

# **GEODETTIC REPORT OF KENYA**

**JANUARY 2000**

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## **REFERENCES**

1.       BLAGOJEVIC D; VASILJEV V; JOK SK D:  
  
          The status and Further Activities on Reference Geodetic Networks in  
          Yugoslavia in the Report on the symposium of the IAG subcommission for the  
          European Reference Frame of May 1996.
2.       Colonial survey committee: Special Report on the triangulations of Eastern  
          and Central Africa, U.K. 1928.
3.       WAINAINA O.M.  
  
          The old Triangulation Networks and their present influence – July 1985.
4.       Proceedings of  
          Third Country Group Training  
          In GPS Surveying held at  
          The Kenya Institute of Surveying & Mapping Nairobi August 1999.

# **GEODETIC REPORT OF KENYA**

## **1. INTRODUCTION**

This paper details the existing geodetic network, the Datum used and how they were derived, the problems experienced currently and the improvements necessary. The recent activities in Global positioning through the effort of Survey of Kenya and Kenya Institute of Surveying & Mapping (KISM) is considered as a means of starting future extension to the GPS Network in Kenya.

### **1.1 Location**

Kenya is in the Eastern region of Africa located between longitudes 34° and 40° East and latitude 5° 30' North and 5° South. It is bounded by the Indian Ocean on the East, Somalia Republic on the North East, Sudan and Ethiopia on the North, Uganda on the West and Tanzania on the South.

#### **Area**

The area of Land only is 571416 square km while Hinter land water (lakes) is 11,230 square km the country has 3km exclusive territorial sea area of 2,717 square km. The total Area with the above included is therefore 585,363 square km.

### **1.2 EARLY GEODETIC ACTIVITIES - A HISTORICAL BACKGROUND**

Since 1892 several major triangulation networks have been observed and computed by various organisations for specific purposes. Each organisation chose the co-ordinate system that appeared suitable resulting in a number of different systems. For each sizeable network, the readily available datum was used resulting in many datums for both planimetric and height control.

At the beginning of the 20th century the Anglo German Boundary Commission (AGBC) of 1893 was established to carry out delimitation of boundaries of colonies in Central and East Africa. This involved the Belgians, Portuguese, British and Germans.

The interterritorial boundaries required geodetic survey points on which they would be based. As is expected, no geodetic control points existed. The colonial powers hence carried out triangulation work along agreed boundaries. The triangulation chains established were not soundly observed and were shaped by the boundaries rather than by geodetic requirements. The first such triangulation in East Africa was observed between Kenya and Tanganyika between 1892 and 1893 - see diagram No. 1.

The triangulation had the longitude of Jombo adopted as the origin. This had been obtained from Admiralty chart No. 1390. The latitude observed at vilima viwili was adopted and carried down by triangulation to Jombo. The height datum was the high water spring tide at vanga and the trigonometric heighting was done

by reciprocal heighting. This triangulation was also used to height kibo, the peak of Mt. Kilimanjaro from vilima viwili.

The second triangulation chain was conducted through the Anglo German Boundary Commission of 1902-1906. This was a triangulation from Zanzibar to Ruwenzori. The Kenyan portion of the same work covered Taveta to Misoma - see diagram 2.

### 1.2.1 **THE KENYA MAJOR TRIANGULATION**

By 1906 only two triangulation chains of the Anglo-German Boundary commission existed. The chains however ran along the Southern boundary of the country and the edge of Lake Victoria. This was considered too far from the areas where surveys for land registration were required. Kenya major triangulation was then started in 1906 to provide control for title surveys as well as control for topographical mapping. Kenya major used cassini co-ordinate system. The diagram No. 3 shows the extent of this network. Kenya major derived its datum from AGBC of 1902 at Kisumu where a base existed and its latitude at Athi River. The longitude was derived at Elemoborasha. After this initial work, several other triangulation chains were conducted between 1906 and 1914. After 1914 the next major work was done between 1939 and 1941 as extensions to the Kenya major triangulation - see diagram No. 4,5,6.

Kenya major triangulation had common points with the AGBC chains. The common points enabled re-computation of AGBC 1902-1906 triangulation based on Kenya major sections. The purpose was to generate co-ordinates consistent with Kenya major triangulation data. This is indicated in Diagram, No.6.

