EXTENSION OF HORIZONTAL CONTROLS USING STATIC GLOBAL NAVIGATION SATELLITE SYSTEM TECHNIQUE IN KWALE AND MOMBASA COUNTIES, KENYA

ODHIAMBO, S.

University of Eldoret, KENYA.

Correspondence: *sodhiambo53@yahoo.com*

Abstract

Static global navigation satellite system (GNSS) surveys provide high positions accuracy by occupying a point for longer periods of time than kinematic systems. It includes a range of survey styles from rapid static surveys to continuously operating stations. This study sought to undertake survey data search for all the existing Survey of Kenya (SoK) old control pillars within the project area; identify appropriate sites for setting up new ground control (GCPs) pillars; monument the new GCPs as per SoK manual requirement and bserve the new GCPs, process and reduce observations to get their adjusted coordinates. Existing old control pillars within the project area were located using three topographical maps i.e. 200/2 (Kwale), 201/1 (Mombasa) and 201/3 (Ukunda). As per section I on survey marks of the SoK manual, eight appropriate sites were selected for new controls pillars and monumented. Two of the five dual frequency GNSS receivers were set up on two base stations and three were used to rove over the new controls for a minimum of one hour before moving them to other new points. The GNSS data was later downloaded, converted into receiver independent exchange (RINEX) format and processed using Leica Geo-Office 8.2 (LGO) GNSS software. The GNSS survey file was compiled as per section VII on presentation of computations of the survey manual and the coordinates of new points plotted in Form 3 as per section VIII on plotting of cadastral survey plan of survey manual. The survey computation file and the plan were forwarded to e director of survey for quality checks and authentication. Static differential GNSS technique provides best accuracy with reasonably low cost and time. The study recommends use of static differential GNSS technique in extension of horizontal controls for use in mapping, planning of land and future surveys since it gives high accuracy results.

Keywords: static GNSS survey; GCPs

Introduction

Global navigation satellite system (GNSS) as explained by Hofmann et al. is made up of a network of satellites transmitting ranging signals used for positioning and navigation anywhere around the world [1]. Madry S states that modern GNSS equipment can track Global Positioning System (GPS) satellite by United States Department of Defense, Global Navigation Satellite System (GLONASS) by Russian, GALILEO system by European, COMPASS system (Beidou "Big Dipper") by China, IRNSS system by India and QZSS system by Japan in either static or real time kinematic (RTK) modes. Initially, GNSS were mainly for the military but slowly also used for surveying and mapping [2].

Gebre agrees that GNSS surveying methods employ satellite signals to determine precise coordinates, enabling professionals in various disciplines to carry out accurate measurements [3]. For instance, companies that by the nature of their operations remove carbon dioxide from the atmosphere by growing trees for sale to polluter companies, require accurate mapping of locations of these farms to ensure carbon offsets claims are backed by factual, verifiable data which can preserve the integrity of the carbon credit system. Mapping locations with traditional survey method is time consuming and expensive. Use of Static differential global navigation satellite systems (GNSS) provides the best accuracy at affordable cost and time [4]. Elsewhere, it has been confirmed that Sino GNSS equipment gives static horizontal/vertical accuracy of 2.5mm/5mm + 0.5ppm and RTK horizontal/vertical accuracy of 8mm/15mm + 1 ppm [5].

Static systems include a range of survey styles from rapid static surveys to continuously operating stations such as CORS and PBO sites. The equipment setup varies significantly, depending on how long the site will be operational, which could vary from 15 minutes to several years [6]. Ground control points that have been fixed and referenced to an existing reference framework provide a basis of uniformity in mapping and planning of the existing land. In this report, the observed GCPs will offer new controls for mapping, planning of land and future surveys.

This study sought to undertake survey data search for all the existing Survey of Kenya old control Pillars within the project area, identify appropriate sites for setting up new GCPs in

Tsimba Golini ward in Kwale County and parts of Tudor, Shimanzi/Ganjoni wards in Mombasa County, monument the new GCPs as per Survey of Kenya manual requirement and observe the new GCPs, process and reduce observations to get their adjusted coordinates.

