**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

My greatest appreciation goes to the Lord Almighty for bringing me this far throughout my course. Next, I wish to convey sincere gratitude to Dr. Kwesi Prah for accepting me as his student and junior colleague in the survey industry. His support, guidance and valuable suggestions were of immense importance to this study. Special thanks go to all the staff members of the Geomatic Engineering Department, KNUST, and more specifically to Rev. John Ayer and Dr. Isaac Dadzie. This thesis also benefited greatly from equipment, suggestions and contributions by The Municipal Chief Executive of Ga East District Hon. John Kwao, Hon.Ebenezer Nii Armah Tarchie, Ga West Municipal chief executives, Mr. Stephen Azu of Lands Commission (SMD) of Ghana. I am also grateful to the Chiefs, Opinion Leaders of the various District Assemblies in the Ga municipality. Last, but not the least, I would like to extend my special thanks to my family, all my friends especially Mr. Samuel Osah, for your company, friendship, invaluable support and encouragement. May God bless you all.

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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 post-processed 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)

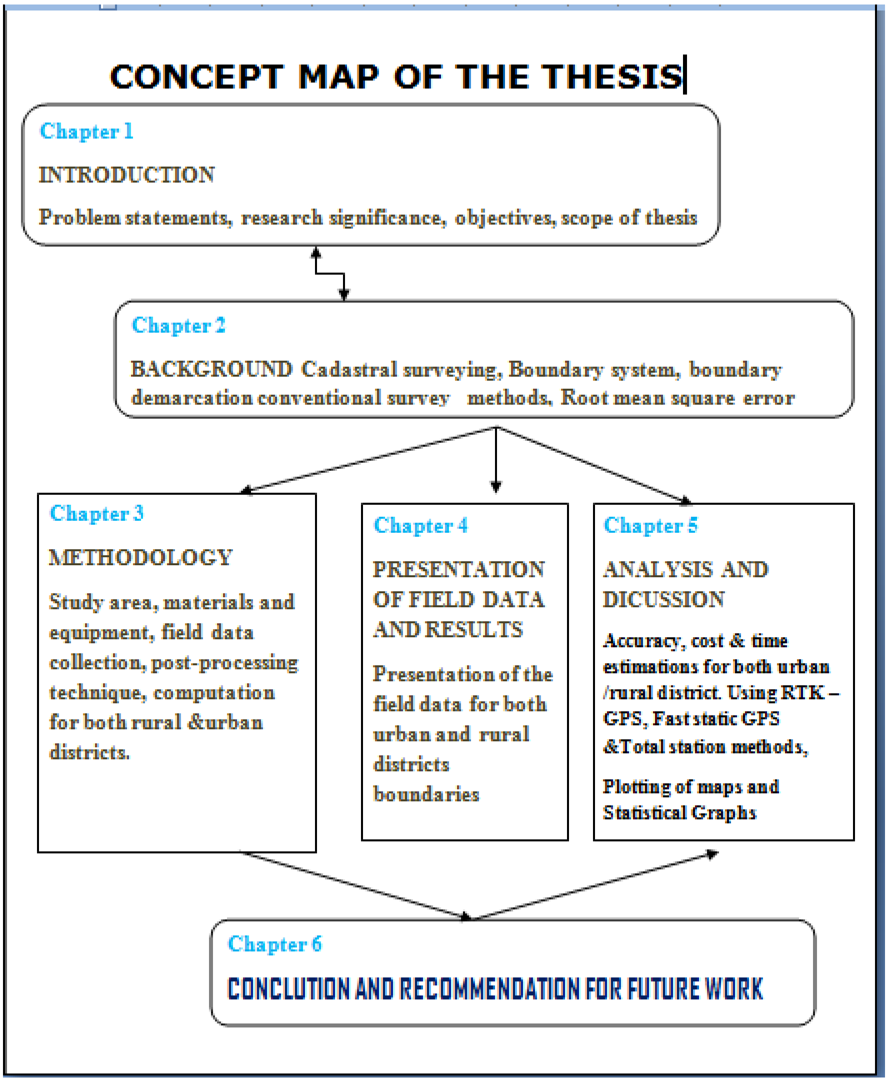


**Figure 1.1: Concept Map of Study**

# 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 La-Nkwantanang-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.

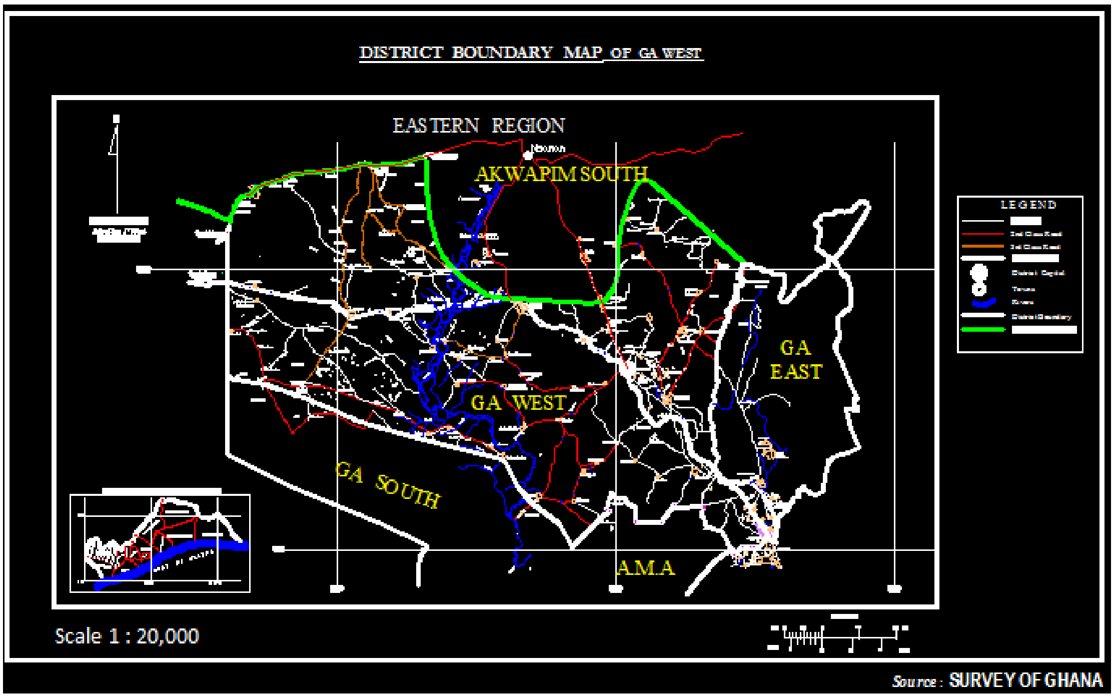


**Figure.2.0: District boundary map of Ga West**

## 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.

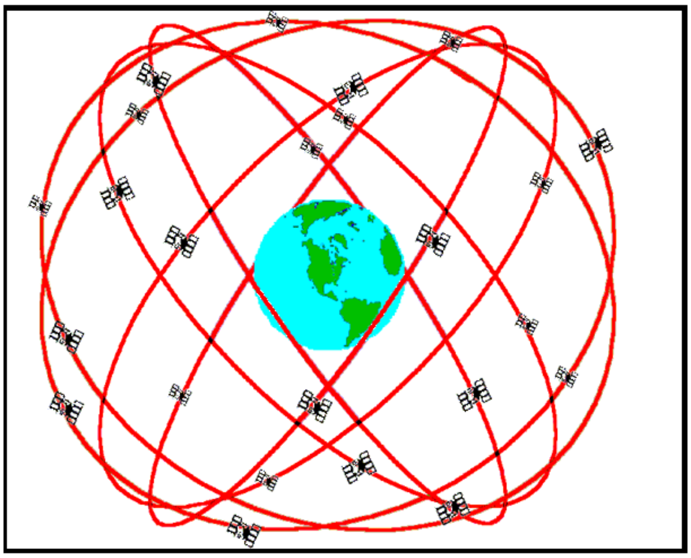

**Figure 2.1: GPS Constellations**

#### 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.

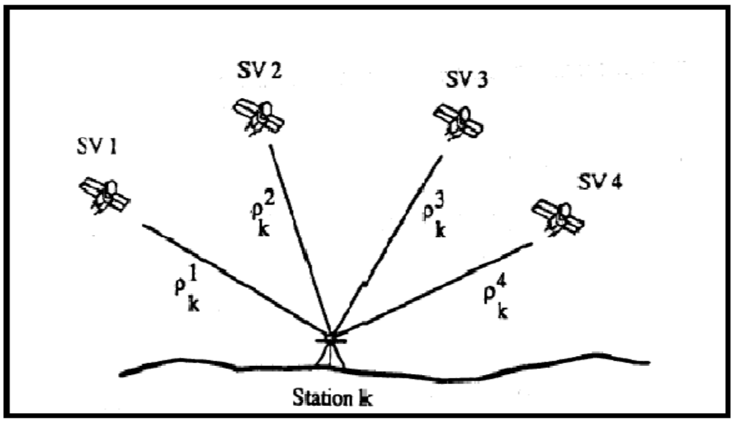


**Figure 2.2: GPS Absolute Positioning Mode**

#### 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, Stop-and-go kinematic and Real Time Kinematics (Wells, et-al.1987). Figure 2.3 shows GPS in Relative position mode.

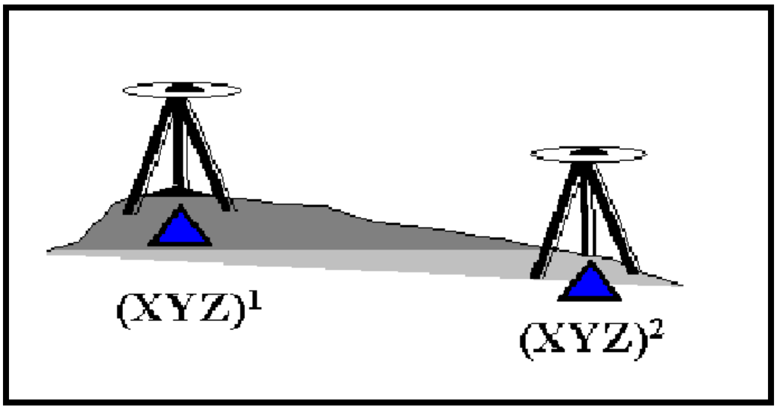


**Figure 2.3: GPS Relative Positioning Mode**

#### 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 third-order 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:

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

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

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

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

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

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

$\sigma_\chi$ = 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,

$$\text{Positional Accuracy}, \quad f_{p_i} = \sqrt{\Delta x_i^2 + \Delta y_i^2} \quad \ldots\ldots\ldots \text{Eqn2.7}$$

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

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

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).

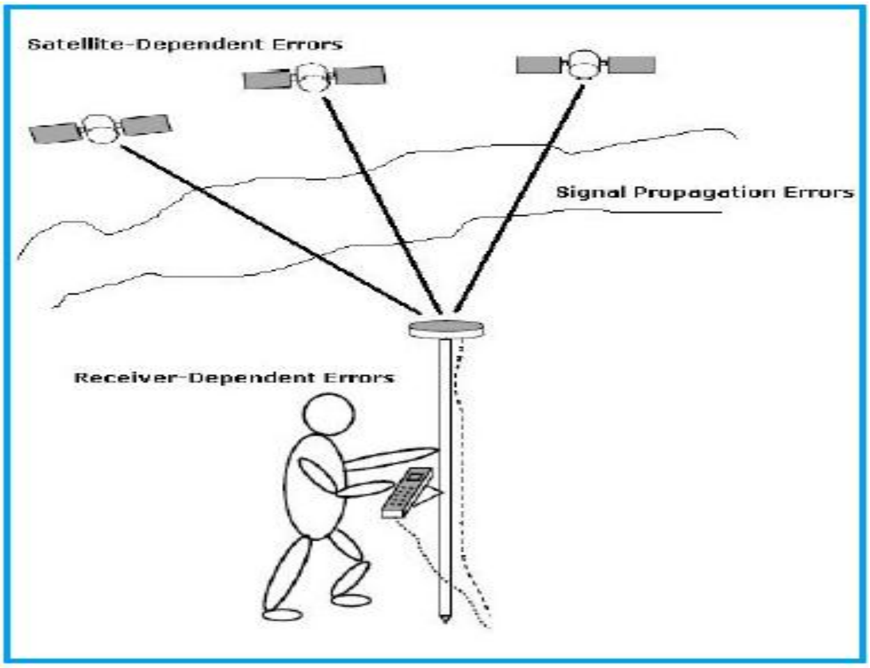


**Figure 2.6: GNSS Error Sources**

#### 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, Earth-fixed orthogonal coordinate system, shown in Figure 2.7.

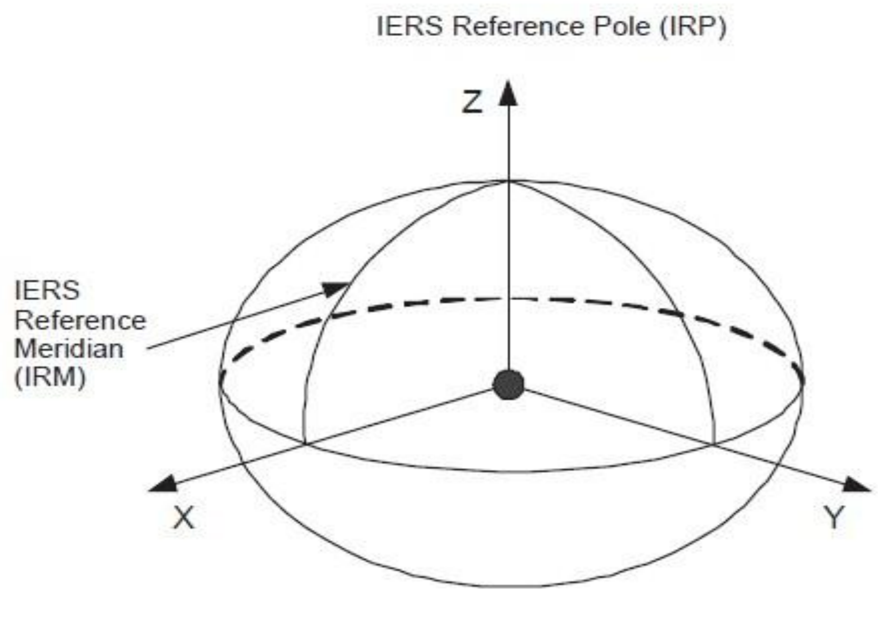


**Figure 2.7: The WGS 84 Coordinate System Definition**

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

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

  $\varpi e$ = 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 $x10^{-8}m^3/sec^2$ ($\sigma_{GM}$ = 0.6 $x10^8$ $m^3/s^3$.

