Ramification of Datum and Ellipsoidal Parameters on Post Processed Differential Global Positioning System (DGPS) Data – A Case Study*

I. Yakubu, and B. Kumi-Boateng

Yakubu, I. and Kumi-Boateng, B. (2015), "Ramification of Datum and Ellipsoidal Parameters on Post Processed Differential Global Positioning System (DGPS) Data – A Case Study", *Ghana Mining Journal*, Vol. 15, No. 1, pp. 1 - 9.

Abstract

The World Geodetic System 1984 (WGS 84) is the global reference frame upon which Global Positioning System (GPS) observations are referenced to. Observations in the frame are in latitudes, longitudes and ellipsoidal heights. For use in a particular locality, it is necessary to convert these into the local coordinate system. In Ghana, the datum and ellipsoidal parameters for Ghana War Office and Clarke 1880 are used for the transformation of the GPS coordinates from the WGS 84 datum system to the Ghana National Grid System. This paper therefore examines post processed DGPS data using these two datum and ellipsoidal definitions separately. Dual frequency DGPS data were collected from 19 survey pillars (*ie* SGW D224/14/1 to SGW D224/14/19) and post processed using Clarke 1880 datum and ellipsoidal parameters. The raw data was also post processed using Ghana War Office datum and ellipsoidal parameters. The results for the two indicated an average difference of 7.23 m (23.72 ft) for 19 stations. This certainly does not fall within the tolerance set by Survey and Mapping Division (SMD) of the Lands Commission for cadastral plans production, which is +/- 0.9114 m (+/-3 ft). A composite plan using the post processed data from the two datum and ellipsoidal definitions was produced. The plan shows an overlapping area by the use of the two coordinates to plot, an indication of a potential conflict between ownership on paper which may not necessary exist on the ground.

Keywords: Differential, Global Positioning System, Datum and Ellipsoidal Parameters

1 Introduction

The national geodetic reference system is at the core of all positioning activities and the collection and management of spatial data. The drive for better accuracies in industry requires that the state agencies responsible for maintaining the geodetic datum continually assess the suitability of the datum for the current and potential applications that rely on the datum (Kotzev, 2013). It is equally important for state institutions charged with the responsibility of managing spatial data to be interested in the datum parameters that are used in processing spatial data. This will not only guarantee reliability in the data generated, but will also help in sanitising spatial data collection, processing and administration. Presently, the Global Positioning System (GPS) has found wide range of use especially in the area of spatial data collection in surveying and mapping.

The GPS is used for relative or absolute positioning. The relative positioning is the preferred positioning method since accuracy assessment of positions can be ascertained. The World Geodetic System 1984 (WGS84) is used as a global standard upon which GPS observations are referenced to. The World Geodetic System 1984, (WGS84), according to El-Rabbany (2002) is a 3-D Earth-Centered reference system developed by the former United State Defense Mapping Agency now incorporated into a new agency, National Imagery and Mapping Agency (NIMA). It is argued that it is the official GPS reference system. In other words, a GPS user who employs the broadcast ephemeris in the solution process will obtain coordinates in the WGS 84 System. The WGS 84 ellipsoid has an equatorial radius, (a), being 6 378.137 km, polar radius (b) 6 356 .752 km and inverse flattening (1/f) as 298.257223563.

Notwithstanding its advantages, GPS usage in Ghana is problematic due to a number of reasons notable among them being the lack of a well-defined coordinate system and parameters needed to transform GPS coordinates into local coordinates and vice versa (Fosu, 2006). Different projections and datum definitions have been applied in Ghana.

One of the first datum was the Accra Datum 1929 used for the ellipsoid of War Office 1926, which can still be found on recent maps. The War Office projection (rectangular polyconic projection) was defined in 1853 and was mainly used in the late 19^{th} Century. In 1977 the datum was changed to

*Manuscript received March 4, 2015
Revised version accepted May 12, 2015*

Leigon Datum 1977 used for the ellipsoid of Clarke 1880 (Anon., 2008).

All the different datum definitions (Clarke 1880 and War Office) that have been used in Ghana have different datum ellipsoid parameters. There, however, appear to be no clear cut regulation as to which datum definition to use and where to use it. This has given rise to a situation where users of these datum definitions use their discretion to choose which datum definition to use and where to use it, with little or no regard to its consequence. This generates a lot of confusion in the data generated, and, therefore, there is no consistency of GPS data from different sources in the country. This makes data integration very difficult.