2.0 Materials and Methods

Study Area

The project covered parts of Tsimba Golini ward in Kwale County with location coordinates 4°12°0°S, 39°27°0°E; Tudor and Shimanzi/Ganjoni wards in Mombasa County with locations coordinates 4°4°30°S, 39°39°0°E. Figure 2.1 shows study area map.

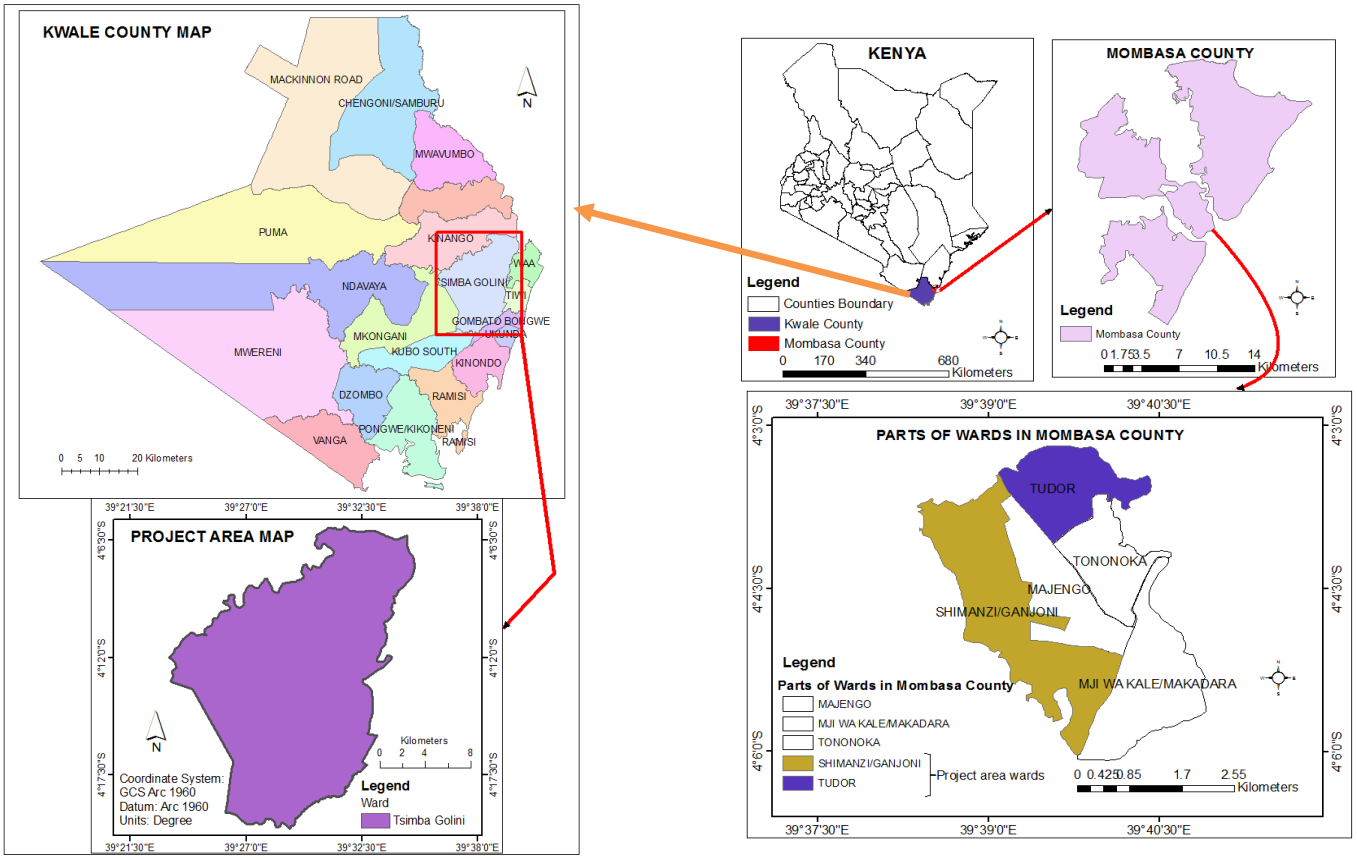

Figure 2.1: Map of Project area

Field work

The field work followed the processes below until the final adjusted coordinates for the new control points were obtained as outlined in the Figure 2.2.

