The Uganda Triangulation Network: -Establishment and Current Status:

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Abstract:

In this paper, we have outlined the Uganda triangulation network (horizontal geodetic network), its establishment by the British Colonial Administration and current status. The realization of the co-ordinate system and establishment of the triangulation chains that controlled the individual national geodetic networks in the continent is mentioned. The determination of heights attached to triangulation points is also given.

1.0: Introduction:

The establishment of the Uganda triangulation network by the British Colonial Administration dates way back to the beginning of the 20th century. The triangulation network was established in phases, starting with the main triangulation often referred to as the primary triangulation or simply the primary network, followed by the secondary network and finally the tertiary network. A total of about ***1,730*** points were established throughout the country.

By 1920's, the computation of this network on Clarke 1858 ellipsoid, using the triangulation chain along the 30th meridian arc as a control was completed [Rainsford, 1948]. And the curvilinear horizontal positions (j, l) of the network points were projected onto UTM projection used for mapping in the country. The re-computations of the triangulation network that followed later were based on Clarke 1880 modified ellipsoid.

However, we would like to point out that the horizontal geodetic network was systematically destroyed in the late 1970's, and there is need now to establish a completely new network based on the Global Positioning System (GPS) satellite observations. There is a program in the department to carry out this exercise, but the funds are not sufficient to cover the whole country. The new network to be established will include some selected points from the existing triangulation network. These common points will help to determine the relationship between the local datum currently used in the country and the GPS datum.

2.0: <u>The geodetic datum:</u>

The reference system used for re-computations of the horizontal geodetic networks in many countries in Africa including Uganda is Clarke 1880 modified ellipsoid. The parameters of this ellipsoid are ***a*** = ***6378249.145 m*** and ***1***/***f*** = ***293.4663***. Before we start discussing the Uganda triangulation network, it suffices to point out first how the triangulation chain along the 30th meridian arc (or simply the 30th meridian arc), which controlled the main triangulation, was established.

To start with, the reference ellipsoid or to be more specific the co-ordinate system, was positioned and oriented with respect to the earth at a point in South Africa known as Buffelsfontein. The geodetic datum is known as the Cape (Arc) with initial point or origin at Buffelsfontein. The horizontal geodetic co-ordinates of this point are: *j* = ***33° 59' 32.000" S*** and *l* = ***25°30' 44.622" E.*** From here, a triangulation chain (comprising of zero-order points) was run along the 30th meridian arc from the Cape in South Africa, all the way up to Cairo in Egypt. Some triangulation chains were also run across the continent, resulting in several circuits spanning the entire continent.

The circuits formed by several triangulation chains have been re-computed a number of times to rectify discrepancies detected in various circuits [Rainsford, 1948]. The last re-computation was done in 1960, and the Uganda main triangulation was adjusted to fit the new co-ordinates of the 1960 re-computation of the 30th meridian arc. In Uganda, our “datum” is now known as the “1960 arc datum”. The 1960 re-computation of the 30th meridian arc replaced the 1950 re-computation of the same arc which earlier, had been used to control the main triangulation network.

3.0: The main triangulation network (primary network):

By the beginning of the 20th century, observations for the main triangulation network had been started [Rainsford, 1948]. These observations resulted in establishment of primary or first-order points commonly known as primary network.

First-order points are about ***130*** in total**,** and they are well spaced throughout the country as shown in appendix **A**. Some of these points were located in neighbouring countries, as a link between the two adjacent national geodetic networks. The distances between adjacent points ranged from ***30 km*** to ***80 km***.

Their locality name and a reference followed by a number that runs serially throughout the country referred to these points. For example, a primary point could be referred as ***Opit UG 45*** or ***Opit UP 45***, where ***Opit*** is the locality name, ***UG*** or ***UP*** is a reference for Uganda Primary and ***45*** is the serial number. The primary network for Uganda was regarded as complete, and according to Rainsford, [1948], the relative accuracy of first-order points is said to be about ***1/500,000***.

In appendix **A**, we have indicated points marked by pillars and the ones marked by cross cuts on hard rock or concrete slab which was then buried underground. In the same appendix, the proposed location of points to be positioned by GPS under the AFRICOVER – E. Africa project have been indicated. These points will be used in generating the transformation parameters between Clarke 1880 modified and WGS 84 ellipsoids.

The National Working Group on Geometry (NWGG) proposed these points for generating transformation parameters, while bearing in mind the suggestion that was made in the meeting of the International Working Group on Geometry for AFRICOVER, held in Addis-Ababa from 23rd to 25th November, 1996. In this meeting, it was suggested that the number of points to be positioned by GPS in each country would vary from three (3) points to a maximum of ten (10) points depending on the size of the country.

In conclusion, it is worthy mentioning that the triangulation chain along the 30th meridian arc passes along the boarder of Uganda and Democratic Republic of Congo (DRC). The zero-order points in this triangulation chain within the portion of the 30th meridian arc lying on Uganda/DRC boarder were used as control for the Uganda main triangulation. The primary network was further densified leading to the creation of secondary network.