An un-informed usage of coordinates from both sources, (Clarke 1880 and War Office datum ellipsoid generated coordinates), without the provision of conversion formulae between the two series and a clear annotation difference between plans in both frames would invariably result in the creation of two parallel map series at large scale with overlaps which may not necessarily exist on the ground (Ayer and Fosu, 2008).

This paper, therefore, examines the post processed Differential Global Positioning System(DGPS) data using different datum and ellipsoid parameters by varying the observation distances from the reference station, and also determines if there are any differences and whether these differences, if any, fall within the tolerances set by the Survey and Mapping Division (SMD).

1.1 Reference Coordinate System for GPS

In determining the positions of points on Earth from satellite observations according to Ghilani and Wolf (2008) three different reference coordinate systems are important. First of all, satellite positions at the instant they are observed are specified in the "space related" satellite reference coordinate systems. There are three dimensional rectangular systems defined by the satellite orbits. Satellite positions are then transferred into a three dimensional rectangular geocentric coordinate system which is physically related to the Earth. As a result of GPS observations, the positions of new points on Earth are determined in this coordinate system. Finally, the geocentric coordinates are transformed into the more commonly used and locally oriented geodetic coordinate system.

1.1.1 The Satellite Reference Coordinate System

The position of a point in space at any instant of time may be defined in terms of coordinates in several different systems (Olliver and Clenddinning, 1978). Once a satellite is launched into orbit, its movement thereafter within that orbit is governed primarily by the Earth's gravitational force. However, there are a number of other lesser factors involved including the gravitational forces exerted by the sun and moon as well as forces due to solar radiation. Because of the movement of the Earth, sun and moon with respect to each other and because of variations in solar radiations, these forces are not uniform and hence satellite movements vary somewhat from their ideal paths (Ghilani and Wolf, 2008).

1.1.2 The Geocentric Coordinate System

The objective of GPS surveys is to locate points on the surface of the Earth; hence it is necessary to have a so-called terrestrial frame of reference, which enables relating points physically to the Earth. The frame of reference used for this is a geocentric coordinate system. To make the conversion from the satellite reference coordinate system to the geocentric system, four angular parameters are required, which define the relationship between the satellite's orbital coordinate system and key reference planes and lines on the Earth. These parameters are (1) the inclination angle, i (2) the argument of perigee, ω, (3) the right ascension of ascending node, Ω, and (4) the Greenwich Hour Angle of vernal equinox, GHA_{Υ}. These parameters are known in real time for each satellite based upon predictive mathematical modelling of the orbits (Ghilani and Wolf, 2008).

1.1.3 The Geodetic Coordinate System

Although the positions of points in a GPS survey are computed in the geocentric coordinate system, in that form, they are inconvenient for use by surveyors (Geomatic Engineers). This is the case for three reasons: (1) with their origin at Earth's center, geocentric coordinate are typically extremely large values, (2) with X-Y plane in the plane of the equator, the axes are unrelated to the conventional directions of the north-south or east-west on the surface of the Earth, and (3) geocentric coordinates give no indication about relative elevations between points. For these reasons, the geocentric coordinates are converted to geodetic coordinates of latitude (ϕ), longitude (λ) and height (h) so that reported point position become more meaningful and convenient for users (Ghilani and Wolf, 2008). In converting the geocentric coordinates to the geodetic coordinate system, the World Geodetic System 1984 (WGS84) is used as a reference frame.

Since the spheroid is a mathematical surface, when the direction and distance are measured from any station A of known position to any station B, the position of B can be computed (Kissam, and

McNair, 1981). A spheroid is the figure described by the rotation of an ellipse about one of its axes; if the rotation is about its minor axis, an oblate spheroid is produced, and if about its major axis a prolate spheroid results (Allan *et al.*, 1968).