Survey of Kenya has adopted Kenya major datums for Emali to Tsavo, Central Embu, Meru, Riftvalley, the Uasin Gishu and Trans-Nzoia triangulations.

### 1.3 **ESTABLISHMENT OF KENYA PRIMARY, SECONDARY AND LOWER ORDER TRIANGULATION**

The Directorate of overseas surveys was the arm of the British Government through which Britain provided survey and mapping services in overseas countries. Originally the Survey Department was known as the Directorate of Colonial Surveys (DCS) but as British colonies attained independence the name was changed to DOS. The DOS began operations in Kenya at around 1950.

The DOS established the present Kenya primary, secondary and lower order triangulation and also observed traverses. The DOS have also mapped this country from 1950 until their departure at the end of 1983. The D.O.S. used U.T.M. as the system of co-ordinates and clarke 1880 as the reference ellipsoid. The geodetic control Diagram covering points in East Africa and the SK81F show the extent of the present controls.

### 1.4 **DATUM USED IN KENYA**

The 30th meridian arc datum is a chain of geodetic triangulation running almost parallel to the 30th meridian east from Port Elizabeth in South Africa to Cairo in Egypt - see diagram 0.7.

During 1950 the DOS computed part of this chain upto Uganda having held fixed some points in Zimbabwe which had been computed from South Africa. By holding the arc results fixed upto Uganda, the rest of East African triangulation chains were adjusted. Their results were then being dependent on the arc results of 1950, referred to as originating from '1950 Arc Datum'. Any re-adjustment of the arc means that all the triangulation chains depending on it would have to be re-adjusted. By 1960 this arc had been revised and the East African triangulation chains were accordingly re-adjusted. The new values were then designated as originating from "1960 Arc Datum".

The current Geodetic network in Kenya is based on the 1960 Arc Datum. The coordinates is in U.T.M.

### 1.5 **DOPPLER OBSERVATIONS**

Survey of Kenya, the Defence Mapping Agency of the U.S.A. and the Directorate of Military Surveys of the United Kingdom first carried out Doppler observations in Kenya in 1972 and 1973. The aim of this exercise was to:-

- (i) Evaluate the accuracy of the primary control in Kenya;
- (ii) Provide geodetic control in remote and un-surveyed area in the country;
- (iii) Strengthen the triangulation with precise position at Optimum Spacing;
- (iv) Contribute to the development of a single well fitting datum for the African continent.

The ITT 5500 Doppler equipment was used. Doppler positioning using precise ephemeris fixed fifteen (15) stations distributed over the country. Further tests show that surveys carried out with this equipment are accurate to 3 meters in each X, Y, Z coordinates. The Doppler station monuments are still intact.

### 1.6 **VERTICAL CONTROL**

A geodetic leveling programme was proposed in 1947 but leveling was carried out between 1950 and 1958. The datum for all heighting in Kenya is the mean sea level referred to a tide gauge at Kilindini Harbour in Mombasa. This gauge has however been submerged and a new one constructed and connected to some fundamental bench marks. Upto date about 3570km has been precisely leveled, the last 70km having been carried out by Kenya institute of Surveying and Mapping during 1992 and 1993.

## **2.0 REFERENCE ELLIPSOIDS**

The two main reference ellipsoids used in Kenya are (i) Clarke 1858 and (ii) Clarke1880.

### 2.1 **System of Co-ordinates**

There are three co-ordinate systems that have been used in Kenya:-

The Cassini-Soldner co-ordinate system  
The East African War system  
The U.T.M. co-ordinate system.

### 2.1.1 Cassini-Soldner co-ordinate system

The origins of this co-ordinate system are the intersections between the equator and the odd meridians. The odd meridians served as the central meridian for each 2° belt which extends one degree to east and west. To give an example, the Central meridians can be 35°E, 37°E, 39°E etc, with belt limits extending from 34°E to 36°E, 36°E to 38°E, 38°E to 40°E etc. The reference ellipsoid used is Clarke 1858, and the unit of measurement is the British foot.

