*Abstract*— **The object of this research was to establish a relationship between the Modified Clarke 1880 and the WGS 84. Multiple regression technique was used as an alternative technique due its efficiency at modelling nonlinear distortions. GNSS raw observation data was collected from various stakeholders and subsequently converted to RINEX format using a software, TEQC. RINEX data was post-processed using AUSPOS online service and then used for datum transformation. RMS errors of 0.155m and 0.39m were obtained using the calculated horizontal and vertical datum transformation parameters respectively. Upon validation of MRE's, it was noticed that residuals increased with distance from used control points. Therefore, the researcher recommends densification of GNSS surveyed control points to sufficiently areas such as Tsholotsho, Manapools and Buhera which were not represented in the datum transformation process.**

*Keywords*— Modified Clarke 1880, WGS 84, RINEX, GNSS, MRE's, AUSPOS

## Introduction

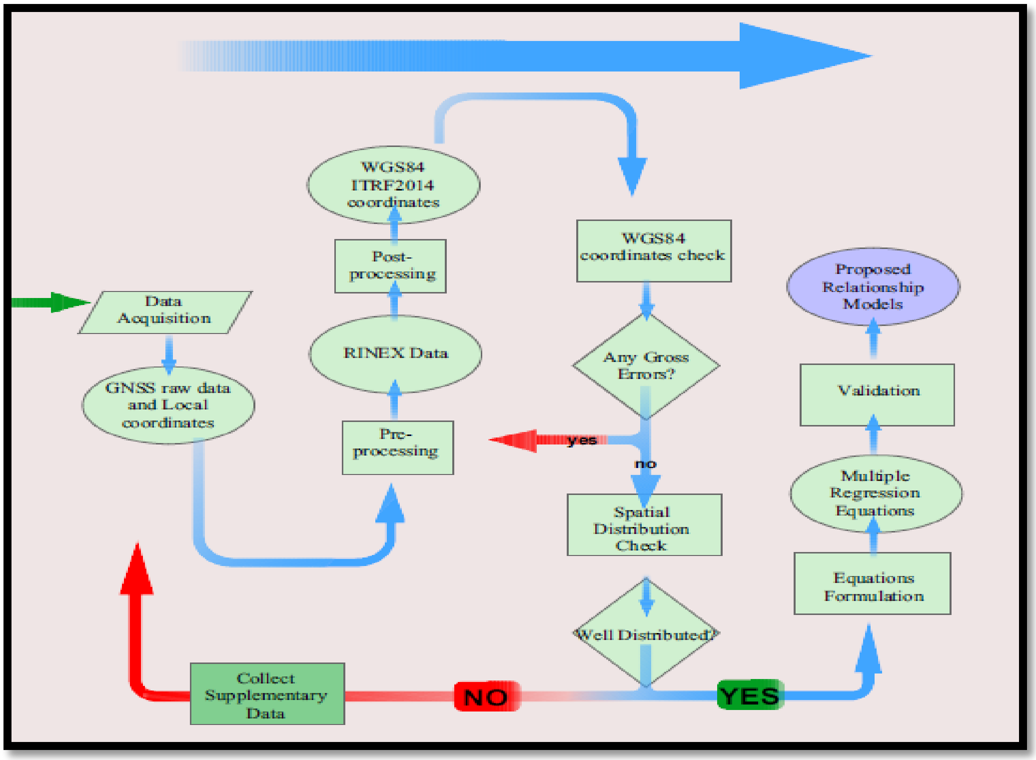
Before the advent of satellite positioning techniques, different nations used different datums as a basis for their co-ordinate systems. Modified Clarke 1880 has served Zimbabwe well for about a century now. It best approximates the earth's figure in the region (Zakiewicz, 2005). Of late, WGS 84 has been replacing the traditional local spheroids in several nations, for instance Modified Clarke 1880, with countries such as Botswana, Zambia among others, in the process of adopting WGS 84. South Africa adopted WGS 84 back in 1999 (Wonnacott, 1999).

In Zimbabwe, steps to undergo such a transition can be traced back to the early nineties. Several campaigns to migrate from local system to global systems such as WGS84 have been conducted. However, the relationship between Modified Clarke1880 and WGS 84 in Zimbabwe has not yet been determined to enable a smooth transition. Merry and Rens (1990), put forward that, large rotations are evident in Zimbabwe geodetic network. However, due to the relatively small size of Zimbabwe, these cannot be considered to represent a true disorientation of the Zimbabwean datum, but probably reflect regional distortions inherent in the network (Mugnier, 2003).

