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Control Extension Using Global Navigation Satellite System Receivers in Auchi, Nigeria

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Abstract. *Auchi is the headquarters of Etsako West Local Government Area of Edo State, which is opening up with many developments and diverse construction activities taking place. It was observed that there are limited numbers of reliable survey controls to check these activities; hence the study focuses on second order control (Class 1) extension along the New Auchi- Igarra road to the Polytechnic (Up Iyekhei) road through the Water Board. The controls serve as references for engineering, topographic, cadastral, and route survey projects in and around the project location. An in-situ check using point positioning technique revealed that they were in good condition for use (FGP/EDY072, FGP/EDY089, and FGP/EDY090) were used for extension, and an in-situ check using point positioning technique revealed that they were in good condition for A total of 15 points (AME 001 to AME 015) were observed in static mode with Hi Target GNSS dual frequency receivers and were post processed based on the Clark 1880 spheroid while the total length was 8.503km (8503m). The interval of the new controls ranged between 58.30m and 1569.76m; which is aimed at providing users within these routes a good proximity to at least three of the controls for effective usage. Not less than fifteen satellites were acquired by the GNSS receivers for every observation, and a time range of not less than 60 minutes (1 hour) was used for data acquisition at every station, with a Positional Dilution of Precision (PDOP) value that ranged between 1.1 and 1.5. The study was intended for horizontal control only, but the vertical control values were obtained as well. For easy future location of the new extended controls, a proper description of the controls was carried and recorded in appropriate field sheets. The entire survey was carried out according to specification and is fit to be used for subsequent lower order surveys within the project area.*

Keywords: *first order controls, in-situ check, control point, point positioning technique, static mode, GNSS dual frequency receivers, dilution of Precision (DOP), Auchi*

1. Introduction

Surveying has been an essential element in the development of the human environment since the beginning of recorded history (5000 years ago). It is required in the planning and execution of nearly every form of construction. Its most familiar modern use is in the fields of transportation, building and construction, communication, mapping, and the definition of legal boundaries for land ownership (as in cadastral surveying), etc. (Ghilani & Wolf, 2012). Surveying is defined as the art, science, and technology of measuring the relative position of natural and man-made features on, above, or below the earth's surface and the presentation of such processed data (information) graphically or numerically (Agor, 2012). Surveying could also be seen as the technique and science of accurately determining the terrestrial or three-dimensional positions of points, and the distances and angles between them. These points are usually on, above, or below the earth's surface, and they are used to establish land maps and boundaries, for individuals, corporate bodies, or for government purposes, as in the case of public and private surveys (Ajibade, 1997).

Uren and Price (2001) defined a control survey as the survey that provides a rigid framework of fixing points on which a detailed survey is based, or which are used as the reference points for setting out work. A control survey (on which this study is centered) is a class of survey that establishes the positions of points with a high degree of accuracy in order to support activities such as mapping and GIS, property boundary surveys, construction projects, etc. (Dashe 1987). Every survey depends on established frame networks or controls. An established control network is a network of monumented control points that can provide a unified coordinate base for survey and other related activities within a given area. These control points can also be referred to as coordinated and correlated horizontal and vertical position data, forming a framework whose surveys are adjusted. The purpose of control survey or control extension generally, is to establish a network of points on the ground that are sufficiently accurate to provide control for any survey project, including boundary, route, locative or construction, planimetry or photogrammetry (Ezeigbo, 1990).

These controls are classified into four orders: zero, first, second, and third (or tertiary). The second and third orders can be sub-divided into classes I and II, respectively. The second order controls are controls which are usually used to control precise engineering surveys, urban control, multi-purpose control densification, inter-cadastral densification in urban areas, and extension and supplementary controls (*Specifications for Geodetic Surveys in Nigeria*, *2007*). Control surveys established precise horizontal and vertical positions of reference monuments (Ezeigbo, 1990). These serve as the basis for originating or checking subordinate surveys. Most of the time, these control points are not easily available for surveyors and engineers within a closer range (a distance within 10 km range) to enable them to carry out survey jobs. They are either destroyed by farmers or engineers during construction, or they are not initially available, necessitating control extension. The various methods for control extension are triangulation, trilateration, traversing, and the Global Navigation Satellite System (GNSS) (Fasehun, 2014). The method adopted for any survey work is subject to the available instruments, time, and accuracy required.

