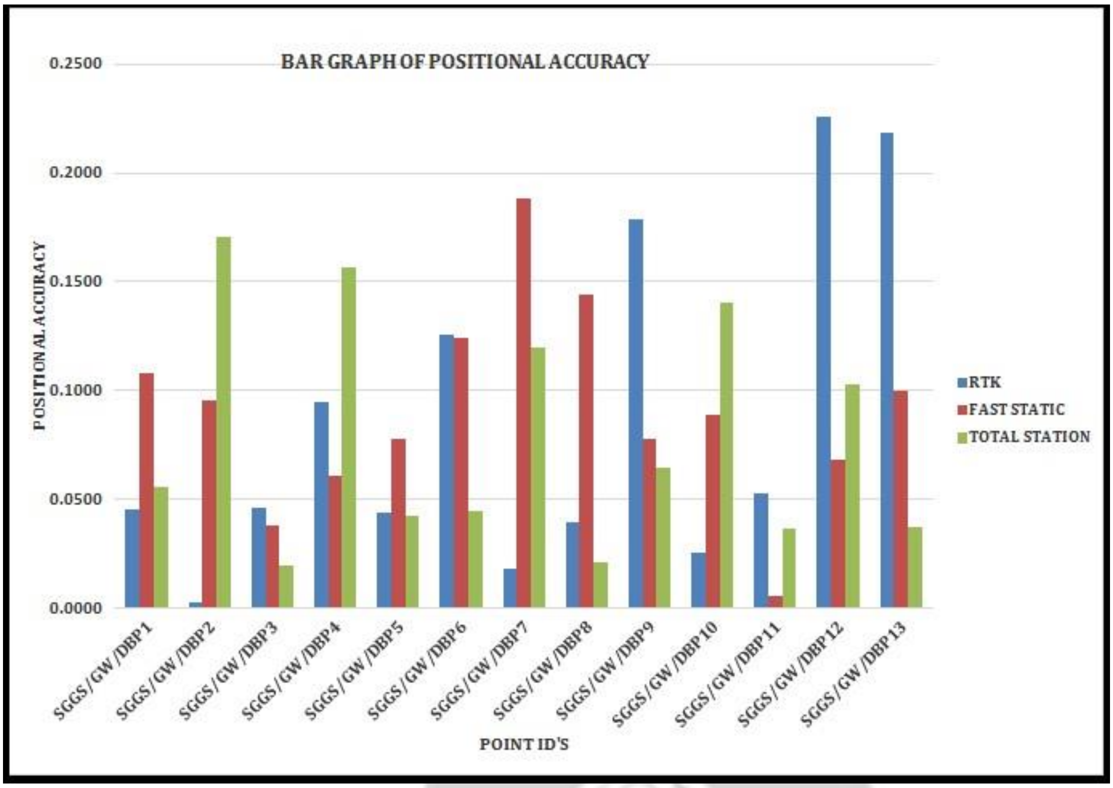

Figure 5.9: Bar Graph Showing the Positional Accuracy of RTK(5min-Fast static) and Total station method for the Urban Boundary Points.

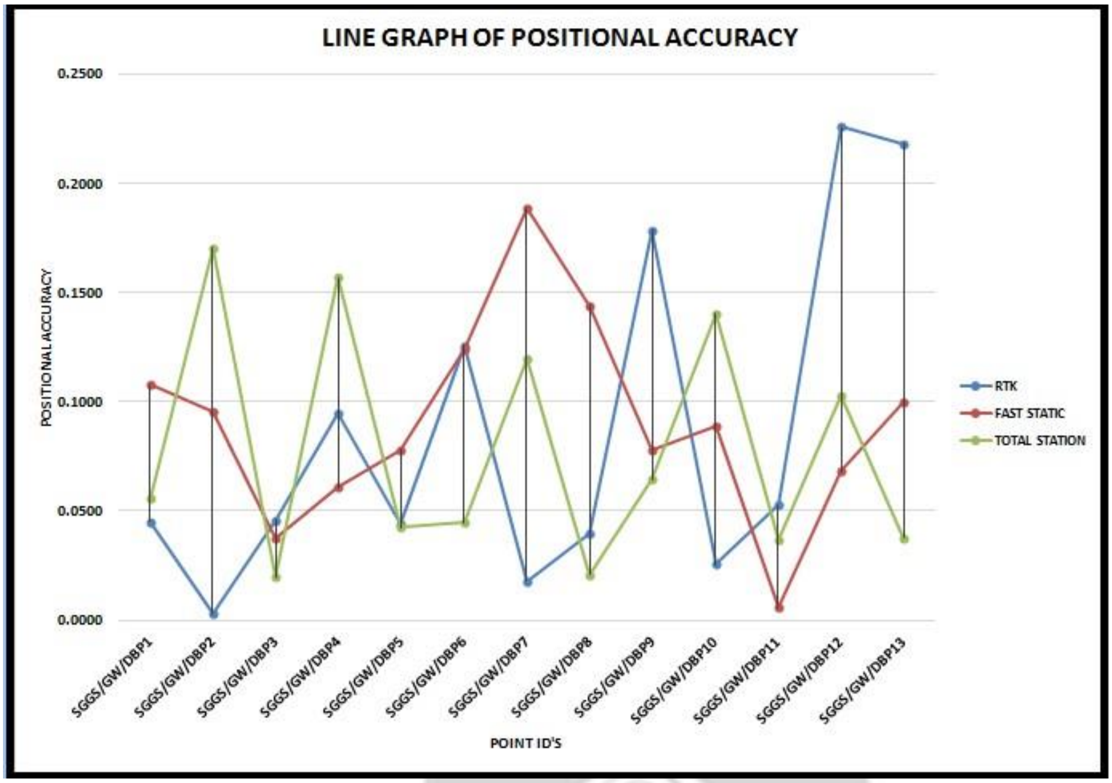

Figure 5.10: Line Graph Showing the Positional Accuracy of RTK(5min-Fast static and Total station methods for the Urban Boundary Points.

Table 5.6: Positional Accuracy of RTK, (10mins-Fast Static) and Total station for the Urban Boundary Points.

PT ID	CLOSURE ERROR(CE)						POSITIONAL ACCURACY(PA)		
	RTK		FAST STATIC		TOTAL STATION		RTK	F STATIC	T STATION
	ΔX(ΔN)	ΔY(ΔE)	ΔX(ΔN)	ΔY(ΔE)	ΔX(ΔN)	ΔY(ΔE)			
SGGS/GW/DBP1	-0.025	0.037	0.022	-0.047	0.016	0.054	0.0451	0.0517	0.0559
SGGS/GW/DBP2	0.002	-0.002	0.061	0.002	-0.170	0.013	0.0029	0.0613	0.1703
SGGS/GW/DBP3	0.033	-0.032	0.090	0.032	-0.016	0.012	0.0457	0.0951	0.0198
SGGS/GW/DBP4	-0.091	0.027	-0.111	-0.073	-0.030	-0.154	0.0946	0.1326	0.1566
SGGS/GW/DBP5	0.033	0.029	0.020	0.002	-0.030	-0.030	0.0440	0.0196	0.0425
SGGS/GW/DBP6	-0.117	-0.046	-0.012	0.023	0.027	0.035	0.1257	0.0256	0.0448
SGGS/GW/DBP7	-0.003	-0.017	0.091	-0.001	-0.117	-0.022	0.0177	0.0905	0.1194
SGGS/GW/DBP8	-0.030	0.026	-0.118	0.025	0.020	0.006	0.0393	0.1206	0.0208
SGGS/GW/DBP9	-0.074	0.162	-0.068	-0.004	-0.005	0.064	0.1785	0.0684	0.0642
SGGS/GW/DBP10	0.014	-0.021	-0.081	-0.112	-0.110	-0.087	0.0255	0.1385	0.1403
SGGS/GW/DBP11	-0.003	0.052	-0.005	0.002	0.029	0.026	0.0525	0.0056	0.0389
SGGS/GW/DBP12	-0.220	0.051	-0.107	-0.035	-0.020	-0.101	0.2258	0.1126	0.1025
SGGS/GW/DBP13	0.090	0.199	0.036	-0.106	0.030	-0.022	0.2181	0.1123	0.0376

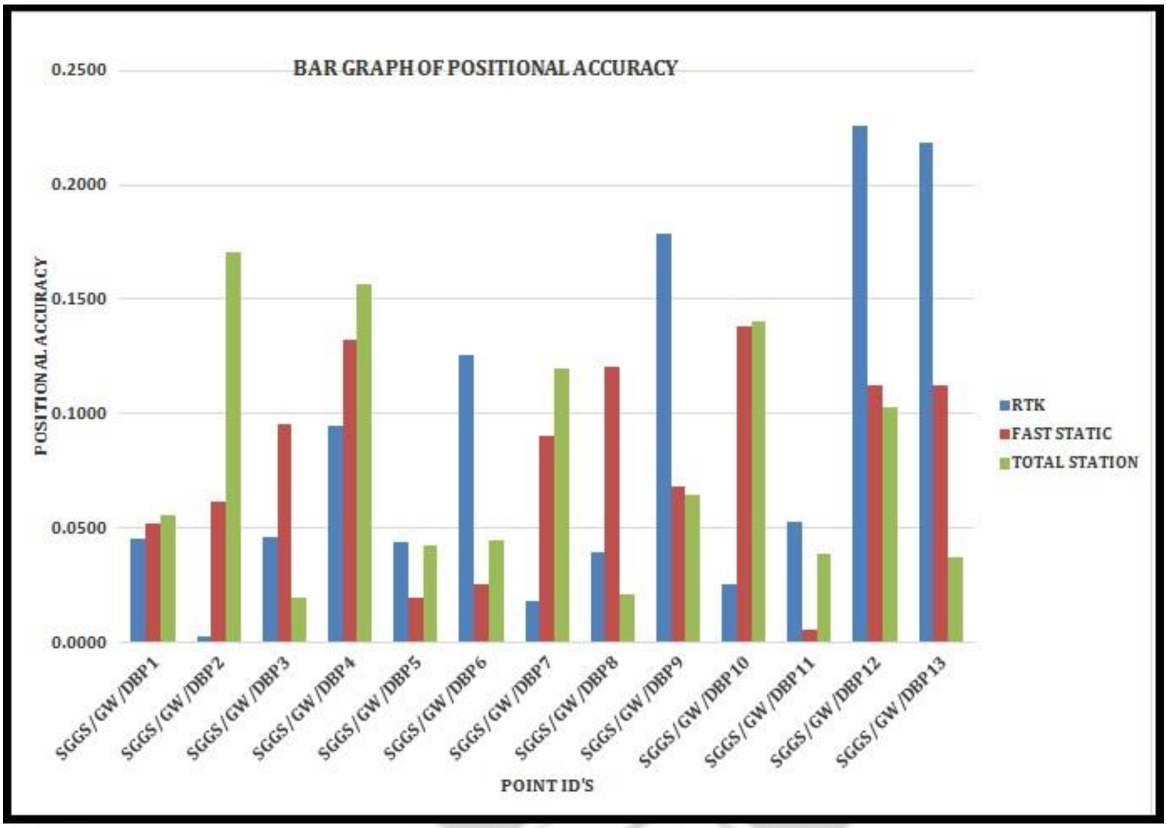

Figure 5.11:Bar Graph Showing the Positional Accuracy of RTK(10min-Fast static) and Total station method for the Urban Boundary Points.

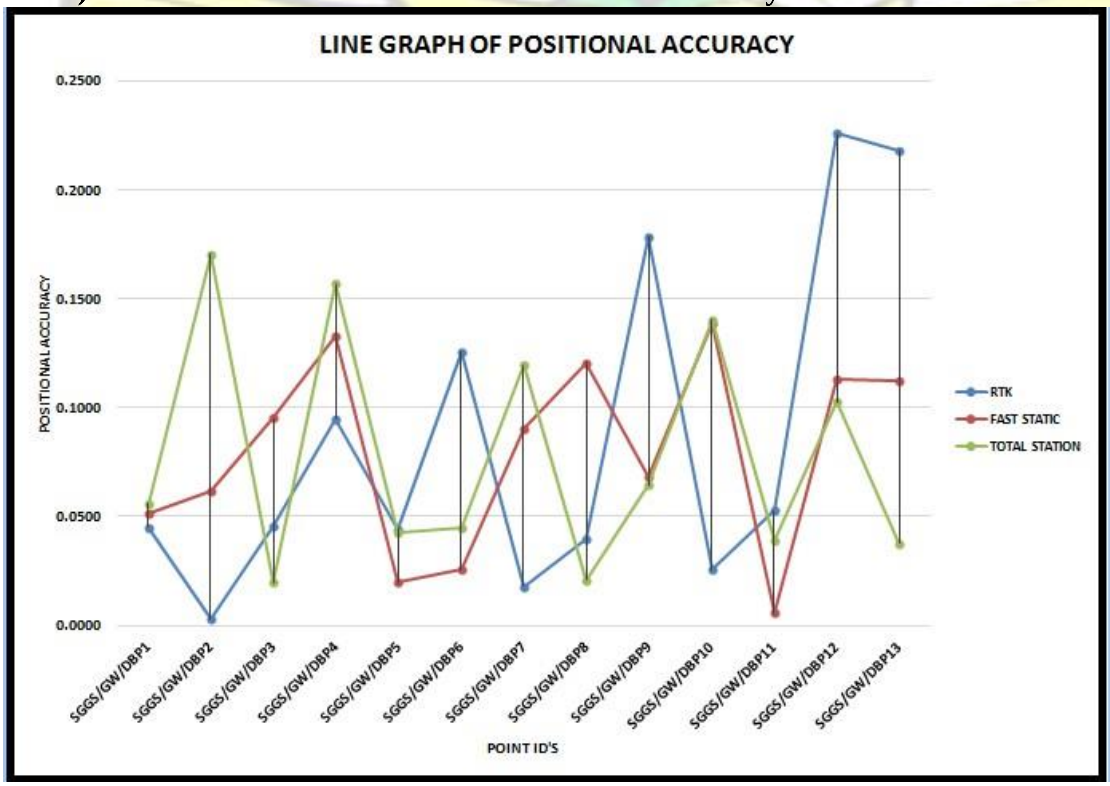

Figure 5.12: Line Graph Showing the Positional Accuracy of RTK(10min-Fast static) and Total station method for the Urban Boundary Points.

Table 5.7: Positional Accuracy of RTK, 15mins-Fast Static and Total station for the Urban Boundary Points.

PT ID	CLOSURE ERROR(CE)						POSITIONAL ACCURACY(PA)		
	RTK		FAST STATIC		TOTAL STATION		RTK	F STATIC	T STATION
	ΔX(ΔN)	ΔY(ΔE)	ΔX(ΔN)	ΔY(ΔE)	ΔX(ΔN)	ΔY(ΔE)			
SGGS/GW/DBP1	-0.025	0.037	0.008	0.023	0.016	0.054	0.0451	0.0240	0.0559
SGGS/GW/DBP2	0.002	-0.002	-0.005	-0.023	-0.170	0.013	0.0029	0.0234	0.1703
SGGS/GW/DBP3	0.033	-0.032	-0.020	0.001	-0.016	0.012	0.0457	0.0198	0.0198
SGGS/GW/DBP4	-0.091	0.027	0.041	-0.030	-0.030	-0.154	0.0946	0.0502	0.1566
SGGS/GW/DBP5	0.033	0.029	-0.006	-0.005	-0.030	-0.030	0.0440	0.0084	0.0425
SGGS/GW/DBP6	-0.117	-0.046	-0.013	0.020	0.027	0.035	0.1257	0.0236	0.0448
SGGS/GW/DBP7	-0.003	-0.017	-0.004	0.013	-0.117	-0.022	0.0177	0.0133	0.1194
SGGS/GW/DBP8	-0.030	0.026	-0.006	0.040	0.020	0.006	0.0393	0.0400	0.0208
SGGS/GW/DBP9	-0.074	0.162	-0.031	0.098	-0.005	0.064	0.1785	0.1024	0.0642
SGGS/GW/DBP10	0.014	-0.021	0.058	-0.027	-0.110	-0.087	0.0255	0.0638	0.1403
SGGS/GW/DBP11	-0.003	0.052	0.027	0.020	0.029	0.026	0.0525	0.0335	0.0389
SGGS/GW/DBP12	-0.220	0.051	0.016	-0.034	-0.020	-0.101	0.2258	0.0376	0.1025
SGGS/GW/DBP13	0.090	0.199	0.096	-0.041	0.030	-0.022	0.2181	0.1041	0.0376

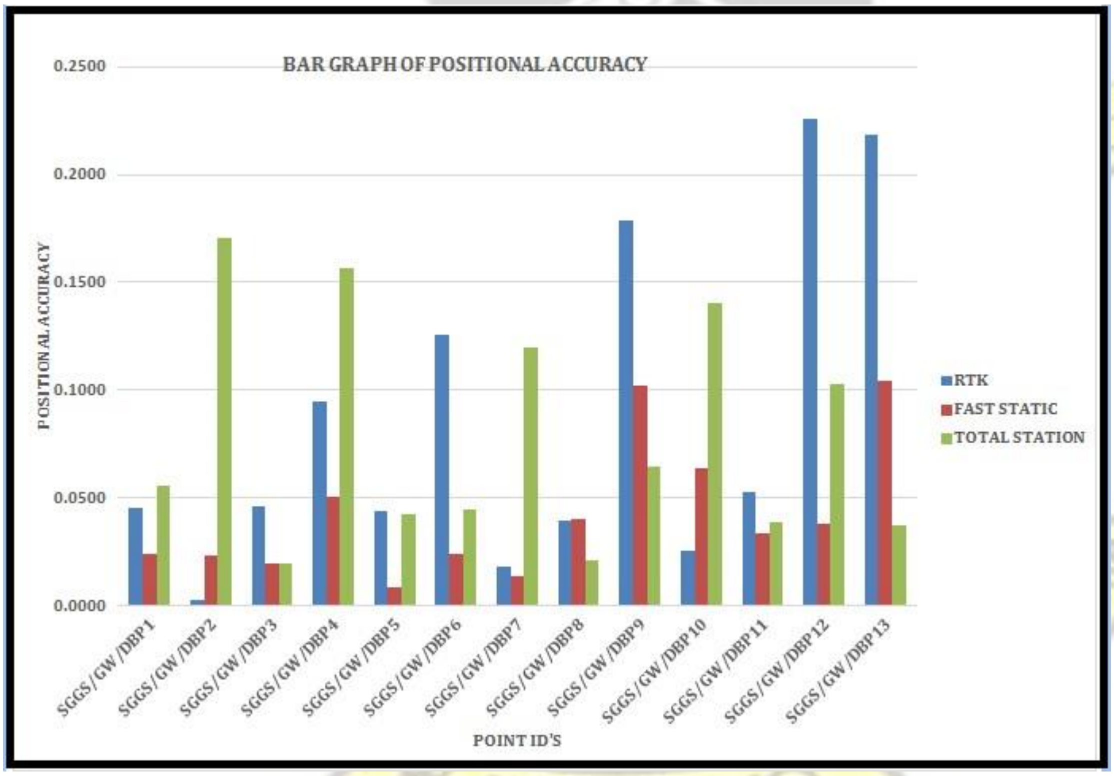

Figure 5.13: Bar Graph Showing the Positional Accuracy of RTK(15min-Fast static) and Total station method for the Urban Boundary Points.