Before 1950, nearly all triangulation network was based on this system. The cadastral surveys in Kenya were also based on this system of co-ordinates.

### 2.1.2 The East African War System of Co-ordinates

This system of co-ordinates was introduced as a military system for East Africa. The extended triangulation to Kenya major triangulation north of and around Mt. Kenya, was based on this system. The main object of East Africa war system was to unify the co-ordinate system for the British commonwealth territories in the South, East and Central Africa to avoid discontinuity in topographical mapping and grid references across territorial boundaries.

The co-ordinates were based on traverse mercator projection of 5 wide belts. The belts were designated C,D,E, etc and Kenya was covered by Belts H and J as follows:-

Belt H: - Central meridian 37°30'E  
Western limits 35°E  
Eastern Limits 40°E

Belt J: - Central Meridian 42°30'E  
Western Limit 40°E  
Eastern Limit 45°E

The projection had the following parameters:-

Origin: Equator and Central meridian

False co-ordinates: Eastings +400 000 meters  
Northings +4,500,000 meters  
Scale factor: 1999/2000 approximately  
equals 0.9995

Spheroid: Clarke 1880.

The Co-ordinates in this system have been converted to the current U.T.M. system.

### **2.1.3 The U.T.M. Co-ordinate System**

The U.T.M. system was introduced in Kenya in 1950 by the Directorate of overseas surveys (D.O.S). This was when D.O.S. began providing control Survey work in Kenya.

The system used Clarke 1880 spheroid. The unit of measurement was the international metre. The survey department has made effort to convert all points to this co-ordinate reference system.

## **3.0 PROBLEMS EXPERIENCED WITH THE CURRENT GEODETIC NETWORK**

The main problems that have been identified with the current network include:-

- (a) The existence of different co-ordinate systems this has caused the need for regular co-ordinate conversion especially from Cassini to U.T.M. system of co-ordinates.
- (b) Pillars located in hills have been difficult to access and many have been destroyed. The Network density is also low.
- (c) Lack of suitable points to base the transformation especially from Cassini to UTM.
- (d) Lack of information or data of previous work. The records of survey work carried out before 1950 are not readily available.
- (e) Height data has been found not consistent having been derived from different datums.
- (f) Equipment used earlier had lower level of precision and the network is generally weak.
- (g) Hydrographic Charts are not fully developed due to lack of controls near the indian ocean, and around the lakes.
- (h) Points established by space techniques are relatively few.
- (i) Re-establishment of destroyed pillars has not been carried out fully due to high cost of classical triangulation method.

## **4.0 MINIMIZING CURRENT PROBLEMS OF GEODETIC NETWORK**

### **4.1 Initial Activities to solve the Geodetic Network Problems using GPS**

In August, 1996 Kenya Institute of Surveying and Mapping (KISM) under the mini-project started to carry out GPS surveys on First order triangulation pillars in an attempt to establish transformation parameters between the world Geodetic System 84

ellipsoid (WGS – 84) and Clarke 1880 reference ellipsoid used in East Africa. The work was not completed due to lack of funding.

As an initial effort, between 1996 and 1997, twelve First Order Triangulation points were occupied and observation made using GPS receivers. The data is available but further work is needed in order to have several points well distributed all over the country.

The United states of America's NIMA (National Imaging and Mapping Agency) has carried out some GPS work to determine the transformation parameters between WGS-84 and Clarke 1880 (Arc '60 Datum) using GPS stations and have determined the transformation parameters as:-

$$\begin{aligned}\text{Shift in X} &= - & 157\text{m} \\ \text{Shift in Y} &= - & 2\text{m} \\ \text{Shift in Z} &= - & 299\text{m}\end{aligned}$$

The error estimates are  $EX = 4\text{m}$ ,  $EY = 3\text{m}$ , and  $EZ = 3\text{m}$ .

The Co-ordinates in WGS-84 have also been requested by the Airport Authorities here in Kenya as it is the co-ordinate system used by all major Airlines. The establishment of proper transformation parameters is crucial to optimizing the results of any GPS work.

## **4.2 Processing Softwares**

KISM is in the process of computing the transformation parameters using the following softwares.