In order to maintain consistency with GPS calculations within this project, it is re-emphasized 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 Earth-Centered 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):

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

### 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 '$\phi$ ', Longitude '$\lambda$' 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):

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

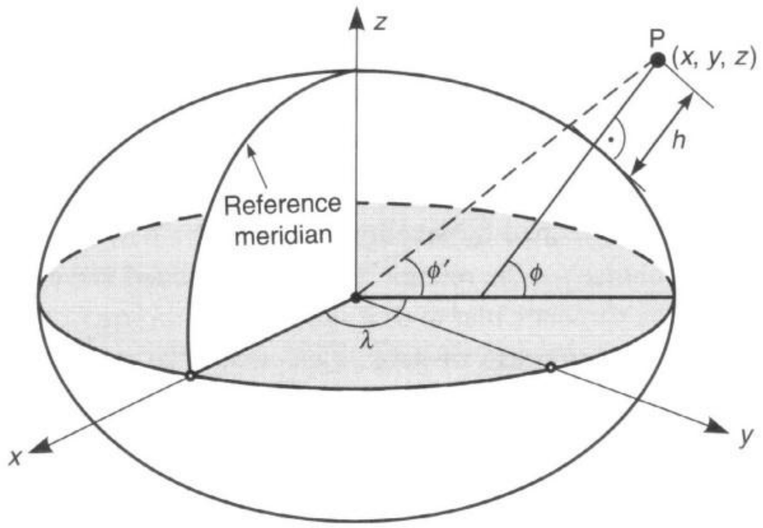


**Figure 2.8: ECEF coordinate system**

## 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 ($\phi$, $\lambda$) 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 |
| $PARAMETERS$ | $PARAMETERS$ |
| $a = 6378299.996m$ $Semi\text{-}major\ axis$ | $a = 6378137.0m$ $Semi\text{-}major\ axis$ |
| $f = 1/296$ $flattening$ | $f = 1/298.257223563$ $flattening$ |
| $PROJECTION\ PARAMETERS$ | $PROJECTION\ PARAMETERS$ |
| $\varphi_0 = [4^o\ \ 40']$ Latitude of origin | $\varphi_0 = 0$ Latitude of origin |
| $\lambda_0 = 1^o w$ Longitude of origin | $\lambda_0 = 3^o w$ Longitude of origin |
| $k_0 = 0.99975$ scale factor | $k_0 = 0.99960$ scale factor |
| $N_0 = 0.0000$ false Northing | $N_0 = 0.000m$ false Northing |
| $E_0 = 900000\,ft$ false Easting | $E_0 = 500000m$ 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

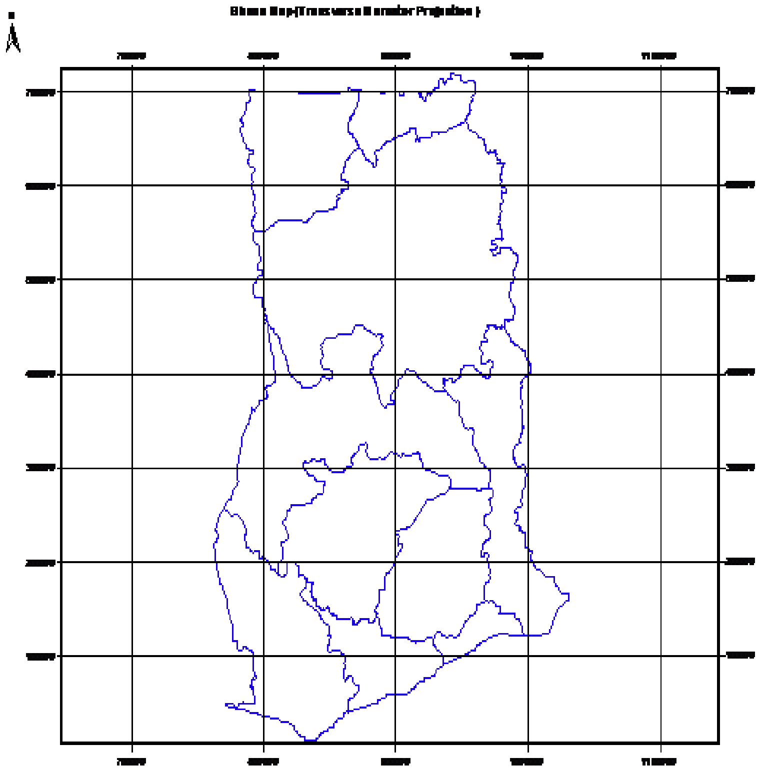

**Figure. 2.9: The Ghana National Grid system**

## 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.

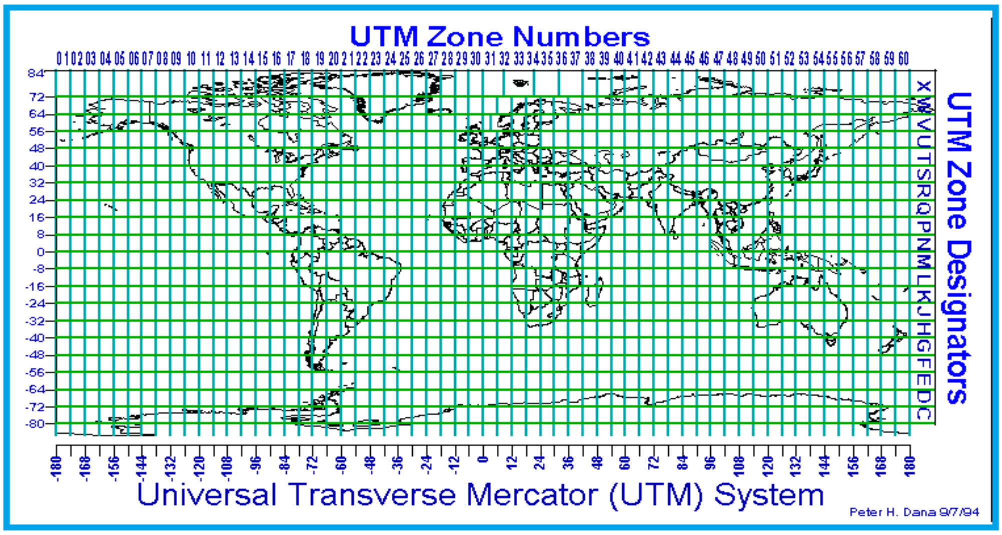


**Figure 2.10: UTM projection Zones**

## 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

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

**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

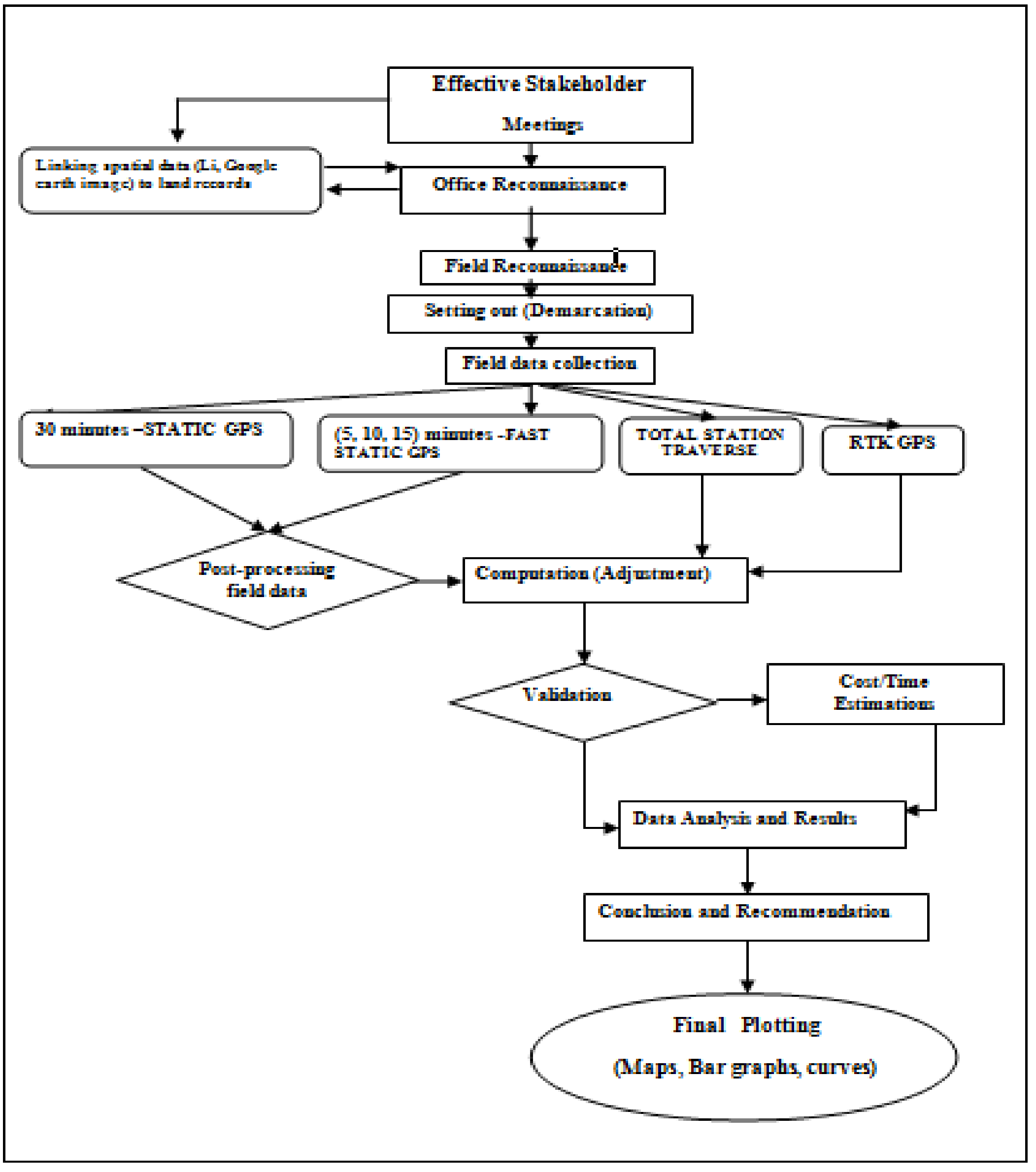


**Figure 3.1: Work Flow Diagram**

## 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.

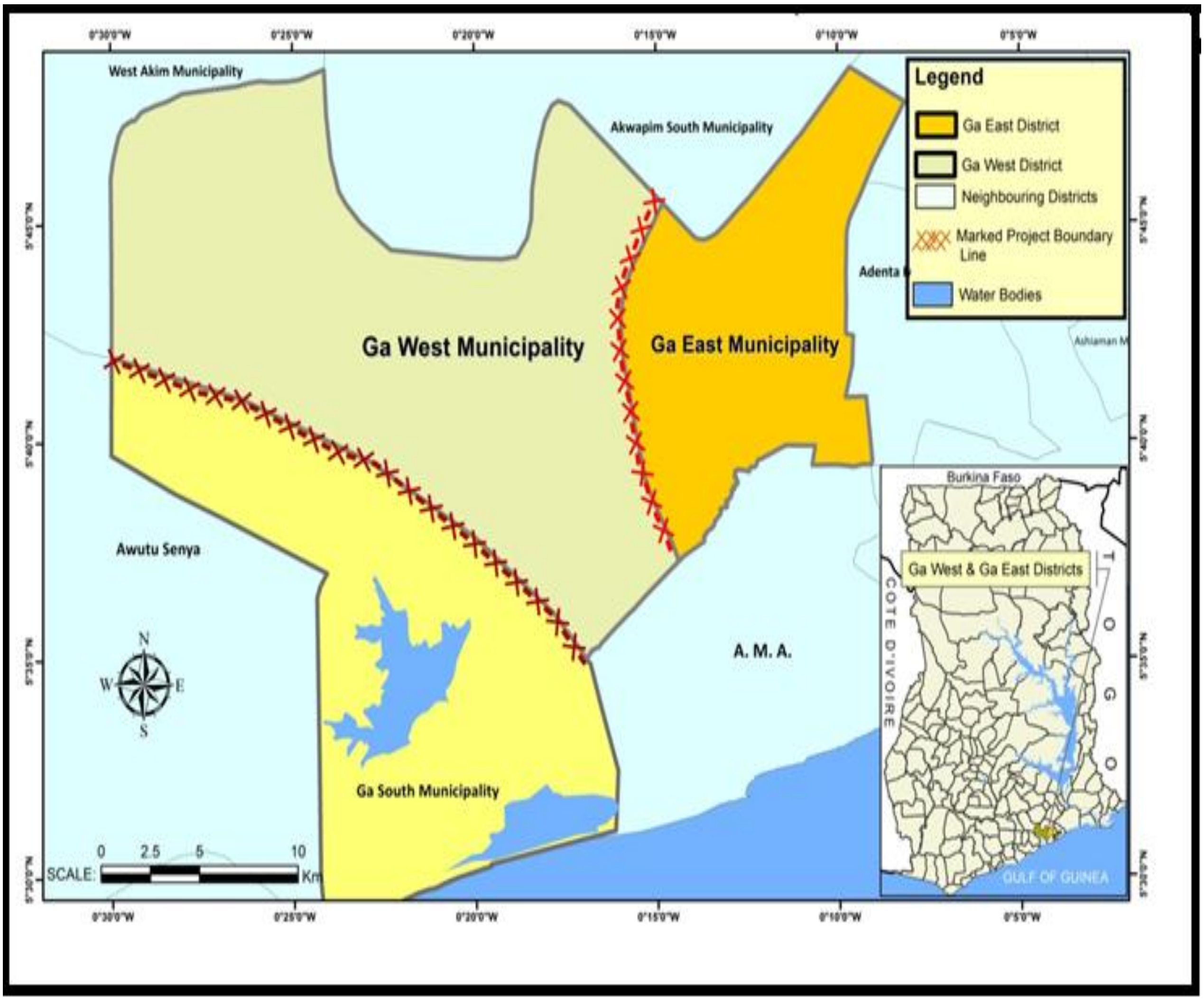


**Figure 3.2: Map Showing the Selected Boundaries for the project.**

## 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.

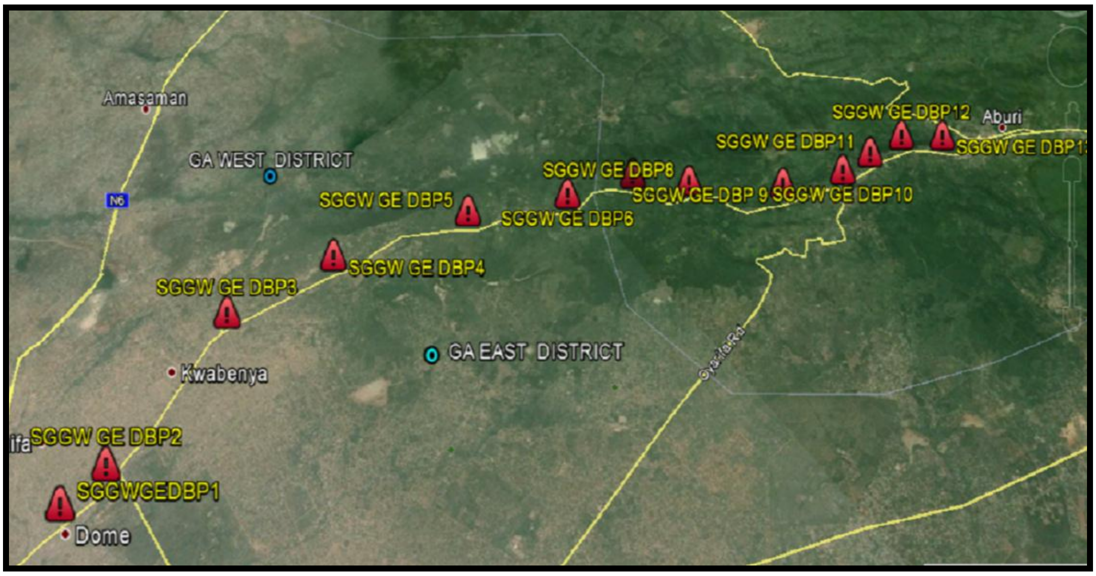


**Figure3.3: Google Earth Image showing the distribution of the selected boundary points (Rural District boundary).**

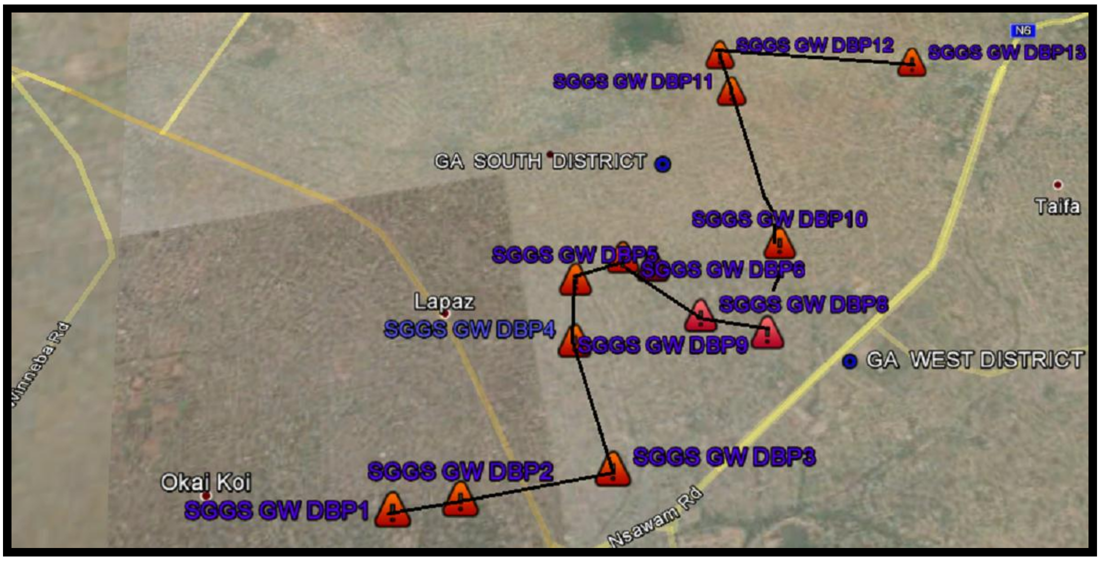


**Figure3.4; Google Earth Image showing the distribution of the selected boundary points (Urban District boundary).**

### 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 29$^{th}$ and 30$^{th}$ 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 7$^{th}$ and 8$^{th}$ April 2014, whiles type 'B' beacons with inscription SGGW/GE/DBP1-13, were used for the rural district boundary line on the 9$^{th}$ and 10$^{th}$ 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.