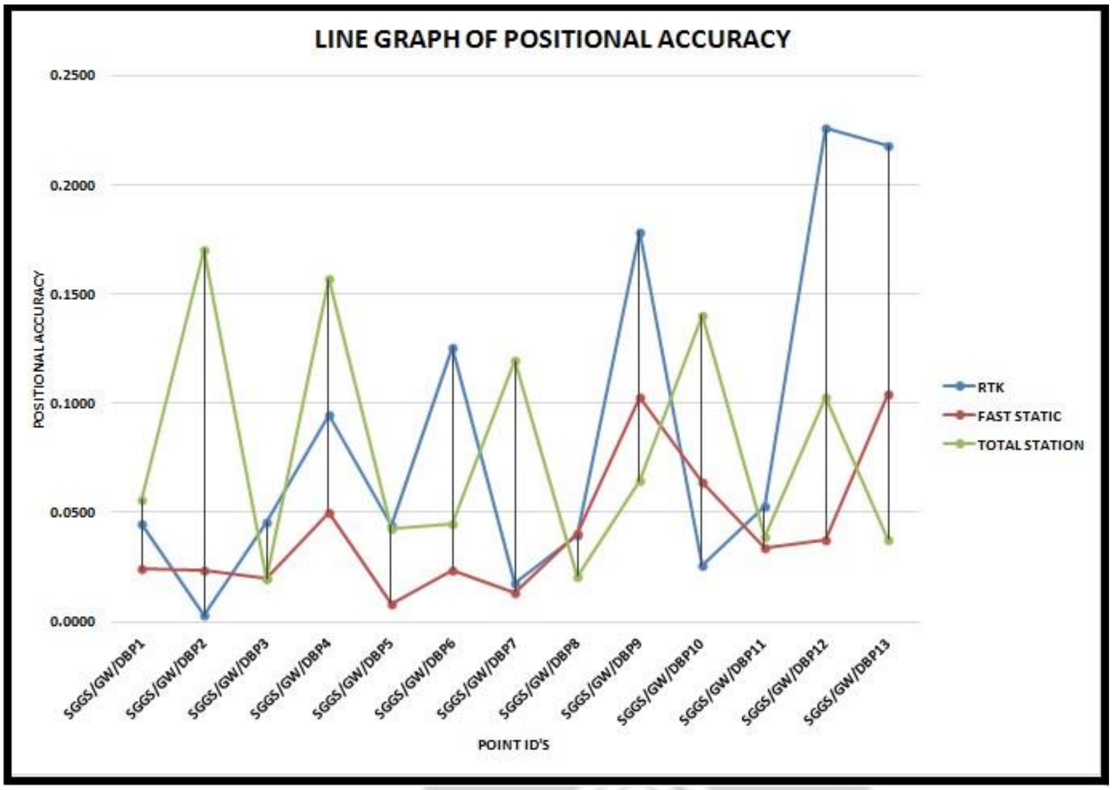

Figure 5.14: Line Graph Showing the Positional Accuracy of RTK(15min-Fast static) and Total station method for the Urban Boundary Points.

Table 5.8: RMS Error for the RTK(5,10,15) mins-fast static GPS method and the Total station method for the Urban Boundary Points.

METHOD	RMS(m)	
	Northing(X)	Eastings(Y)
RTK	0.060	0.056
5 MINS-FAST STATIC	0.044	0.042
10 Mins-FAST STATIC	0.039	0.038
15 Mins-FAST STATIC	0.026	0.023
TOTAL STATION	0.059	0.053

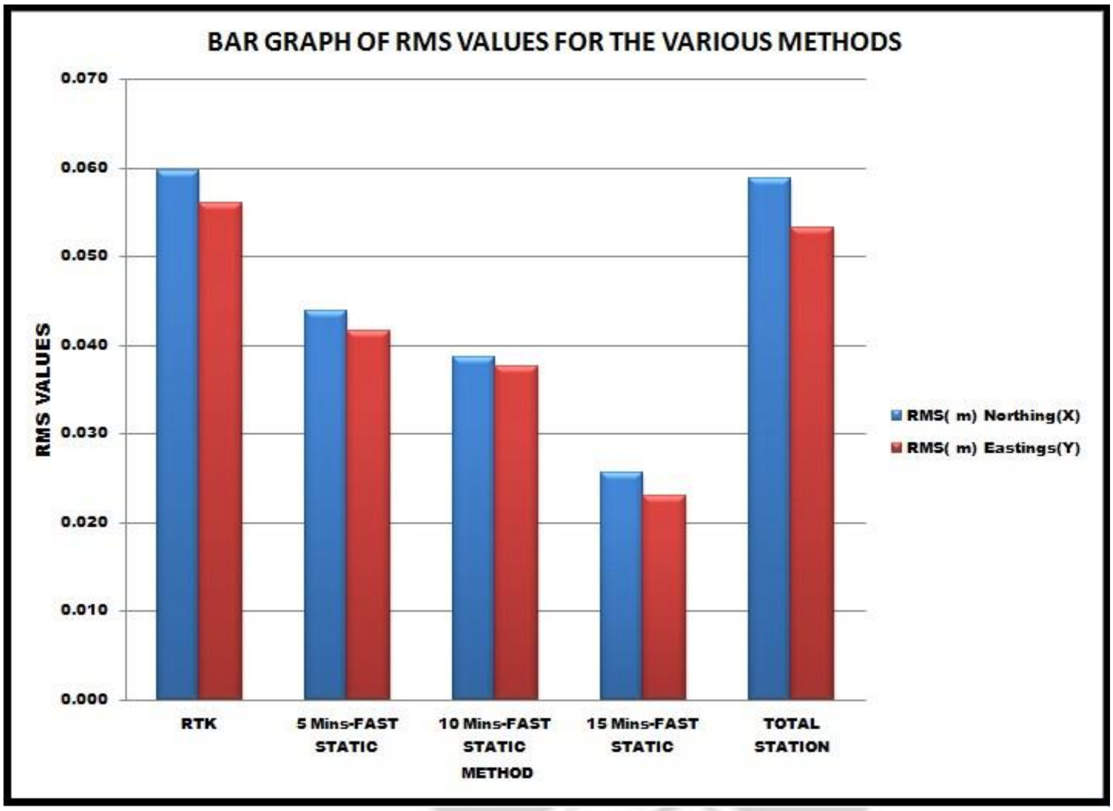

Figure 5.15: Bar Graph showing RMS Error(m) of the RTK (5,10,15) min-Fast static and Total station methods for the Urban Boundary Points.

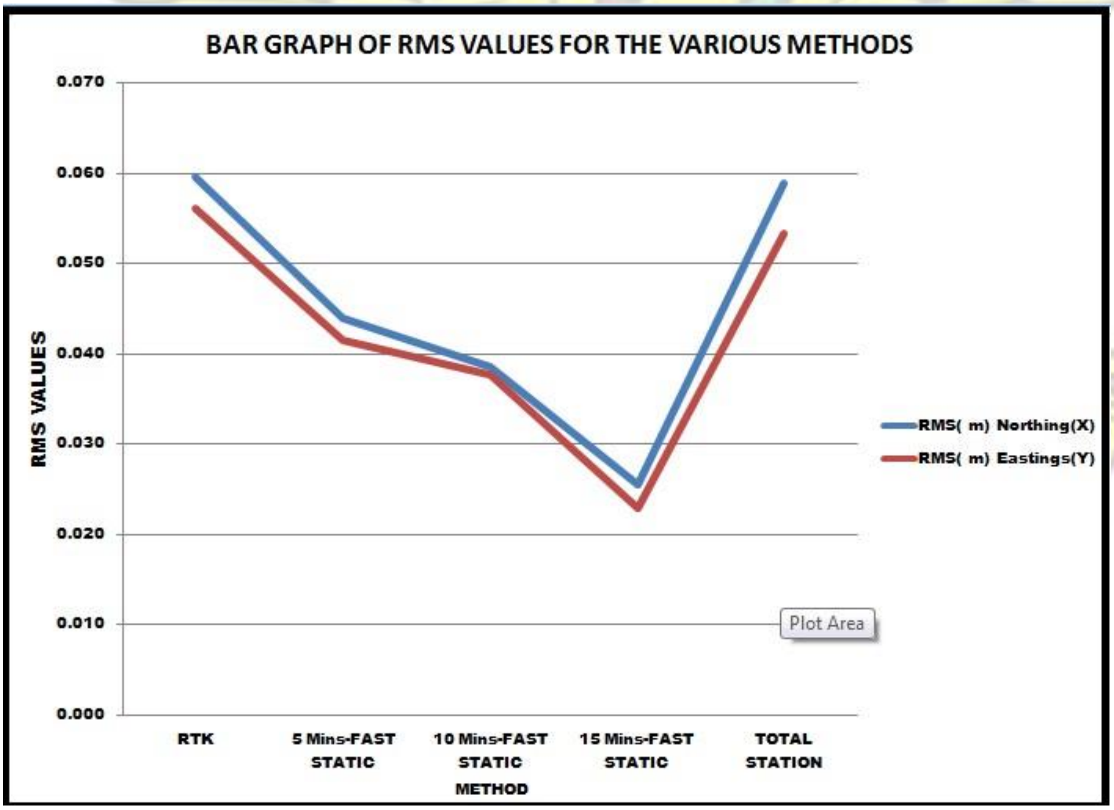

Figure 5.16: Line Graph showing RMS Error(m) of the RTK (5,10,15) min-Fast static and Total station methods for the Urban Boundary Points..

5.2.2. Cadastral survey standards for district boundary surveys in Ghana

5.2.2.1. Accuracy standards for GPS Surveys

Table 5.9: Accuracy Specifications

Static GPS Survey Performance(rms)	
Horizontal	0.005m+1ppm(0.016ft+1ppm)
Vertical	0.01m+2ppm(0.32ft+2ppm)

(Source;SMD, 2008)

5.2.2.2. Accuracy standards for Total station Surveys

The horizontal accuracy requirement for a district boundary survey is of the third order accuracy (Source; SMD, 2008).

(i) plus/minus 0.05m, plus 0.01m per 100m, for each boundary point to each other boundary point.

Table 5.11: Final Accuracies of the survey methods compared with the cadastral standards of (Rural district boundary)

Survey Method	**ACCURACY(m)**		**Cadastral Standard (1km)**	
	Northings (N)	**Easting(E)**	**Northings (N)**	**Eastings (E)**
RTK(stop & Go kinematics)	**0.052m**	**0.052m**	**Within threshold**	**Within threshold**
5 mins-Fast Static	**0.043m**	**0.045m**	✓	✓
10 mins-Fast Static	**0.039m**	**0.036m**	✓	✓
15 mins-Fast Static	**0.037m**	**0.024m**	✓	✓
Total Station	**0.053m**	**0.054m**	✓	✓

Table 5.12: Final Accuracy of the various survey methods compared with the cadastral standards(Urban district boundary)

Survey Method	**ACCURACY**		**Cadastral Standard**	
	Northings (N)	**Easting(E)**	**Northings (N)**	**Eastings (E)**
RTK(stop & Go kinematics)	**0.06m**	**0.056m**	**Within threshold**	**Within threshold**
5 mins-Fast Static	**0.044m**	**0.042m**	✓	✓
10 mins-Fast Static	**0.039m**	**0.038m**	✓	✓
15 mins-Fast Static	**0.026m**	**0.023m**	✓	✓

Total Station	**0.044m**	**0.036m**	✓	✓

Table 5.13: Performance comparisons for a Rural district boundary

Survey Method	Required man power	Required observation time per station	Total Operational cost (GH¢)
RTK(stop & go kinematic)	3	(1-2) minutes	**1180.00**
5m-Fast Static	3	5 minutes	**1070.00**
10m-Fast Static	3	10 minutes	**1170.00**
15m-Fast Static	3	15 minutes	**1260.00**
Total Station	5	(4-10) minutes	**2500.00**

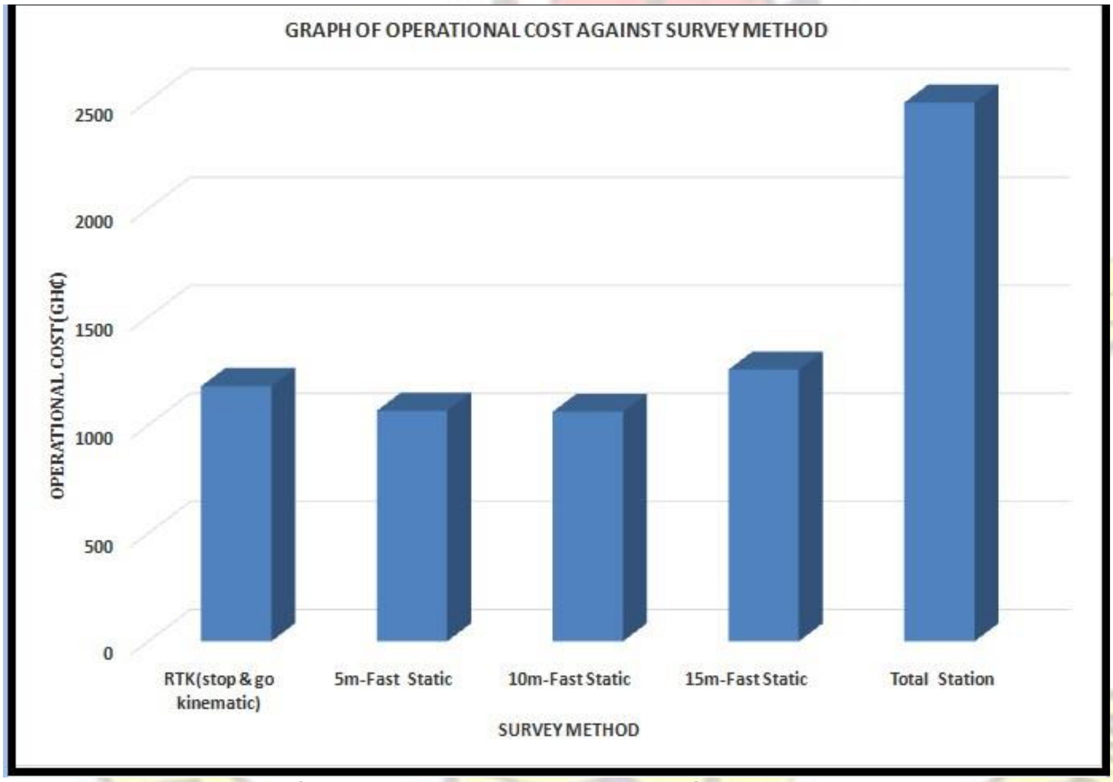

Figure 5.17: Graph of cost against survey method for rural district boundary survey.