1.2 Reduction to Desired Coordinate System

The X, Y, Z coordinates of a ground station determined from a single satellite by any method are with respect to an earth-centred Cartesian coordinate system defined by the plane of the satellite's orbit and its point of perigee. A transformation must then be made to place the station in an earth-centered coordinate system with the Z-axis in the direction of the mean polar axis and the X-axis passing through the Greenwich meridian. Of particular importance to GPS users is the 3-D geodetic coordinate system, in which the coordinates of a point are identified by the geodetic latitude (ϕ), the geodetic longitude (λ) and the height above the reference surface (h) (El-Rabbany, 2002). Another transformation must be made to bring the station into the desired reference ellipsoid used in the area of interest. This transformation establishes the elevation of the station. Finally, the plane rectangular coordinates of the station can be transformed into any desired system such as the Transverse Mercator system.

The WGS84 plays a central role in the transformation of the GPS coordinates obtained to the Ghana National Grid system. The semi-major axis, a, as well as the inverse flattening, 1/f, are made use of in this regard.

1.2.1 The World Geodetic System 1984 (WGS84)

The World Geodetic System of 1984 (WGS84) is a 3-D Earth-centered reference system developed by the former U. S Defense Mapping Agency now incorporated into a new agency, National Imagery and Mapping Agency (El-Rabbany, 2002). Each satellite in the GPS constellation transmits positional information enabling its coordinates on the WGS84 ellipsoid to be computed at any given time (Uren and Price, 2006). Coordinates resulting from GPS measurements are in the system of the satellite datum, which is the World Geodetic System of 1984 (WGS84), an earth centred Cartesian coordinate system (X, Y, Z). So, in order to use these coordinates, they need to be transformed to the reference ellipsoid and to the National Grid System. In Ghana, this will involve changing the coordinates into values based on the Ghana National Grid. The Ghana National Grid is a traditional horizontal coordinate system which has been established for surveying and mapping purposes (Uren and Price, 2006).

For convenience, these coordinates are easier to use if they are an eastern and northern based on a plane rectangular grid. If this was the case, calculation of position could be carried out using plane trigonometry instead of much more complicated calculations on the ellipsoid. To represent ellipsoidal latitude and longitude on a curved surface as Easting and Northings on a flat surface requires map projection (Uren and Price, 2006). The one chosen for Ghana by the Survey and Mapping Division is the Transverse Mercator projection. It is a cylindrical projection and touches the ellipsoid along a north-south line called the central meridian. The central meridian of the Transverse Mercator projection used is at 1˚ 00′ W and this defines the direction of the north axis of a plane rectangular coordinate system. The eastern axis is at 4˚ 40′ N and these two axes define a rectangular grid for coordinates covering Ghana.

1.3 Coordinate Referencing in Ghana

Coordinates are an ordered set of numbers that are used to describe the positions of features on the surface of the earth (Featherstone and Vanicek, 1999). El-Rabbany (2002) on the other hand defines coordinate system as a set of rules for specifying the locations (also called coordinates) of points. This usually involves specifying an origin of the coordinates as well a set of reference lines (called axis with known orientation). To provide grid coordinates, each local coordinate will have to be projected onto a plane surface using the projection that better suits the area to be represented.

Coordinates resulting from GPS measurements are in the system of the satellite datum, which is the World Geodetic Datum of 1984 (WGS 84), an earth-centred Cartesian coordinate system. For use in Ghana, the derived coordinates have to be transformed to the Ghana Local Grid System and this is achieved by the use of manual coordinate transformations or software in a computer which makes use of either the War Office datum ellipsoid parameters or Clarke 1880 datum ellipsoid parameters, depending on which one of these has is being adopted.

1.3.1 The Geodetic Datum System

Coordinates are normally tied to a set of reference points called geodetic datum. A geodetic datum according to Smith (1997) is any numerical or geometrical quantity or of such quantities that serve as a reference or base for other quantities. Hundreds of different datums have been used to frame position descriptions since the first estimates of the earth's size were made by Aristotle (Dana, 1997). There are basically two types of datum namely:

(i) Horizontal datum, based on ellipsoids; and

(ii) Vertical datum, based on the geoid.

Geoid and mean sea level are examples of datums used for height referencing and the ellipsoid used for spherical coordinate definitions. The simplest mathematical approximation of the shape and the size of the earth, on which coordinate systems are based are ellipsoids and geoids (Ayer and Fosu, 2008). The above underscore the critical role geodetic datums play in the definition and representation of coordinate system and for that matter GPS coordinates.