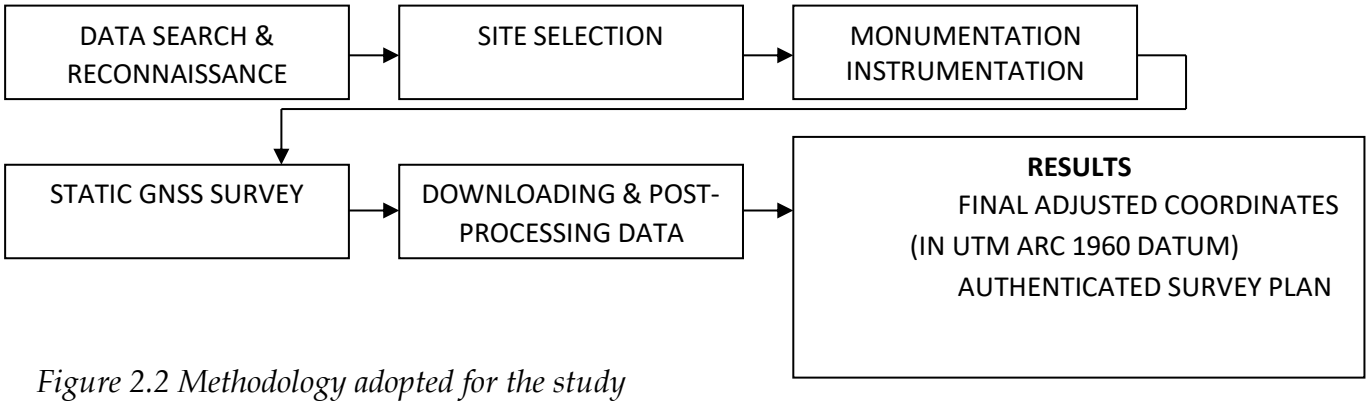

Figure 2.2 Methodology adopted for the study

Data Search and Reconnaissance

Topographical map sheet index at a scale of 1:1,000, 000 was used to identify the topographical maps of the project area. These were used to identify existing old Survey of Kenya (SoK) control pillars. Some of these control pillars were used as base stations for the study. The Topographical maps included; 200/2 (Kwale), 201/1 (Mombasa) and 201/3 (Ukunda). Trigonometric Index Cards for SKP 59, 201.S.5, a printout of excel sheet containing coordinates of 201.TT.17 and Survey plan TC & ST 1207 containing coordinates of NR RALLI all obtained from Survey of Kenya Ruaraka were used to get their coordinates that helped in locating them on the ground using handheld GPS during reconnaissance.

Site Selection

Eight sites for new control points were successfully identified between 5th to 6thApril, 2019. These sites were accessible, away from overhead structures such as powerline, buildings, walls among other objects that can hinder the sky view and create multi-path signal error. The new sites selected formed good geometry. These sites were in Kwale Cultural centre, Golini market, Kwale County water offices, Mtasarani ECD Kwale, Road junction to Godoni, Vuga market, Junction between Makande road Masai street and Junction connecting Tom Mboya road and Taratibu Street (Tudor).

Monumentation

After selecting the sites and ensuring they were all spread within the project area, monumentation was done on 12th April, 2019 where a total of eight new control points were

monumented. The control points were SKW002, SKW003, SKW004, SKW005, SKW007, K6, A7 and HMB9.

Model of Short Truncated Pillar from Survey Manual with dimensions as indicated in figure 2.3 was adopted for this exercise [7].