Table 5.14: Performance comparisons for Urban district boundary

Survey Method	Required man power	Required observation time per station	Total Operational cost (GH¢)
RTK(stop & go kinematic)	2	(1-2) minutes	**1130.00**
5m- Fast Static	3	5 minutes	**1020.00**
10m-Fast Static	3	10 minutes	**1120.00**
15m-Fast Static	3	15 minutes	**1210.00**

Total Station	4	(4-10) minutes	**2170.00**

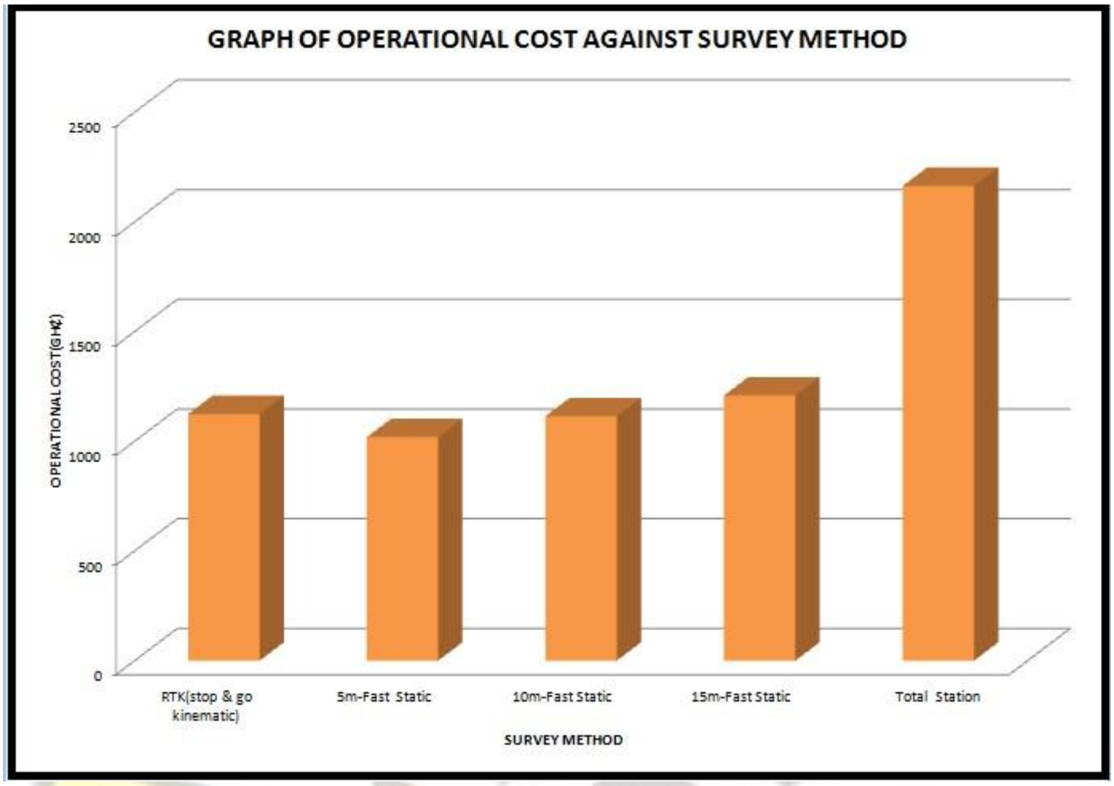

Figure 5.18: Graph of cost against survey method for urban district boundary survey.

5.3. DISCUSSION

5.3.1 District Boundary Survey located in Rural Area

5.3.1.1. Accuracies

The aim of this project was to assess the suitability of GPS (Fast static, RTK) and total station technologies in a district boundary survey and to determine the feasibility of the three methods. Each survey technique was critically evaluated by analyzing the effects of each on managerial resources. It must be pointed out that all the methods met the cadastral requirement for the district boundary surveys as far as positional accuracy is concerned.

For a district boundary with rural location, it is more efficient to use the 10mins-Fast static GPS technology, the Positional accuracy achieved was (0.05m ±0.04m) for Northings and (0.05m ±0.04m) Eastings co-ordinates respectively. The RTK-GPS and the 5mins-fast static methods though satisfied cadastral requirement produced larger differences in some co-ordinates as can be seen in station SGGWGE/DBP (2, 3, 5, 11, and 13) of Figure 5.1. This may be due to longer distances (10-20) km from the base station coupled with short observation time. The Total station technique ranked fourth in positional accuracy of (0.05m±0.05m) for Northings and (0.04m±0.05m) Eastings co-ordinates respectively. However, this technique is best suited where GPS Signals are greatly affected by dense forest canopy.

5.3.1.2. Cost

For a district with rural location it was cheapest to complete the session with the 10mins-fast static method at a cost of GH¢ 1170.00 cedis as can be seen in Figure 5.17. The Total station method from tables 5.13 is the most expensive technique with a cost of GH¢ 2500.00 cedis. It is instructive to note that the cost difference per day between the GPS based techniques is rather marginal. The operational cost of the Total station technique is more expensive than any of the GPS based techniques. This is because extra labourers are needed due to the extended clearing that needs to be done before the intervisibilty criteria can be obtained for the measurements to be carried out. This situation is true for rural areas of heavy vegetation. However, in rural areas where the vegetation is light and especially in the dry season, the extra labourer differential between the two main techniques may be removed and therefore the cost per day decreases accordingly.

5.3.1.3. Time

In terms of the time agent it is clear from tables 4.9 and 4.10 that the longest and shortest operational time are the Total Station and the RTK techniques respectively.

5.3.2. District Boundary Surveys located in Urban Area

5.3.2.1. Accuracy

The 15min-fast static GPS method achieved the best positional accuracy of 0.03m± 0.03m for Northings and 0.03m ±0.02m Eastings co-ordinates respectively as indicated in Figure 5.19. The RTK-GPS obtained the lowest Positional accuracy of 0.06m±0.01m for Northings and 0.05m ±0.02m Eastings co-ordinates respectively with larger differences at stations SGGSGW/DBP7,10,11 due vehicular obstructions which affects the radio link between the RTK base station and the rover station as indicated in Figure 5.11

5.3.2.2. Cost

The total station cost GH¢ 2170.00 (per day) and is the most expensive method of urban boundary survey as indicated in table 5.18. It was cheapest to complete the survey with the 5 min-fast static technique as indicated in Figure 5.18.

5.3.2.3. Time

When the time spent for the actual field measurement was considered it came out that the longest and shortest times were with the Total Station and the RTK techniques respectively (table 4.9). However, when the monuments have been fixed the time on which to traverse for the measurement from point to point is shorter with the Total Station than the GPS especially when many points are involved, this is because with the Total Station there is a cleared line on which to traverse whereas with the GPS there is not.

CHAPTER 6
CONCLUSION AND RECOMMENDATION

6.1. CONCLUSION

The main purpose of the present study is to test and analyze the performances of the techniques of the GPS (Static, Fast Static, and RTK) and the Total Station in the establishment and survey of a district boundary in a rural and urban setting. The analysis was essentially at three main levels, the accuracy of the survey, the cost of the survey operations and the time used for each of the techniques in the execution of the project. In terms of accuracy the 15mins-fast static GPS technique is the most accurate, while in terms of time spent on the actual measurement the RTK GPS technique had the shortest duration. When the cost item is considered the 5min-fast static GPS technique was the least expensive for both the urban and rural district boundary survey. However, the most efficient in terms of accuracy, cost and time is the 10mins- Fast static GPS technique. This is because its operation is optimal in both the forest and built up environments. Where the forest canopies are seriously closed and the built up area is made up of very tall structures this will seriously block GPS Signals and therefore the Total station technique becomes the best option in such situations. Therefore, the Total station and the 10mins-Fast static GPS techniques can be used in combination for optimum results in a district boundary survey when the environment is a mixture of built up and densely forested areas. The RTK GPS technique is a preferred option for open areas where speed in execution of the project is of essence. The other outcome of the project was the determination of the procedure for the setting out of the boundary on the ground prior to the actual measurement and the provision of accuracy threshold for district boundary survey. This has been outlined in the recommendation.

6.2. RECOMMENDATION

Based on the research studies and test results obtained in this research, the following recommendations are made.

6.2.1. Recommended Accuracy thresholds for district boundary Surveys in both Rural and Urban area in Ghana

The following accuracy thresholds obtained from the thesis are recommended for the various survey techniques as part of the objective of the project and can be used as part of the National cadastral survey requirement for a district boundary survey project. It is hoped that the Survey and Mapping Division of the Lands Commission of Ghana will be guided by these accuracy thresholds developed through this research project as presented in Tables 6.1 and 6.2.

Table 6.1: Recommended Accuracy Thresholds for Rural District Boundary Survey

Survey Method	**Accuracy Threshold(Rms)**	
	Northings (N)	**Eastings (E)**
RTK(stop & go kinematics)	0.06m±0.01m	0.06m ±0.01m
5 mins-Fast Static	0.05m ±0.01m	0.05m±0.01m
10 mins-Fast Static	0.04m ±0.01m	0.04m ±0.01m
15 mins-Fast Static	0.03m ±0.01m	0.03m ±0.01m
Total Station	0.05m ±0.01m	0.05m ±0.01m

Table 6.2: Recommended Accuracy Thresholds for Urban District Boundary Survey

Survey Method	**Accuracy Threshold (Rms)**	
	Northings (N)	**Eastings (E)**
RTK(stop & go kinematics)	0.06m±0.01m	0.06m±0.01m
5 mins-Fast Static	0.04m ±0.01m	0.04m ±0.01m
10 mins-Fast Static	0.03m ±0.01m	0.03m ±0.01m
15 mins-Fast Static	0.03m ±0.01m	0.02m ±0.01m
Total Station	0.05m ±0.01m	0.05m ±0.01m

6.2.2. Recommended Procedure for setting out (demarcating) a district administrative boundary located in a Rural area on the ground

There should be at least ***TWO EFFECTIVE*** stakeholders meeting before the actual field work

- Initial Stakeholder discussions with the chiefs, elders, opinion leaders, town development committee members from the adjoining district independently to be involved in participatory mapping using Goggle Earth Images, the Legislative Instruments relating to the district boundaries involved,Town Sheets and Topographical Sheets covering the area. At this meeting the surveyor will brief them about the project and solicit for any other information any of the stakeholders will have. There is a general discussion about the benefit of the survey of the administrative boundary on the ground to all the stakeholders. It is after this that the participatory mapping will commence using all the data available with the High Resolution Goggle Earth Image/Map being the main tool.

- Final stakeholder meeting with the Land Surveyor, chiefs, elders, opinion leaders, Town development committee members,

  District/municipal chief executives from the two adjoining districts. These meeting will finally agree on the boundary positions for setting out (Demarcation) on the ground. This meeting will agree on the composition of the adjudication committee which will assist the Surveyor in the setting out (Demarcation) and measurement process.

- The need to use field teams from the towns on both sides of the boundary line for capacity/confidence building and to be able obtain, understand and use information about the prevailing situations on the ground for the sake of peace is paramount in the successful execution of the project.

- Major crossings of the boundary (rivers, roads, rail lines) must be detailed, and pillared with large and tall solid pillars, with the names of the respective districts written on them. All major crossing boundary pillars should have underneath them buried Type "C" beacons.

6.2.2.1. Methodology

- Mostly the boundaries are areas of dense forest canopies; hence a combination of fast static GPS technique and total station traverse is advisable.

- The Boundaries should be cleared of all trees, bushes etc for a width (about 4 to 6 feet) during total station traverse.

- Boundaries in a farming area, the width should be reduced considerably to avoid the need for compensation and open hostility from farmers.

- Type "C" beacons are planted along the boundary. Teak trees are also established along major intersection in the form of star/rectangles/squares or crosses with the boundary point in the middle so as to be unique or conspicuous on future images/photographs.

- Where there are conflicts/discrepancies on the ground it is advisable to use pegs.

- River that crosses the boundary must be detailed; using the perpendicular offset method or GPS with data logger as on the boundary plan.

6.3.3. Recommended Procedure for setting out (demarcating) a district administrative boundary located in an Urban area on the ground.

A stakeholder meeting is held with the chiefs, elders, opinion leaders, District/municipal chief executives from the two adjoining districts for public awareness. Mostly the districts in the urban areas passes through major towns, most prominent buildings in the towns are used to define the boundary.

6.3.3.1. Methodology

Mostly the boundaries are areas of administrative centre with towns. Most of the district boundaries in the urban areas follow towns, a (5, 10, 15) minutes fast static- GPS technique or a Total station traverse is advisable. The accuracy standard for most districts residing in urban areas reduces where there are high rise buildings when using GPS. In such area control points are established with the Static GPS, followed by a Total station traverse. Type “C” beacons together with sigh post that bear BOLDLY the names of the respective districts. Rivers, streams, waterways, roads and railways that cross the boundary must be detailed

Flow chart of the methodology used in setting out (demarcating) a district boundary with Rural/Urban location

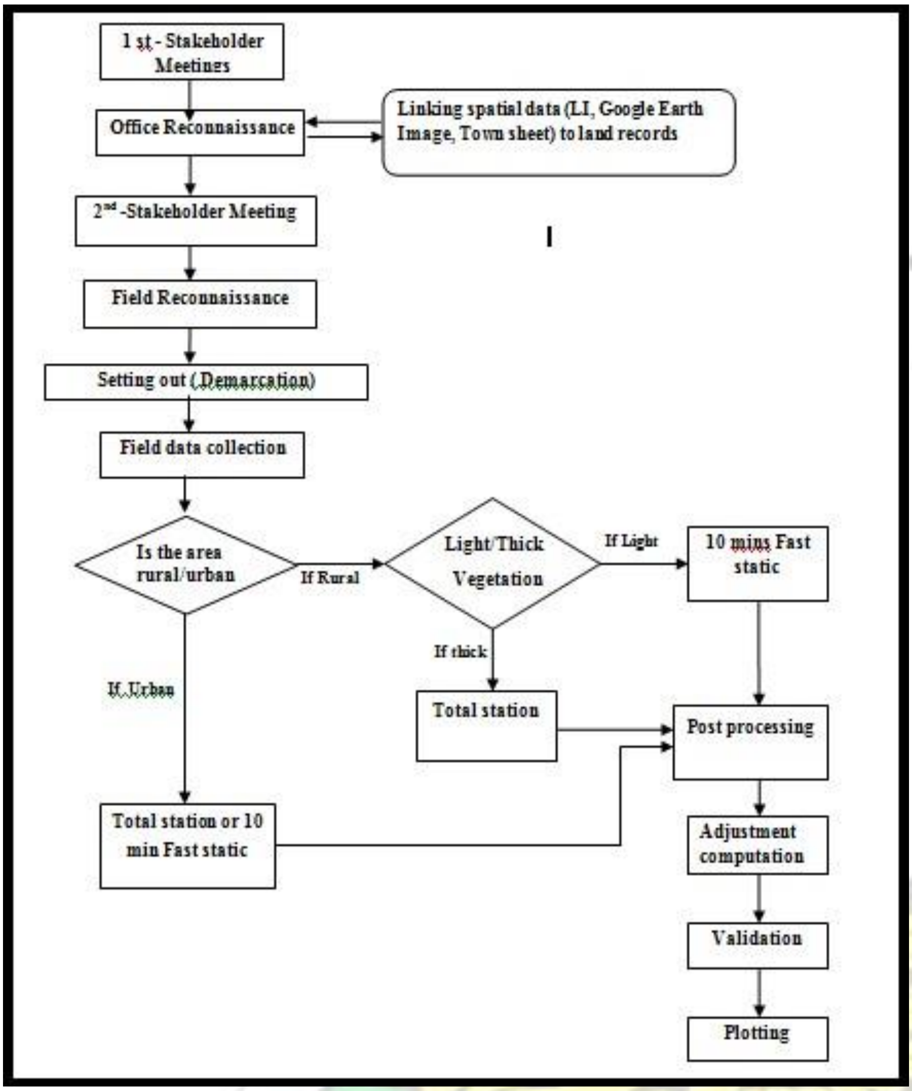

Figure 6.1: Recommended Workflow diagram for Urban/Rural District boundary project

Further research work can be done in other to improve on the accuracy of these results.

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APPENDICES

Appendix A: Field Records of the various survey methods under investigation.