1.3.2 Common Reference Ellipsoids

The datum ellipsoid parameters used in post-processing DGPS data have an impact on the output (coordinates) generated. Many nations established their own national datums using various national standards and procedures by calculating ellipsoids that fit well locally. They also established initial point location and orientations usually with astronomic observations. The results of the different datums would require transformations that are necessary to convert between them because ellipsoid shape and size differences result in origin shifts and rotations (Ayer, 2008; Kotzev, 2013).

1.3.3 Types of Datum Ellipsoid Parameters Used in Ghana

The ellipsoid cannot fit the Geoid exactly, hence, many different ellipsoids are in use, some of which fit a region or a country well and some of which are a best fit to the whole Earth. The best fitting global ellipsoid at present is GRS80 (Geodetic Reference System 1980) which is very similar to the WGS84 (World Geodetic System 1984) ellipsoid often used to define GPS coordinates (Uren and Price, 2006). Referencing geodetic coordinates to the wrong datum can result in position errors of hundreds of meters. Different nations and agencies use different datums as the basis for coordinate system used to identify positions. Datum (sets of data) is the basis for all geodetic survey work. They act as reference points (Ayer, 2008). It then implies that the choice of a datum definition is very central in obtaining acceptable coordinates as two different datum definitions may not give the same coordinates because of the different datum ellipsoid parameters associated with these datum definitions.

Ghana's original Geodetic Reference Frame (GRF) used various datums: Accra datum uses War Office 1926 ellipsoid, and Leigon 1977 datum (use) the Clarke 1880 ellipsoid (Byamugisha, 2012). These datums vary in many ways with regards to their datum-ellipsoid parameters. The use of different datums in Ghana is as a result of the original local coordinate system which uses the War Office as its datum in Ghana. The demand for the use of GPS which uses the WGS 1984 as its reference surface for various surveys resulted in the use of the two datums in Ghana since transformation between the two surfaces have not properly been established. In addressing the rising demand for cost-effective land delivery and management process in Ghana, the Survey Department, through the Land Administration Project, embarked on the renewal of the Ghana's Geodetic Reference Network, which was based on the War Office 1926 ellipsoid into the international organisations including the committee in the African Reference Frame (AFREF), to utilise the Global Navigation Satellite System (GNSS) technology (Poku-Gyamfi and Schueler, 2008).

1.3.4 Ghana War Office Ellipsoid/Accra Datum

The National framework for Ghana is composed of monuments erected at points whose coordinates are known to a certain degree of accuracy. National geodetic controls in Ghana dates back to June 1904 when observations for latitude were done by Captain P. G. Guggisberg from a pillar established in the house of the then Secretary of Native Affairs (Anon., 1936; Ayer, 2008; Kotzev, 2013). This pillar was connected by traverse to GCS 547 in Accra and longitude for GCS 547 was determined by telegraphic signal exchange with Cape Town in November 1904 to establish both latitude and longitude values for GCS 547. The initial pillars, GCS 547 and GCS 121 at Legon, were connected by triangulation to obtain their latitudes and longitudes (Ayer, 2008; Kotzev, 2013).

Other series of triangulation nets were established to obtain latitude and longitude of trigonometric points. The controls in Northern territories and low lying regions were established by traversing. The Main Horizontal framework therefore consists of five chains of triangulations of various orders and a number of primary and secondary traverses.

The calculated best fitting local ellipsoid that fitted the measurements done in the then Gold Coast was suggested by the British war office using initial measurements. This ellipsoid has subsequently come to be known as the War Office ellipsoid. Ghana Horizontal Datum therefore comprises the following:

Parameters of ellipsoid (Ghana War Office):

a = 6 378 299.996 m;
b = 6 356 751.69 m;
Inverse flattening = 1/ 296; and
Feet to meter conversion factor = 0.304799706846.

Easting and northing coordinates are derived using a Transverse Mercator projection. The origin of coordinates is the intersection of latitude 4 degrees 40 minutes North (4^{o} 40' N) and longitude 1 degree west (1^{o} W). This origin is given values of X =0.00

ft., Y = 900 000.00 ft. To avoid distortion at the eastern and western edges, true distance along the central meridian was decreased by 1/4000. This is equivalent to a scale of 0.99975 along the central meridian and this secant implementation of the transverse Mercator meant that scale is correct at Y=434 000 and Y=1 366 000. *i.e*, 466 000 ft from the central meridian on either side. (W 002^o 16′ 5′′ and E 000^o 16' 50") (Ayer, 2008; Kotzev, 2013).