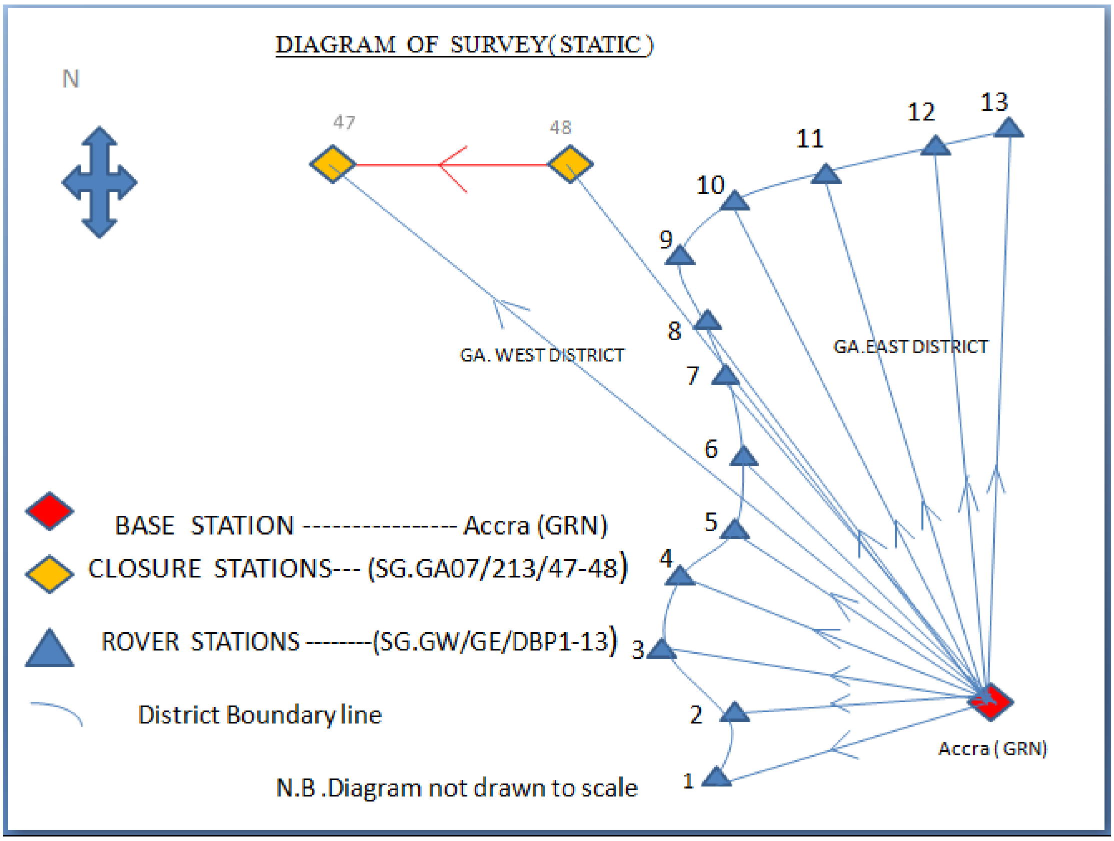


**Figure 3.5: Diagram of Survey for the Static Method**

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.

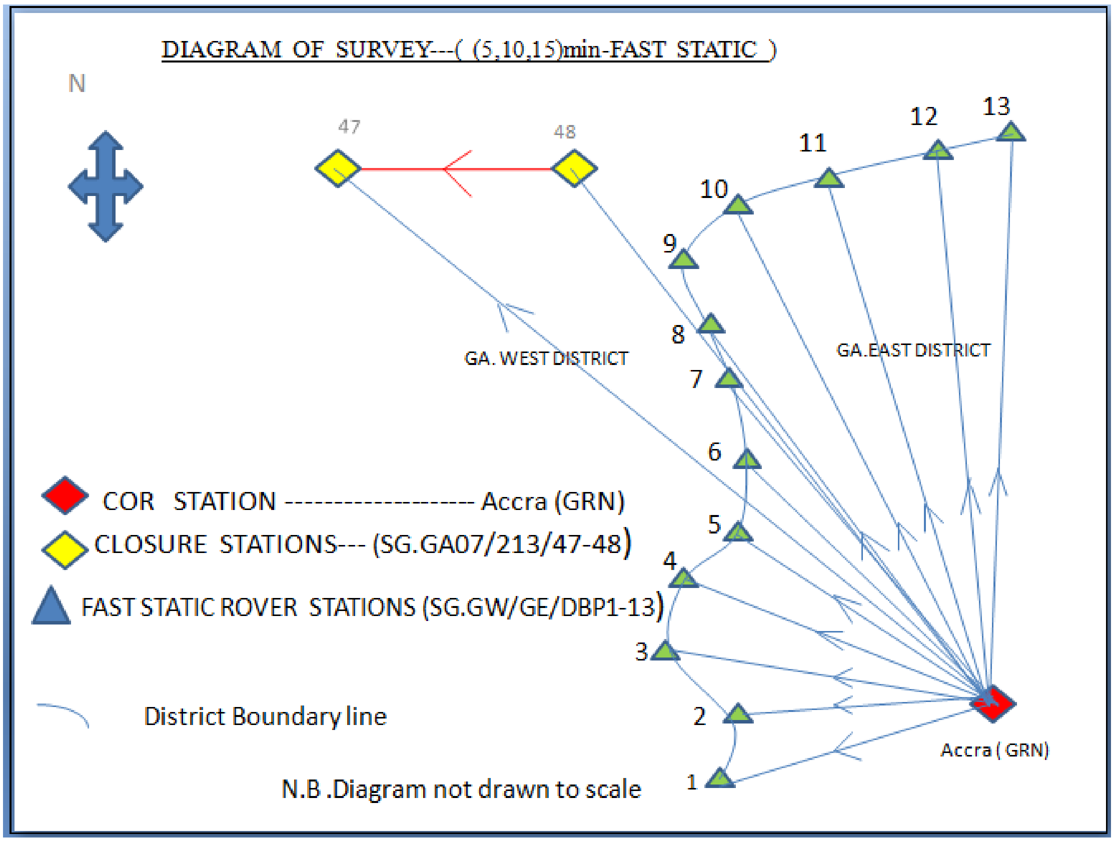


**Figure 3.6: Diagram of Survey for the Fast Static Methods for the rural district boundary line.**

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.

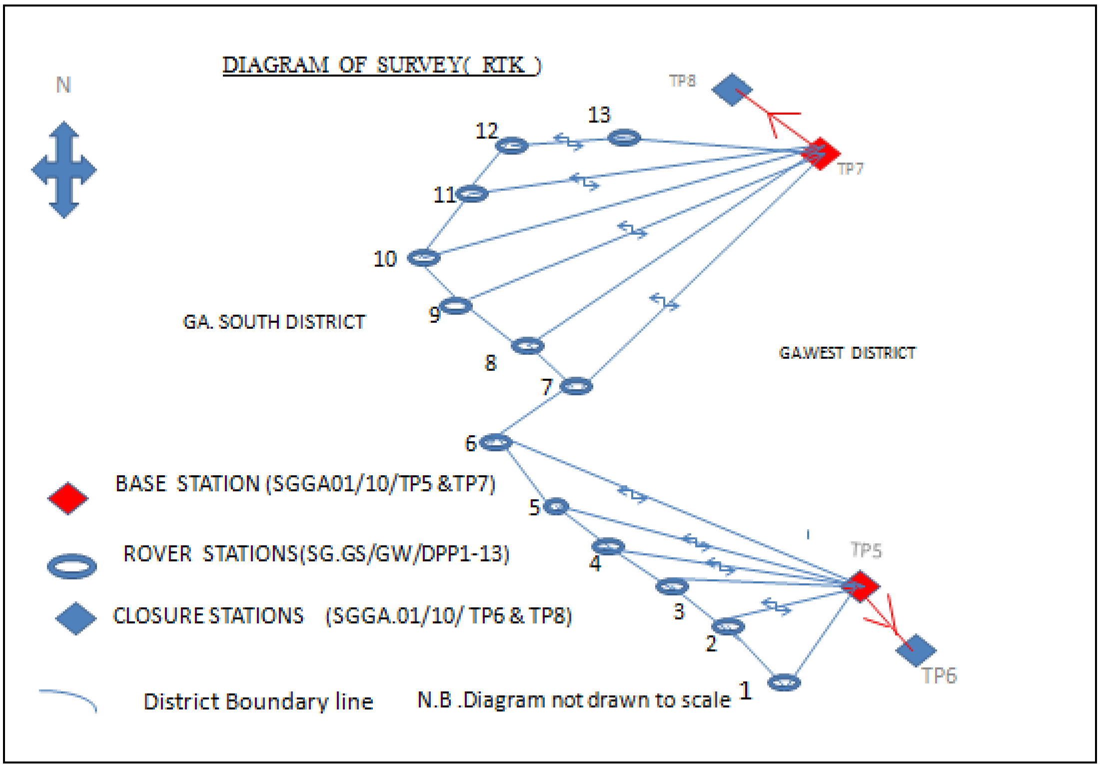


**Figure 3.7: Diagram of Survey for the RTK Method**

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.

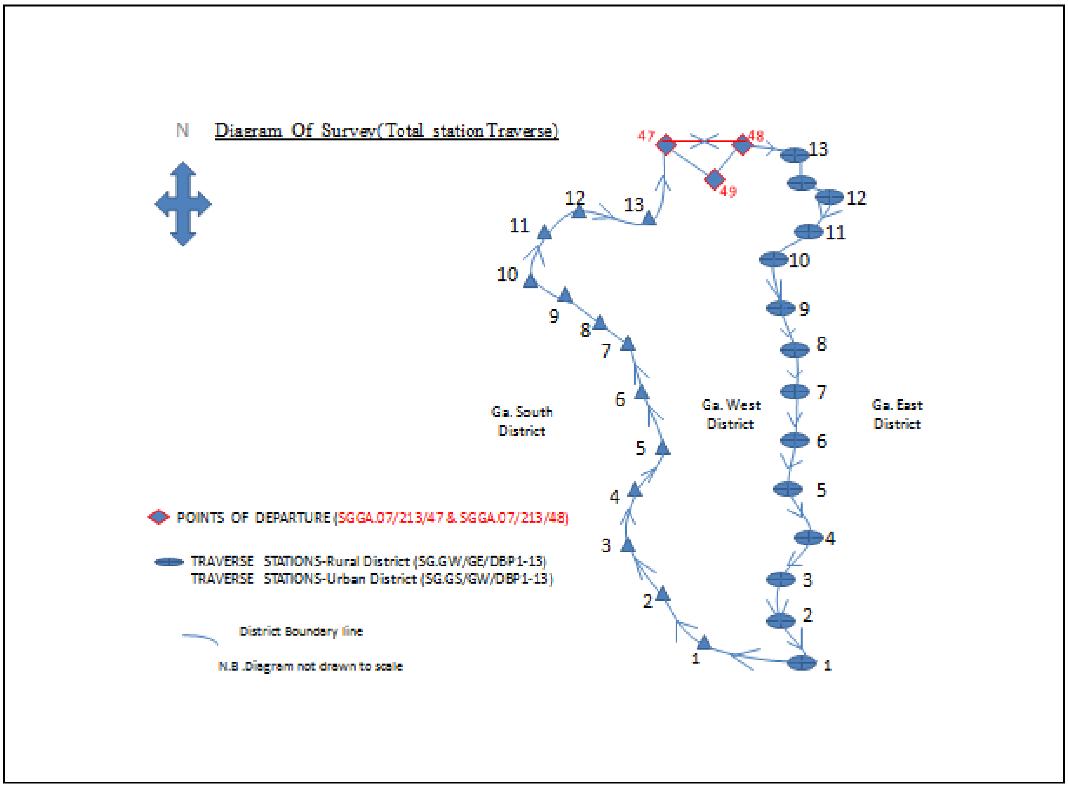


**Figure 3.8: Diagram of Survey for the Total station Method for the Rural and Urban district boundary lines.**

### 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.

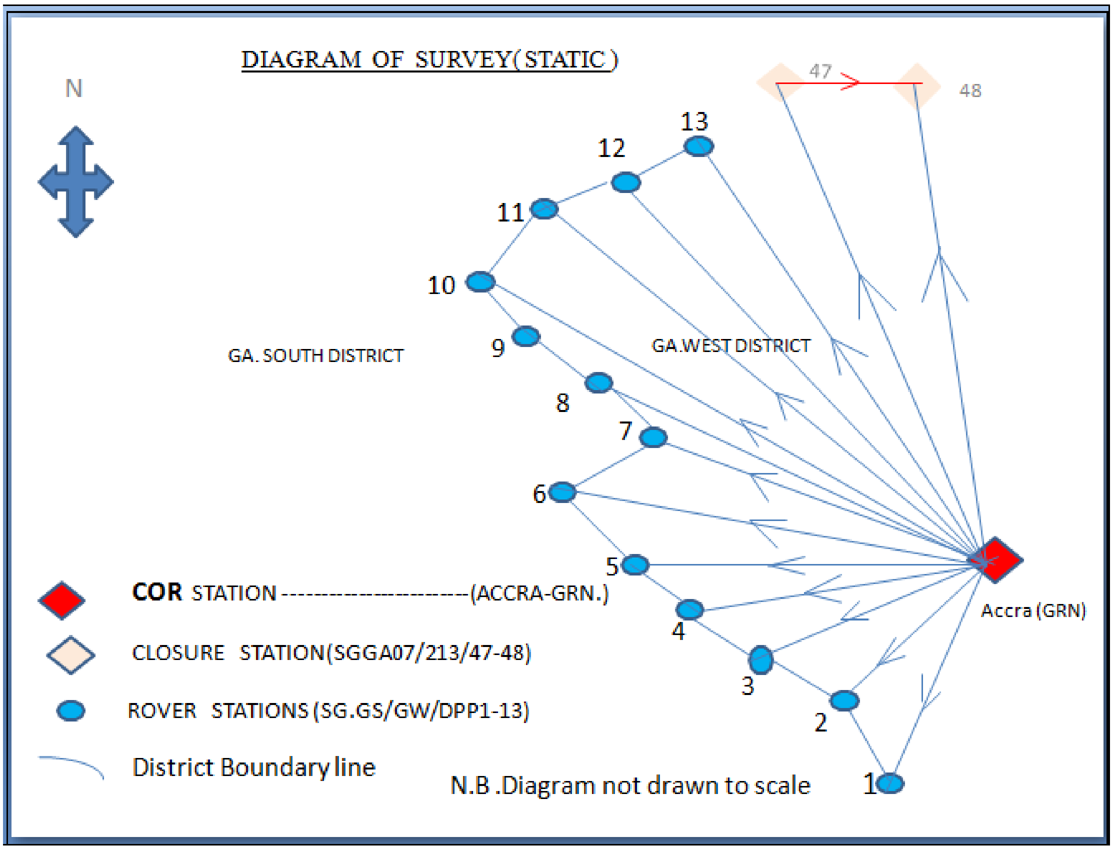


**Figure 3.9: Diagram of Survey for the Static Method**

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.

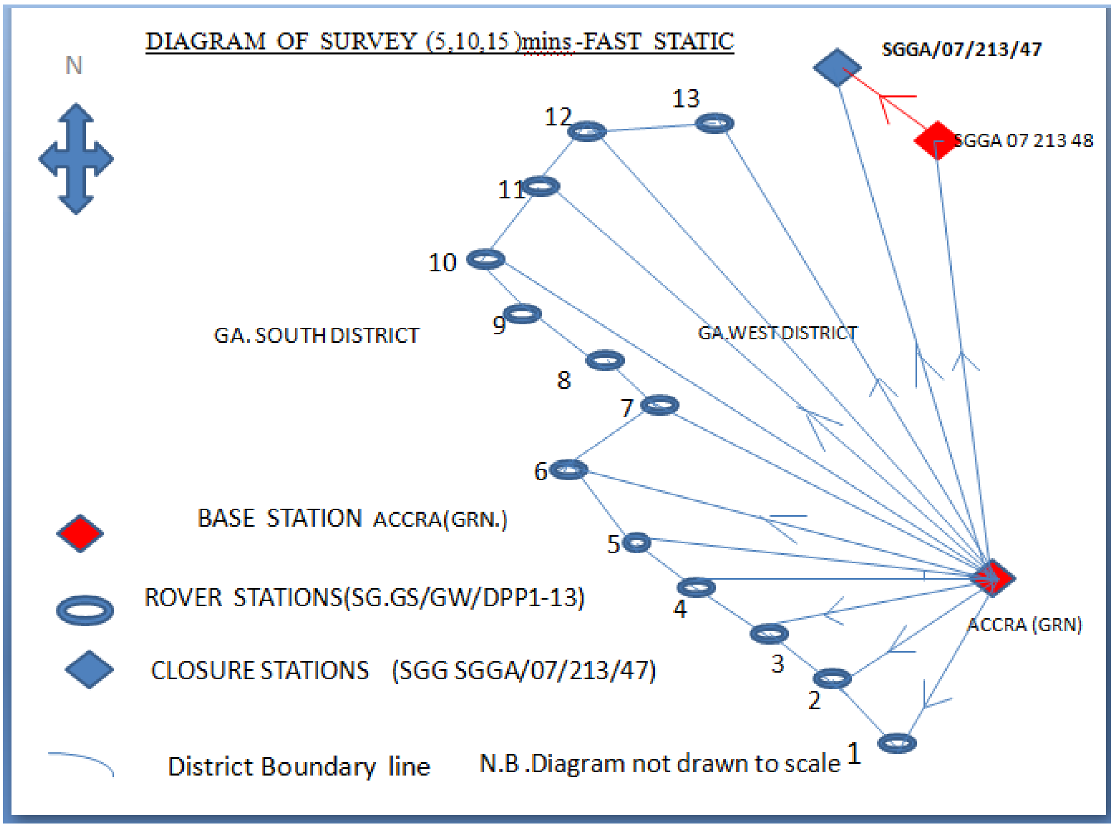


**Figure 3.10: Diagram of Survey for the Fast Static GPS Method.**

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.