1 Rural District boundary

Point Name	Original Na	Ant Height	Start Time	Stop Time	Duration	Method
SGGWGE DBP12	log0531qb	Vertical	31-05-14 16:46	31-05-14 17:18	0:32:26	Static
SGGWGE DBP1	log0531c_	Vertical	31-05-14 10:30	31-05-14 11:00	0:30:00	Static
SGGWGE DBP2	log0531d_	Vertical	31-05-14 11:28	31-05-14 11:58	0:30:00	Static
SGGA 07 213 48	log0531a_	Vertical	31-05-14 9:54	31-05-14 18:38	8:44:15	Static
SGGWGE DBP3	log0531e_	Vertical	31-05-14 12:08	31-05-14 12:37	0:28:15	Static
SGGWGE DBP4	log0531g_	Vertical	31-05-14 12:46	31-05-14 13:17	0:30:45	Static
SGGWGE DBP5	log0531h_	Vertical	31-05-14 13:23	31-05-14 13:54	0:30:45	Static
SGGWGE DBP6	log0531j_l	Vertical	31-05-14 14:07	31-05-14 14:38	0:31:30	Static
SGGWGE DBP7	log0531k_	Vertical	31-05-14 14:49	31-05-14 15:07	0:30:00	Static
SGGWGE DBP9	log0531l_l	Vertical	31-05-14 15:29	31-05-14 15:59	0:30:00	Static
SGGWGE DBP10	log0531m	Vertical	31-05-14 16:15	31-05-14 16:47	0:31:45	Static
SGGWGE DBP11	log0531n_	Vertical	31-05-14 17:08	31-05-14 17:34	0:30:00	Static
SGGA 07 213 47	log0531o_	Vertical	31-05-14 17:58	31-05-14 18:35	0:30:15	Static
SGGWGE DBP13	log0531qa	Vertical	31-05-14 16:09	31-05-14 16:40	0:31:26	Static
SGGWGE DBP8	log0531ne	Vertical	31-05-14 13:25	31-05-14 13:55	0:30:24	Static
ACCRA	CREF0001	Vertical	31-05-14 7:00	31-05-14 8:00	1:00:00	Static
ACCRA	CREF0001	Vertical	31-05-14 8:00	31-05-14 9:00	1:00:00	Static
ACCRA	CREF0001	Vertical	31-05-14 9:00	31-05-14 10:00	1:00:00	Static
ACCRA	CREF0001	Vertical	31-05-14 10:00	31-05-14 11:00	1:00:00	Static

2 Urban District boundary(Static)

Point Name	Original Name	Start Time	Stop Time	Duration	Method
ACCRA	CREF0001	02-06-14 0:00	03-06-14 0:00	24:00:00	Static
SGGA O7 213 48	log0602a1_BZEO	02-06-14 9:08	02-06-14 17:29	8:21:15	Static
SGGSGW DBP1	log0602l_KVLS	02-06-14 11:37	02-06-14 12:08	0:30:15	Static
SGGSGW DBP2	log0602q_KVLS	02-06-14 16:33	02-06-14 17:03	0:30:45	Static
SGGSGW DBP3	log0602n_KVLS	02-06-14 13:32	02-06-14 14:17	0:30:45	Static
SGGSGW DBP4	log0602o_KVLS	02-06-14 14:54	02-06-14 15:27	0:30:45	Static
SGGSGW DBP5	log0602pi_TUDC	02-06-14 15:07	02-06-14 15:26	0:30:16	Static
SGGSGW DBP6	log0602o_TUDC	02-06-14 14:25	02-06-14 15:01	0:30:44	Static
SGGSGW DBP7	log0602n1_TUDC	02-06-14 13:12	02-06-14 13:45	0:30:46	Static
SGGSGW DBP8	log0602ma_TUDC	02-06-14 12:36	02-06-14 13:07	0:30:14	Static
SGGSGW DBP9	log0602m_TUDC	02-06-14 12:01	02-06-14 12:31	0:30:00	Static
SGGSGW DBP10	log0602li_TUDC	02-06-14 11:21	02-06-14 11:52	0:30:58	Static
SGGSGW DBP11	log0602ja_TUDC	02-06-14 9:58	02-06-14 10:30	0:31:42	Static
SGGSGW DBP12	log0602k_TUDC	02-06-14 10:38	02-06-14 11:11	0:30:22	Static
SGGSGW DBP13	log0602ji_TUDC	02-06-14 9:17	02-06-14 9:49	0:01:28	Static

Table A1: 5min -Fast static GPS field records.

Point Name	Ant Height(m)	Start Time	Stop Time	Duration
SGGA 07 213 48	1.30	30-05-14 7:54	30-05-14 19:59	12:05:00
SG GW.GE DBP 1	1.30	30-05-14 10:43	30-05-14 10:48	0:05:02
SG GW.GE DBP 2	1.30	30-05-14 11:27	30-05-14 11:32	0:05:00
SG GW.GE DBP 3	1.30	30-05-14 12:19	30-05-14 12:24	0:05:01
SGGA 07 213 47	1.30	30-05-14 18:01	30-05-14 18:06	0:05:02

Table A2: 10min- Fast static GPS field records.

Point Name	Ant Height(m)	Start Time	Stop Time	Duration
SGGA 07 213 48	1.30	30-05-14 7:54	30-05-14 19:59	12:05:00
SG GW.GE DBP 1	1.30	30-05-14 10:11	30-05-14 10:48	0: 10:00
SG GW.GE DBP 2	1.30	30-05-14 11:27	30-05-14 11:32	0: 10:00
SG GW.GE DBP 3	1.30	30-05-14 12:19	30-05-14 12:24	0: 10:00
SGGA 07 213 47	1.30	30-05-14 18:01	30-05-14 18:06	0: 10:00

Table A3: 15 min Fast static GPS field records.

Point Name	Ant Height(m)	Start Time	Stop Time	Duration
SGGA 07 213 48	1.30	30-05-14 7:54	30-05-14 19:59	12:05:00
SG GW.GE DBP 1	1.30	30-05-14 10:43	30-05-14 10:48	0:15:00
SG GW.GE DBP 2	1.30	30-05-14 11:27	30-05-14 11:32	0:15:00
SG GW.GE DBP 3	1.30	30-05-14 12:19	30-05-14 12:24	0:15:00
SGGA 07 213 47	1.30	30-05-14 18:01	30-05-14 18:06	0:15:00

Table A4: RTK field records.

Point Name	Ant Height(m)	Start Time	Stop Time	Duration
SGGW/GE/ DBP/ 1	1.30	30-06-14 10:12:00	02-06-14 10:14	0:02:00
SGGW/GE/ DBP/ 2	1.30	30-06-14 11:18:01	02-06-14 11:20	0:02:00
SGGW/GE/ DBP/ 3	1.30	30-06-14 12:19:00	02-06-14 12:21	0:02:00
SGGW/GE/ DBP/ 4	1.30	30-06-14 12:46:00	02-06-14 12:48	0:02:00

FIGURE A1: Urban District boundary (National Co-ordinates)

Point Summary		
Name	Grid Northing (Ift)	Grid Easting
SGGA 07 213 47	367796.918	1161444.374
SGGA 07 213 48	367768.610	1161678.140
SGGS.GW DBP1	344631.575	1177287.336
SGGS.GW DBP 2	344394.730	1175390.933
SGGS.GW DBP 3	344410.549	1173992.439
SGGS.GW DBP 4	345121.313	1171401.771
SGGS.GW DBP 10	351638.559	1167218.673
SGGS.GW DBP 12	352100.635	1161761.143
SGGS.GW DBP 13	359068.034	1165054.948
SGGS.GW DBP 6	348206.677	1167453.437
SGGS.GW DBP 7	348919.504	1166997.070
SGGS.GW DBP 8	351070.612	1168532.032
SGGS.GW DBP 9	350151.985	1166862.502
SGGS.GW DBP 11	352027.878	1161945.317
SGGS.GW DBP 5	346357.835	1170924.121

Urban District Boundary (EFEC Coordinates)

GPS OBSERVATIONS- URBAN DISTRICT			
Point Summary			
Name	**X (m)**	**Y (m)**	**Z (m)**
ACCRA	6348052.681	-20212.882	617243.597
SGGA 07 213 47	6346994.177	-31037.241	627396.948
SGGA 07 213 48	6346999.2	-30968.486	627387.78
SGGSGW DBP1	6347684.013	-26219.484	620360.394
SGGSGW DBP2	6347691.48	-26797.795	620289.63
SGGSGW DBP3	6347692.686	-27224.098	620295.337
SGGSGW DBP4	6347710.529	-27974.941	620160.249
SGGSGW DBP5	6347648.519	-28158.544	620888.962
SGGSGW DBP6	6347592.009	-29215.594	621451.576
SGGSGW DBP7	6347566.626	-29354.363	621667.799
SGGSGW DBP8	6347540.939	-29323.375	621946.648
SGGSGW DBP9	6347532.404	-29394.767	622041.976
SGGSGW DBP10	6347507.475	-29285.487	622494.715
SGGSGW DBP11	6347528.732	-30893.091	622618.813
SGGSGW DBP12	6347281.298	-30948.231	622617.175
SGGSGW DBP13	6347265.531	-29941.125	624747.824

Fast Static GPS Process Summary (Urban District Boundary)

GPS Observations			
Name	dN (Ift)	dE (Ift)	dHt (Ift
47–SGGA 07 213 48	-28.308	233.766	6.488
SGGA 07 213 48–SGGS.GW DBP1	-23137.035	15609.196	-97.161
SGGA 07 213 48–SGGS.GW DBP 2	-23373.880	13712.793	-87.785
SGGA 07 213 48–SGGS.GW DBP 3	-23358.061	12314.299	-76.141
SGGA 07 213 48–SGGS.GW DBP 3	-24591.047	10879.807	-34.153
SGGA 07 213 48–SGGS.GW DBP 4	-22647.770	9723.925	-47.704
SGGA 07 213 48–SGGS.GW DBP 10	-16129.491	5540.420	57.361
SGGA 07 213 48–SGGS.GW DBP 13	-8700.576	3376.808	4.111
SGGA 07 213 48–SGGS.GW DBP 6	-19561.949	5775.439	-4.132
SGGA 07 213 48–SGGS.GW DBP 7	-18848.382	5318.803	-17.067
SGGA 07 213 48–SGGS.GW DBP 8	-17930.030	5419.049	-10.098
SGGA 07 213 48–SGGS.GW DBP 9	-17617.001	5176.569	-0.150
SGGA 07 213 48–SGGS.GW DBP 11	-15740.732	267.177	190.935
SGGA 07 213 48–SGGS.GW DBP 5	-23805.087	9860.919	-57.825

10mins Fast Static GPS Process Summary (Urban district Boundary)

Loop Closures urban district boundary

Loop	dHz (m)	dU (m)	Horz Tolerance (m)	Vert Tolerance (m)	dHz (ppm)	dU (ppm)	Length (m)
SGGA 07 213 48-SGGS.GW DBP 5(02-Jun-14 3:07:42 PM) SGGA 07 213 48-SGGS.GW DBP 4(02-Jun-14 2:54:30 PM) SGGS.GW DBP 4-SGGS.GW DBP 5(02-Jun-14 3:07:42 PM)	0.1699	0.04	0.1051	0.1351	11.31	2.66	15027.7896
SGGA 07 213 48-SGGS.GW DBP 5(02-Jun-14 3:53:45 PM) SGGA 07 213 48-SGGS.GW DBP 4(02-Jun-14 2:54:30 PM) SGGS.GW DBP 4-SGGS.GW DBP 5(02-Jun-14 3:07:42 PM)	753.4414	12.7936	0.1089	0.1389	47767.49	811.1	15773.1007
SGGA 07 213 48-SGGS.GW DBP 6(02-Jun-14 2:25:08 PM) SGGA 07 213 48-SGGS.GW DBP 4(02-Jun-14 2:54:30 PM) SGGS.GW DBP 4-SGGS.GW DBP 6(02-Jun-14 2:54:30 PM)	0.1467	0.1455	0.1063	0.1363	9.61	9.53	15259.4668
SGGA 07 213 48-SGGS.GW DBP 7(02-Jun-14 1:12:24 PM) SGGA 07 213 48-SGGS.GW DBP 3(02-Jun-14 12:31:00 PM) SGGS.GW DBP 3-SGGS.GW DBP 7(02-Jun-14 1:12:24 PM)	0.2208	0.7415	0.113	0.143	13.3	44.66	16604.8834
SGGA 07 213 48-SGGS.GW DBP 7(02-Jun-14 1:12:24 PM) SGGA 07 213 48-SGGS.GW DBP 3(02-Jun-14 12:31:00 PM) SGGS.GW DBP 3-SGGS.GW DBP 7(02-Jun-14 1:32:45 PM)	576.7635	13.2836	0.1135	0.1435	34525.72	795.17	16705.328
SGGA 07 213 48-SGGS.GW DBP 7(02-Jun-14 1:12:24 PM) SGGA 07 213 48-SGGS.GW DBP 3(02-Jun-14 1:32:45 PM) SGGS.GW DBP 3-SGGS.GW DBP 7(02-Jun-14 1:12:24 PM)	576.547	12.0951	0.1123	0.1423	35033.45	734.95	16457.0415
SGGA 07 213 48-SGGS.GW DBP 7(02-Jun-14 1:12:24 PM) SGGA 07 213 48-SGGS.GW DBP 3(02-Jun-14 1:32:45 PM) SGGS.GW DBP 3-SGGS.GW DBP 7(02-Jun-14 1:32:45 PM)	0.2242	0.447	0.1128	0.1428	13.54	27	16557.4862
SGGA 07 213 48-SGGS.GW DBP 8(02-Jun-14 12:36:06 PM) SGGA 07 213 48-SGGS.GW DBP 3(02-Jun-14 12:31:00 PM) SGGS.GW DBP 3-SGGS.GW DBP 8(02-Jun-14 12:36:06 PM)	0.3162	0.2163	0.1127	0.1427	19.13	13.08	16533.4252
SGGA 07 213 48-SGGS.GW DBP 8(02-Jun-14 12:36:06 PM) SGGA 07 213 48-SGGS.GW DBP 3(02-Jun-14 1:32:45 PM) SGGS.GW DBP 3-SGGS.GW DBP 8(02-Jun-14 12:36:06 PM)	576.5444	12.5494	0.1119	0.1419	35186.08	765.88	16385.5834
SGGA 07 213 48-SGGS.GW DBP 9(02-Jun-14 12:01:44 PM) SGGA 07 213 48-SGGS.GW DBP1(02-Jun-14 11:37:30 AM) SGGS.GW DBP1-SGGS.GW DBP 9(02-Jun-14 12:01:44 PM)	2.3784	1.8402	0.1185	0.1485	134.35	103.95	17702.4645

Fast Static GPS Process summary (Urban district boundary)

GPS Observations

Name	dN (m)	dE (m)	dHt (m)
47−SGGA 07 213 48	-8.628	71.252	1.978
SGGA 07 213 48−SGGS.GW DBP1	-7052.168	4757.683	-29.615
SGGA 07 213 48−SGGS.GW DBP 2	-7124.359	4179.659	-26.757
SGGA 07 213 48−SGGS.GW DBP 3	-7119.537	3753.398	-23.208
SGGA 07 213 48−SGGS.GW DBP 3	-7495.351	3316.165	-10.410
SGGA 07 213 48−SGGS.GW DBP 4	-6903.040	2963.852	-14.540
SGGA 07 213 48−SGGS.GW DBP 10	-4916.269	1688.720	17.484
SGGA 07 213 48−SGGS.GW DBP 13	-2651.935	1029.251	1.253
SGGA 07 213 48−SGGS.GW DBP 6	-5962.482	1760.354	-1.260
SGGA 07 213 48−SGGS.GW DBP 7	-5744.987	1621.171	-5.202
SGGA 07 213 48−SGGS.GW DBP 8	-5465.073	1651.726	-3.078
SGGA 07 213 48−SGGS.GW DBP 9	-5369.662	1577.818	-0.046
SGGA 07 213 48−SGGS.GW DBP 11	-4797.775	81.436	58.197
SGGA 07 213 48−SGGS.GW DBP 5	-7255.791	3005.608	-17.625
SGGA 07 213 48−SGGS.GW DBP 5	-6526.004	2818.175	-4.836
SGGS.GW DBP1−SGGS.GW DBP 10	2135.729	-3068.929	46.859
SGGS.GW DBP1−SGGS.GW DBP 9	1682.621	-3177.490	27.729
SGGS.GW DBP 3−SGGS.GW DBP 12	1750.153	-1694.950	5.937
SGGS.GW DBP 3−SGGS.GW DBP 7	1374.329	-2132.189	18.453
SGGS.GW DBP 3−SGGS.GW DBP 8	2029.987	-1664.332	7.555
SGGS.GW DBP 4−SGGS.GW DBP 6	940.419	-1203.452	13.135
SGGS.GW DBP 4−SGGS.GW DBP 5	376.892	-145.588	9.664

Table A5: The GPS field records.

Point Name	Ant Height(m)	Start Time	Stop Time	Duration
SGGA 07 213 48	1.32	31-05-14 9:08	31-05-14 5:30	8:21:00
SG GW.GE DBP 1	1.32	31-05-14 10:26	31-05-14 10:31	0:05:00
SG GW.GE DBP 2	1.32	31-05-14 12:15	31-05-14 12:17	0:05:00
SG GW.GE DBP 3	1.32	31-05-14 13:01	31-05-14 13:06	0:05:00
SGGA 07 213 47	1.32	31-05-14 17:42	31-05-14 17:47	0:05:00

Table A6: RTK field records.