For Ghana, horizontal datum has been defined by Survey of Ghana, 2009 as:

Ellipsoid = War office;
Semi major axis a = 6 378 299.996 m;
Inverse flattening 1/f = 296;
Latitude of origin 4^o 40$'$ N;
Longitude of origin = 1^o W;
False Northing = 0.000 ft.
False Easting = 900 000.000 ft. and
Scale along central meridian = 0.99975
This datum definition is referred to in some publications as Accra Datum (Ayer, 2008).

The War Office datum parameters for the Golden Triangle as published by the Survey of Ghana, 2009 are:

ΔX = -196.557 m;
ΔY = 33.385 m;
ΔZ = 322.452 m;
R_x = 1.786E-7 radians;
R_y = -3.872E-8 radians;
R_z = -5.767E-8 radians;
Scale = 0.9999940;
X_o = 6 339 239.290 m;
Y_o = -120 750.511 m; and
Z_o = 686 012.361 m.

1.3.5 Clarke 1880 Ellipsoid / Leigon 1977 Datum

In 1977, the triangulation and traverse framework was re-adjusted together using the method of variation of Geographical coordinates. In this new adjustment, it was agreed to hold the existing latitude and longitude values for GCS 121 (5^o 38′ 52.2700′′ N, 0^o 11′ 46.08′′ W) at Legon as fixed (error free). Following this adjustment, projected coordinates were computed on the original Transverse Mercator projection using the same origin of the intersection of latitude 4^o 40′N and longitude 1^o W to which again false origin values of 0.00 ft. for Northing and 900 000.00 ft. for Easting were adopted.

However, the ellipsoid proposed for projection was Clarke 1880 because other African Nations around were already using that ellipsoid and it was thought that this would enhance future regional mapping (Anon., 1978; Ayer, 2008; Kotzev, 2013). Although this re-computation was completed in August 1978, the results were not implemented or made public. However, it has come to be severally known as "Leigon datum", or Ghana metric grid in some publications.

The positional shift between the two different ellipsoidal projected coordinates is on the average of 25 feet, perhaps explaining why it was never used (Ayer, 2008; Kotzev, 2013).

The datum-ellipsoid parameters for Clarke 1880 are (Ayer and Fosu, 2008):
Datum Parameters:

ΔX = -158.635 m;
ΔY = 32.174 m;
ΔZ = 326.783 m;
R_x = 0.03683 sec;
R_y = -0.00798 sec;
R_z = -0.01189 sec; and
Scale = 0.99999

Ellipsoid Parameters:

Semi major axis (a) = 6 378 306.064 m;
Semi minor axis (b) = 6 356 757.924 m;
Inverse flattening (1/f) = 296.00262779;
False Easting = 274 320 m; and
False Northing = 0.00 m.

2 Materials and Methods Used

2.1 Materials

Primary data was collected by field visit using Sokkia dual frequency DGPS receivers. The Spectrum Survey Software 4.2 version was used to download and post process the DGPS data. Microsoft Excel spreadsheet (MS excel) was used for analysis of the post processed GPS data.

2.2 Methods

The data covered three different parcels at varied distances from the reference station. These parcels were coordinated using the same reference station and employing the same observation technique, that is, Differential Global Positioning System. The methods that were employed in the GPS data acquisition and the subsequent post processing using the GNSS Solution software are explained:

2.2.1 Data Collection

After extensive reconnaissance survey was carried out, data collection was done on 19 survey pillars by using an existing control station (SGW 10 05 3A) as reference station. The coordinates of this control was obtained from the Municipal Office of SMD, Tarkwa. The area surveyed covered three different parcels at varied distances from the reference station. These parcels were coordinated using the same reference station.

2.2.2 Data Downloading and Processing

The data was downloaded using Spectrum Survey Software. For the purposes of this research, Regional Number SGW D224/14/ from the SMD was used for all the parcels. The Clarke 1880 and War Office datum ellipsoid parameters were configured in the processing software and respectively selected as the datum and ellipsoidal definitions for the post processing.