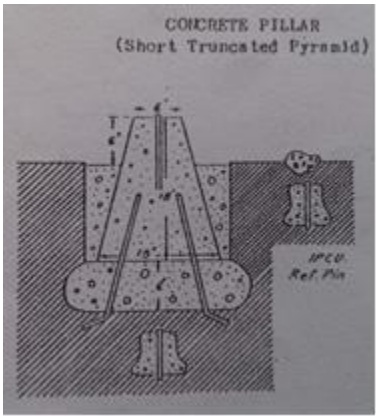

Figure 2.3: Short Truncated Pillar (Source, Survey Manual)

Instrumentation

Equipment used for this project were five Trimble Geodetic GNSS survey receivers (two series 5700 of Serial numbers were: 0220329256, 0220311835 and three series 5800 of serial numbers 4808145829, 4320121736 and 4534155875). The two receivers of series 5700 were set on the two base stations (SKP 59 and NR RALLY) and the three of series 5800 were used to rove over the eight new control points. They receive signals from the antenna and compare the satellite and receiver time code to calculate distance between them. Time difference was fed into a complex code for determining position based on at least 4 satellite signals. The receiver is responsible for sending the position data to the controller computer for user viewing and for taking user input and executing commands.

Static GNSS Survey

Two receivers of series 5700 of Trimble Geodetic GNSS were set over the two old SoK control pillars that were used as base stations for the static survey while three 5800 series of the receivers were set over the new pillars. The project name, vertical/slant heights, station name, location, physical location, date of observation, name of observer, geographical location, point ID, start and end recording time, receiver model/serial number, photograph of the point and

sketch of the point were recorded in the field observation log sheet. All receivers powered on at the same time to start logging in data. The three rovers were left to log in data for a minimum of one hour before being switched off and moving them to other new pillars. The two base station receivers remained on until all the new pillars had been proved. This process was repeated until all the new pillars had been proved.

Downloading and Post-Processing Static GNSS Survey Data

In the office, the five receivers were connected to a personal computer via Trimble data transfer utility and all the files that had earlier been collected and saved in the field downloaded into the computer hard disk.

The raw data collected by the GNSS receivers was translated into different formats for data processing or sharing. GNSS receivers collected the data in .TO1 file format. This file format needed to be converted into a format that can be read into any geodetic processing software. Thus, raw data was converted into RINEX (Receiver Independent Exchange Format) since it is a widely readable data format for raw GNSS observation data since RINEX is read by most processing software, including Leica Geo-Office 8.2, GNSS Solution and Topcon Tools among others. Leica Geo-Office 8.2 (LGO) GNSS post-processing software was used to find the coordinates of the eight unknown new control points by differentially processing data relative to a fixed base location. The processing begins by correcting base and rover position to establish a baseline vector from base to rover position that the GNSS receivers acquired simultaneously. SKP 59 base station was held as fixed with its known coordinates and its relative position used to solve coordinates for the other base station (NR RALLI) and the other new control pillars.

Results and Discussions

Existing Survey of Kenya old control Pillars within the project area

From reconnaissance survey that was carried out within the project site on 25th and 26th March 2019, four SoK pillars were found i.e. SKP 59 at Kwale KWS gate, NR RALLI on top of Ralli house Mombasa Central Business District (CBD), 201.S.5 at Diani Veterinary offices and 201.TT.17 at Ukunda. 201.S.5 and 201.TT.17 were physically partially vandalized hence were not used since it could have interfered with their location. Plate 3.1 shows four SoK control

pillars and Figure 3.1 shows their overlay on the georeferenced topographical maps 200/2 (Kwale), 201/1 (Mombasa) and 201/3 (Ukunda).