Point Name	Antenna Height(m)	Start Time	Stop Time	Duration
SGGA 07 213 48	1.75	02-06-14 9:08:00	02-06-14 05:30	8:21:00
SG.GS/GW /DBP1	1.72	02-06-14 10:12:01	02-06-14 10:11	0:01:01
SG.GS/GW/ DBP2	1.63	02-06-14 11:18:00	02-06-14 11:19	0:01:00
SG.GS/GW/DBP3	1.75	02-06-14 12:19:00	02-06-14 12:20	0:01:01
SG.GS/GW/DBP4	1.70	02-06-14 12:43:00	02-06-14 12:44	0:01:00

Table A7 Static GPS Observation (ITRF Coordinates) for Rural District

Point Summary			
Name	X (m)	Y (m)	Z (m)
ACCRA	6348052.681	-20212.882	617243.597
SGGA 07 213 47	6346997.204	-31040.11	627396.276
SGGA 07 213 48	6346999.119	-30968.523	627387.713
SGGWGE DBP1	6347631.441	-25846.485	620984.247
SGGWGE DBP2	6347597.715	-26127.965	621389.375
SGGWGE DBP3	6347527.481	-26567.356	622076.25
SGGWGE DBP4	6347490.876	-26836.461	622500.66
SGGWGE DBP5	6347453.16	-27057.01	622882.217
SGGWGE DBP6	6347426.914	-27357.676	623261.52
SGGWGE DBP7	6347375.113	-27845.995	623641.637
SGGWGE DBP8	6347370.439	-27873.405	623651.383
SGGWGE DBP9	6347338.603	-28229.345	623949.88
SGGWGE DBP10	6347306.686	-28542.035	624277.747
SGGWGE DBP11	6347260.262	-29324.959	624764.601
SGGWGE DBP12	6346951.259	-28738.849	628173.453
SGGWGE DBP13	6346970.405	-27777.356	628214.774

Table A8: Rural district boundary GPS Observations

Name	dN (m)	dE (m)	dHt (m)
ACCRA−SGGA 07 213 47	10187.042	-10842.694	-9.234
ACCRA−SGGA 07 213 47	10186.919	-10842.963	-9.627
ACCRA−SGGA 07 213 48	10178.327	-10771.362	-8.98
ACCRA−SGGA 07 213 48	10178.419	-10771.483	-8.835
ACCRA−SGGA 07 213 48	10178.34	-10771.363	-8.939
ACCRA−SGGA 07 213 48	10178.329	-10771.394	-9.031
ACCRA−SGGA 07 213 48	10178.334	-10771.375	-8.917
ACCRA−SGGA 07 213 48	10178.406	-10771.363	-8.83
ACCRA−SGGA 07 213 48	10178.451	-10771.402	-8.842
ACCRA−SGGA 07 213 48	10178.308	-10771.344	-8.90
ACCRA−SGGA 07 213 48	10178.334	-10771.37	-8.918
ACCRA−SGGA 07 213 48	10178.355	-10771.35	-8.964
ACCRA−SGGWGE DBP1	3753.506	-5639.095	-34.203
ACCRA−SGGWGE DBP2	4159.362	-5921.562	-26.772
ACCRA−SGGWGE DBP4	5274.601	-6631.587	-20.173
ACCRA− GGWGE DBP4	5274.609	-6631.603	-20.175
ACCRA−SGGWGE DBP5	5573.109	-6821.307	-21.583
ACCRA−SGGWGE DBP6	6026.723	-7127.338	-6.231
ACCRA−SGGWGE DBP7	6429.527	-7670.535	-23.452
ACCRA−SGGWGE DBP7	6429.527	-7670.658	-23.574
ACCRA−SGGWGE DBP8	6514 143	-7702.432	-20.919
ACCRA−SGGWGE DBP8	6524.198	-7729.969	-24.74
ACCRA−SGGWGE DBP8	6429.61	-7670.372	-22.577

ACCRA−SGGWGE DBP9	6729.318	-8026.663	-23.3
ACCRA−SGGWGE DBP10	7057.555	-8339.98	-20.502
ACCRA−SGGWGE DBP11	7545.677	-9123.591	-16. 36
ACCRA−SGGWGE DBP12	10968.693	-8543.294	10.754
ACCRA−SGGWGE DBP12	10968.66	-8543.349	10.878
ACCRA−SGGWGE DBP13	11009.536	-7582.008	29.767
SGGA 07 213 47−SGGA 07 213 48	-8.613	71.271	0.377
SGGA 07 213 48−SGGWGE DBP1	-6424.659	5132.132	-24. 33
SGGA 07 213 48−SGGWGE DBP2	-6018.728	4850.033	-17.128
SGGA 07 213 48−SGGWGE DBP3	-5329.148	4409.528	-17.804
SGGA 07 213 48−SGGWGE DBP4	-4903.73	4139.765	-11.42
SGGA 07 213 48−SGGWGE DBP5	-4605.299	3950.73	-11.972
SGGA 07 213 48−SGGWGE DB 6	-4151.661	3644.034	2.55
SGGA 07 213 48−SGGWGE DBP7	-3748.769	3100.988	-13.827
SGGA 07 213 48−SGGWGE DBP8	-3688.177	3087.793	18.377
SGGA 07 213 48−SGGWGE DBP9	-3449.208	2744.599	-14.385
SGGA 07 213 48−SGGWGE DBP10	-3120.295	2431.428	-12.381
SGGA 07 213 48−SGGWGE DBP11	-2632.802	1647.813	-7.298
SGGA 07 213 48−SGGWGE DBP12	790.599	2227.988	19.104
SGGA 07 213 48−SGGWGE DBP13	831.371	3189.296	38.231
SGGWGE DBP5−SGGWGE DBP8	856.568	-849.66	-1.48
SGGWGE DBP6−SGGWGE DBP8	477.105	-548.4 6	-13.946
SGGWGE DBP7−SGGWGE DBP8	94.643	-59.499	-1.914
SGGWGE DBP10−SGGWGE DBP13	3951.589	757.958	51.143

SGGWGE DBP11−SGGWGE DBP12	3423.089	580.226	26.909

Appendix B: 1. STATIC GPS ADJUSTMENT (RURAL DISTICT)

Ref Unit Variance = 0.005 m

Ref Se(σ_o) = 0.071 m

STATIONS	PROVISIONAL XYZ COORD			PARAMETERS			ADJUSTED PARAMETERS			STANDARD ERRORS		
	X(m)	Y(m)	Z(m)	□X(m)	□Y(m)	□Z(m)	ADJ X(m)	ADJ Y(m)	ADJ Z(m)	σx(m)	σy(m)	σz(m)
SGGA 07 213 48	6346999.119	-30968.523	627387.713	0.413962	-0.00683	-0.36734051	6346999.533	-30968.53	627387.346	0.051	0.051	0.051
SGGWGE DBP1	6347631.441	-25846.485	620984.247	0.457924	-0.00691	-0.40711651	6347631.899	-25846.492	620983.84	0.051	0.051	0.051
SGGWGE DBP2	6347597.715	-26127.965	621389.375	0.425605	-0.06168	-0.47558296	6347598.141	-26128.027	621388.899	0.051	0.051	0.051
SGGWGE DBP3	6347527.481	-26567.356	622076.25	0.580119	-0.00707	-0.51762966	6347528.061	-26567.363	622075.732	0.051	0.051	0.051
SGGWGE DBP4	6347490.876	-26836.461	622500.66	0.611479	-0.03331	-0.50072321	6347491.487	-26836.494	622500.159	0.036	0.036	0.036
SGGWGE DBP5	6347453.16	-27057.01	622882.217	0.655004	-0.06099	-0.50874314	6347453.815	-27057.071	622881.708	0.036	0.036	0.036
SGGWGE DBP6	6347426.914	-27357.676	623261.52	0.70088	-0.06756	-0.56366401	6347427.615	-27357.744	623260.956	0.036	0.036	0.036
SGGWGE DBP7	6347375.113	-27845.995	623641.637	0.718368	0.003294	-0.66175232	6347375.831	-27845.992	623640.975	0.027	0.027	0.027
SGGWGE DBP8	6347370.439	-27873.405	623651.383	0.740809	-0.0073	-0.66285626	6347371.18	-27873.412	623650.72	0.051	0.051	0.051
SGGWGE DBP9	6347338.603	-28229.345	623949.88	0.773059	-0.0987	-0.65688085	6347339.376	-28229.444	623949.223	0.037	0.037	0.037
SGGWGE DBP10	6347306.686	-28542.035	624277.747	0.830281	-0.00742	-0.74363581	6347307.516	-28542.042	624277.003	0.051	0.051	0.051
SGGWGE DBP11	6347260.262	-29324.959	624764.601	1.203501	-0.00801	-1.08183021	6347261.466	-29324.967	624763.519	0.051	0.051	0.051
SGGWGE DBP12	6346951.259	-28738.849	628173.453	1.191109	0.024875	-0.90380119	6346952.45	-28738.824	628172.549	0.037	0.037	0.037
SGGWGE DBP13	6346970.405	-27777.356	628214.774	1.116147	-0.01412	-0.99509902	6346971.521	-27777.37	628213.779	0.016	0.016	0.016

TABLE B2: BASELINE ADJUSTMENT RURAL DISTRICT

BASELINES		OBSERVED VECTORS			RESIDUALS(v)			ADJUSTED VECTORS			STANDARD ERRORS		
FROM	**TO**	**ΔX(m)**	**ΔY(m)**	**ΔZ(m)**	**VΔx(m)**	**VΔy(m)**	**VΔz(m)**	**ADJ Δz(m)**	**ADJ Δy(m)**	**ADJ Δz(m)**	**σΔX(m)**	**σΔY(m)**	**σΔZ(m)**
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.348	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGWGE DBP 1	-6424.659	5132.132	-24.433	-0.4174	0.0005	0.3774	-6425.076	5132.133	-24.056	0.051	0.051	0.051
Accra	SGGWGE DBP 1	3753.506	-5639.095	-34.203	-0.7056	0.0010	0.6378	3752.8	-5639.094	-33.565	0.051	0.051	0.051
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.348	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGWGE DBP 2	-6018.728	4850.033	-17.128	-0.4614	0.0006	0.4172	-6019.189	4850.034	-16.711	0.051	0.051	0.051
Accra	SGGWGE DBP 2	4159.362	-5921.562	-26.772	-0.6617	0.0009	0.5981	4158.7	-5921.561	-26.174	0.051	0.051	0.051
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.348	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGWGE DBP 3	-5329.148	4409.528	-17.804	-0.3208	0.1101	0.4854	-5329.469	4409.638	-17.319	0.051	0.051	0.051
Accra	SGGWGE DBP 3	2682.933	-7455.271	-21.675	-0.5857	0.0008	0.5293	2682.347	-7455.27	-21.146	0.051	0.051	0.051
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.348	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGWGE DBP 4	-4903.73	4139.765	-11.42	-0.5836	0.0008	0.5277	-4904.314	4139.766	-10.892	0.051	0.051	0.051
Accra	SGGWGE DBP 4	5274.601	-6631.587	-20.173	-0.5395	0.0008	0.4875	5274.062	-6631.586	-19.685	0.051	0.051	0.051
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.348	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGWGE DBP 5	-4605.299	3950.73	-11.972	-0.6172	-0.0023	0.5660	-4605.916	3950.728	-11.406	0.036	0.036	0.036
Accra	SGGWGE DBP 5	5573.109	-6821.307	-21.583	-0.5059	0.0039	0.4493	5572.603	-6821.303	-21.134	0.038	0.038	0.038
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.348	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGWGE DBP 6	-4151.661	3644.034	2.55	-0.6652	-0.0018	0.6024	-4152.326	3644.032	3.152	0.036	0.036	0.036
Accra	SGGWGE DBP 6	6026.723	-7127.338	-6.231	-0.4579	0.0033	0.4128	6026.265	-7127.335	-5.818	0.038	0.038	0.038
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.348	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGWGE DBP 7	-3748.769	3100.988	-13.827	-0.7106	0.0037	0.6421	-3749.48	3100.992	-13.185	0.036	0.036	0.036
Accra	SGGWGE DBP 7	6429.527	-7670.535	-23.452	-0.4124	-0.0021	0.3732	6429.115	-7670.537	-23.079	0.038	0.038	0.038
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.348	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGWGE DBP 8	-3688.177	3087.793	18.377	-0.7196	0.0042	0.6428	-3688.897	3087.797	19.02	0.027	0.027	0.027
Accra	SGGWGE DBP 8	6514.143	-7702.432	-20.919	-0.4059	-0.0007	0.3754	6513.737	-7702.433	-20.544	0.029	0.029	0.029

Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.348	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGWGE DBP 9	-3449.208	2744.599	-14.385	-0.7443	0.0010	0.6729	-3449.952	2744.6	-13.712	0.051	0.051	0.051
Accra	SGGWGE DBP 9	6729.318	-8026.663	-23.3	-0.3788	0.0005	0.3423	6728.939	-8026.662	-22.958	0.051	0.051	0.051
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.348	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGWGE DBP 10	-3120.295	2431.428	-12.381	-0.7803	0.0011	0.7054	-3121.075	2431.429	-11.676	0.037	0.037	0.037
Accra	SGGWGE DBP 10	7057.555	-8339.98	-20.502	-0.3428	0.0005	0.3097	7057.212	-8339.979	-20.192	0.038	0.038	0.038
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.348	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGWGE DBP 11	-2632.802	1647.813	-7.298	-0.8337	0.0012	0.7537	-2633.636	1647.814	-6.544	0.051	0.051	0.051
Accra	SGGWGE DBP 11	7545.677	-9123.591	-16.536	-0.2894	0.0004	0.2616	7545.388	-9123.591	-16.274	0.051	0.051	0.051
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.348	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGWGE DBP 12	790.599	2227.988	19.104	-1.2069	0.0017	1.0918	789.392	2227.99	20.196	0.051	0.051	0.051
Accra	SGGWGE DBP 12	10968.66	-8543.349	10.878	0.0838	-0.0002	-0.0767	10968.744	-8543.349	10.801	0.051	0.051	0.051
Accra	SGGA 07 213 48	10178.355	-10771.35	-8.964	-1.1231	0.0016	1.0152	10177.232	-10771.348	-7.949	0.016	0.016	0.016
SGGA 07 213 48	SGGWGE DBP 13	831.371	3189.296	38.231	-1.2091	0.0018	1.0941	830.162	3189.298	39.325	0.037	0.037	0.037
Accra	SGGWGE DBP 13	11009.536	-7582.008	29.767	0.0860	-0.0002	-0.0789	11009.622	-7582.008	29.688	0.038	0.038	0.038
Accra	SGGWGE DBP 5	5573.109	-6821.307	-21.583	-0.6027	0.0906	0.4167	5572.506	-6821.216	-21.166	0.036	0.036	0.036
SGGS.GW DBP 5	SGGWGE DBP 8	856.568	-849.66	-1.48	-0.7139	0.0558	0.6038	855.854	-849.604	-0.876	0.027	0.027	0.027
Accra	SGGWGE DBP 8	6514.143	-7702.432	-20.919	0.1027	0.0380	-0.1873	6514.246	-7702.394	-21.106	0.041	0.041	0.041
Accra	SGGWGE DBP 6	6026.723	-7127.338	-6.231	-0.6481	0.1212	0.4152	6026.075	-7127.217	-5.816	0.036	0.036	0.036
SGGS.GW DBP 6	SGGWGE DBP 8	477.105	-548.446	-13.946	-0.7191	0.0069	0.6418	476.386	-548.439	-13.304	0.027	0.027	0.027
Accra	SGGWGE DBP 8	6514.143	-7702.432	-20.919	0.0700	0.1170	-0.2266	6514.213	-7702.315	-21.146	0.041	0.041	0.041
Accra	SGGWGE DBP 7	6429.527	-7670.535	-23.452	-0.6954	0.1316	0.4856	6428.832	-7670.403	-22.966	0.036	0.036	0.036
SGGS.GW DBP 7	SGGWGE DBP 8	94.643	-59.499	-1.914	-0.7191	0.0069	0.6418	93.924	-59.492	-1.272	0.027	0.027	0.027
Accra	SGGWGE DBP 8	6514.143	-7702.432	-20.919	0.0247	0.1219	-0.1567	6514.168	-7702.31	-21.076	0.041	0.041	0.041
Accra	SGGWGE DBP 10	7057.555	-8339.98	-20.502	-0.7582	0.1985	0.4852	7056.797	-8339.781	-20.017	0.037	0.037	0.037
SGGS.GW DBP 10	SGGWGE DBP 13	3951.589	757.958	51.143	-1.1691	-0.0078	0.6377	3950.42	757.95	51.781	0.037	0.037	0.037
Accra	SGGWGE DBP 13	11009.536	-7582.008	29.767	0.4108	0.2064	-0.1524	11009.947	-7581.802	29.615	0.045	0.045	0.045

TABLE B3: NATIONAL GRID CO-ORDINATES (RURAL DISTRICT)