2.2.3 Data Analysis

After downloading and post processing the DGPS data, a comparison was made between the posts processed data using Clarke 1880 datum ellipsoid parameters and War Office datum ellipsoid parameters. These two datum definitions yielded different results. Of the 19 points that were post processed, an average of about 7.23 m, (23.7205 ft.), positional change was detected by the use of Clarke 1880 and War Office datum ellipsoid parameters. This is a significant positional change that has the tendency of distorting the layout of a particular locality or creating disagreement and possibly litigation between parties if not managed well.

3 Results and Discussions

3.1 Results

The results were obtained after statistical analysis of the data. The following are the various techniques adopted.

3.1.1 Comparison of the Post Processed DGPS Data

Table 1 shows the post processed DGPS data using Clarke 1880 and War Office datum ellipsoid parameters. The positional shift as indicated in Table 1 is calculated by finding the magnitude of the differences between the two set of coordinates (Clarke 1880 generated coordinates and War Office generated coordinates) for each point. Thus, if the change in the Eastings coordinates is say, ΔE and ΔN for the change in the Northings coordinates, then, the positional change (ΔP) is given as:

$$\Delta P = \sqrt{\left[(\Delta E)^2 + (\Delta N)^2\right]}$$

3.1.2 Tolerance Set by the SMD

Comparing the post processed coordinates using the two datum definitions separately has yielded differences which fall outside the tolerance set by the SMD for cadastral plans which is in the range of ±3 ft (0.194 m). The difference, an average of 7.23 m, for 19 stations fall outside the tolerance set by SMD.

3.1.3 Production of a Plan

The two set of coordinates were used to produce the plan as shown in Fig. 1

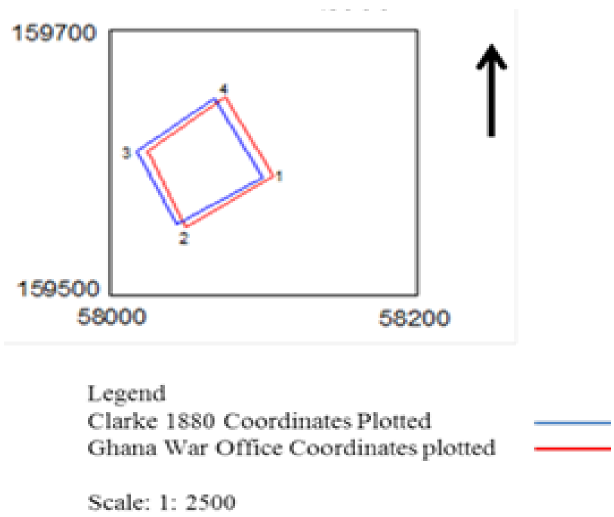

Fig. 1 Composite Plan Produced From the Two Set of Coordinates

3.2 Discussions

3.2.1 Ghana War Office and Clarke 1880

It has been established from the post processed data that the use of Clarke 1880 datum parameters and ellipsoid parameters to post process GPS data yields different result compared with using Ghana War Office datum parameters and ellipsoid parameters to post process the same GPS data. The margin of difference in comparative terms is so significant that it is totally unacceptable for the choice of a datum definition to post process GPS data to be left to the discretion of the user. If steps are taken to regularise and standardise the use of these datum definitions, it will go a long way to facilitate data integration and harmonise post processed DGPS data administration.

A lot of the day to day running of the SMD is in regards to administering GPS data. Often, post processed GPS data are used in the preparation of cadastral plans. Acknowledging the likelihood of discrepancies in the post processed GPS data, the SMD has set an allowable range of ± 0.9144 m (± 3 ft), for cadastral plans. However, the use of the two different datum definitions has yielded an average difference of about 7.23 m (23.72 ft.), for the 19 stations that were considered for this project. The post processed coordinates that were generated, by using Clarke 1880 datum parameters and ellipsoid parameters and Ghana War Office datum parameters and ellipsoid parameters, were used to prepare a plan (Fig. 1).