As such, previous studies using similarity datum transformation models could not yield a reliable set of transformation parameters. Molodensky-Badekas and Bursa-Wolf, only define the translation, rotation and scale change between the origins and axes of the ellipsoids used for each datum, and have a nominal accuracy of ± 4m (Jang, 2008).

However, it cannot be that simple as implied by those models, in actuality. This research therefore seeks to administer a stepwise multiple regression approach to determine a best fit relationship between the Modified Clarke 1880 and WGS 84 systems.

RESEARCH FRAMEWORK




### 3.2 Data Acquisition

Local Arc 1950 coordinates, benchmark orthometric heights and some GNSS raw data in receiver native formats were acquired from the DSG geodesy department.

### 3.3 Pre-Processing

The 1994 GNSS campaign was done in a way that a single station could be occupied for many sessions, with some stations being observed for up to ten sessions. An investigation was undertaken to determine which WGS84 session station coordinates to use for datum transformation, given a station was occupied for several sessions. Individual session Trimble 'DAT' files for several stations were converted to Receiver Independent Exchange format (RINEX) using both the University NAVSTAR Consortium (UNAVCO) TEQC and Trimble Convert to RINEX applications and then post-processed using online AUSPOS services. Consecutive sessions were combined for sessions with same antenna height. Ultimately, a station would have more than one set of coordinates, thus a mean was calculated.

### 3.4 Post Processing

GNSS raw data was post-processed using AUSPOS online service. AUSPOS unlike CSRS – PPP, returns coordinates calculated in the latest ITRF2014 reference frame, which in this case ITRF2014, resonates with the objective of this research. CSRS – PPP, on the other hand outputs coordinates referenced in the ITRF realized by IGS at the epoch for which the precise GPS orbits were computed, not necessarily ITFR2014. With the production of orbit estimates on a daily basis, the ITRF realization epoch will always be within a day of the submitted GPS data and this would entail different ITRF realizations for different RINEX files. The RINEX file, antennae type and height were uploaded to the AUSPOS website. Results were sent back via email.

### 3.6 Control Points Selection and Spatial Distribution Check

Spatial Distribution was checked in ArcMap. This is important since the trustworthiness of the established datum relationship also lies in the distribution of common points used in calculation (Rens and Merry, 1990).

### 3.7: Relationship determination between Zimbabwe systems and WGS84

#### 3.7.1: MRE's Formulation

MRE's were formulated for use in the datum transformation procedure from modified Clarke 1880 to WGS 84 using MINITAB 18 statistical commercial software.

1. Local coordinates where subtracted from calculated WGS 84, ITRF2014 referenced coordinates to get the statistical responses ($\Delta\varphi$, $\Delta\lambda$, $\Delta h$), for each control point using Excel 2016.

2. Network centroid ($\varphi_{\circ}$; $\lambda_{\circ}$), was determined using PostgreSQL from a national boundary shape file geo-referenced using local Arc1950 control points.

3. Using Ms Excel, u and v were calculated for each control point using equation 3.

4. Subsequently, multiples of u ( $u^2$, $u^3$,…..,$u^9$) and v ($v^2$, $v^3$, …..,$v^9$) were calculated.

5. Finally, ($\Delta\varphi$, $\Delta\lambda$, $\Delta h$, u's and v's), were fed into MINITAB software for relationship determination.

6. Equations were generated for DEL_LAT, DEL_LON and DEL_H: $\alpha$ to enter = 0.15, $\alpha$ to remove = 0.15

## RESULTS

### HORIZONTAL DATUM TRANSFORMATION PARAMETERS

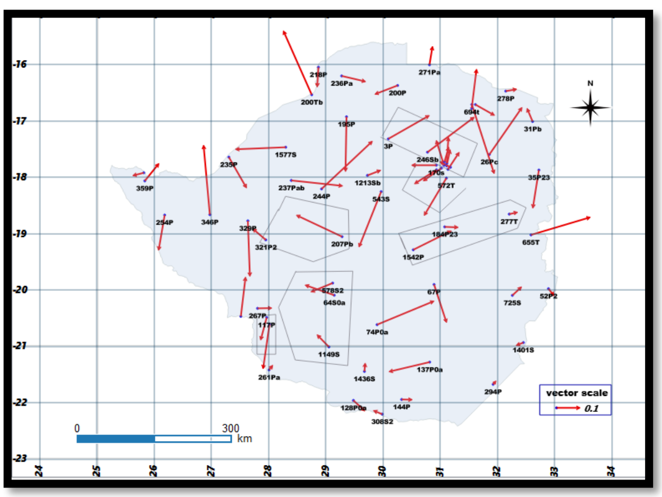
$$\begin{aligned}DEL\_LAT^{\circ} = {} & -0.001068 - 0.000463\,u - 0.000153\,v - 0.000010\,u2 + 0.000043\,v2 + 0.000211\,u3 \\ & - 0.000042\,v3 + 0.000132\,v4 - 0.000449\,u5 + 0.000132\,u6 - 0.000278\,v6 \\ & - 0.000070\,u{*}v + 0.000174\,u{*}v2 - 0.000109\,v{*}u2 - 0.000404\,v{*}u3 - 0.000382\,u2{*}v2 \\ & - 0.002556\,v2{*}u5 - 0.00352\,u3{*}v4 + 0.00891\,v3{*}u5 + 0.01045\,v3{*}u6\end{aligned}$$