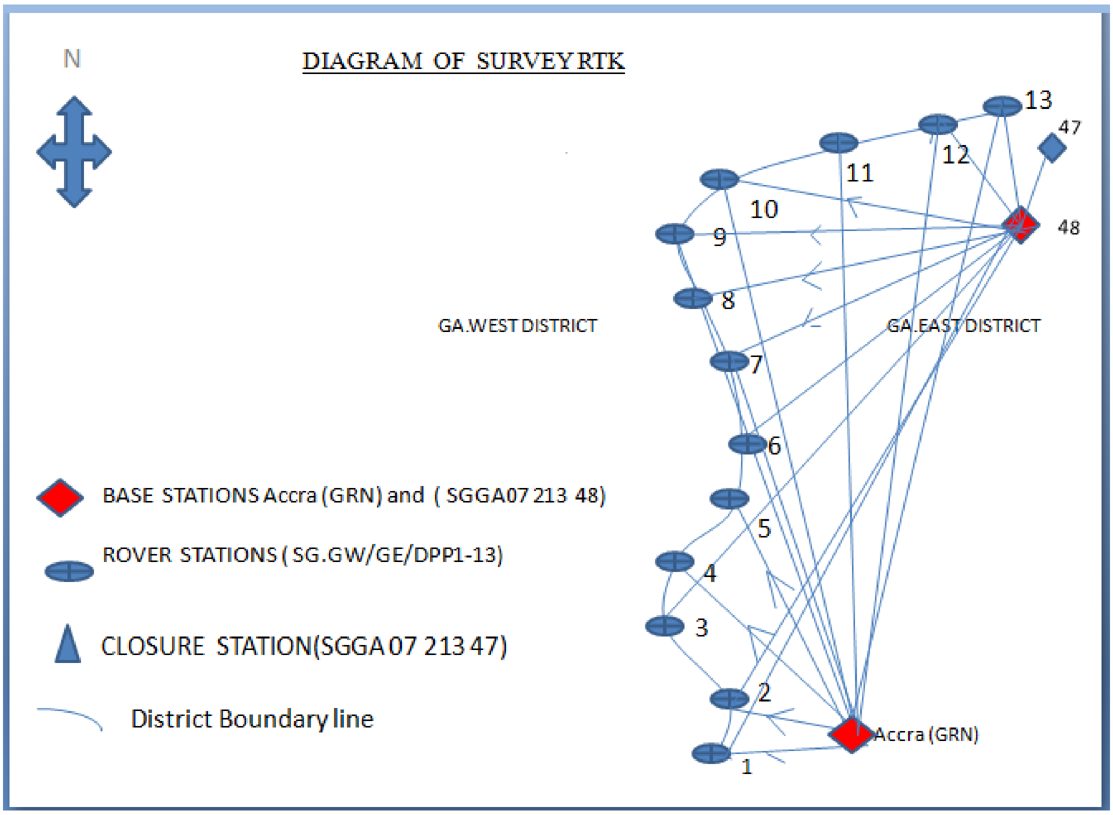


**Figure 3.11: Diagram of Survey for the RTK Method for the urban district boundary line.**

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.

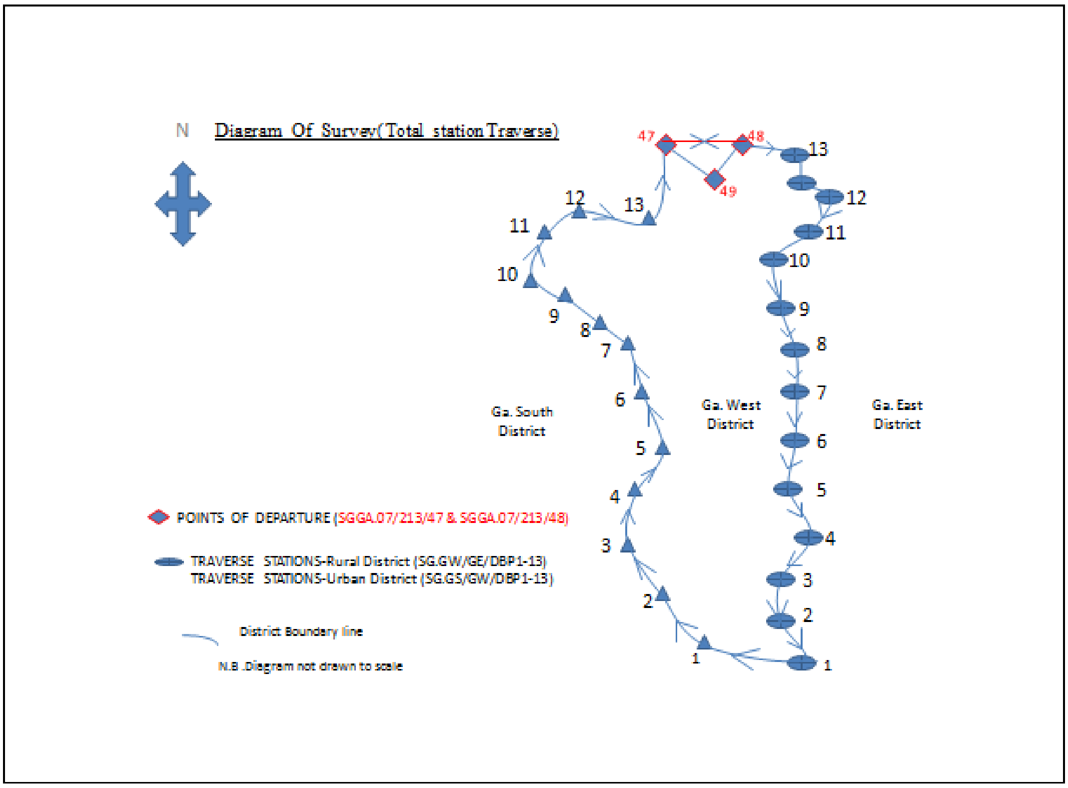


**Figure3.12: Diagram of survey for the Total station method for both Rural and Urban district.**

### 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.

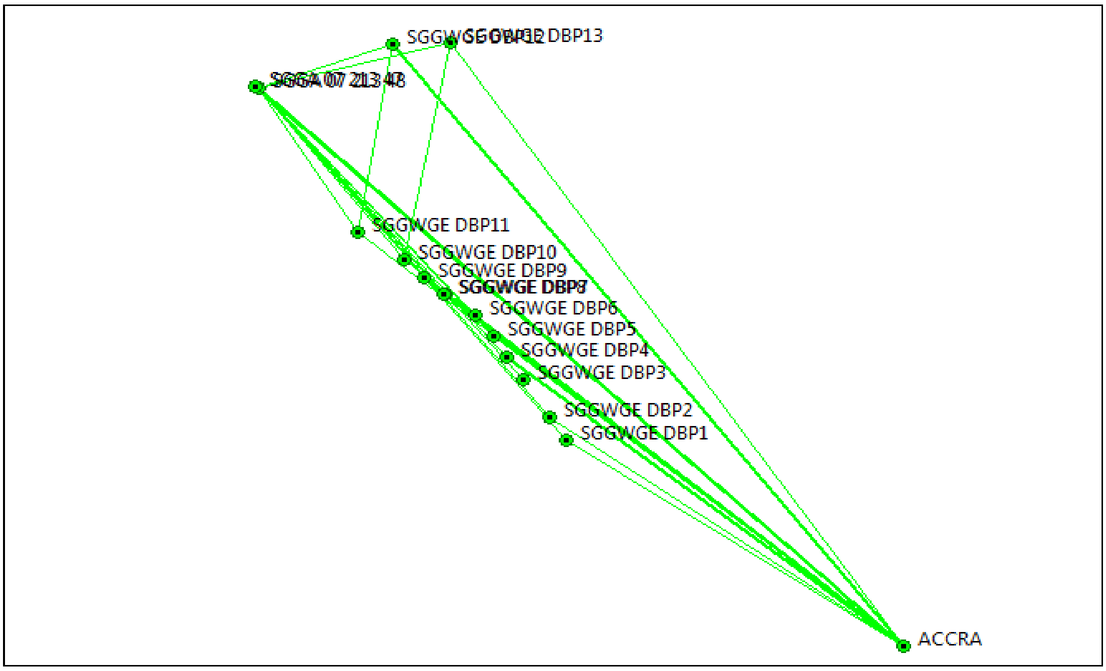


**Figure 4.1: Graphical view of the reference network for Rural district boundary**

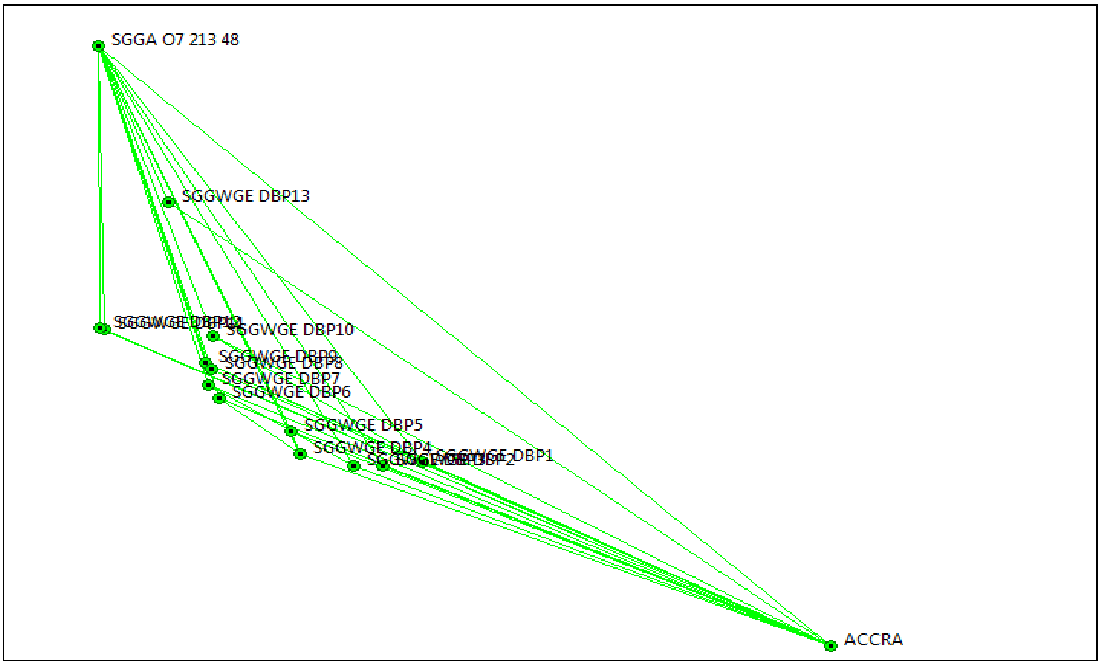


**Figure 4.2: Graphical view of the reference network for Urban district boundary**

### 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**

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

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

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

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

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

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

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

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

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

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

**Normalize Equation (N) is**

$$A_x = L + V \text{ ----------------------------Eqtn. 10}$$

$$(A^T WA)_X = (A^T WL) + (A^T WV) \text{ -------------------- Eqtn. 11}$$

$$\text{But}(A^T WV) = 0 \quad \text{------------------------------------ Eqtn. 12}$$

$$X = (A^T WA)^{-1}.\ (A^T WL) \quad \text{------------------------------Eqtn. 13}$$

$$\text{Standard deviation } (\delta_0) = \sqrt{\frac{V^T WV}{m-n}} \quad \text{----------Eqtn. 14}$$

Where m = number of equations and n = number of unknowns.
The covariance matrix ($\sum$) = $\delta_0^2(A^TWA)^{-1}$

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

**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 |
| 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** |

**Table 4.20: 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 | 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.

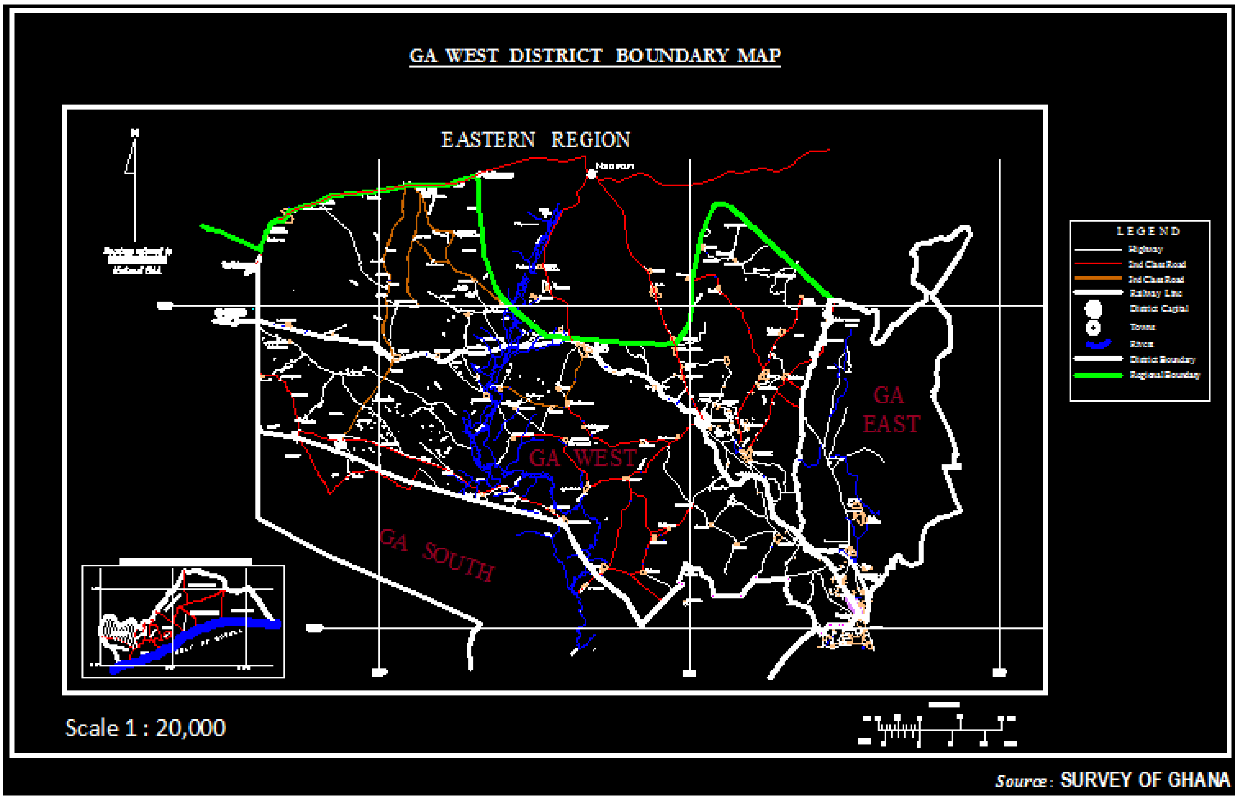

Figure 4.3: Final District Boundary Map

# 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 |

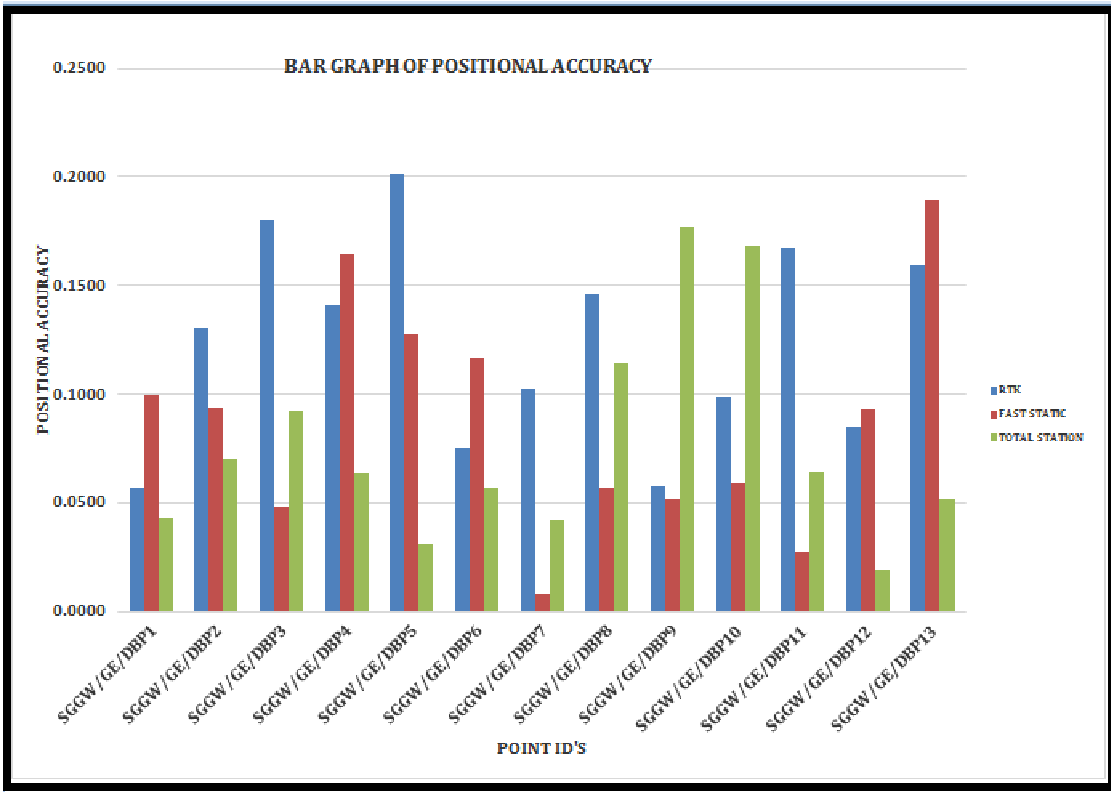


**Figure 5.1: Bar Graph Showing the Positional Accuracy of RTK(5min-Fast static) and Total station methods for the Rural Boundary Points.**