Table 1 Comparison of Clarke 1880 and War Office Datum Definitions Post Processed Coordinates

	Clarke 1880 Coordinates		War Office Coordinates		Positional Change (Δp)
Point ID	**N(m)**	**E(m)**	**N(m)**	**E(m)**	**(m)**
SGW D224/14/1	65221.074	164121.977	65227.344	164122.773	6.3203
SGW D224/14/2	65212.402	164120.694	65219.751	164121.505	7.3936
SGW D224/14/3	65204.297	164148.000	65211.951	164149.539	7.8071
SGW D224/14/4	65180.285	164134.768	65186.247	164135.295	5.9852
SGW D224/14/5	65188.411	164108.050	65195.187	164108.691	6.8062
SGW D224/14/6	65198.389	164102.153	65206.491	164102.808	8.1284
SGW D224/14/7	65050.351	164156.698	65057.663	164157.571	7.3639
SGW D224/14/8	65054.223	164158.475	65061.925	164159.618	7.7863
SGW D224/14/9	65125.034	164175.192	65132.526	164176.210	7.5608
SGWD224/14/10	65056.599	164185.984	65064.527	164186.935	7.9848
SGWD224/14/11	65051.995	164231.539	65059.136	164239.702	10.8456
SGWD224/14/12	65021.611	164226.596	65028.673	164227.218	7.08933
SGWD224/14/13	65026.231	164184.954	65033.735	164186.512	7.66403
SGWD224/14/14	65025.602	164154.684	65031.957	164155.693	6.4346
SGWD224/14/15	58063.240	159625.571	58069.949	159626.571	6.7831
SGWD224/14/16	58035.712	159603.651	58042.247	159604.215	6.5592
SGWD224/14/17	58049.728	159574.839	58055.217	159573.629	5.6207
SGWD224/14/18	58052.258	159568.382	58058.348	159569.833	6.2604
SGWD224/14/19	58080.152	159593.708	58087.129	159594.577	7.0309

From the plan, it is evident that there is a positional shift of the parcel by the use of the two sets of coordinates to plot. A positional change of 6.783 m, 6.559 m, 5.621 m and 7.031 m were realised for the points 1, 2, 3 and 4 respectively. This is an average of 6.499 m (21.32 ft.) positional change for the parcel. There is a slight difference in the shape resulting in a change in their areas. The red shaded line gave an area of 0.236 acres and the blue shaded an area of 0.226 acres. Comparatively a difference of 0.010 acres was obtained for the two plotted coordinates.

4 Conclusions and Recommendations

4.1 Conclusions

Based on the literature reviewed and the results obtained by using the Clarke 1880 and War Office datum ellipsoid parameters to post process the GPS data, the following conclusions are arrived at:

(i) The use of Clarke 1880 datum parameters and ellipsoid parameters and War Office datum parameters and ellipsoid parameters to post process GPS data yields different results, with an average positional change of 7.23 m, an equivalent of about 23.7205 ft., for the 19 points that were examined;
(ii) These differences, certainly, fall outside the acceptable limits set by the Survey and Mapping Division, which is ±0.9144 m (±3 ft.), for cadastral parcels; and
(iii) A plan using the two set of coordinates generated has been produced with a slight difference in the shape and areas. This is 0.010 acres. This clearly shows that different datums used can cause significant differences in shape and areas for plan production.

4.2 Recommendations

From the conclusions, the following are recommendations to help address the findings of this research:

(i) Publicising, by the Director of Survey, which of the two datum definitions is recommended to be used and where to use it and insisting on its strict adherence; and
(ii) Standardising the conduct of surveying and mapping operations as prescribed by the Legislative Instrument 1444 (LI 1444) in order to harmonise and sanitise such practices in Ghana.

References

Allan, A. L., Hollwey, J. R. and Maynes, J. H. B. (1968), "*Practical Field Surveying and Computations*", William Heinemann Ltd., London, pp. 148-149.

Anderson, M. James and Mikhail, M. Edward (1998), "*Surveying Theory and Practice",* 7th edition, McGraw-Hill Companies Inc., New York, pp. 697-700.

Anon. (2008), "United States of America Department of Defense: GPS Standard Positioning System Performance Standard", *http://www.gps.gov/technical /ps/2008-SPS-performance-standard.pdf* 4th edition, pp. 1-2, Accessed: Janaury, 2015.

Arthur, B., Stanley, R. and Raymond, B. (1998), "*Surveying"* 7th edition, Pearson Education Ltd., London, pp. 173-174.