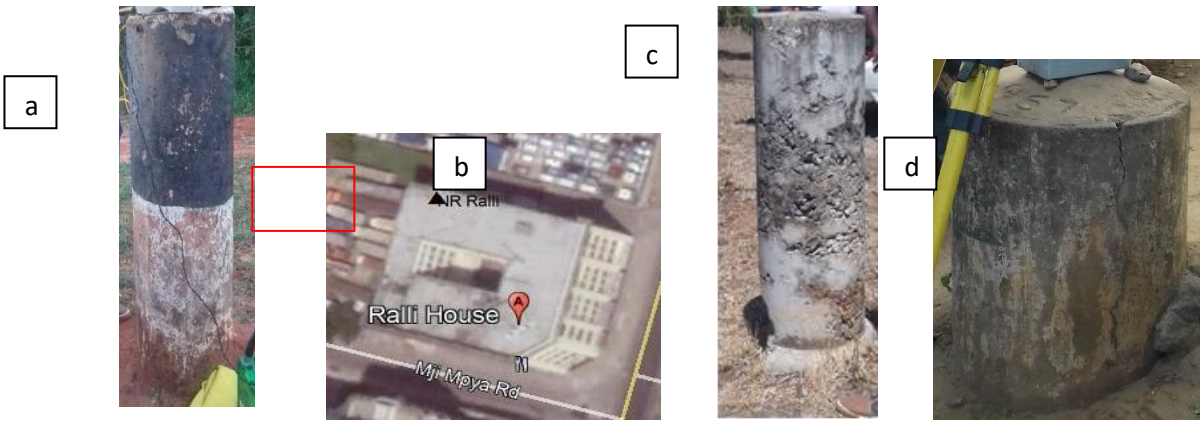

Plate 3.1: (a) SKP 59 (I order); (b) NR RALLI; (c) 201.S.5 (II order) and (d) 201.TT.17 control pillars

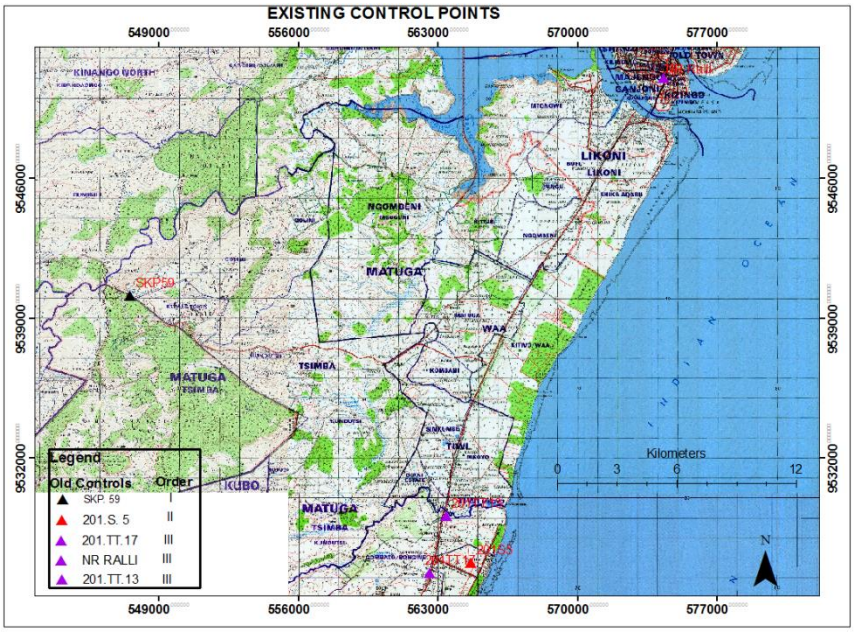

Figure 3.1: Map of old SoK pillars (SKP 59 (I order); NR RALLI; 201.S.5 (II order) and 201.TT.17)

Appropriate sites for setting up new GCPs within the project area

Figure 3.2 shows an overlay of eight new control sites selected on the georeferenced topographic maps 200/2 (Kwale), 201/1 (Mombasa) and 201/3 (Ukunda).