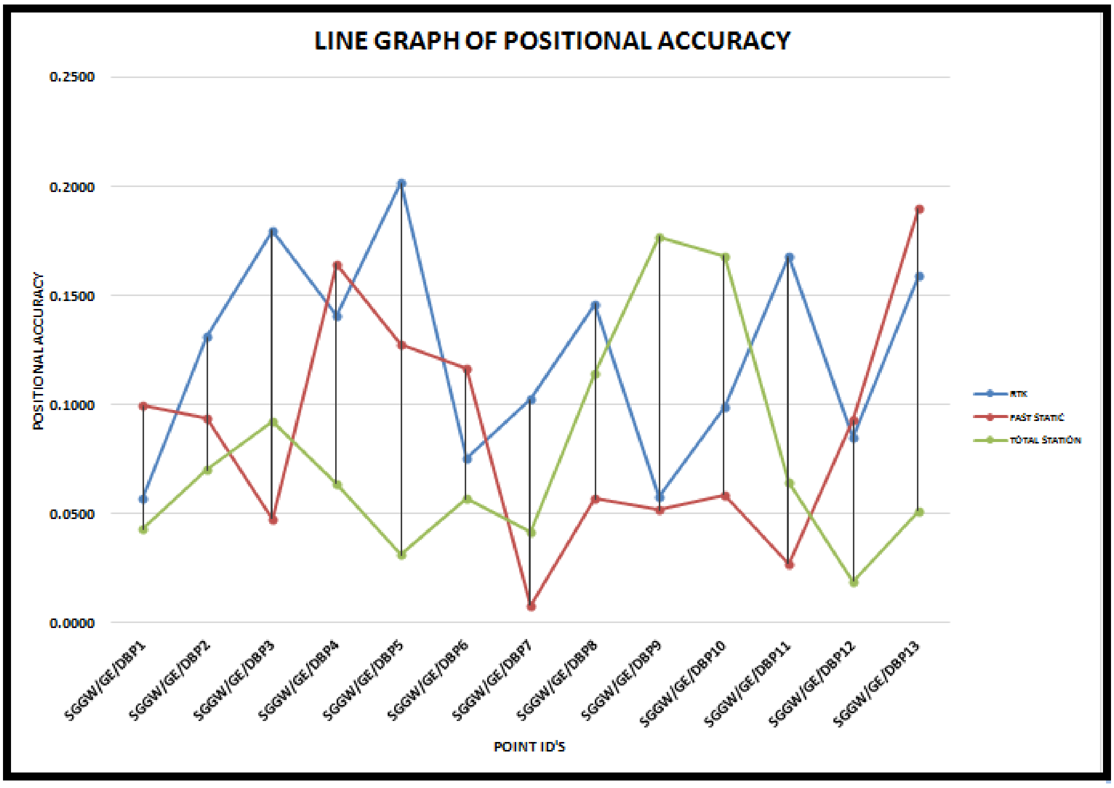


**Figure 5.2: Line Graph Showing the Positional Accuracy of RTK(5min-Fast static) and Total station methods for the Rural Boundary Points.**

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

| PT ID | FnI 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 |

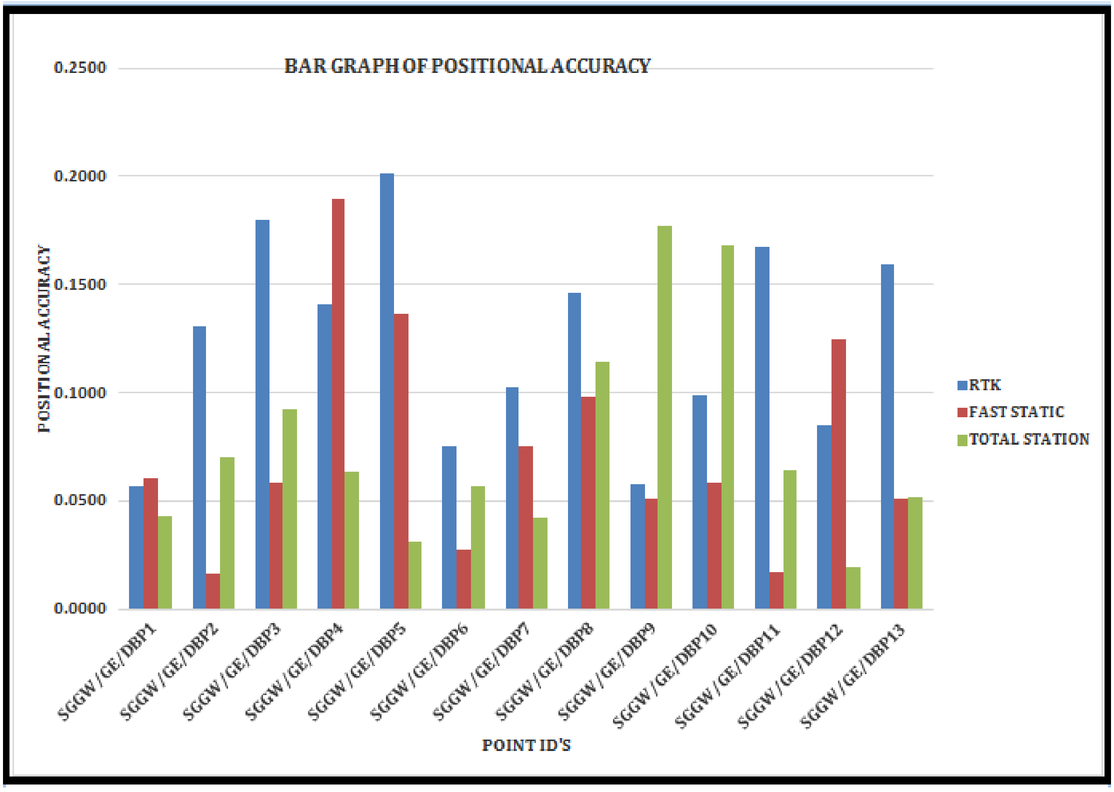


**Figure 5.3: Bar Graph Showing the Positional Accuracy of RTK(10min-Fast static) and Total station method for the Rural Boundary Points.**

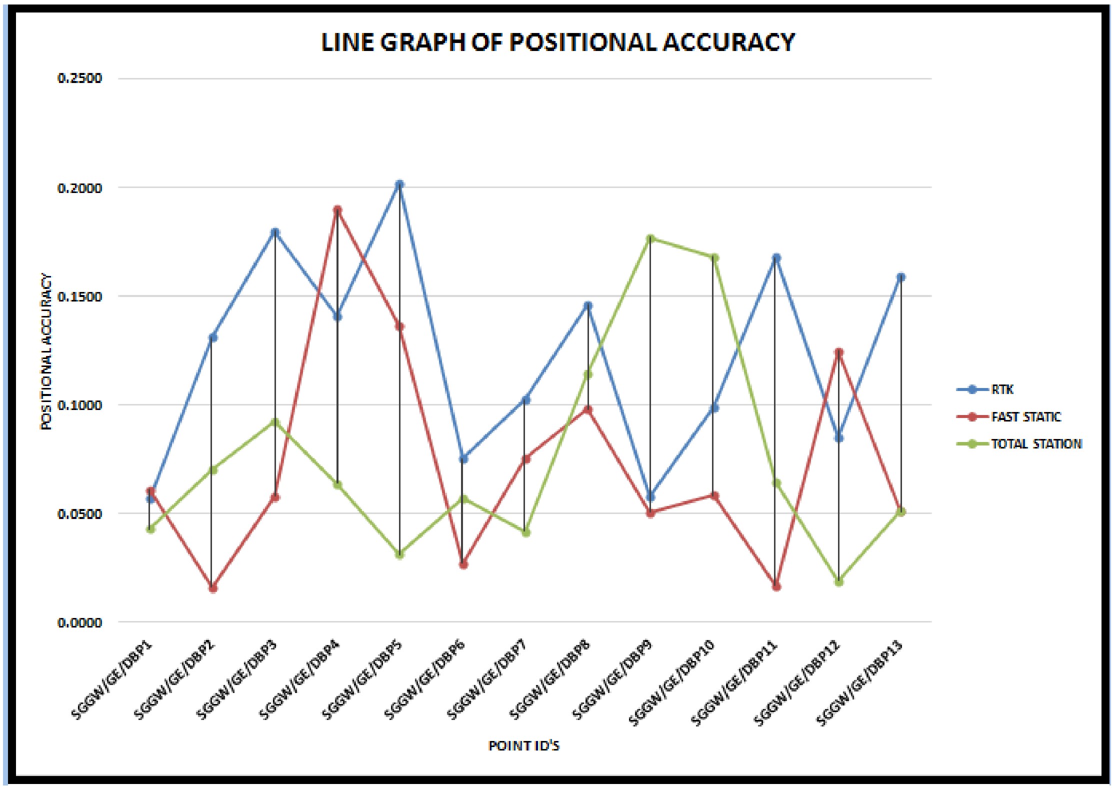


**Figure 5.4: Line Graph Showing the Positional Accuracy for RTK(10min-Fast static)and Total station method for the Rural Boundary Points.**

**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 |

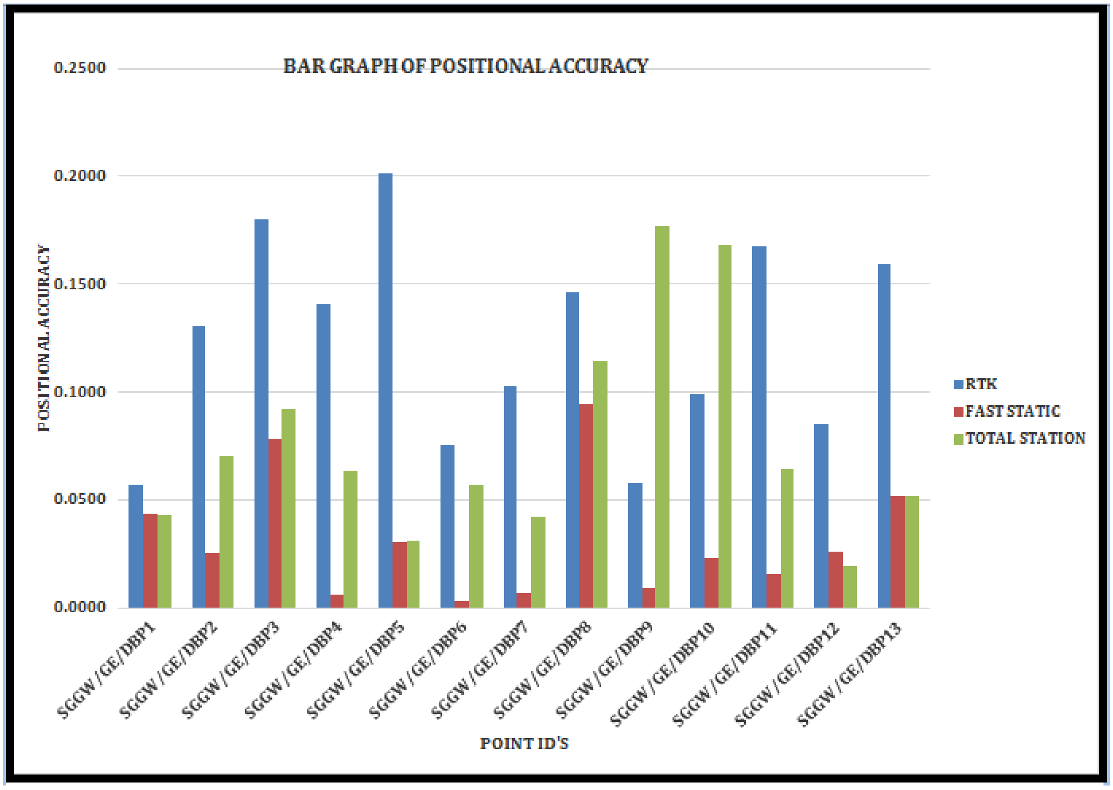


**Figure 5.5: Bar Graph Showing the Positional Accuracy of RTK(15min-Fast static) and Total station method for the Rural Boundary Points.**

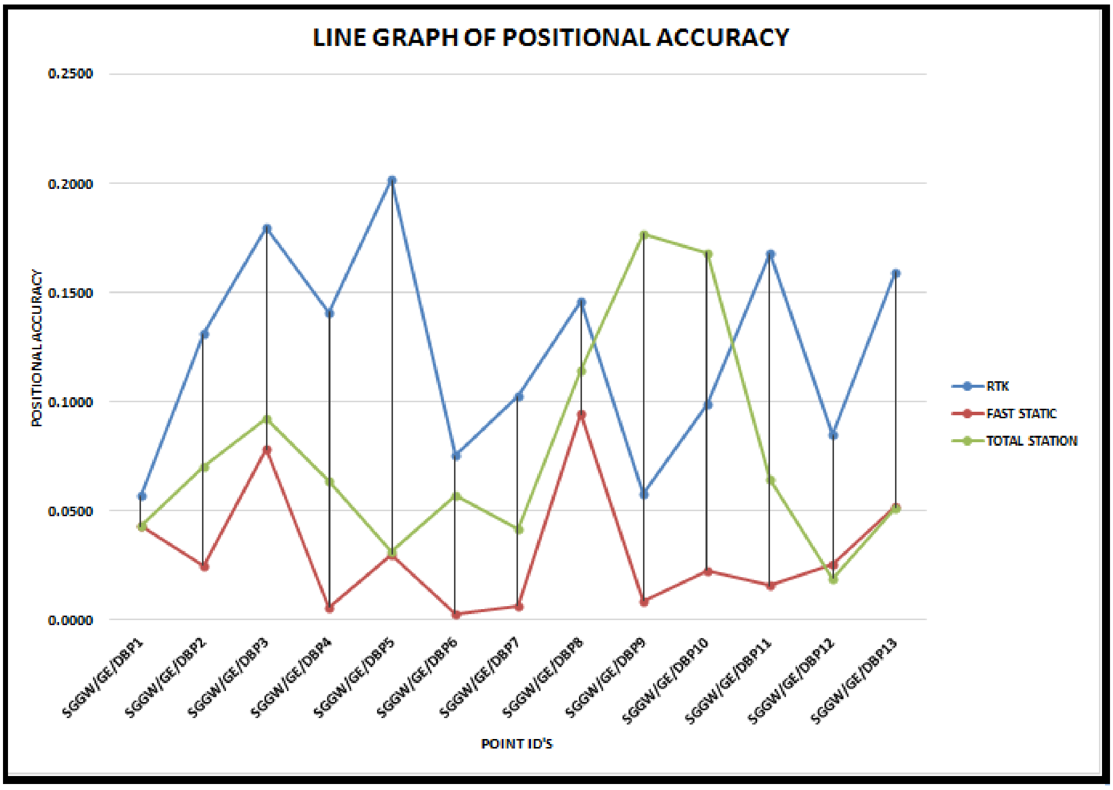


**Figure 5.6: Line Graph Showing the Positional Accuracy for RTK(15min-Fast static)and Total station method for the Rural Boundary Point.**