1. SKI – This is Leica software suitable for computations of GPS Surveys using Leica's GPS receivers. The software is suitable for small and medium scale surveys. The software is however limited to short baseline computations.
2. BERNESE – This is also a commercial software suitable for long lines.
3. GARMIT/GLOBK – This is academic software running on Linux operating system. In all cases precise ephemeris is used other than the broadcast ephemeris.

## **4.3 Existence of IGS Stations**

In Kenya there are two continuous GPS observation stations connected to the IGS (International Geodynamic GPS Services) stations. One is in Malindi while the is in KISM.

The one in KISM was established by KISM in 1997. The data is collected using Leica's SR 399E sensor run by Multistation V 2.3 software. The antenna is placed high enough such that it is able to obtain data without obstruction, 15 degrees above the horizon. The

data from these continuous recording stations are used for the computations of the baselines and eventual co-ordination of all other points.

The data from the IGS stations is available through the internet.

#### **4.3.1 Data Processing**

For ordinary surveys, data is processed using SKI software which has the option of processing RINEX (Receiver Independent data Exchange format) data. For geodetic surveys the data require processing by GAMIT/GLOBK or BERNESE software, these have means of dealing with finer errors caused by procession and radiation.

#### **4.3.2 KISM IGS Co-ordinates**

The co-ordinates of KISM IGS was determined from 6 months of data using precise ephemeris and other IGS stations using the ITRF94 (International Terrestrial Reference Frame of 1994) Co-ordinates System. This was later transformed to WGS-84 Co-ordinates with assistance of the GSI – Japan (Geographical Survey institute of Japan) using GAMIT software.

The WGS-84 geographical co-ordinates are given as:-

Hat	1	15	0.777775
Hang	36	51	24.03925
Ellip.Height	1630.229		

#### **4.3.3 Malindi IGS Station**

Information and data about this station is available from the Internet.

The co-ordinates of Malindi IGS which was used to Compute the co-ordinates of KISM IGS is given as:-

X	=	4865366.8060
Y	=	4110737.5960
Z	=	-331121.7800

The co-ordinates are referenced to ITRF94.

#### **4.3.4 The GPS Equipment at KISM**

The GPS equipment available are:-

4 No. - SR399 sensors (L1/L2 with C/A, P1, P2 capabilities) CR 399 control

2 No. - SR 260 Sensors (LI band only) CR 261 control; and

2 No. SR 399E sensors for continuous observations (L1/L2 bands) with antenna. The multistation 2.3 or apc is used as a control, running on windows 95/98.

#### **4.4 Establishment of Geodetic controls with GPS**

Once the transformation parameters between the local Datum and the WGS 84 is established to an accurate level, and the geoid undulations over the country, then the rest of the control points can be established using GPS which is faster, accurate and convenient to work with. For accurate Geodetic control, three or more GPS receivers would be required, such a combination would enable a network adjustment to be possible.

#### **5.0 WHAT NEEDS TO BE DONE TO IMPROVE ON GEODETIC NETWORK**

The following listed points may contribute to improvement on the current network:-

- (1) The formation of Geoinformation system for Geodetic control. This can be used to store the current Geodetic points and their conditions.

The inventory created can be used effectively for decision making on the type of monumentation analysis of the data quality, the adjustment of the network, reconstruction and modification of the network, measurement of all needed gravity differences by modern gravimeters and the measurement of absolute gravity by special instruments.

- (2) Establishment of modern three dimensional network based on satellite observations. This is easily achieved owing to remarkable accuracy, independence of weather conditions, and high performances of Global positioning system (GPS).
- (3) The potential of GPS can be realized through projects such as:-
  - (1) Establishment of more GPS permanent stations at convenient locations.
  - (2) Establishment of national reference GPS networks
  - (3) Realization of urban network projects
  - (4) Provision of WGS 84 co-ordinates to all Airports.
- (4) Direct connection of our fundamental networks with neighbouring networks is necessary in order to provide Cartographic continuity and to participate in international projects.
- (5) The choice of receivers is an important factor and specifications need to be studied in relation to the processing software and datatypes it can handle.
- (6) More receivers should be purchased based on specifications that meet Geodetic standards.
- (7)

(7) Data processing centers should be established and funded as a project.