The principle of the GNSS/Global Positioning System (GPS) is based on the fact that if the orbit of a satellite is accurately known, the position of a receiver on earth can be determined using satellite positions. A GPS receiver calculates distances to satellites as a function of the amount of time it takes for the satellite signals to reach the ground/receiver position. To calculate it, the receiver must be able to determine precisely when the signal was transmitted and when it was received. The satellites are equipped with extremely accurate automatic clocks, so the firmness of transmission is always known. GPS employs the principle of trilateration to calculate the coordinates of positions at or near the earth's surface. Trilateration is based on the trigonometric law that if the distances of all three sides of a triangle are known, then the interior angles can be calculated. As a result, this study employs the established controls for the second order (Class I) using GNSS instrumentation along Tonny Annenih road to Otaru road via Water Board and connects the new Auchi Igarra road, Auchi, Edo State.

2. Materials and Methods

This study used primary data sets which were obtained through observations from the DGPS instrument. To complement the observation, necessary information such as the location of the existing control points used and their coordinates (Northing, Easting, and Height) were obtained from the Ministry of Land and Survey, Benin City, as shown in Table 1.

Table 1. Coordinates and Locations of the control points used

Pillar Number	Easting (m)	Northing (m)	Height(m)	Location
FGP/EDY/072	198513.794	782022.800	199.974	Akpekpe Model Primary School, Auchi
FGP/EDY/089	205874.631	777157.276	96.922	Iyerekhu Primary School, Iyerekhu
FGP/EDY/090	209318.674	772977.317	61.189	Udame Primary Schoo

Source: Ministry of Land and Survey, Benin-City, 2020

Also, the appropriate instrument was used for the observation pattern and the time to capture data per station was carefully taught out. Necessary arrangements were made concerning the molding of pillars (beacons) to be buried at each observation station. Observations were planned to be made for at least one hour per station. A Hi-Target GNSS receiver instrument, which has the capability of tracking both GPS and GLONNAS data, was chosen. The following precautions were taken in deciding the most suitable positions for the stations:

i. The site should be located such that local settlement along the project area has good proximity to any three controls for effective usage;
ii. The ground's stability; and
iii. Excellent horizon for GNSS observation

According to specifications, concrete beacons measuring 150cm in length and 40cm by 40cm in section were cast in-situ at each. The following instruments point as presented in Figure 1. After burying the pillars, they were numbered serially, starting from AME001 to AME015 (AME represents Auchi Mapping Extension).