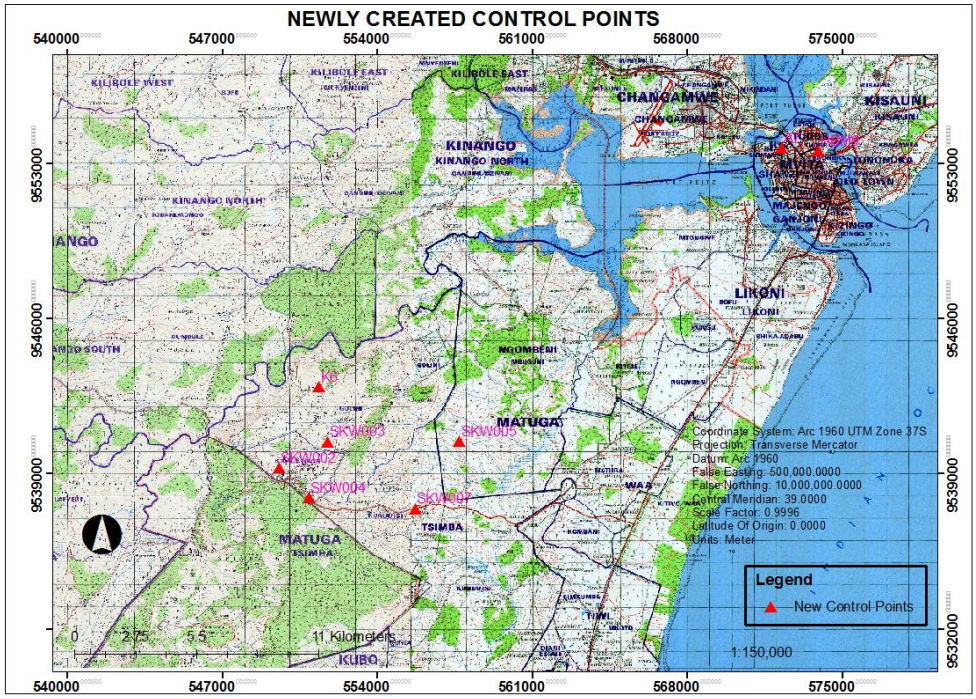

Figure 3.2: Map of new control sites (SKW002, SKW003, SKW004, SKW005, K6, A7, HBM9)

Monument of the new GCPs within the project area

A model was constructed from timber with measurements as per Survey Manual for Short Truncated Pillar. The height was 18 inches, the base was 15 inches and its top surface was 6 inches. Eight holes were then dug at those selected sites for new points and the model inserted. Concrete was made to a mixture of 1:3:6 (cement:sand:ballast) as per the survey manual. They were then monumented, left to dry and the station name marked on top of their bases. Plate 3.2 shows a model of short truncated pillar and already monumented and marked new pillar. Table 3.2 shows a list of site names against their station names.

Plate 3.2: Model of Short Truncated Pillar and Monumented new control pillar (SKW 007) at Vuga market.

S/No	SITE NAME	STATION NAME
1.	Kwale Cultural centre	SKW002
2.	Golini market	SKW003
3.	Kwale County water offices	SKW004
4.	Mtasarani ECD Kwale	SKW005
5.	Road junction to Godoni	K6
6.	Vuga market	SKW007
7.	Junction between Makande road Masai street	A7
8.	Junction connecting Tom Mboya road and Taratibu Street	HBM9

Table 3.1: Final Adjusted coordinates (Arc 1960_UTM_Zone_37S)

2.1 Adjusted Coordinates for new GCPs.

Coordinates of two old SoK control pillars and newly established GCPs are given on table 3.2.

UTM ARC 1960 Zone 37S adjusted final coordinates				
STATION	**PCLASS**	**CLASS OF BEACONS**	**EASTINGS (m)**	**NORTHINGS (m)**
SKP. 59	Control	SoK standard pillar	547557.042	9540130.909
NR RALLI	Control	Corner of metal plate on roof	574327.783	9551029.426
SKW007	Adjusted	I.P.C	555724.8565	9537438.288

SKW005	Adjusted	I.P.C	557732.5896	9540456.797
SKW004	Adjusted	I.P.C	550922.0658	9537927.172
SKW003	Adjusted	I.P.C	551783.1219	9540437.619
SKW002	Adjusted	I.P.C	549569.2772	9539280.893
K6	Adjusted	I.P.C	551369.0972	9542919.417
HBM09	Adjusted	I.P.C	573941.5765	9553552.536
A7	Adjusted	I.P.C	572277.914	9553669.484

Table 3.3: Final Adjusted coordinates (Arc 1960_UTM_Zone_37S)

Computations

The main result for this project was an authenticated survey plan number TC & ST 1372 (Standard Traverse and Chart) that shows the control network and their coordinates values (Northings, and Eastings). The authenticated survey plan was achieved by compilation of field survey data as per section VII of the survey manual, plotting the coordinates of new pillars in Form 3 as per section VIII on plotting of cadastral survey plan of survey manual and forwarded to Director of Survey-Ruaraka Nairobi on 1st July, 2019 for quality checks and authentication. The survey plan was authenticated on 17th September, 2019. Figure 3.3 shows authenticated survey plan drawn in Form 3.