**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 |

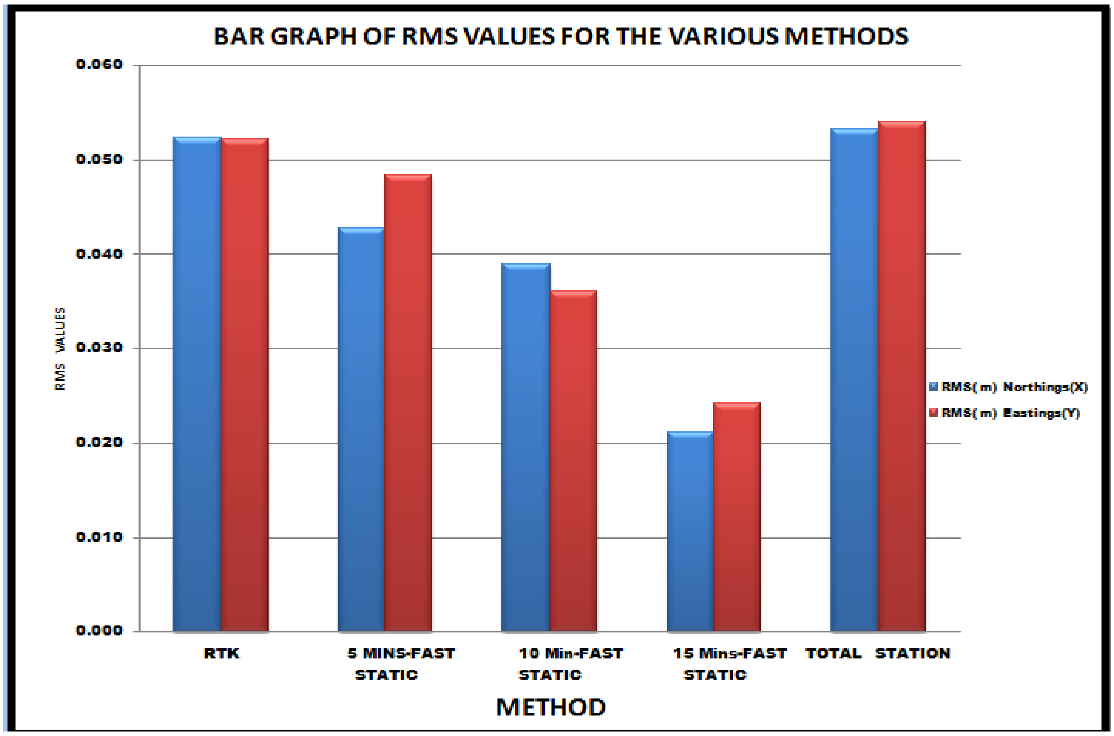


**Figure 5.7: Line Graph showing RMS Error (m) of the RTK GPS(5, 10, 15) mins-Fast static and Total station method for the Rural Boundary Points.**

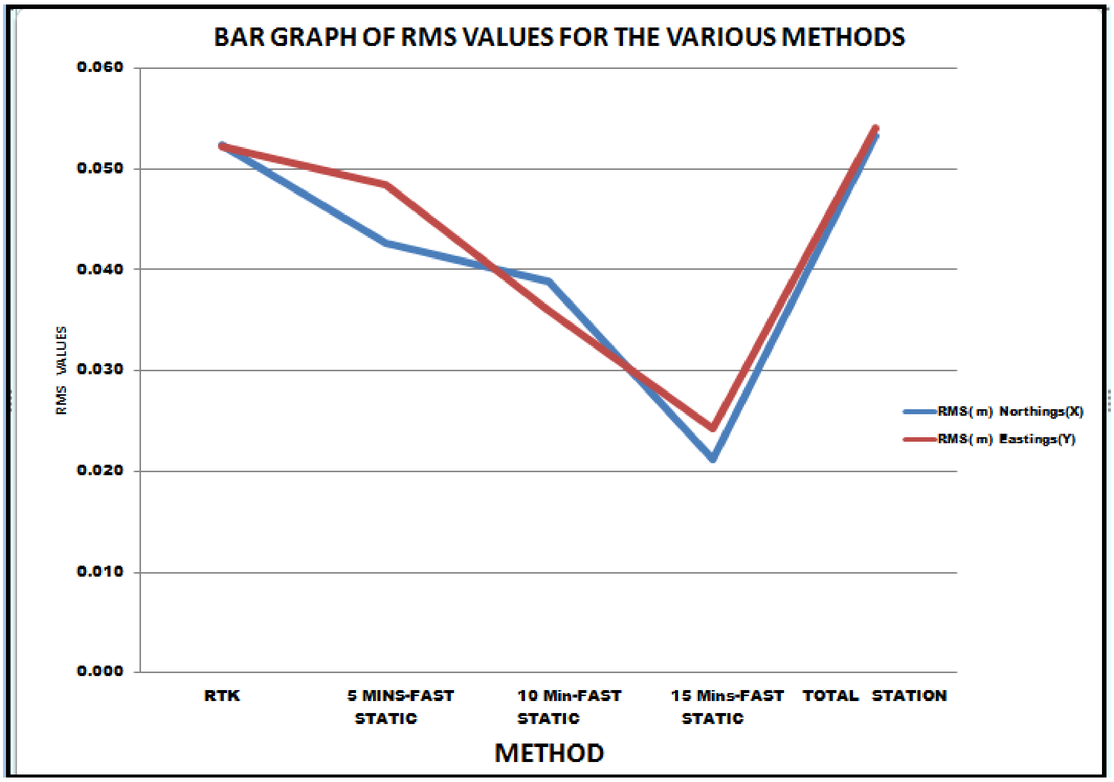


**Figure 5.8: Line Graph showing RMS Error (m) of the RTK GPS (5, 10, 15) mins-Fast static and Total station method for the Rural Boundary Points.**

### 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 |

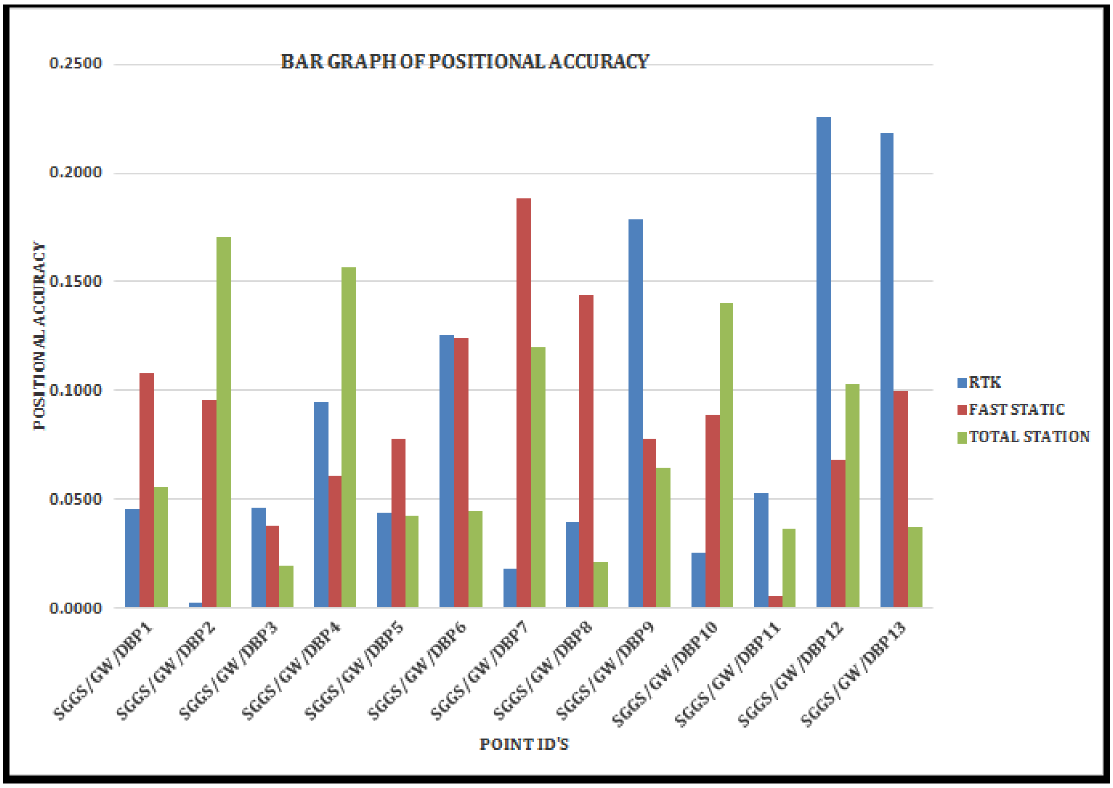


**Figure 5.9: Bar Graph Showing the Positional Accuracy of RTK(5min-Fast static) and Total station method for the Urban Boundary Points.**

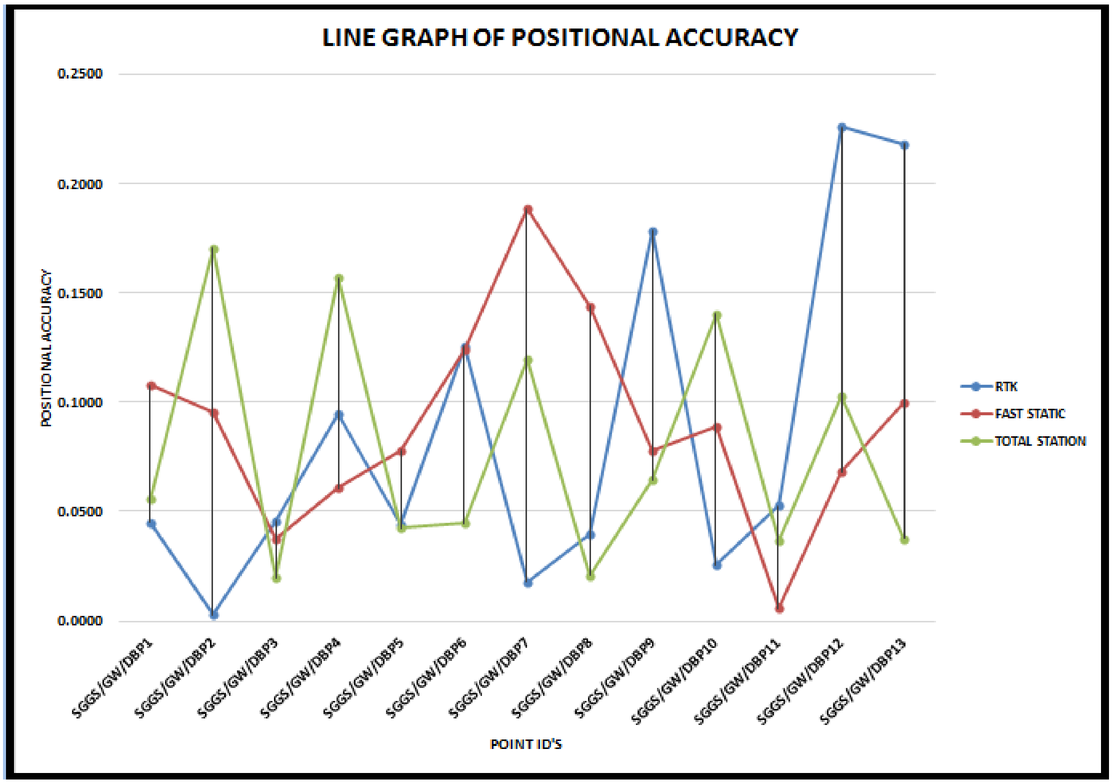


**Figure 5.10: Line Graph Showing the Positional Accuracy of RTK(5min-Fast static and Total station methods for the Urban Boundary Points.**

**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 |

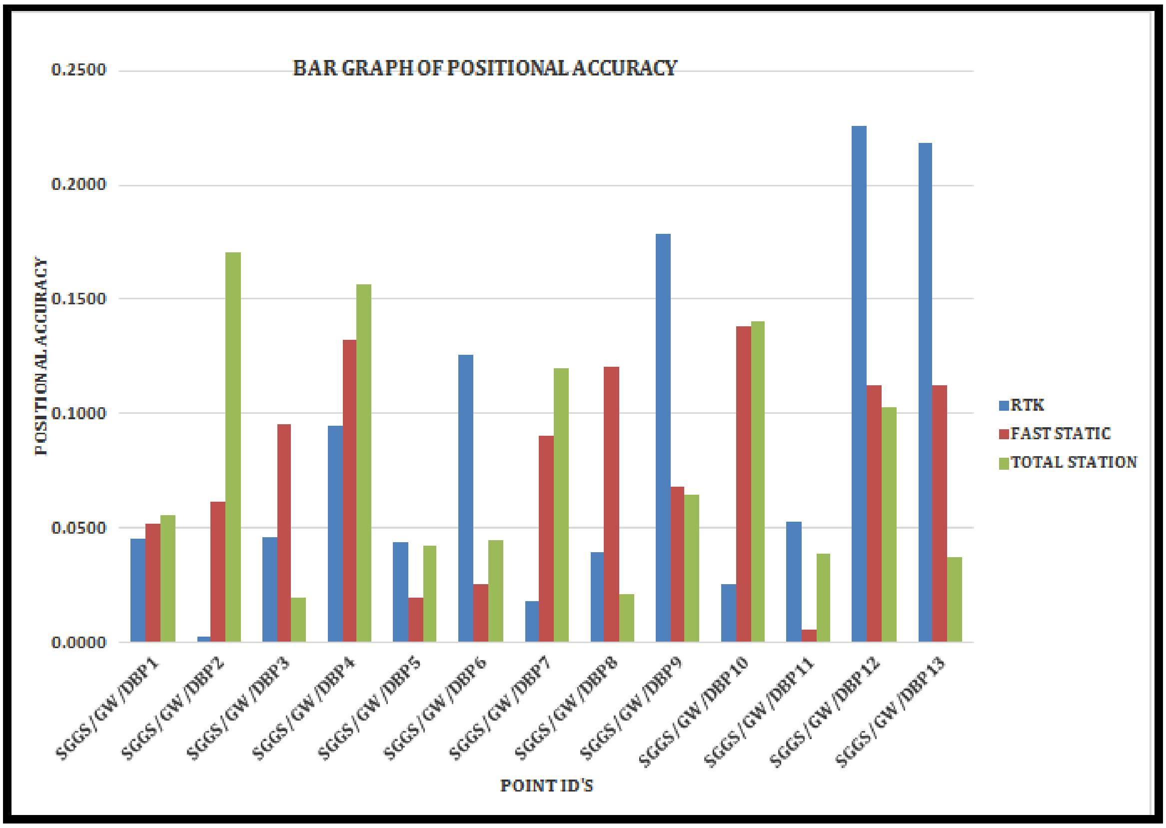


**Figure 5.11:Bar Graph Showing the Positional Accuracy of RTK(10min-Fast static) and Total station method for the Urban Boundary Points.**

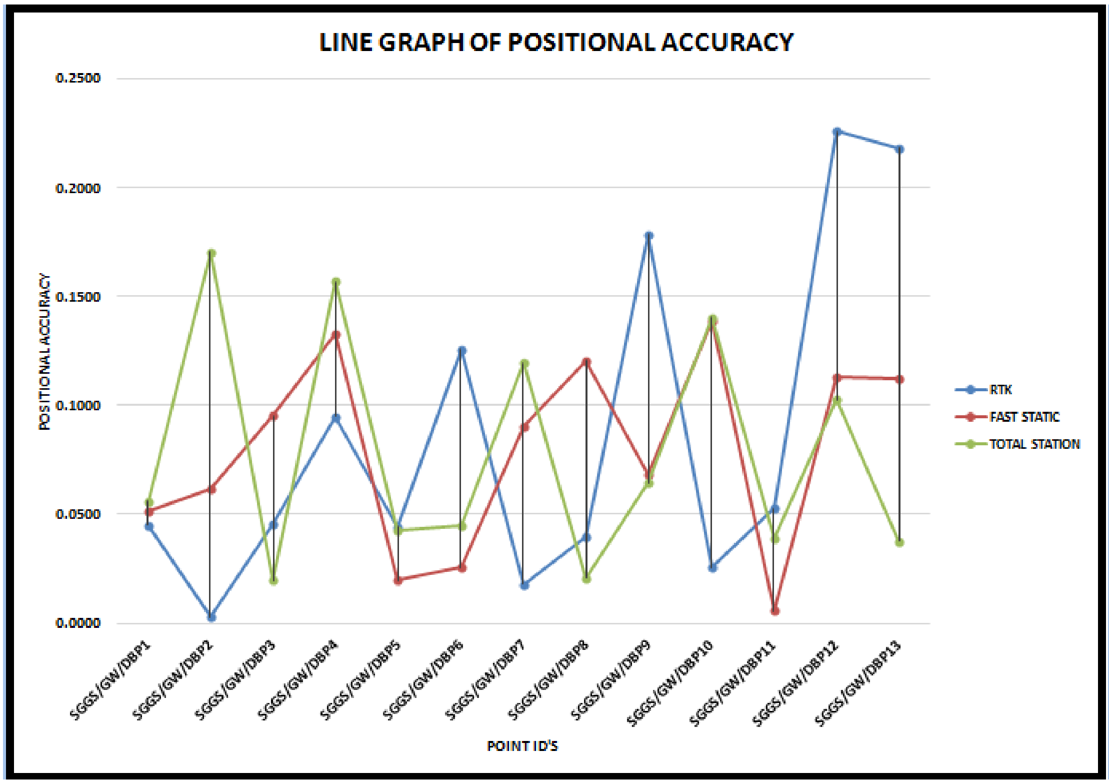


**Figure 5.12: Line Graph Showing the Positional Accuracy of RTK(10min-Fast static) and Total station method for the Urban Boundary Points.**