STATIONS	GRID CO-ORDINATES		STANDARD ERRORS			
	N(X)	E(Y)	σN(ft)	σE(ft)	σN(m)	σE(m)
SGGWGE DBP1	346690.288	1178515.684	0.509	0.509	0.155	0.155
SGGWGE DBP2	348022.047	1177590.173	0.509	0.509	0.155	0.155
SGGWGE DBP3	350284.075	1176145.208	0.509	0.509	0.155	0.155
SGGWGE DBP4	351680.050	1175260.223	0.365	0.365	0.111	0.111
SGGWGE DBP5	352659.347	1174639.867	0.365	0.365	0.111	0.111
SGGWGE DBP6	354147.656	1173633.636	0.365	0.365	0.111	0.111
SGGWGE DBP7	355469.487	1171851.972	0.267	0.267	0.081	0.081
SGGWGE DBP8	355781.38	1171656.464	0.509	0.509	0.155	0.155
SGGWGE DBP9	356452.297	1170682.684	0.371	0.371	0.113	0.113
SGGWGE DBP10	357531.422	1169655.255	0.509	0.509	0.155	0.155
SGGWGE DBP11	359130.834	1167084.349	0.509	0.509	0.155	0.155
SGGWGE DBP12	370361.425	1168987.950	0.371	0.371	0.113	0.113
SGGWGE DBP13	370495.923	1172141.906	0.156	0.156	0.048	0.048

TABLE B4: 2. STATIC GPS ADJUSTMENT (URBAN DISTRICT)

Ref Unit variance)	=	0.0043	m									
Ref Se(σo)	=	0.066	m									
STATIONS	PROVISIONAL XYZ COORD			PARAMETERS			ADJUSTED PARAMETERS			STANDARD ERRORS		
	X(m)	Y(m)	Z(m)	∂X(m)	∂Y(m)	∂Z(m)	ADJ X(m)	ADJ Y(m)	ADJ Z(m)	σx(m)	σy(m)	σz(m)
SGGA 07 213 48	6346999.076	-30968.465	627387.742	0.342224	-0.42162	-0.00045955	6346999.418	-30968.465	627387.434	0.047	0.047	0.047
SGGSGW DBP1	6347693.26	-26800.277	620288.801	-0.00014	0.489327	-0.52404428	6347693.602	-26800.277	620288.493	0.028	0.028	0.028
SGGSGW DBP2	6347694.467	-27226.586	620294.505	-0.30795	-0.00042	0.60762811	6347694.768	-27226.586	620294.234	0.028	0.028	0.028
SGGSGW DBP3	6347741.866	-27664.644	619922.088	0.342221	-0.44151	0.00398705	6347742.273	-27664.641	619921.723	0.047	0.047	0.047
SGGSGW DBP4	6347650.299	-28161.027	620888.133	-0.00028	0.492306	-0.54517323	6347650.767	-28161.027	620887.711	0.047	0.047	0.047
SGGSGW DBP5	6347593.776	-29218.078	621450.746	-0.30848	-0.00046	0.59272411	6347594.265	-29218.078	621450.304	0.034	0.034	0.034
SGGSGW DBP6	6347577.257	-29210.726	621645.02	0.300514	-0.44394	-0.00339035	6347577.749	-29210.726	621644.576	0.028	0.028	0.028
SGGSGW DBP7	6347568.569	-29356.899	621666.862	-0.00017	0.526764	-0.53142413	6347569.096	-29356.899	621666.385	0.034	0.034	0.034
SGGSGW DBP8	6347542.872	-29325.814	621945.524	-0.27086	-0.00034	0.83206381	6347543.445	-29325.808	621945.046	0.047	0.047	0.047
SGGSGW DBP9	6347536.026	-29399.633	622041.166	0.40679	-0.47711	-0.00087195	6347536.607	-29399.633	622040.642	0.047	0.047	0.047
SGGSGW DBP10	6347509.436	-29287.995	622494.066	0.003343	0.573121	-0.75091948	6347510.044	-29287.991	622493.521	0.047	0.047	0.047
SGGSGW DBP11	6347283.059	-30950.719	622616.359	-0.36538	0.006139	1.12494982	6347283.652	-30950.722	622615.828	0.047	0.047	0.047
SGGSGW DBP12	6347530.511	-30895.574	622617.984	0.468348	-0.47812	-0.0010001	6347531.343	-30895.575	622617.233	0.047	0.047	0.047
SGGSGW DBP13	6347267.311	-29943.608	624746.996	-0.00031	0.581419	-1.01495685	6347268.436	-29943.609	624745.981	0.015	0.015	0.015

TABLE B5: BASELINE ADJUSTMENT URBAN DISTRICT

BASELINES		OBSERVED VECTORS			RESIDUALS(v)			ADJUSTED VECTORS			STANDARD ERRORS		
FROM	**TO**	**ΔX(m)**	**ΔY(m)**	**ΔZ(m)**	**VΔx(m)**	**VΔy(m)**	**VΔz(m)**	**ADJ Δx(m)**	**ADJ Δy(m)**	**ADJ Δz(m)**	**σΔX(m)**	**σΔY(m)**	**σΔZ(m)**
Accra	**SGGS.GW DBP 48**	**10178.367**	**-10771.312**	**-8.958**	**-1.1231**	**0.0016**	**1.0152**	**10177.244**	**-10771.31**	**-7.943**	**0.015**	0.015	0.015
SGGS.GW DBP 48	**SGGS.GW DBP 1**	**-7124.253**	**4179.638**	**-27.11**	**-0.3413**	**0.0004**	**0.3081**	**-7124.594**	**4179.638**	**-26.802**	**0.047**	0.047	0.047
Accra	**SGGS.GW DBP 1**	**3054.007**	**-6591.691**	**-36.019**	**-0.7818**	**0.0011**	**0.7071**	**3053.225**	**-6591.69**	**-35.312**	**0.047**	0.047	0.047
Accra	**SGGS.GW DBP 48**	**10178.367**	**-10771.312**	**-8.958**	**-1.1231**	**0.0016**	**1.0152**	**10177.244**	**-10771.31**	**-7.943**	**0.015**	0.015	0.015
SGGS.GW DBP 48	**SGGS.GW DBP 2**	**-7119.423**	**3753.405**	**-23.545**	**-0.3417**	**0.0005**	**0.3084**	**-7119.765**	**3753.405**	**-23.237**	**0.028**	0.028	0.028
Accra	**SGGS.GW DBP 2**	**3058.977**	**-7018.221**	**-33.837**	**-0.7814**	**0.0012**	**0.7069**	**3058.196**	**-7018.22**	**-33.13**	**0.030**	0.030	0.030
Accra	**SGGS.GW DBP 48**	**10178.367**	**-10771.312**	**-8.958**	**-1.1231**	**0.0016**	**1.0152**	**10177.244**	**-10771.31**	**-7.943**	**0.015**	0.015	0.015
SGGS.GW DBP 48	**SGGS.GW DBP 3**	**-7495.374**	**3316.115**	**-10.939**	**-0.2993**	**0.0004**	**0.2700**	**-7495.673**	**3316.115**	**-10.669**	**0.028**	0.028	0.028

Accra	SGGS.GW DBP 3	2682.933	-7455.271	-21.675	-0.8237	0.0012	0.7454	2682.109	-7455.27	-20.93	0.030	0.030	0.030
Accra	SGGS.GW DBP 48	10178.367	-10771.312	-8.958	-1.1231	0.0016	1.0152	10177.244	-10771.31	-7.943	0.015	0.015	0.015
SGGS.GW DBP 48	SGGS.GW DBP 4	-6526.026	2818.182	-5.296	-0.4063	-0.0066	0.3652	-6526.432	2818.175	-4.931	0.047	0.047	0.047
Accra	SGGS.GW DBP 4	3661.161	-7882.036	-7.902	-0.7177	0.0011	0.6494	3660.443	-7882.035	-7.253	0.047	0.047	0.047
Accra	SGGS.GW DBP 48	10178.367	-10771.312	-8.958	-1.1231	0.0016	1.0152	10177.244	-10771.31	-7.943	0.015	0.015	0.015
SGGS.GW DBP 48	SGGS.GW DBP 5	-5962.492	1760.359	-1.632	-0.4674	0.0006	0.4218	-5962.959	1760.36	-1.21	0.047	0.047	0.047
Accra	SGGS.GW DBP 5	4215.743	-9011.446	-11.145	-0.6557	0.0010	0.5935	4215.087	-9011.445	-10.552	0.047	0.047	0.047
Accra	SGGA 07 213 48	10178.367	-10771.312	-8.958	-1.1231	0.0016	1.0152	10177.244	-10771.31	-7.943	0.015	0.015	0.015
SGGA 07 213 48	SGGS.GW DBP 6	-5767.673	1767.275	0.52	-0.4889	0.0006	0.4421	-5768.162	1767.276	0.962	0.034	0.034	0.034
Accra	SGGS.GW DBP 6	4413.651	-9003.672	-20.128	-0.6345	0.0010	0.5743	4413.016	-9003.671	-19.554	0.035	0.035	0.035
Accra	SGGA 07 213 48	10178.367	-10771.312	-8.958	-1.1231	0.0016	1.0152	10177.244	-10771.31	-7.943	0.015	0.015	0.015
SGGA 07 213 48	SGGS.GW DBP 7	-5744.954	1621.12	-5.545	-0.4917	0.0006	0.4438	-5745.446	1621.121	-5.101	0.028	0.028	0.028
Accra	SGGS.GW DBP 7	4433.308	-9149.934	-15.581	-0.6314	0.0010	0.5715	4432.677	-9149.933	-15.01	0.030	0.030	0.030
Accra	SGGA 07 213 48	10178.367	-10771.312	-8.958	-1.1231	0.0016	1.0152	10177.244	-10771.31	-7.943	0.015	0.015	0.015
SGGA 07 213 48	SGGS.GW DBP 8	-5465.073	1651.742	-3.36	-0.5297	0.0004	0.4824	-5465.603	1651.742	-2.878	0.034	0.034	0.034
Accra	SGGS.GW DBP 8	4788.092	-9116.835	-122.768	-0.6008	0.0009	0.5438	4787.491	-9116.834	-122.224	0.035	0.035	0.035

Accra	SGGA 07 213 48	10178.367	-10771.312	-8.958	-1.1231	0.0016	1.0152	10177.244	-10771.31	-7.943	0.015	0.015	0.015
SGGA 07 213 48	SGGS.GW DBP 9	-5369.673	1577.825	-0.328	-0.6119	-0.0124	0.4759	-5370.285	1577.813	0.148	0.047	0.047	0.047
Accra	SGGS.GW DBP 9	5602.894	-9062.954	38.442	-0.5906	0.0009	0.5346	5602.303	-9062.953	38.977	0.047	0.047	0.047
Accra	SGGA 07 213 48	10178.367	-10771.312	-8.958	-1.1231	0.0016	1.0152	10177.244	-10771.31	-7.943	0.015	0.015	0.015
SGGA 07 213 48	SGGS.GW DBP 10	-4916.243	1688.747	17.179	-0.5805	0.0007	0.5242	-4916.823	1688.748	17.703	0.047	0.047	0.047
Accra	SGGS.GW DBP 10	5262.24	-9082.58	8.297	-0.5426	0.0008	0.4910	5261.697	-9082.579	8.788	0.047	0.047	0.047
Accra	SGGA 07 213 48	10178.367	-10771.312	-8.958	-1.1231	0.0016	1.0152	10177.244	-10771.31	-7.943	0.015	0.015	0.015
SGGA 07 213 48	SGGS.GW DBP 11	-4775.174	25.07	-188.232	-0.5962	-0.0082	0.5337	-4775.77	25.062	-187.698	0.047	0.047	0.047
Accra	SGGS.GW DBP 11	5192.599	-10655.419	35.715	-0.5059	0.0007	0.4583	5192.093	-10655.418	36.173	0.047	0.047	0.047
Accra	SGGA 07 213 48	10178.367	-10771.312	-8.958	-1.1231	0.0016	1.0152	10177.244	-10771.31	-7.943	0.015	0.015	0.015
SGGA 07 213 48	SGGS.GW DBP 12	-4797.774	81.439	57.912	-0.5934	0.0066	0.5306	-4798.367	81.446	58.443	0.047	0.047	0.047
Accra	SGGS.GW DBP 12	5412.023	-10749.046	67.803	-0.5329	0.0009	0.4827	5411.49	-10749.045	68.286	0.047	0.047	0.047
Accra	SGGA 07 213 48	10178.367	-10771.312	-8.958	-1.1231	0.0016	1.0152	10177.244	-10771.31	-7.943	0.015	0.015	0.015

SGGA 07 213 48	**SGGS.GW DBP 13**	**-2651.963**	**1029.281**	**1.03**	**-0.8311**	**0.0012**	**0.7510**	**-2652.794**	**1029.282**	**1.781**	**0.047**	0.047	0.047
Accra	**SGGS.GW DBP 13**	**7526.606**	**-9742.588**	**-7.198**	**-0.2920**	**0.0004**	**0.2642**	**7526.314**	**-9742.588**	**-6.934**	**0.047**	0.047	0.047
Accra	**SGGS.GW DBP 2**	**3058.977**	**-7018.221**	**-33.837**	**-0.3417**	**0.0005**	**0.3084**	**3058.635**	**-7018.221**	**-33.529**	**0.028**	0.028	0.028
SGGS.GW DBP 2	**SGGS.GW DBP 6**	**1351.866**	**-1986.018**	**24.499**	**-0.4889**	**0.0006**	**0.4421**	**1351.377**	**-1986.017**	**24.941**	**0.034**	0.034	0.034
Accra	**SGGS.GW DBP 6**	**4413.651**	**-9003.672**	**-20.128**	**0.1469**	**-0.0002**	**-0.1326**	**4413.798**	**-9003.672**	**-20.261**	**0.039**	0.039	0.039
Accra	**SGGS.GW DBP 2**	**3058.977**	**-7018.221**	**-33.837**	**-0.3417**	**0.0005**	**0.3084**	**3058.635**	**-7018.221**	**-33.529**	**0.028**	0.028	0.028
SGGS.GW DBP 2	**SGGS.GW DBP 7**	**1374.322**	**-2132.183**	**18.52**	**-0.4917**	**0.0006**	**0.4438**	**1373.83**	**-2132.182**	**18.964**	**0.028**	0.028	0.028
Accra	**SGGS.GW DBP 7**	**4433.308**	**-9149.934**	**-15.581**	**0.1500**	**-0.0002**	**-0.1354**	**4433.458**	**-9149.934**	**-15.716**	**0.036**	0.036	0.036
Accra	**SGGS.GW DBP 3**	**2682.933**	**-7455.271**	**-21.675**	**-0.2993**	**0.0004**	**0.2700**	**2682.634**	**-7455.271**	**-21.405**	**0.028**	0.028	0.028
SGGS.GW DBP 3	**SGGS.GW DBP 7**	**1750.151**	**-1694.941**	**6.062**	**-0.4917**	**0.0006**	**0.4438**	**1749.659**	**-1694.94**	**6.506**	**0.028**	0.028	0.028
Accra	**SGGS.GW DBP 7**	**4433.308**	**-9149.934**	**-15.581**	**0.1923**	**-0.0003**	**-0.1739**	**4433.5**	**-9149.934**	**-15.755**	**0.036**	0.036	0.036
Accra	**SGGS.GW DBP 3**	**2682.933**	**-7455.271**	**-21.675**	**-0.2993**	**0.0004**	**0.2700**	**2682.634**	**-7455.271**	**-21.405**	**0.028**	0.028	0.028
SGGS.GW DBP 3	**SGGS.GW DBP 8**	**2029.992**	**-1664.333**	**7.695**	**-0.5297**	**0.0004**	**0.4824**	**2029.462**	**-1664.333**	**8.177**	**0.034**	0.034	0.034
Accra	**SGGS.GW DBP 8**	**4788.092**	**-9116.835**	**-122.768**	**0.2229**	**-0.0003**	**-0.2016**	**4788.315**	**-9116.835**	**-122.97**	**0.039**	0.039	0.039

Table B6: National Grid Coordinates

STATIONS	GRID COORDINATES		STANDARD ERRORS			
	N(X)	E(Y)	σN(ft)	σE(ft)	σN(m)	σE(m)
SGGSGW DBP1	344631.575	1177287.336	0.474	0.474	0.144	0.144
SGGSGW DBP2	344394.730	1175390.933	0.474	0.474	0.144	0.144
SGGSGW DBP3	344410.549	1173992.439	0.474	0.341	0.144	0.104
SGGSGW DBP4	345121.313	1171401.771	0.283	0.341	0.086	0.104
SGGSGW DBP5	346357.835	1170924.121	0.283	0.341	0.086	0.104
SGGSGW DBP6	348206.677	1167453.437	0.283	0.281	0.086	0.086
SGGSGW DBP7	348919.504	1166997.070	0.283	0.281	0.086	0.086
SGGSGW DBP8	351070.612	1168532.032	0.283	0.281	0.086	0.086
SGGSGW DBP9	350151.985	1166862.502	0.283	0.341	0.086	0.104
SGGSGW DBP10	351638.559	1167218.673	0.474	0.341	0.144	0.104
SGGSGW DBP11	352100.635	1161761.143	0.474	0.341	0.144	0.104
SGGSGW DBP12	352027.878	1161945.317	0.474	0.474	0.144	0.144
SGGSGW DBP13	359068.034	1165054.948	0.474	0.474	0.144	0.144

Table B7: Total Station Traverse Adjustment (Rural District)