Ayer, J. (2008), "Towards Implementing Universal Mercator Coordinates in Ghana",*www.researchgate.net/publication/266179617, Ghana*, pp. 5-7, Accessed: January, 2015.

Ayer, J. and Fosu, C. (2008), "Map Coordinate Referencing and the Use of GPS Datasets in Ghana", *Journal of Science and Technology*, KNUST, Kumasi, Ghana, Vol. 28, No. 1, pp. 116-127.

Charles, D. Ghilani and Paul, R. Wolf (2008), "*Elementary Surveying: An Introduction to Geomatics"*, Pearson Education Inc., Upper Sadle River, New Jersey, 931pp.

El-Rabbany, A. (2002), "*Introduction to GPS: Global Positioning System*", Artech House, Boston-London, 193 pp.

Featherstone, W.E. (1997). "A comparison of existing co-ordinate transformation model and parameters in Australia", *Cartography*, Vol. 26, No.1, pp. 13-26.

Fosu, C. (2006), "Introduction to Geodesy", *Unpublished MSc Lecture Notes*, Kwame Nkrumah University of Science and Technology, Kumasi-Ghana, 68 pp.

Frank, F. K. Byamugisha (2012), "*Securing Africans Land for Shared Prosperity: A Program to Scale Up Reforms and Investments*", Creative Commons Attribution, Washington DC., pp. 128-129.

George, M. Cole, CE, PLS and Andrew, L. Harbin (2006), "*Surveyor Reference Manual*" 4th edition, Butterworth and Co Publishers Ltd, London, pp. 23-24.

Gregory, T. French (2006,) "*Understanding the GPS, Introduction to the Global Positioning System",* 1st edition, GeoResearch Inc., Woodmont Avenue 264 pp.

J., Uren and W., F. Price (2006), "*Surveying for Engineers: 4th edition"*, Palgrave Macmillan, London, 824 pp.

Kotzev, V. (2013), "Selection of a New Projection System for Ghana", *Draft Final Report Unpublished*, 88 pp.

Olliver, J. G. and Clendinning J. (1978), "*Principles of Surveying",* 4th edition., Vol. 2, Haddon Craftsmen Inc., Pennsylvania, pp. 125-126.

Philip, Kissam, C. E. and Arthur, J. McNair (1981), "*Surveying for Civil Engineers: 2nd edition*", Constable and Company Ltd. London, pp. 392 – 393.

Smith, J.R. (1997), "*Introduction to Geodesy: The history and concepts of modern Geodesy*", John Willey & Sons, New York, 83 pp.

Yaw, Poku-Gyamfi and Torben, Schueler (2008), "Renewal of Ghana's Geodetic Reference Network" FIG 2008 *13th FIG Symposium on Deformation Measurement and Analysis*, LNEC, Lisbon, pp. 1-2.

Authors

Dr Issaka Yakubu is a Lecturer at Geomatic Engineering Department of the University of Mines and Technology (UMaT), Tarkwa-Ghana. He is currently the University Training Coordinator. He holds a Certificate in Disaster Risk Management and Environmental Assessment for Spatial Plaining from the International Institute for Geo-information Science and Earth Observation (ITC) - University of Twente, The Netherlands and Bachelor of Science degree in Geomatic Engineering from the Kwame Nkrumah University of Science and Technology, Kumasi-Ghana. He obtained his Master of Philosophy degree and Doctor of Philosophy from UMaT. His research interest includes Global Navigation Satellite System (GNSS) and applications, Disaster Risk Management, Geographic Information System (GIS) and applications, Engineering/Cadastral Surveys and Fleet Management.

Dr Kumi-Boateng Bernard is the Head of Mathematics Department and a Senior Lecturer by rank at the Department of Geomatic Engineering of the University of Mines and Technology (UMaT), Tarkwa-Ghana. He holds a Bachelor of Science degree in Geomatic Engineering from the Kwame Nkrumah University of Science and Technology, Kumasi-Ghana. He obtained his Master of Science degree and Doctor of Philosophy from the International Institute for Geo-information Science and Earth Observation (ITC), Enschede -The Netherlands and UMaT respectively. His research interest includes application of Remote Sensing and GIS in Environmental Management, Spatial Statistics, Land and Compensation Surveys.