**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 |

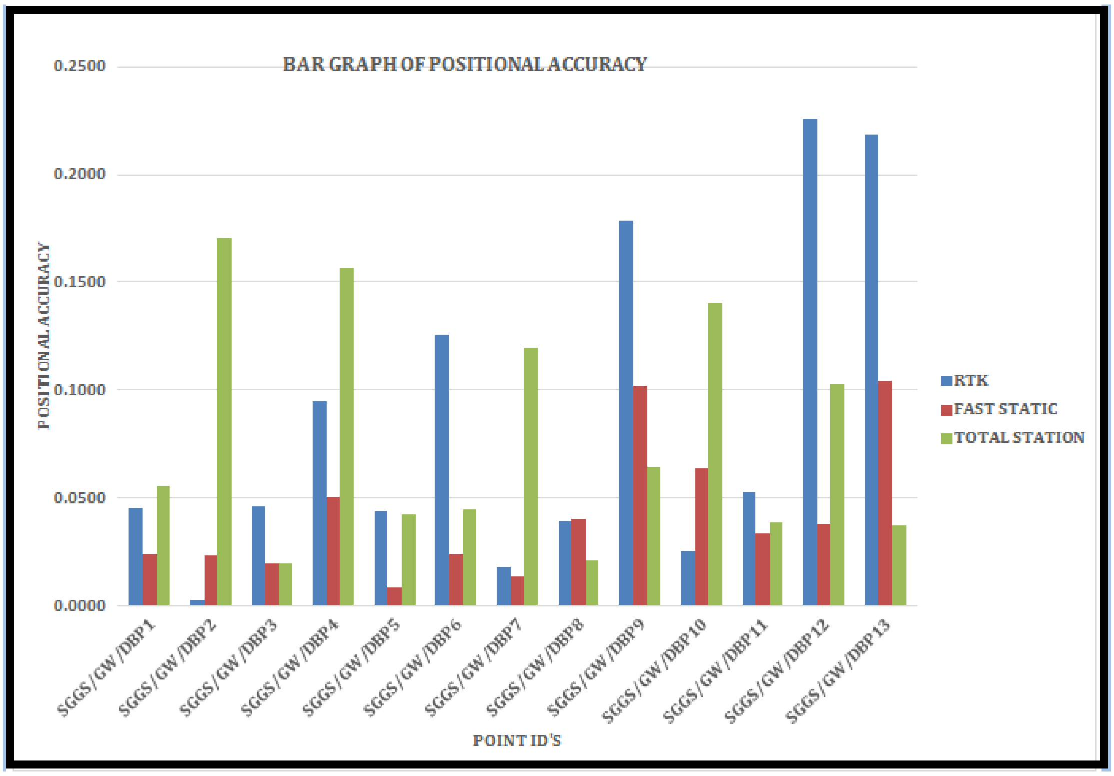


**Figure 5.13: Bar Graph Showing the Positional Accuracy of RTK(15min-Fast static) and Total station method for the Urban Boundary Points.**

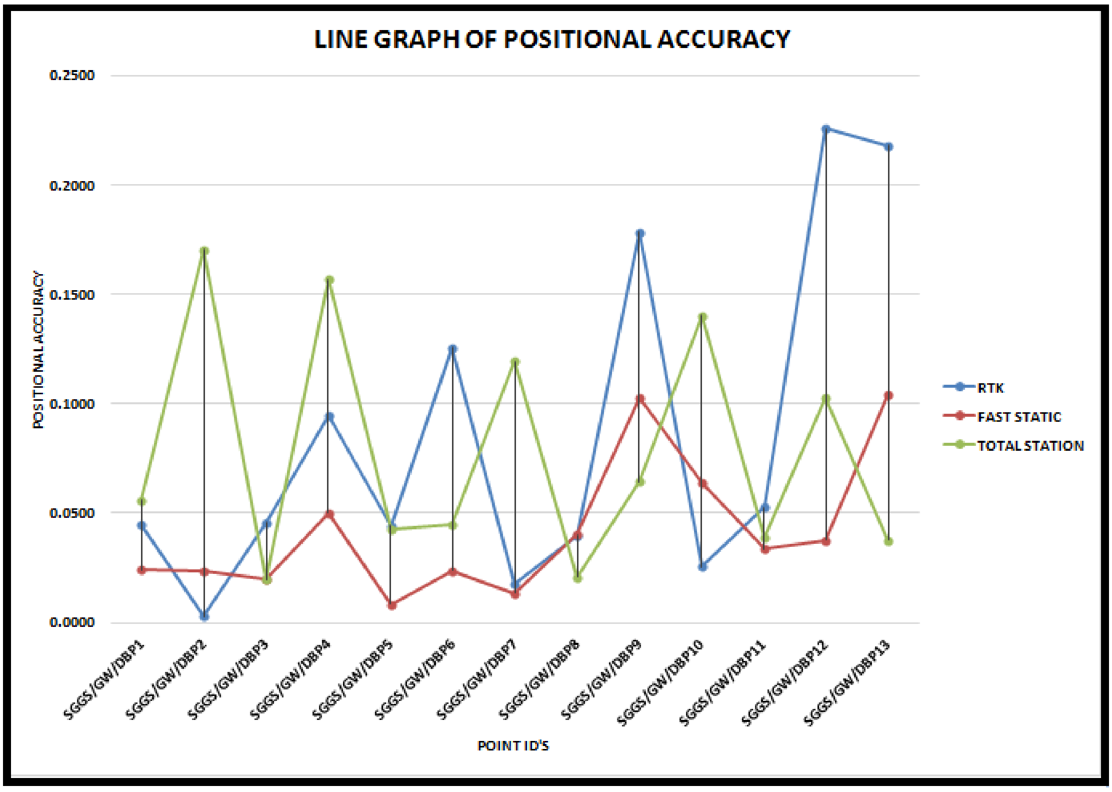


**Figure 5.14: Line Graph Showing the Positional Accuracy of RTK(15min-Fast static) and Total station method for the Urban Boundary Points.**

**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 |

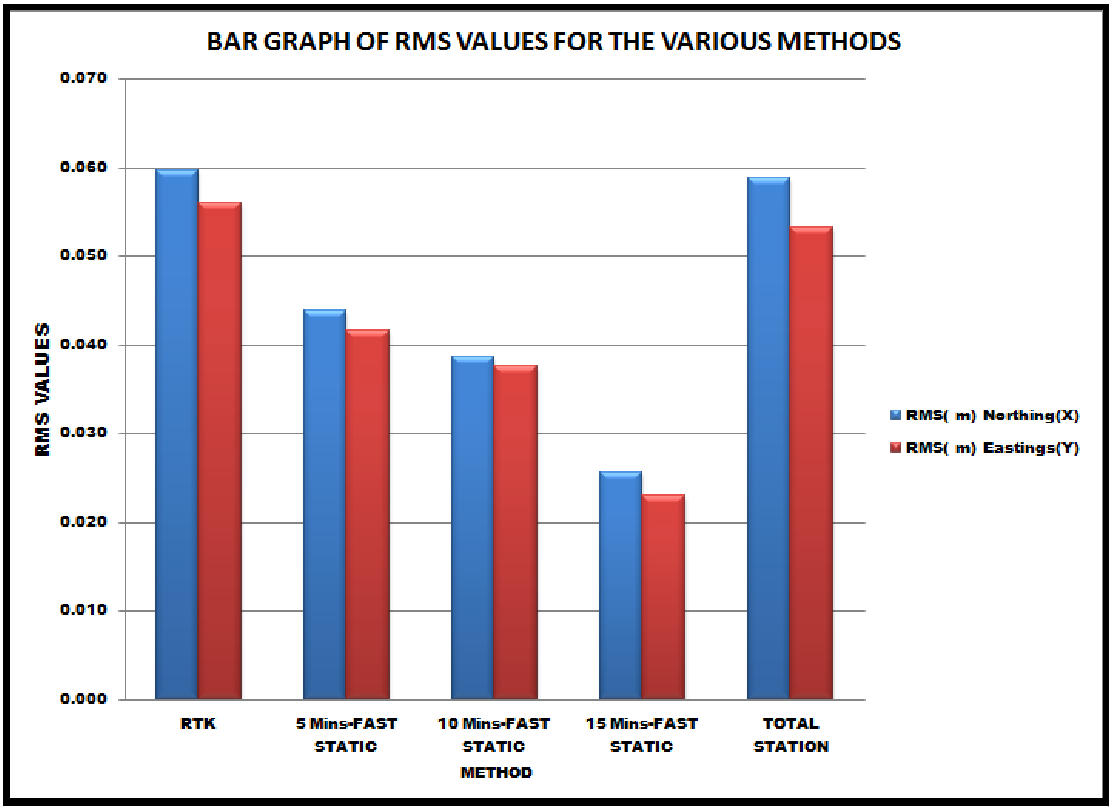


**Figure 5.15: Bar Graph showing RMS Error(m) of the RTK (5,10,15) min-Fast static and Total station methods for the Urban Boundary Points.**

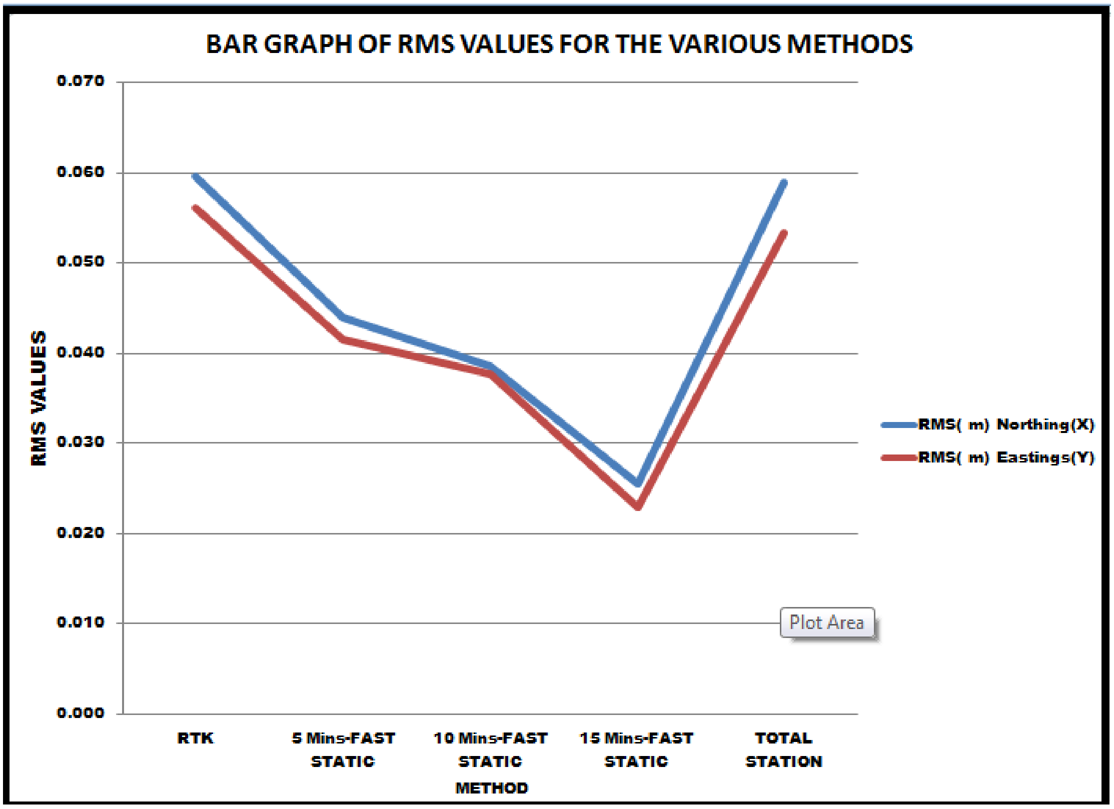


**Figure 5.16: Line Graph showing RMS Error(m) of the RTK (5,10,15) min-Fast static and Total station methods for the Urban Boundary Points..**

### 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) Northings (N) | Easting(E) | Cadastral Standard (1km) 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 Northings (N) | Easting(E) | Cadastral Standard 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** |