Ref Unit variance = **0.037** ft = **0.011** m

Ref Se(σo) = **0.193** ft = **0.059** m

STATIONS		UNADJUSTED ANGLES			ADJUSTED ANGLES			UNADJUSTED BEARINGS			ADJUSTMENT(x)	ADJUSTED BEARINGS			S. ERRORS	UNADJUSTED DIST
FROM	**TO**	**Deg**	**Min**	**Sec**	**Deg**	**Min**	**Sec**	**Deg**	**Min**	**Sec**	**Sec**	**Deg**	**Min**	**Sec**	**Sec**	**ft**
SGGWGE/DBP/1	CP28	046	10	31	046	10	31	196	55	08	-0.00016	196	55	08	0.1933	924.47
CP28	CP29	202	03	50	202	03	50	218	58	58	-0.00015	218	58	58	0.1933	1393.59
CP29	SGGSGW/DBP/1	183	16	56	183	16	56	222	15	54	-0.00001	222	15	54	0.1933	123.05
SGGSGW/DBP/1	CP30	216	05	46	216	05	46	258	21	40	0.00003	258	21	40	0.1933	863.78
CP30	CP31	185	09	02	185	09	02	263	30	42	0.00004	263	30	42	0.1933	749.35
CP31	SGGSGW/DBP/2	007	48	38	007	48	38	091	19	20	-0.00003	091	19	20	0.1933	303.23
SGGSGW/DBP/2	CP32	179	33	26	179	33	26	090	52	46	-0.00009	090	52	46	0.1933	1089.76
CP32	CP33	013	58	31	013	58	31	284	51	17	0.00296	284	51	17	0.1933	22659
CP33	SGGSGW/DBP/3	351	22	08	351	22	08	096	13	25	-0.00005	096	13	25	0.1933	531
SGGSGW/DBP/3	CP34	194	16	60	194	17	00	110	30	25	-0.00016	110	30	25	0.1933	1067.18
CP34	CP35	176	01	32	176	01	32	106	31	57	-0.00012	106	31	57	0.1933	907.08
CP35	SGGSGW/DBP/4	169	48	48	169	48	48	096	20	45	-0.00007	096	20	45	0.1933	726.34
SGGSGW/DBP/4	CP36	260	05	49	260	05	49	176	26	34	-0.00011	176	26	34	0.1933	528.71
CP36	CP37	144	22	13	144	22	13	140	48	47	-0.00014	140	48	47	0.1933	680.37
CP37	SGGSGW/DBP/5	214	43	59	214	43	59	175	32	46	-0.00004	175	32	46	0.1933	181.97
SGGSGW/DBP/5	CP38	137	22	01	137	22	01	132	54	47	-0.00027	132	54	47	0.1933	1359.21
CP38	CP39	161	55	35	161	55	35	114	50	22	-0.00025	114	50	22	0.1933	1539.98
CP39	CP40	165	50	54	165	50	54	100	41	16	-0.00013	100	41	16	0.1933	1084.23
CP40	SGGSGW/DBP/6	250	45	04	250	45	04	171	26	20	-0.00002	171	26	20	0.1933	77.51
SGGSGW/DBP/6	CP41	230	50	50	230	50	50	222	17	10	-0.00006	222	17	10	0.1933	596.95
CP41	CP42	161	45	02	161	45	02	204	02	12	-0.00023	204	02	12	0.1933	1487.33

CP42	SGGSGW/DBP/7	209	19	11	209	19	11	233	21	23	-0.0001	233	21	23	0.1933	1823.42
SGGSGW/DBP/7	CP43	147	33	04	147	33	04	200	54	27	-0.00022	200	54	27	0.1933	1338.71
CP43	CP44	229	24	57	229	24	57	250	19	24	0.00000	250	19	24	0.1933	31.22
CP44	SGGSGW/DBP/8	158	48	29	158	48	29	229	07	53	-0.0001	229	07	53	0.1933	1360.19
SGGSGW/DBP/8	CP45	192	27	36	192	27	36	241	35	29	-0.00004	241	35	29	0.1933	1698.56
CP45	CP46	181	17	20	181	17	20	242	52	49	-0.00003	242	52	49	0.1933	1579.2
CP46	SGGSGW/DBP/9	179	25	35	179	25	35	242	18	24	-0.00004	242	18	24	0.1933	1785.77
SGGSGW/DBP/9	CP47	149	43	13	149	43	13	212	01	37	-0.00021	212	01	37	0.1933	1574.23
CP47	SGGSGW/DBP/10	075	31	20	075	31	20	107	32	57	-0.00007	107	32	57	0.1933	502.16
SGGSGW/DBP/10	CP48	171	00	19	171	00	19	098	33	16	-0.00024	098	33	16	0.1933	2204.33
CP48	CP49	175	01	07	175	01	07	093	34	23	-0.0002	093	34	23	0.1933	2176.92
CP49	SGGSGW/DBP/11	176	28	23	176	28	23	090	02	46	-0.00009	090	02	46	0.1933	1104.38
SGGSGW/DBP/11	SGGSGW/DBP/12	003	29	44	003	29	44	273	32	30	0.00011	273	32	30	0.1933	1185.99
SGGSGW/DBP/12	CP50	090	26	21	090	26	21	183	58	51	-0.0005	183	58	51	0.1933	2538.88
CP50	CP51	198	57	40	198	57	40	202	56	31	-0.00032	202	56	31	0.1933	2038.98
CP51	CP52	187	18	58	187	18	58	210	15	29	-0.00021	210	15	29	0.1933	1532.53
CP52	CP53	173	52	53	173	52	53	204	08	22	-0.00014	204	08	22	0.1933	939.69
CP53	SGGSGW/DBP/13	153	50	32	153	50	32	177	58	54	-0.00009	177	58	54	0.1933	448.03
SGGSGW/DBP/13	CP54	168	05	45	168	05	45	166	04	39	-0.00036	166	04	39	0.1933	1665.58
CP54	CP55	174	39	55	174	39	55	160	44	34	-0.00032	160	44	34	0.1933	1473.72

CP55	CP56	180	51	31	180	51	31	161	36	05	-0.00051	161	36	05	0.1933	2339.24
CP56	CP57	179	02	27	179	02	27	160	38	32	-0.00039	160	38	32	0.1933	1786.76
CP57	CP58	150	46	36	150	46	36	131	25	08	-0.00030	131	25	08	0.1933	1540.72
CP58	CP59	213	41	33	213	41	33	165	06	41	-0.00014	165	06	41	0.1933	626.04
CP59	SGGA07/213/47	172	23	38	172	23	38	157	30	19	-0.00003	157	30	19	0.1933	156.79
SGGA07/213/47	SGGA07/213/48	119	27	19	119	25	52	096	57	38	0.000	096	56	11	0.0000	235.494

Table B8: Final Adjusted Co-ordinates

STATIONS	PROVISIONAL COORDINATES		ADJUSTMENT		ADJUSTED GRID COORDINATES		STANDARD ERRORS			
	N(X)	E(Y)	N(X)	E(Y)	N(X)	E(Y)	σN(ft)	σE(ft)	σN(m)	σE(m)
SGGSGW/DBP/1	346690.2797	1178515.471	0.0083	0.2134	346690.188	1178515.584	0.624	0.607	0.190	0.185
SGGSGW/DBP/2	348022.034	1177589.918	0.0130	0.2552	348022.243	1177590.293	0.626	0.617	0.191	0.188
SGGSGW/DBP/3	350284.0667	1176144.913	0.0083	0.2952	350284.377	1176145.221	0.623	0.610	0.190	0.186
SGGSGW/DBP/4	351680.0511	1175259.893	-0.0011	0.3301	351680.259	1175260.233	0.618	0.589	0.188	0.179
SGGSGW/DBP/5	352659.3428	1174639.534	0.0042	0.3327	352659.356	1174639.765	0.603	0.581	0.184	0.177
SGGSGW/DBP/6	354147.66	1173633.277	-0.0040	0.3589	354147.521	1173633.507	0.581	0.547	0.177	0.167
SGGSGW/DBP/7	355469.4619	1171851.587	0.0251	0.3847	355469.373	1171851.894	0.574	0.538	0.175	0.164
SGGSGW/DBP/8	355781.3309	1171656.051	0.0491	0.4133	355781.577	1171656.782	0.562	0.516	0.171	0.157
SGGSGW/DBP/9	356452.2266	1170682.23	0.0704	0.4543	356452.354	1170682.106	0.555	0.464	0.169	0.141
SGGSGW/DBP/10	357531.3449	1169654.784	0.0771	0.4714	357531.95	1169655.415	0.542	0.429	0.165	0.131
SGGSGW/DBP/11	359130.76	1167083.836	0.0740	0.5126	359130.632	1167084.41	0.541	0.308	0.165	0.094
SGGSGW/DBP/12	370361.3514	1168987.424	0.0736	0.5257	370361.384	1168987.998	0.541	0.248	0.165	0.076

SGGSGW/DBP/13	370495.8072	1172141.366	0.1158	0.5402	370495.852	1172141.753	0.434	0.196	0.132	0.060

TABLE B9: Total Station Traverse Adjustment (Urban District)

Ref Unit variance = **0.037** ft = **0.011** m

Ref Se(σo) = **0.193** ft = **0.059** m

STATIONS		**UNADJUSTED ANGLES**			**ADJUSTED ANGLES**			**UNADJUSTED BEARINGS**			**ADJUSTMENT (x)**	**ADJUSTED BEARINGS**			**S. ERRORS**	**UNADJUSTED DIST**	**ADJUSTMENT**	**ADJ. DIST**
FROM	**TO**	**Deg**	**Min**	**Sec**	**Deg**	**Min**	**Sec**	**Deg**	**Min**	**Sec**	**Sec**	**Deg**	**Min**	**Sec**	**Sec**	**ft**	**ft**	**ft**
SGGA 07 213 48	CP1	325	40	46	325	40	46	242	36	57	-0.00003	242	36	57	0.1933	1416.5	-0.0451	1416.455
CP1	CP2	195	42	17	195	42	17	258	19	14	0.00006	258	19	14	0.1933	1516.21	-0.0447	1516.165
CP2	CP3	151	57	46	151	57	46	230	17	00	-0.00024	230	17	00	0.1933	3445.27	-0.0431	3445.227
CP3	CP4	041	40	40	041	40	40	091	57	40	-0.00042	091	57	40	0.1933	4788.66	0.0416	4788.702
CP4	SGGWGE/DBP/13	221	22	44	221	22	44	133	20	24	-0.00008	133	20	24	0.1933	391.92	0.0192	391.939
SGGWGE/DBP/13	CP5	138	09	39	138	09	39	091	30	03	-0.001	091	30	03	0.1933	11603.66	0.0417	11603.7
CP5	SGGWGE/DBP/12	352	00	36	352	00	36	263	30	39	0.00009	263	30	39	0.1933	1560.65	-0.0438	1560.606
SGGWGE/DBP/12	CP6	112	32	06	112	32	06	196	02	45	-0.00049	196	02	45	0.1933	2840.61	-0.0277	2840.582
CP6	CP7	183	46	24	183	46	24	199	49	09	-0.0003	199	49	09	0.1933	1843.69	-0.03	1843.66
CP7	CP8	166	30	07	166	30	07	186	19	16	-0.00075	186	19	16	0.1933	3868.88	-0.0212	3868.859
CP8	SGGWGE/DBP/11	175	01	12	175	01	12	181	20	28	-0.00059	181	20	28	0.1933	2921.5	-0.0176	2921.482
SGGWGE/DBP/11	CP9	287	25	25	287	25	25	288	45	53	0.0003	288	45	53	0.1933	2119.82	-0.0346	2119.785
CP9	CP10	202	41	53	202	41	53	311	27	46	0.0003	311	27	46	0.1933	1514.44	-0.0206	1514.419
CP10	SGGWGE/DBP/10	174	28	14	174	28	14	305	56	00	0.00006	305	56	00	0.1933	347.07	-0.0244	347.046
SGGWGE/DBP/10	CP11	181	06	15	181	06	15	307	02	15	0.00015	307	02	15	0.1933	807.98	-0.0236	807.956
CP11	CP12	201	27	04	201	27	04	328	29	19	0.00014	328	29	19	0.1933	634.03	-0.0078	634.022
CP12	SGGWGE/DBP/9	167	44	14	167	44	14	316	13	33	0.00001	316	13	33	0.1933	72.65	-0.0171	72.633
SGGWGE/DBP/9	CP13	165	53	45	165	53	45	302	07	18	0.00009	302	07	18	0.1933	494.13	-0.0269	494.103

CP3	CP14	183	38	38	183	38	38	305	45	56	0.0001	305	45	56	0.1933	542.47	-0.0245	542.446
CP14	SGGWGE/DBP/8	182	19	02	182	19	02	308	04	58	0.00003	308	04	58	0.1933	147.31	-0.0229	147.287
SGGWGE/DBP/8	SGGWGE/DBP/7	199	59	14	199	59	14	328	04	12	0.00008	328	04	12	0.1933	368.48	-0.0082	368.472
SGGWGE/DBP/7	CP15	152	01	01	152	01	01	300	05	13	0.0002	300	05	13	0.1933	1142.49	-0.0281	1142.462
CP15	CP16	191	00	43	191	00	43	311	05	56	0.00016	311	05	56	0.1933	812.75	-0.0208	812.729
CP16	SGGWGE/DBP/6	188	58	53	188	58	53	320	04	49	0.00006	320	04	49	0.1933	285.18	-0.0143	285.166
SGGWGE/DBP/6	CP17	170	50	37	170	50	37	310	55	26	0.00005	310	55	26	0.1933	281.29	-0.021	281.269
CP17	CP18	193	55	14	193	55	14	324	50	40	0.00027	324	50	40	0.1933	1275.55	-0.0107	1275.539
CP18	SGGWGE/DBP/5	202	57	51	202	57	51	347	48	31	0.00006	347	48	31	0.1933	264.45	0.0074	264.457
SGGWGE/DBP/5	CP19	146	02	20	146	02	20	313	50	51	0.00016	313	50	51	0.1933	806.3	-0.0189	806.281
CP19	SGGWGE/DBP/4	220	47	35	220	47	35	354	38	26	0.00009	354	38	26	0.1933	422.27	0.0126	422.283
SGGWGE/DBP/4	CP20	171	40	36	171	40	36	346	19	02	0.00015	346	19	02	0.1933	677.89	0.0062	677.896
CP20	CP21	138	01	37	138	01	37	304	20	39	0.00015	304	20	39	0.1933	851.01	-0.0254	850.985
CP21	CP22	036	11	15	036	11	15	160	31	54	-0.00017	160	31	54	0.1933	752.09	-0.0016	752.088
CP22	CP23	355	24	50	355	24	50	335	56	44	0.00015	335	56	44	0.1933	705.7	-0.002	705.698
CP23	SGGWGE/DBP/3	026	45	36	026	45	36	182	42	20	-0.00006	182	42	20	0.1933	322.29	-0.0186	322.271
SGGWGE/DBP/3	CP24	315	25	11	315	25	11	318	07	31	0.00023	318	07	31	0.1933	1115.87	-0.0157	1115.854
CP24	CP25	190	19	12	190	19	12	328	26	43	0.00024	328	26	43	0.1933	1104.38	-0.0079	1104.372
CP25	SGGWGE/DBP/2	197	35	48	197	35	48	346	02	31	0.00011	346	02	31	0.1933	505.33	0.006	505.336
SGGWGE/DBP/2	CP26	141	53	55	141	53	55	307	56	26	0.00012	307	56	26	0.1933	647	-0.023	646.977
CP26	CP27	208	44	27	208	44	27	336	40	53	0.0002	336	40	53	0.1933	913.52	-0.0014	913.519
CP27	SGGWGE/DBP/1	174	03	44	174	03	44	330	44	37	0.00002	330	44	37	0.1933	108.8	-0.0061	108.794

TABLE B10: FINAL ADJUSTED CO-ORDINATES URBAN

STATIONS	PROVISIONAL COORDINATES		ADJUSTMENT		ADJUSTED GRID COORDINATES		STANDARD ERRORS			
	N(X)	E(Y)	N(X)	E(Y)	N(X)	E(Y)	σN(ft)	σE(ft)	σN(m)	σE(m)

SGGWGE DBP1	344631.5951	1177287.143	-0.0201	0.1933	344631.626	1177287.512	0.616	0.591	0.188	0.180
SGGWGE DBP2	344394.7427	1175390.747	-0.0127	0.1860	344394.173	1175390.975	0.621	0.594	0.189	0.181
SGGWGE DBP3	344410.5577	1173992.257	-0.0087	0.1818	344410.498	1173992.479	0.617	0.596	0.188	0.182
SGGWGE DBP4	345121.326	1171401.596	-0.0130	0.1755	345121.213	1171401.267	0.586	0.594	0.179	0.181
SGGWGE DBP5	346357.8483	1170923.949	-0.0133	0.1721	346357.735	1170924.024	0.569	0.591	0.173	0.180
SGGWGE DBP6	348206.6854	1167453.272	-0.0084	0.1650	348206.767	1167453.553	0.540	0.584	0.165	0.178
SGGWGE DBP7	350152.515	1168431.43	0.0050	0.1488	348919.119	1166996.998	0.519	0.564	0.158	0.172
SGGWGE DBP8	350151.9773	1166862.355	0.0077	0.1472	351070.677	1168532.053	0.504	0.560	0.154	0.171
SGGWGE DBP9	351070.5896	1168531.905	0.0224	0.1266	350151.968	1166862.712	0.480	0.525	0.146	0.160
SGGWGE DBP10	351638.5255	1167218.559	0.0335	0.1144	351638.199	1167218.386	0.433	0.493	0.132	0.150
SGGWGE DBP11	352027.8317	1161945.225	0.0463	0.0917	352100.714	1161761.234	0.398	0.433	0.121	0.132
SGGWGE DBP12	352100.6023	1161761.065	0.0157	0.0852	352027.813	1161944.987	0.203	0.430	0.062	0.131
SGGWGE DBP13	359068.0189	1165054.89	0.0151	0.0577	359068.134	1165054.876	0.202	0.360	0.061	0.110

Table B11: Measured distance compared to ground distances

Controls Stations (SGGA .07/213/..)	Bearing-Distance(m)	Scale factor	Ground-Distance(m)	Total Station-Distance(m)
47-48	96° 56´ 11” - 71.777	0.99984	71.788	71.778
48-49	108° 43´23”- 239.172		239.133	239.123
47-49	106° 00´ 37”-309.784		309.734	309.745

Appendix C:

C1: Recommended Accuracy thresholds for district boundary Surveys in both rural and urban area in Ghana.