4.0: Secondary network:

This network was also regarded as being complete for the whole country. The spacing between adjacent points ranged from ***20 km*** to ***50 km***. The points were referred to by their locality name as in the primary network and a unique reference, e.g. ***Opit 65X10***, where ***65*** refers to ***1/50,000*** block of four map sheets in which the station falls, ***X*** denotes a secondary station and ***10*** a number which runs serially throughout the block. Again, just like the primary network, some of the points for secondary network were located in neighbouring countries as well. It is also important to note that, the primary network was used as a control for the secondary network.

The second-order points are about ***650*** in total**,** and they are well distributed through out the country as shown in appendix **B**. We have also shown in the same appendix, points marked by pillars and those marked by cross cuts on hard rock or concrete slabs. The second-order points were further broken down leading to the creation of tertiary network.

5.0: Tertiary network:

Third-order points were also distributed throughout the country, though not uniformly like its two cousins discussed above. It should be borne in mind that second-order points were used as control for third-order points. In appendix **C**, much of these points are located in Southwestern, Western, Central and West Nile regions of the country, which are generally hilly. A few were established in eastern part of the country, mainly on the hilly slopes of Mt. Elgon. North, East and Northeast regions of the country had very few third-order points due to the fact that these areas are generally very flat. Pillars marked the majority of these points, and a small number of them were marked by cross cuts.

In all, a total of about ***950*** third-order points were established throughout the country. Their spacing ranged from ***5 km*** to ***10 km***. These points were referred to by their locality name, and a unique reference similar to that used for secondary network, e.g. ***Opit 65Y10***, where ***Y*** denotes tertiary, and the remaining labels are as in secondary network.

From appendix **C**, all third-order points were located within the Uganda boundary. This network is also complete for the whole country, and was further broken down creating fourth-order points. Fourth-order points are not part of the geodetic network, and they were mainly created as control for cadastral surveys in rural areas where the geodetic points are very far from the plot to be surveyed.

Generally, the accuracy of these networks falls as you move from primary down to tertiary. It should also be noted that heights are attached to all points in the geodetic network.

6.0: Heights attached to horizontal points:

Horizontal points have got heights attached to them, but these heights were determined using trigonometric technique. Trigonometric heights have got poor accuracy due to atmospheric refraction effect. In addition, there is no geoidal model in the country to convert trigonometric heights to geodetic heights. Inclusion of these heights into co-ordinate transformation will introduce distortions to our estimated transformation parameters.

Some points (very few) of the horizontal network were leveled using spirit leveling, a technique that was employed in establishing the vertical network. And these points are all on lower ground. Spirit leveling is more accurate than trigonometric heighting.

The vertical network was maintained separately from its horizontal cousin due to the following reasons:

(a) The observations leading to establishment of the two networks were completely different, and could not be observed together since different equipment and field techniques were used to gather field data,

(b) The stations for the two networks were sited on different surroundings [Bomford, 1980; Vanicek and Krakiwsky, 1986], namely: on high hills for the horizontal network and along roads and railway lines for the vertical network,

(c) The horizontal network was referred to ellipsoidal surface, while; the vertical network was referred to the mean sea level or to be more specific to the geoid.

7.0: Current status of the triangulation network:

It can be said that about ***90%*** of the markers [pillars] of the horizontal points have been destroyed on the ground [cf. Section 1.0]. Pillars marked the majority of the network points and the local people generally believed that these pillars contained mercury, which was by then on a high demand in the market. People pulled down almost all the pillars in the country in search for mercury.

The remaining ***10%*** of the network points are expected to be existing on the ground. These points comprise of points located in the Northeast of the country (area occupied by the Karamojong people) and those marked by cross cuts. Since the Karamojong people know cattle as the only precious commodity, they did not tamper with the pillars and by the 1970's, the commercial activities between the Karamojong people and those outside Karamoja was limited to cattle only. Because of this reason, we expect the pillars located in the two districts of Karamoja to be existing on the ground. The cross cuts on hard rock or concrete slabs should be existing on the ground also since they could not be mistaken to contain mercury.

From the attached appendices, there are about ***49*** points, which were marked with cross cuts on hard rock or concrete slabs. Out of these ***49*** points, ***15*** are first-order points and they are shown in appendix **A**, while ***26,*** are second-order and ***8*** are third-order points indicated respectively in appendices **B** and **C**.

8.0: <u>Conclusion:</u>

We have sorted out all the geodetic data according to their classes, i.e. primary, secondary and tertiary, and the data is in the computer ready for transformation.

From the attached appendix **A**, we have suggested some points to be observed with GPS to facilitate the transformation of the triangulation network to WGS 84. However, the number and location of these points can be changed depending on the approach that will be adopted to generate the transformation parameters. The NWGG had wanted more points than the proposed number to be used for estimating the transformation parameters. Using more points will result in more reliable transformation parameters.

<u>References:</u>

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