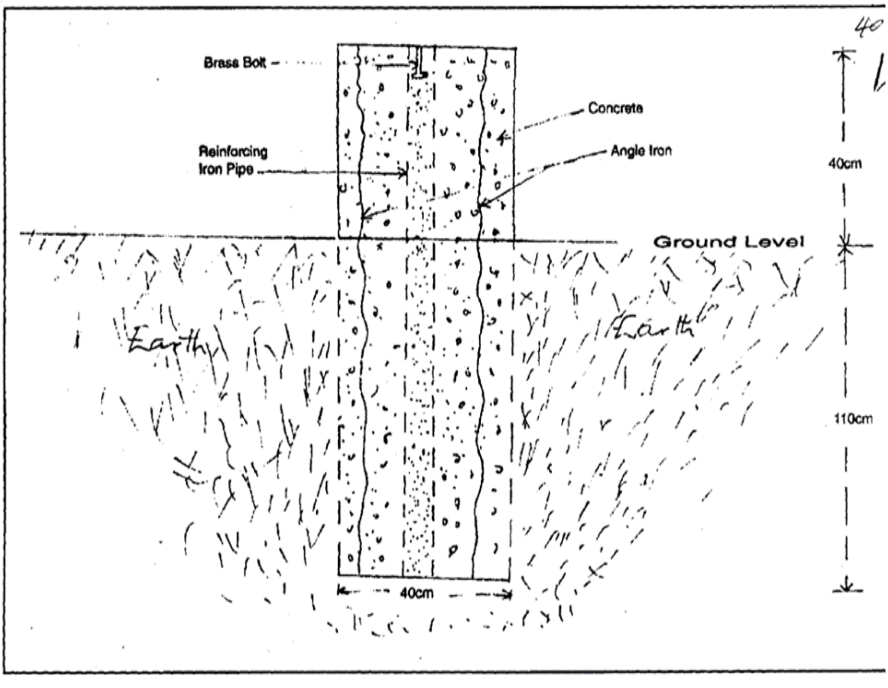

Figure 1. Specification for Secondary Control Beacon
Source: Specifications for Geodetic Surveys in Nigeria (SURCON, 2007)

2.1. Material selection

The following tools, materials and softwares applications were used to carry out the project:

i. Hi Target Double Frequency Differential GPS (Master and Rover Receivers) and Accessories (H32 series GNSS RT1)
ii. Tripod
iii. Hammer,
iv. Field Book
v. Cutlasses
vi. Iron rods
vii. Toyota Highlander jeep
viii. Shovel, trowel and beacon box
ix. Hand held (Garmin GPS)
x. Linen tape
xi. Prismatic Compass

2.1.1. Selected software applications

The following softwares were selected:

i. Hi-Target Geomatics Office (HGO) and
ii. GEOCAL

2.1.2. Instrument Used (Hi-Target Receiver) Configuration

The instrument used, Hi-Target DGPS receiver was configured in such a way that is most appropriate for the project at hand. The configuration is listed below:

i. Logging device-	Data-Logger (Qmini H)
ii. Antenna type-	Hi-Target H32
iii. Survey mode-	Static
iv. Logging Interval-	Five seconds (5 sec)
v. Satellite cut of angle-	Fifteen degrees (15°)
vi. Antenna measurement reference-	Top of Antenna
vii. Time zone-	GMT + 1 Hour

2.2. Data Acquisition using Static Relative Positioning

For the highest accuracy (geodetic control surveys), static GNSS procedures are used (Ghilani, 2008). The procedure is such that the base station remained continuously on a known station while the roving station was moved from one unknown station to the other. The instrument, Hi-Target GNSS receiver, and its accessories and other items were taken to the base/reference station as described by Agor (2012), Ajibade (1997), and Dashe (1987). The receiver (reference) was centered and leveled properly (temporary adjustments) on the base station (FGP/EDY072). Then the slant height of the antennae was measured from the center of the bumper of the receiver to the top of the iron rod (which was 1.960m), which defines the center of the base station. Then the station ID (FGP/EDY072), instrument serial number, interval of record time (5 secs) and cut off angle (15^0) were inputted into the data logger. Then the instrument was turned on and was connected to the data logger via in-built bluetooth. It was observed that PDOP was 1.1 and the number of satellites available (GPS and GLONASS satellites) was 17. The instrument (rover) was configured in the same way and set up on AME001. At this station, the slant height was measured to be 1.80m. The instrument possessed the capacity to pick signals from L1, L2, Lc, Ln, Lw, and L1L2 frequencies. Typically, an observation session for a static method of positioning for a dual frequency receiver is to be about 20 min + 2 min/km (Ghilani, 2008). The distance from the base to the points to be positioned ranges between 666.483m and 3415.155m. But due to the capacity of the instrument (the number of channels includes L1, L2, L1L2, LC, Ln and Lw) and the ability to track both GPS and GLONASS satellites, therefore, for this study, the roving receiver was allowed to pick observational and navigational data for a minimum of one hour at an epoch rate of 5 seconds. These procedures were repeated for all the points to be coordinated (Fig 2). Due to the number of stations to be coordinated (15) and the time spent on each station (1 hour plus), the entire data acquisition exercise lasted for three days (14^{th} to 16^{th} of January 2022) and the above explained procedures were observed on all the points established.