The following accuracy thresholds obtained from the thesis are recommended for the various survey techniques as part of the objective of the project and can be used as part of the National cadastral survey requirement for a district boundary survey project. It is the hope that the Survey and Mapping Division of the Lands Commission of Ghana will be guided by this accuracy thresholds developed through this research project.

Table C1: Recommended Accuracy threshold for rural district boundary Survey

Survey Method	Accuracy(Rms) Threshold Northings (N)	Eastings (E)
RTK(stop & go kinematics)	0.06m±0.01m	0.06m ±0.01m
5 mins-Fast Static	0.05m ±0.01m	0.05m±0.01m
10 mins-Fast Static	0.04m ±0.01m	0.04m ±0.01m
15 mins-Fast Static	0.03m ±0.01m	0.03m ±0.01m
Total Station	0.05m ±0.01m	0.05m ±0.01m

Table C2: Recommended Accuracy threshold for urban district boundary

Survey Method	Accuracy (Rms) Threshold Northings (N)	Eastings (E)
RTK(stop & go kinematics)	0.06m±0.01m	0.06m±0.01m
5 mins-Fast Static	0.04m ±0.01m	0.04m ±0.01m
10 mins-Fast Static	0.03m ±0.01m	0.03m ±0.01m
15 mins-Fast Static	0.03m ±0.01m	0.02m ±0.01m
Total Station	0.05m ±0.01m	0.05m ±0.01m

C2: Recommended Procedure for setting out (demarcating) a district administrative boundary located in a rural area on the ground.

There should be at least ***TWO EFFECTIVE*** stakeholders meeting before the actual field work

- Initial Stakeholder discussions with the chiefs, elders, opinion leaders, town development committee members from the adjoining district independently to be involved in participatory mapping using Goggle Earth Images, the Legislative

Instruments relating to the district boundaries involved ,Town Sheets and

Topographical Sheets covering the area. At this meeting the surveyor will brief them about the project and solicit for any other information any of the stakeholders will have. There is a general discussion about the benefit of the survey of the administrative boundary on the ground to all the stakeholders. It is after this that the participatory mapping will commence using all the data available with the High Resolution Goggle Earth Image/Map being the main tool.

- Final stakeholder meeting with the Land Surveyor, chiefs, elders, opinion leaders, Town development committee members, District/municipal chief executives from the two adjoining districts. These meeting will finally agree on the boundary positions for setting out (Demarcation) on the ground. This meeting will agree on the composition of the adjudication committee which will assist the Surveyor in the setting out (Demarcation) and measurement process. The need to use field teams from the towns on both sides of the boundary line for capacity/confidence building and to be able obtain, understand and use information about the prevailing situations on the ground for the sake of peace is paramount in the successful execution of the project.

- Major crossings of the boundary (rivers, roads, rail lines) must be detailed, and pillared with large and tall solid pillars, with the names of the respective districts written on them. All major crossing boundary pillars should have underneath them buried Type "C" beacons.

C2.1 Methodology

- Mostly the boundaries are areas of dense forest canopies; hence a combination of fast static GPS technique and total station traverse is advisable.

- The Boundaries should be cleared of all trees, bushes etc for a width (about 4 to 6 feet) during total station traverse.

- Boundaries in a farming area, the width should be reduced considerably to avoid the need for compensation and open hostility from farmers.

- Type "C" beacons are planted along the boundary. Teak trees are also established along major intersection in the form of star/rectangles/squares or crosses with the boundary point in the middle so as to be unique or conspicuous on future images/photographs.

- Where there are conflicts/discrepancies on the ground it is advisable to use pegs.

- River that crosses the boundary must be detailed; using the perpendicular offset method or GPS with data logger as on the boundary plan.

C3: Recommended Procedure for setting out (demarcating) a district administrative boundary located in an urban area on the ground.

A stakeholder meeting is held with the chiefs, elders, opinion leaders, District/municipal chief executives from the two adjoining districts for public awareness. Mostly the districts in the urban areas passes through major towns, most prominent buildings in the towns are used to define the boundary.

C3.1 Methodology

Mostly the boundaries are areas of administrative centre with towns. Most of the district boundaries in the urban areas follow towns, a (5, 10, 15) minutes fast static-GPS technique or a Total station traverse is advisable. The accuracy standard for most districts residing in urban areas reduces where there are high rise buildings when using GPS. In such area control points are established with the Static GPS, followed by a Total station traverse. Type"C" beacons together with sigh post that bear

BOLDLY the names of the respective districts. Rivers, streams, waterways, roads and railways that cross the boundary must be detailed

C3: Flow chart of the methodology used in setting out (demarcating) a district boundary with rural/urban location

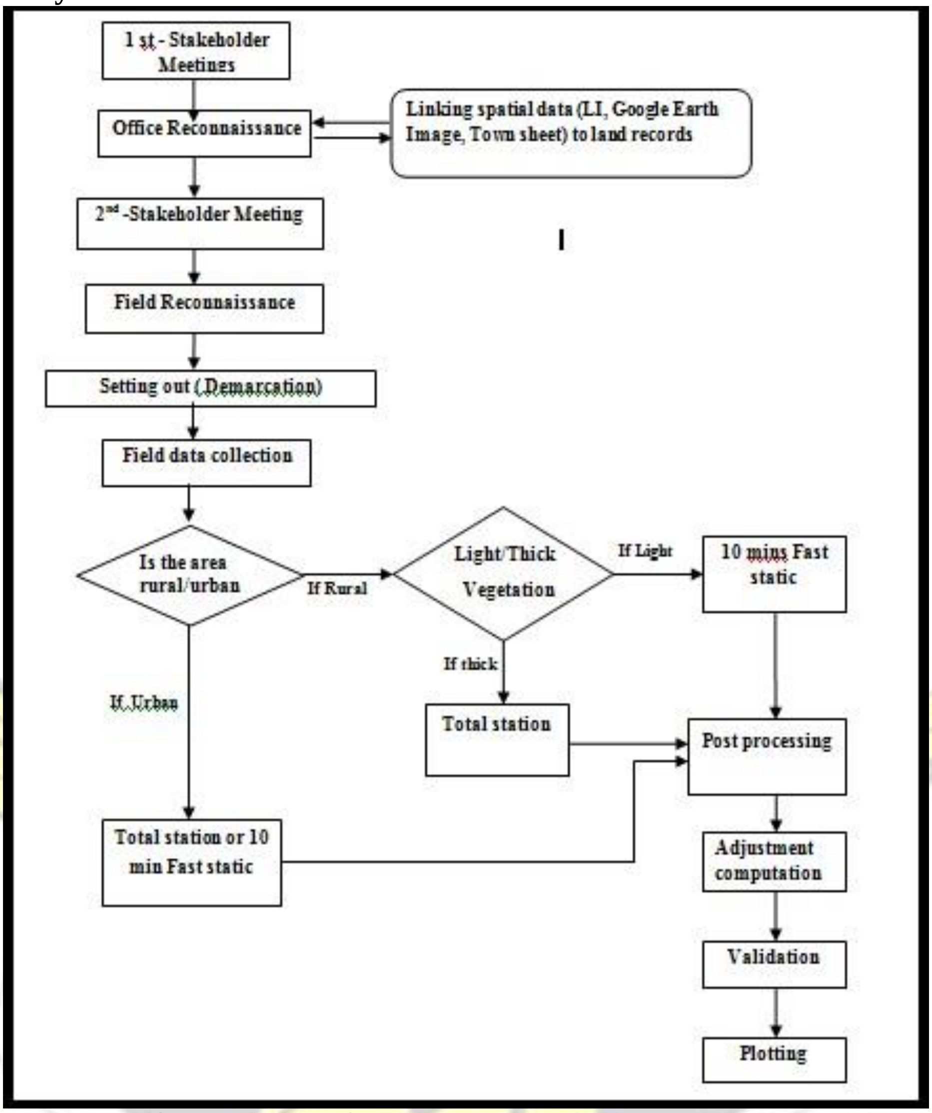

Figure AC: 1 Workflow diagram for Urban / Rural District boundary project

Appendix D: Projection Formulae

1. Transverse Mercator projection Formulae

Transverse Mercator mapping from Ellipsoid to the plane

t □ tan□

□□ □□□$_0$ □□ $\sqrt{\quad}$ ^{2} sin^2□ □□ □1□

e_2 sin□ $e^2{}_2$□□ □$_{32}$ a a□1

1□ e

□

$$f = \frac{a - b}{a} \text{ flattening} \qquad e^2 = 2f - f^2 \text{ eccentricity squared}$$

$$m = a(A_0\phi - A_2 \sin 2\phi + A_4 \sin 4\phi - A_6 \sin 6\phi)$$

$$m_0 = a(A_0\phi_0 - A_2 \sin 2\phi_0 + A_4 \sin 4\phi_0 - A_6 \sin 6\phi_0)$$

Where

$$A_0 = 1 - \frac{e^2}{4} - \frac{3e^4}{64} - \frac{5e^6}{256} \qquad A_2 = \frac{3}{8}\left(e^2 + \frac{e^4}{4} + \frac{15e^6}{128}\right) \qquad A_4 = \frac{15}{256}\left(e^4 + \frac{3e^6}{4}\right) \qquad A_6 = \frac{35e^6}{3072}$$

Easting Coordinate of point (E)

$$E = E' + E_0$$

$$E' = k_0 \nu \omega \cos\phi (1 + Term1 + Term2 + Term3)$$

$$Term1 = \frac{\omega^2}{6} \cos^2\phi (\psi - t^2)$$

$$Term2 = \frac{\omega^4}{120} \cos^4\phi \left[4\psi^3(1 - 6t^2) + \psi^2(1 + 8t^2) - \psi 2t^2 + t^4\right]$$

$$Term3 = \frac{\omega^6}{5040} \cos^6\phi (61 - 479t^2 + t^6)$$

Northing Coordinate of point (N)

$$N = N' + N_0$$

$$N' = k_0(m - m_0 + Term1 + Term2 + Term3 + Term4)$$

$$Term1 = \frac{\omega^2}{2} \nu \sin\phi \cos\phi$$

$$Term2 = \frac{\omega^4}{24} \nu \sin\phi \cos^3\phi (4\psi^2 + \psi - t^2)$$

sin□cos □ 24

Term3 □ $\square^{6}$ □sin□cos^{5}□ □8□^{4}□11□ 24t^{2}□□ 28□^{3}□1□ 6t^{2}□□□^{2}□1□ 32t^{2}□□□□2t^{2}□□t^{4}□ 720

Term4 □ $\square^{8}$ □sin□cos^{7}□□1385 □ 3111t^{2} □ 543t^{4} □t^{6}□
40320

Transverse Mercator Inverse Mapping from Plane to Ellipsoid

□3n 27n³ □ □ 21n² 55n⁴ □ □151n³ □ □1097n⁴ □

$\phi' \square \square \square \square \square \square$ 2 □ 32 □□□sin2□□□□□ 16 □ 32 □□□sin4□□□□□ 96

□□□sin6□□□□□ 512 □□□sin8□

n □ aa □ bb $_2$□ □□□1□ 94n_2 □ 22564n_4□□□□ □□□180□ □□□

G □ a□1□ n□ □1□ n

□ □

m'□

N' □□ m'□ m_0 □

180G k_0

E' □E'□^{2}

N'□ N □ N_0

t □ tan□' ; x □ k_0□ ; y □ k_{02}□□ ; E'□ E □ E_0

LONGITUDE OF POINT□□□

□□□$_0$ □*Term*1□*Term*2 □*Term*3□*Term*4

*Term*1□ $x$sec□' ; *Term*2 □ x_3 sec□' $_2$□

□□□ 2t 6 *Term*3 □ x_5

sec□' 4□$_3$□1□ 6t_2□□□$_2$□9 □ 68t_2□□ 72□t_2 □

24t_4□

□□

120

$Term4 \quad \frac{}{5040} \quad x_7 \sec\phi'(61 + 662t_2 + 1320t_4 + 720t_6)$

LATITUDE OF POINT ϕ

$\phi = \phi' - Term1 + Term2 - Term3 + Term4$

$Term1 = \frac{t}{k_0 t}\ E2'x$; $Term2 = \frac{}{k_0 t}\ E24'x_3$

$(4\psi_2 + 9\psi(1 - t_2) + 12t_2)$

$t\ E'x^5\ (8\psi^4(11 - 24t^2) - 12\psi^3(21 - 71t^2) + 15\psi^2(15 - 98t^2 + 15t^4) +$

$Term3 = k_0\ 720\ 180\psi(5t_2 + 3t_4) + 360t_4$

$t\ E'x^7 \quad {}^2 \quad 4095t^4 + 1575t^6)$

$Term4 = k_0\ 40320\ (1385 + 3633t$

2. Universal Transverse Mercator projection Formulae
Universal Transverse Mercator mapping from Ellipsoid to the plane

$Easting\ E, = FE + k_0 \nu [A + (1 - T + C) A^3/6 + (5 - 18T + T^2 + 72C - 58e'^2) A^5/120]$

$Northing\ N, = FN + k_0 \{M - M_0 + \nu \tan\phi [A^2/2 + (5 - T + 9C + 4C^2) A^2/24 +$

$(61 - 58T + T^2 + 600C - 330e'^2) A^6$

$/720]\}$

Where

$T = \tan^1\phi \quad \frac{e^2}{\cos^2\phi}$

---

[1] ; $C_1 = e'^2 \cos^2\phi_1$; $e'^2 = \frac{e^2}{2}$; $D = \frac{E - FE_0}{\nu_1 k}$

$T_1 = \tan\phi_1$

C □ ———— 1□ 2

e

A □ (□ □ □ □ □□ 0)cos , with and 0 in radians

a

□□ ——————

□1□e² sin²□□½

□□1□e² 2 3□ e² 64 5□ e⁶ 256 ...□ □□□□3e² 8 3□ e⁴ 32□45e⁶ 1024□... sin□2□□

M □ a□□

□□ □□15e⁴ 256□ 45e⁶ 1024□... sin□4□□□35e⁶ 3072□... sin□6□□...   □□

ZW□□□□□□1 □ W2 □□□

□0 □□

Z □INT□□□□□ □1 W W□/□ with ,□□1 and W in degrees. If <0, =□ □ □□ +360□degrees

Universal Transverse Mercator Inverse Mapping from Plane to Ellipsoid

□ □ □ □□□ 1 □□ 1tan 11□□□D²/2□□5 3□ T1 □10C1 □4C1² □9e□²□D⁴/24

□□61 9□ 0T1 □ 298C1 □ 45T1² □252e□² □3C1²□D² 720□□

□ □□ 0 □ □D□□1 2□ T1 □C D1□ ³ 6□□5 2□ C1 □28T1 □3C1² □8e□² □24T1²□D⁵

120□□ cos□1

a   a□1□e²□

□1 □ ——————   □1 □ ——————

□1□e²sin²□1□½   □1□e² sin²□1□³⁄₂

□1□ e

ϕ_1 is the latitude of the point on the central meridian which has the same Northing as the point whose coordinates are sought, and is found from?

$$\phi_1 = \mu_1 + \left(3e_1/2 - 27e_1^3/32 + \ldots\right)\sin 2\mu_1 + \left(21e_1^2/16 - 55e_1^4/32 + \ldots\right)\sin 4\mu_1 + \left(151e_1^3/96 + \ldots\right)\sin 6\mu_1 + \left(1097e_1^4/512 - \ldots\right)\sin 8\mu_1 + \ldots$$

Where

$$e_1 = \frac{1 - \left(1 - e^2\right)^{\frac{1}{2}}}{1 + \left(1 - e^2\right)^{\frac{1}{2}}}; \quad \mu_1 = M_1 / \left[a\left(1 - e^2/4 - 3e^4/64 - 5e^6/256 - \ldots\right)\right]; \quad M_1 = M_0 + \left(N - FN\right)/k_0$$