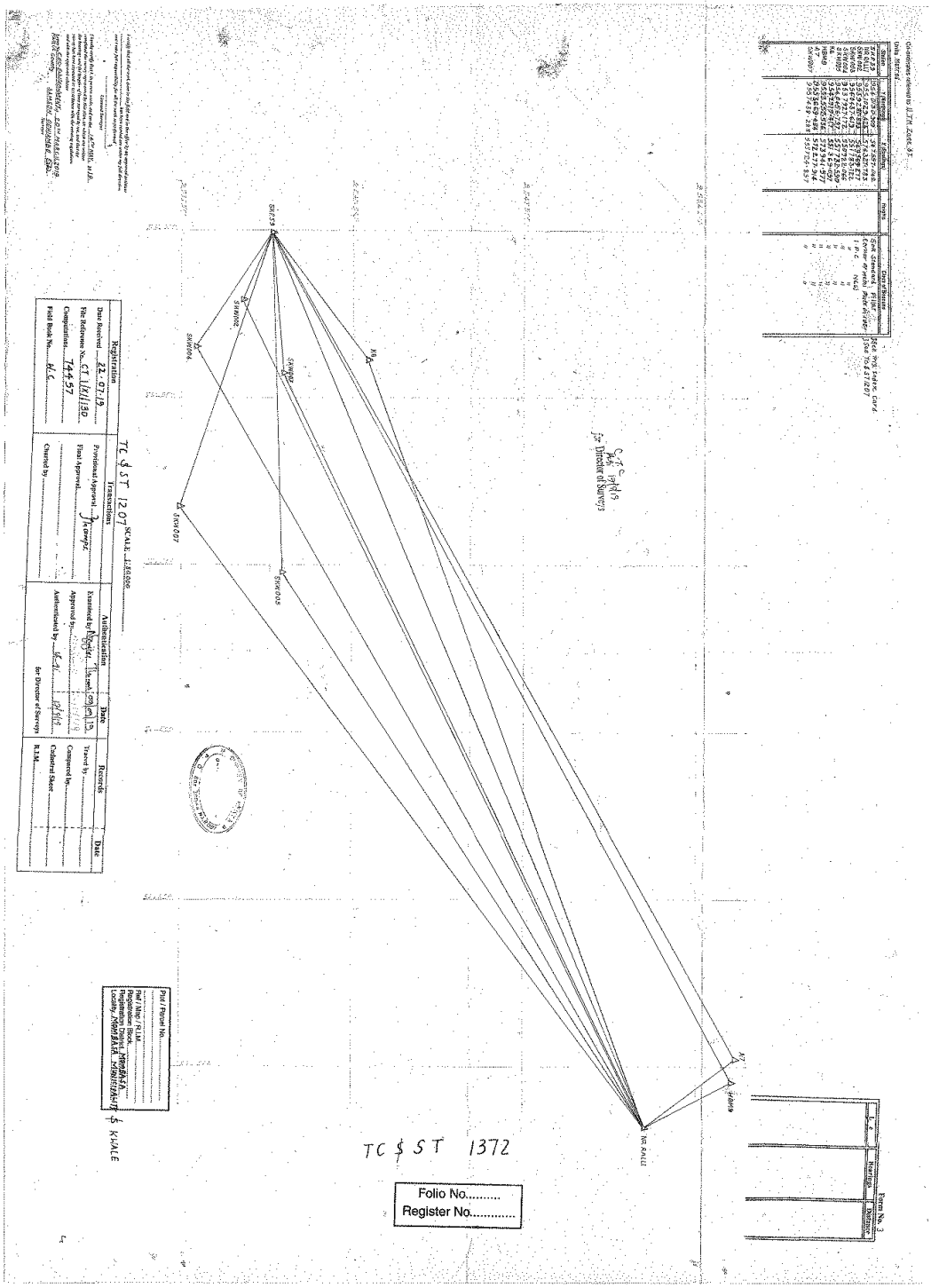

Figure 3.3: Authenticated Survey Plan No. TC & ST 1372 (Form No. 3)

Conclusion

The best accuracy, reasonable low cost and time is provided by Static differential GNSS technique. Therefore, coordinates of adjusted new controls points for this project should be used for further survey as control pillars since the data has been Approved and Authenticated by the Director of Survey.