Note: 1 hour or more is sufficient for GNSS data acquisition at respective stations since the longest vector line from the base station FGP/EDY 072 was 3415.155m, a minimum of 15 satellites was observed and there was increased strength in satellite geometry since PDOP varies from 1.1 to 1.5 during observation (PDOP less than 3 is ideal).

2.2.1. Precautions taken During Observation

Among the precautions taken to ensure successful data acquisition were the following:

i. Slant heights of station above station mark was carefully measured before and after data collection at respective stations and recorded appropriately;
ii. Antenna set up with tribrach on tripod were carefully centered and leveled over station mark before data collection at respective stations;
iii. Time for observation on each unknown stations not less than 1 hour.

Figure 2. Hi-Target instrument set-up on one of the stations

3. Results and Discussion

3.1. Data Processing and Adjustment

Data downloading is the process of transferring the observed observational and navigational data (ON data) from the memory of the Hi-Target instrument into a computer (Laptop) for further preprocessing, processing, and data analysis. For efficient data management, a folder was created for each day's observation (the observation was done for three days (14^{th} to 16^{th} of January 2022)) and the raw data from each receiver was downloaded into separate folders and saved on the computer's desktop. The data was later sorted out by adding reference/base data with the rover's data for each day. Within Hi-Target Geomatics Office (HGO) software, there are provisions to import GNSS observation files. The observation files contained the phase and other observables, the broadcast ephemeris, and site data consisting of station identifiers and antenna height. Then, the software was launched, and, through the navigation field, a new project was created and okayed. The coordinates' parameters/properties for the new project were set through the navigation field, North Africa was selected, and then Nigeria was picked. Zone 32 was selected via the navigation field while WGS 84 was chosen as the reference ellipsoid. The target ellipsoid was selected as Clarke in 1880. Then the files containing the

GNSS raw data files in a folder on the desktop were selected, clicked and all files opened, and then the static observation file for the first day (14^{th}) was selected and imported into the software (HGO) environment. The HGO software then automatically generated the baseline, but this was inverted to reflect that the observation was made from control point FGP/EDY072 to the unknown points. To process the observed data, the mask angle was increased from 150 to 250, and various frequency channels available in the instrument processing software, such as L1L2, L1, L2, LC, and others, were used until all of the data was processed and passed using the Process Baseline button in the navigation field (Fig. 3). At first, the data observed was edited by checking the data plot, and observations that were lost were filtered out before processing the data. This is the preprocessing stage.

The essence of this stage is to analyze the data observed for internal consistency and to eliminate possible blunders. After all the points were passed, the slant height of the antenna as measured on the field (2.0068) for the base was entered. Likewise, the corresponding heights for other points (1.9117) were equally entered. In order to carry out network adjustment, FGP/EDY072 (the control point used on the field) was edited by right clicking on it and the *Set as Control Point* item from a dialogue box was selected. The coordinates of the control point as observed by the receiver were then edited by inputting its register value (198513.794 mE, 782022.800mN) and also the height (199.974m). Adjust the report options in the navigation field so that text file format is selected. Thereafter, the data is post processed and adjusted, and the report is generated automatically. These processes were carried out on the data observed for the three days (14^{th} to 16th), while the slant height of the antenna for base station and rover stations was inputted accordingly and reports were generated. The coordinates of the new control points were tabulated in geographic and rectangular systems. The coordinates of the newly established controls were later converted into Nigeria Transverse Mercator adopting Minna Datum using GEOCAL software (Table 2).

The issue of standards is of paramount importance to surveyors and, with the ever increasing advancement in technology, surveys have become faster and milestone successes have been achieved. Standards are clear statements of the requirements of acceptable surveys. Fortunately, there are various indicators for determining the quality of GNSS surveys and the processing software. Therefore, after network adjustment, the misclosure ratio for each baseline vector was computed in order to ascertain the accuracy of each baseline (Table 3). The misclosure ratios computed above imply the extremely high accuracies that are now possible with GNSS receivers. The misclosure also indicates that the result is within the acceptable limit (Second order Horizontal Controls Class 1 Accuracy is 1:50,000; *Specifications for Geodetic Surveys in Nigeria, SURCON, 2007*). Also, bearing and distance between the control points were computed as additional information for control location (Table 4).