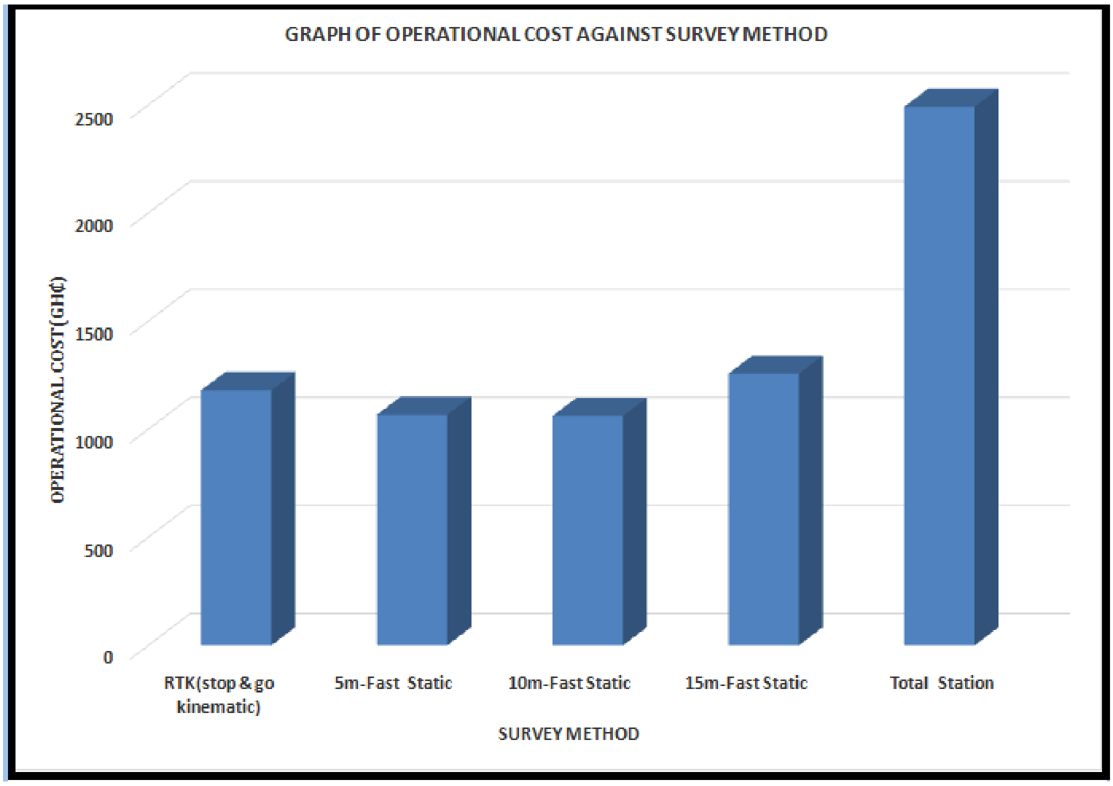


**Figure 5.17: Graph of cost against survey method for rural district boundary survey.**

**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** |

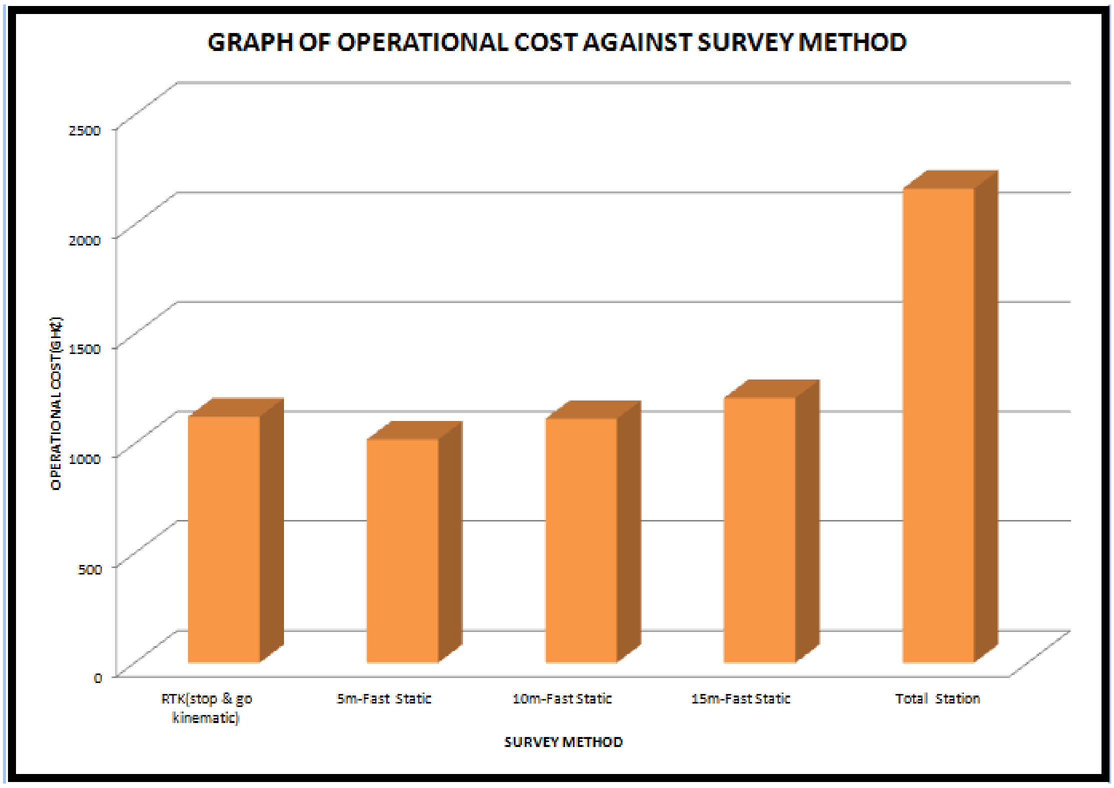


**Figure 5.18: Graph of cost against survey method for urban district boundary survey.**

## 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 **t**he 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**

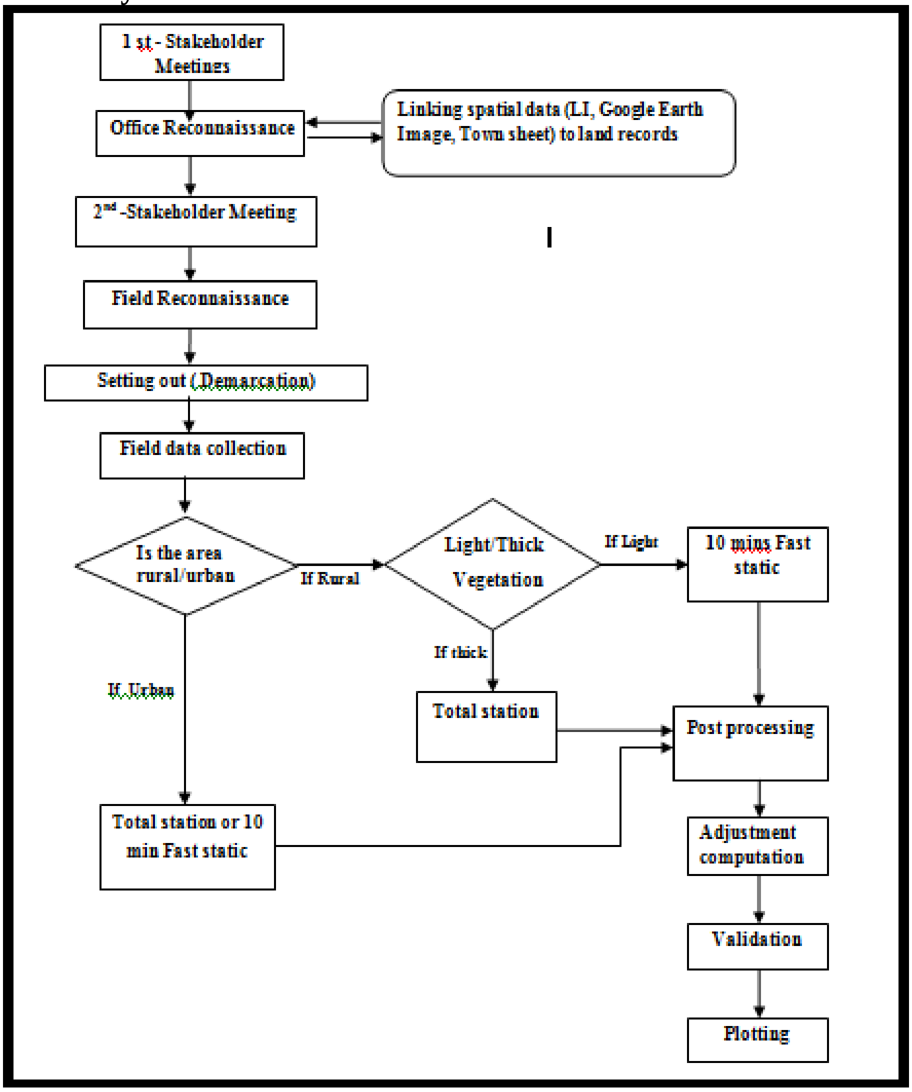


**Figure 6.1: Recommended Workflow diagram for Urban/Rural District boundary project**

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)<br>SGGA 07 213 48-SGGS.GW DBP 4(02-Jun-14 2:54:30 PM)<br>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)<br>SGGA 07 213 48-SGGS.GW DBP 4(02-Jun-14 2:54:30 PM)<br>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)<br>SGGA 07 213 48-SGGS.GW DBP 4(02-Jun-14 2:54:30 PM)<br>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)<br>SGGA 07 213 48-SGGS.GW DBP 3(02-Jun-14 12:31:00 PM)<br>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)<br>SGGA 07 213 48-SGGS.GW DBP 3(02-Jun-14 12:31:00 PM)<br>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)<br>SGGA 07 213 48-SGGS.GW DBP 3(02-Jun-14 1:32:45 PM)<br>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)<br>SGGA 07 213 48-SGGS.GW DBP 3(02-Jun-14 1:32:45 PM)<br>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)<br>SGGA 07 213 48-SGGS.GW DBP 3(02-Jun-14 12:31:00 PM)<br>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)<br>SGGA 07 213 48-SGGS.GW DBP 3(02-Jun-14 1:32:45 PM)<br>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)<br>SGGA 07 213 48-SGGS.GW DBP1(02-Jun-14 11:37:30 AM)<br>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(**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 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<br>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<br>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**

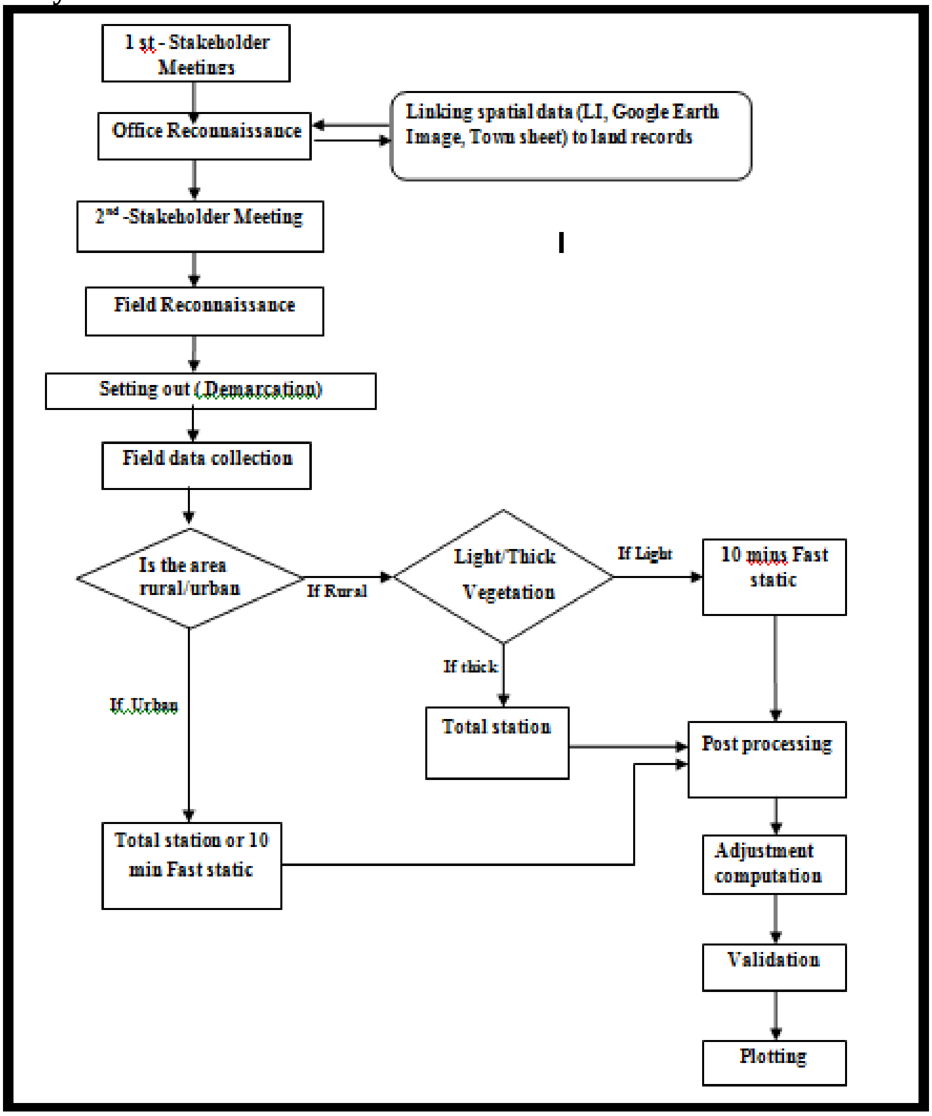


**Figure AC: 1 Workflow diagram for Urban / Rural District boundary project**

## Appendix D: Projection Formulae

### 1. Transverse Mercator projection Formulae

**Transverse Mercator mapping from Ellipsoid to the plane**

$$t = \tan\phi$$

$$\omega = \lambda - \lambda_0 \qquad \nu = \frac{a}{\sqrt{1-e^2\sin^2\phi}} \qquad \rho = \frac{a\left(1-e^2\right)}{\left(1-e^2\sin^2\phi\right)^{\frac{3}{2}}}$$

$$\psi = \frac{\nu}{\rho}$$

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

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

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

*Where*

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

**Easting Coordinate of point (E)**

$$E = E' - E_0$$

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

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

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

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

**Northing Coordinate of point (N)**

$$N = N' + N_0$$

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

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

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

$$Term3 = \frac{\omega^6}{720}\nu\sin\phi\cos^5\phi\left[8\psi^4\left(11-24t^2\right) - 28\psi^3\left(1-6t^2\right) + \psi^2\left(1-32t^2\right) - \psi\left(2t^2\right) + t^4\right]$$

$$Term4 = \frac{\omega^8}{40320}\nu\sin\phi\cos^7\phi\left(1385 - 3111t^2 + 543t^4 - t^6\right)$$

**Transverse Mercator Inverse Mapping from Plane to Ellipsoid**

$$\phi' = \sigma + \left(\frac{3n}{2} - \frac{27n^3}{32}\right)\sin 2\sigma + \left(\frac{21n^2}{16} - \frac{55n^4}{32}\right)\sin 4\sigma + \left(\frac{151n^3}{96}\right)\sin 6\sigma + \left(\frac{1097n^4}{512}\right)\sin 8\sigma$$

$$n = \frac{a-b}{a+b} \qquad G = a(1-n)\left(1-n^2\right)\left(1 + \frac{9n^2}{4} + \frac{225n^4}{64}\right)\left(\frac{\pi}{180}\right)$$

$$\sigma = \frac{m'\pi}{180G} \qquad m' = m_0 + \frac{N'}{k_0} \qquad N' = N - N_0$$

$$t = \tan\phi' \;;\; x = \frac{E'}{k_0\nu} \;;\; y = \frac{(E')^2}{k_0^{\,2}\rho\nu} \;;\; E' = E - E_0$$

$LONGITUDE OF\ POINT(\lambda)$

$$\lambda = \lambda_0 + Term1 - Term2 + Term3 - Term4$$

$$Term1 = x\sec\phi' \;;\quad Term2 = \frac{x^3\sec\phi'}{6}\left(\psi + 2t^2\right)$$

$$Term3 = \frac{x^5\sec\phi'}{120}\left[-4\psi^3\left(1-6t^2\right) + \psi^2\left(9-68t^2\right) + 72\psi t^2 + 24t^4\right]$$

$$Term4 = \frac{x^7\sec\phi'}{5040}\left(61 + 662t^2 + 1320t^4 + 720t^6\right)$$

$LATITUDE\ OF\ POINT(\phi)$

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

$$Term1 = \left(\frac{t}{k_0\rho}\right)\left(\frac{E'x}{2}\right) \;;\; Term2 = \left(\frac{t}{k_0\rho}\right)\left(\frac{E'x^3}{24}\right)\left[-4\psi^2 + 9\psi\left(1-t^2\right) + 12t^2\right]$$

$$Term3 = \left(\frac{t}{k_0\rho}\right)\left(\frac{E'x^5}{720}\right)\left[\begin{array}{l}8\psi^4\left(11-24t^2\right) - 12\psi^3\left(21-71t^2\right) + 15\psi^2\left(15-98t^2+15t^4\right)\\ +180\psi\left(5t^2-3t^4\right) + 360t^4\end{array}\right]$$

$$Term4 = \left(\frac{t}{k_0\rho}\right)\left(\frac{E'x^7}{40320}\right)\left[1385 + 3633t^2 + 4095t^4 + 1575t^6\right]$$

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

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

$$Northing,\ N = FN + k_0\left\{M - M_0 + \upsilon\tan\phi[A^2/2 + \left(5-T+9C+4C^2\right)A^2/24 + \left(61-58T+T^2+600C-330e'^2\right)A^6/720]\right\}$$

Where

$T = \tan^2 \phi$

$C = \dfrac{e^2 \cos^2 \phi}{1-e^2}$

$A = (\lambda - \lambda_0)\cos\phi,$ with $\lambda$ and $\lambda_0$ in radians

$$\upsilon = \frac{a}{\left(1-e^2 \sin^2 \phi\right)^{\frac{1}{2}}}$$

$$M = a\left[\begin{array}{l}\left(1-e^2/2-3e^2/64-5e^6/256-...\right)\phi-\left(3e^2/8+3e^4/32+45e^6/1024+...\right)\sin 2\phi \\ \quad +\left(15e^4/256+45e^6/1024+...\right)\sin 4\phi-\left(35e^6/3072+...\right)\sin 6\phi+...\end{array}\right]$$

$$\lambda_0 = [ZW]-\left[\lambda_1+\frac{W}{2}\right]$$

$Z = INT\left(\left(\lambda+\lambda_1+W\right)/W\right)$ with $\lambda,\lambda_1$ and $W$ in degrees. If $\lambda$<0, $\lambda$=$\left(\lambda+360\right)$degrees

**Universal Transverse Mercator Inverse Mapping from Plane to Ellipsoid**

$$\phi = \phi_1-\left(\upsilon_1 \tan\phi_1/\rho_1\right)\Big[D^2/2-\left(5+3T_1+10C_1-4C_1^2-9e'^2\right)D^4/24$$
$$+\left(61+90T_1+298C_1+45T_1^2-252e'^2-3C_1^2\right)D^2/720\Big]$$

$$\lambda = \lambda_0+\frac{\left[D-\left(1+2T_1+C_1\right)D^3/6+\left(5-2C_1+28T_1-3C_1^2+8e'^2+24T_1^2\right)D^5/120\right]}{\cos\phi_1}$$

$$\upsilon_1 = \frac{a}{\left(1-e^2\sin^2\phi_1\right)^{\frac{1}{2}}} \qquad \rho_1 = \frac{a\left(1-e^2\right)}{\left(1-e^2\sin^2\phi_1\right)^{\frac{3}{2}}}$$

$\phi_1$ 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?

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

Where

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

$$T_1 = \tan^2\phi_1\ ;\ C_1 = e'^2\cos^2\phi_1\ ;\ e'^2 = \frac{e^2}{\left(1-e^2\right)}\ ;\ D = \frac{E-FE}{\upsilon_1 k_0}$$