$$\begin{aligned}DEL\_LON^{\circ} = {} & -0.000113 + 0.000180\,u + 0.000172\,v + 0.000073\,u2 - 0.000061\,v2 + 0.000036\,u3 \\ & + 0.000145\,v3 + 0.000003\,u4 + 0.000076\,v4 - 0.000242\,u7 - 0.001138\,v7 + 0.001771\,v9 \\ & - 0.000014\,u{*}v - 0.000114\,u{*}v2 - 0.000212\,u{*}v3 + 0.000296\,v{*}u2 - 0.000553\,v{*}u4 \\ & - 0.000195\,u2{*}v2 - 0.003084\,u2{*}v3 - 0.001259\,v2{*}u3 + 0.00750\,u3{*}v4 + 0.1738\,u4{*}v7 \\ & + 0.1032\,v4{*}u7\end{aligned}$$

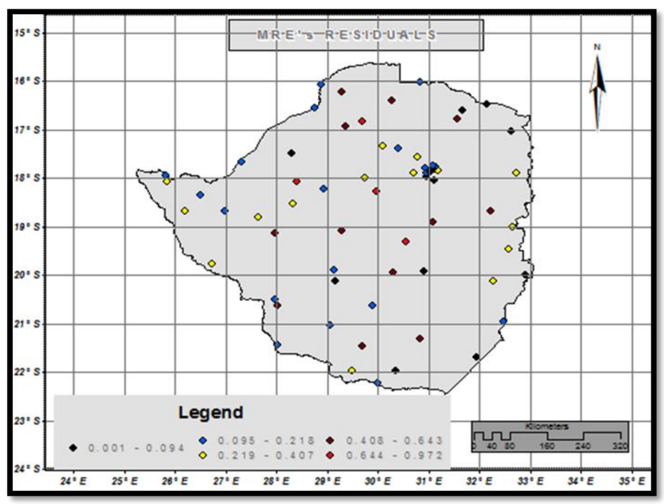
### VERTICAL DATUM TRANSFORMATION PARAMETERS

$$\begin{aligned}N = {} & 6.606 - 7.09\,u - 3.968\,v - 12.623\,u2 - 5.02\,v2 - 121.8\,u3 - 35.42\,v3 - 50.8\,v4 + 1528\,u5 \\ & - 6863\,u7 + 303.9\,v7 + 551\,v8 + 9475\,u9 + 57.63\,u{*}v - 193.5\,u{*}v3 - 1004\,u{*}v8 - 4586\,v{*}u5 \\ & + 27133\,v{*}u7 - 51023\,v{*}u9 - 580\,v2{*}u3 + 2448\,u3{*}v4 + 6990797\,v7{*}u9\end{aligned}$$

a. Horizontal datum residuals plot




b. Vertical datum residuals plot




## CONCLUSIONS

The main objective of this research which sought to establish a relationship between Modified Clarke 1880 and WGS84, referenced to ITFR2014 was accomplished. Multiple regression approach gave better results than those previously calculated using similarity transformation. For horizontal datum transformation, the best fit model had an RMS error of 0,155 m, a considerably high accuracy, bearing in mind the non-homogeneity of the Zimbabwe geodetic network. For vertical transformation, MRE’s gave an RMS error of 0,39 m. This could have been smaller, had it not been the fact that the orthometric heights were given to 1d.p. Upon validation of MRE’s, it was noticed that residuals increased with distance from used control points. To achieve better results for national coverage, control points should be well distributed nationwide. Therefore, the researcher recommends densification of GNSS surveyed control points in areas such as Tsholotsho, Manapools and Buhera since these were not represented. However, resources being available, a GNSS campaign should be carried out for Zimbabwe and a vast number of official control points should be occupied to obtain an excellent spatial representation of Zimbabwe, the study area. This process can be enhanced and speeded up by setting up (CORS).

## ACKNOWLEDGMENT

I would like to register my indebtedness to my highly capable and supportive overseer, Mr T.P Masarira. To Jehovah, all goes the glory, for without His mercies and favour, we labour only in vain!

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