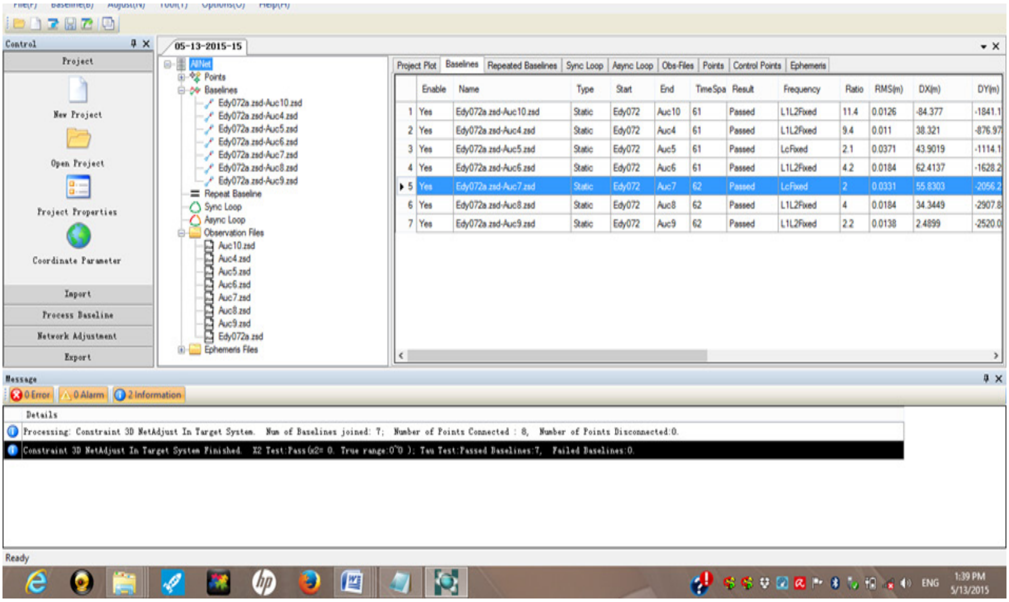

Figure 3. Processed Data for Day 2 before Adjustment (Result: Passed)

Table 2. Summary of the Processed Coordinates of the Newly Established Controls

Station	UTM (m)		NTM (m)		Geodetic (Deg)		Height (m)
	Easting	Northing	Easting	Northing	Longitude	Latitude	
AME001	198953.555	781448.493	424811.120	339006.190	06⁰ 16' 32.61"E	07⁰03' 40.73"N	230.093
AME002	198909.103	781486.209	424766.637	339043.849	06⁰ 16' 31.16"E	07⁰ 03' 41.95"N	229.298
AME003	198846.929	781481.335	424704.482	339038.910	06⁰ 16' 29.13"E	07⁰ 03' 41.78"N	228.301
AME004	197639.963	782485.020	423496.706	340041.075	06⁰ 15' 49.64"E	07⁰ 04' 14.20"N	198.532
AME005	197404.182	782614.411	423260.844	340170.170	06⁰ 15' 41.94"E	07⁰04' 18.36"N	193.921
AME006	196892.982	782990.465	422749.357	340545.626	06⁰15' 25.22"E	07⁰04' 30.50 "N	202.247

Station	UTM (m)		NTM (m)		Geodetic (Deg)		Height (m)
	Easting	Northing	Easting	Northing	Longitude	Latitude	
AME007	196469.811	783303.868	422325.459	340858.318	$06^0$15' 11.37"E	07^0 04' 40.61"N	187.239
AME008	195628.160	783849.361	421483.878	341402.948	06^0 14' 43.87"E	07^0 04' 58.20"N	139.397
AME009	196017.628	783874.940	421873.251	341428.951	06^0 14' 56.55"E	07^0 04' 59.10"N	153.478
AME010	196702.919	783962.497	422558.282	341517.208	06^0 15' 18.85"E	07^0 05' 02.08"N	152.330
AME011	197608.403	784045.197	423463.472	341600.867	06^0 15' 48.32"E	07^0 05' 04.95"N	166.203
AME012	198103.070	784109.626	341665.815	423957.959	06^0 16' 04.41"E	07^0 05' 07.14"N	183.786
AME013	199348.363	784005.538	341563.093	425203.087	06^0 16' 44.98"E	07^0 05' 03.99"N	242.877
AME014	199419.882	783785.003	341342.684	425274.828	06^0 16' 47.35"E	07^0 04' 56.83"N	246.204
AME015	199448.609	783570.131	341127.891	425303.781	06^0 16' 48.33"E	07^0 04' 49.84"N	245.549

Table 3. Base Vector Analysis

Base Vector	X Misclosure (sX) (m)	Y Misclosure (sY) (m)	Length (m)	Misclosure Ratio	Parts Per Million (ppm)
Edy072 – AME001	0.0022	0.0014	723.4647	1:277,000	4ppm
Edy072 – AME002	0.0021	0.0007	666.6664	1:301,000	3ppm
Edy072 – AME003	0.0017	0.0009	635.9253	1:331,000	3ppm
Edy072 – AME004	0.0013	0.0009	987.8608	1:625,000	2ppm
Edy072 – AME005	0.0057	0.0039	1256.6114	1:182,000	5ppm
Edy072 – AME006	0.005	0.0022	1886.3832	1:345,000	3ppm
Edy072 – AME007	0.0071	0.0034	2410.6013	1:306,000	4ppm

Base Vector	X Misclosure (sX) (m)	Y Misclosure (sY) (m)	Length (m)	Misclosure Ratio	Parts Per Million (ppm)
Edy072 – AME008	0.0034	0.0026	3413.2613	1:797,000	1ppm
Edy072 – AME009	0.0029	0.0014	3106.4107	1:965,000	1ppm
Edy072 – AME010	0.0022	0.0009	2652.1795	1:1,116,000	0.9ppm
Edy072 – AME011	0.0057	0.0027	2214.5093	1:351,000	3ppm
Edy072 – AME012	0.0064	0.0046	2125.4335	1:270,000	4ppm
Edy072 – AME013	0.0101	0.0028	2817.1727	1:269,000	4ppm
Edy072 – AME014	0.0068	0.0049	1980.6783	1:236,000	4ppm
Edy072 – AME015	0.007	0.0044	1807.689	1:219,000	5ppm
Edy072 – Edy089	0.0034	0.0013	8818.2487	1:2,423,000	0.4ppm

Source: Authors' field work, 2022

Table 4. Bearing and Distance between Control Points

From Station	Bearing 0 ' "	Distance (m)	To Station
AME 001	310 18 48	58.296	AME 002
AME 002	265 31 03	62.365	AME 003
AME 003	309 44 46	1569.761	AME 004
AME 004	298 45 25	268.951	AME 005
AME 005	306 20 22	634.620	AME 006
AME 006	306 31 26	526.588	AME 007
AME 007	302 56 53	1002.965	AME 008
AME 008	086 14 33	390.307	AME 009
AME 009	082 43 08	690.862	AME 010

From Station	Bearing ⁰ ‘ “	Distance (m)	To Station
AME 010	084 46 53	909.253	AME 011
AME 011	082 31 03	498.734	AME 012
AME 012	094 42 58	1249.358	AME 013
AME 013	162 01 56	231.842	AME 014
AME 014	172 23 06	216.784	AME 015

Source: Authors’ field work, 2022

3. Conclusion

A total of 15 new stations were established, covering a total length of 8.503km. Observations from three (3) different stations over the course of three (3) days. Accuracy after adjustment ranges between 1:182,000 and 1: 1,115,780. The following recommendations are hereby suggested:

i. Although the established control points can now be used as connections for other lower order survey work, more control points must be established around town to ensure completeness.
ii. There is a need for public enlightenment on the usefulness of the controls for the safety of the newly established controls.
iii. The National Horizontal Control Accuracy Standard as detailed in *SURCON Specifications for Geodetic Surveys in Nigeria (2007, pg 6)* needs to be reviewed in the light of modern high-accurate GNSS receivers as already done in some other countries.

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