Acknowledgment

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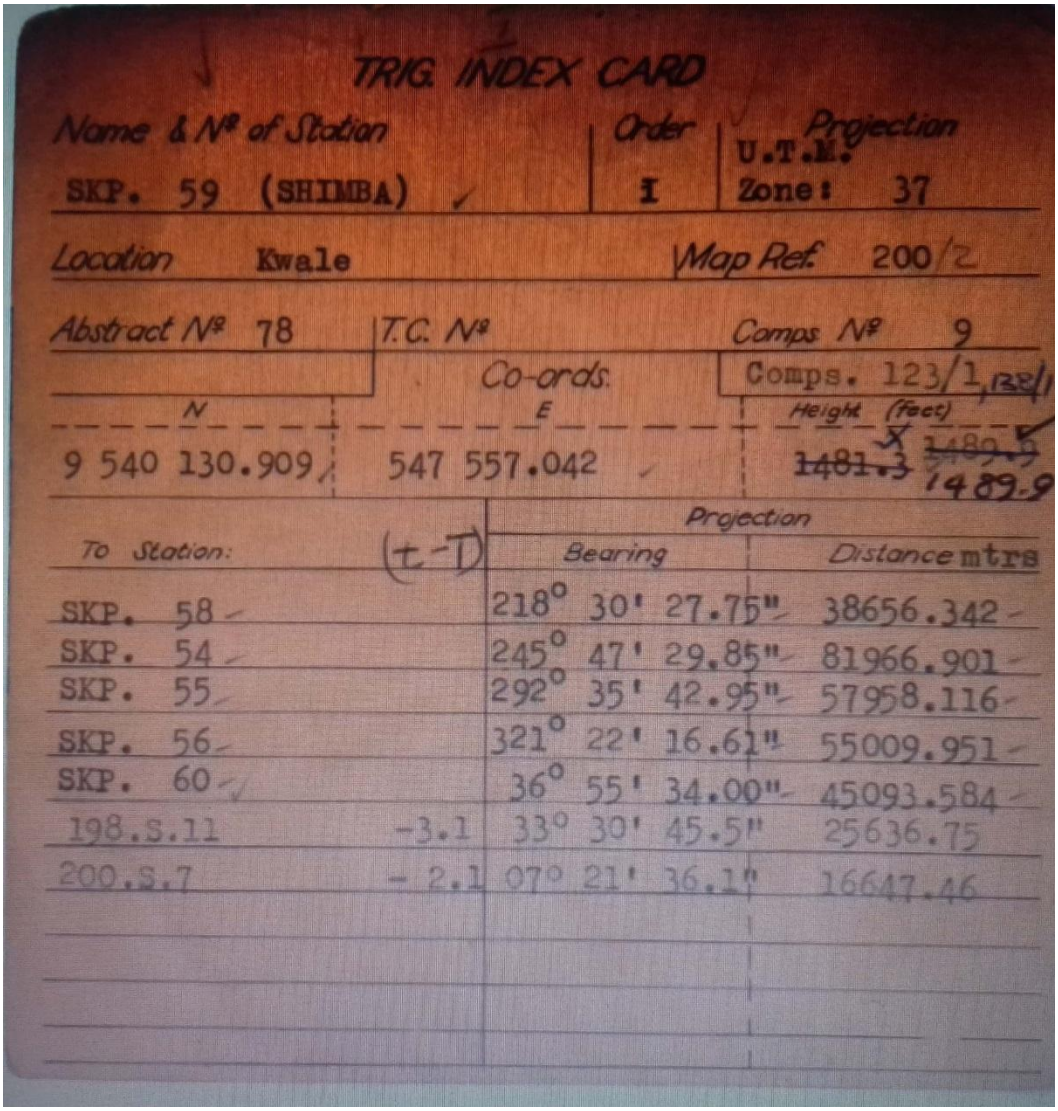
7. Kenya Survey manual

Annexure

Annex 1: Trig Index Card for SKP. 59



TRIG. INDEX CARD

Name & Nº of Station	Order	Projection
SKP. 59 (SHIMBA)	I	U.T.M. Zone: 37

Location: Kwale — Map Ref: 200/2

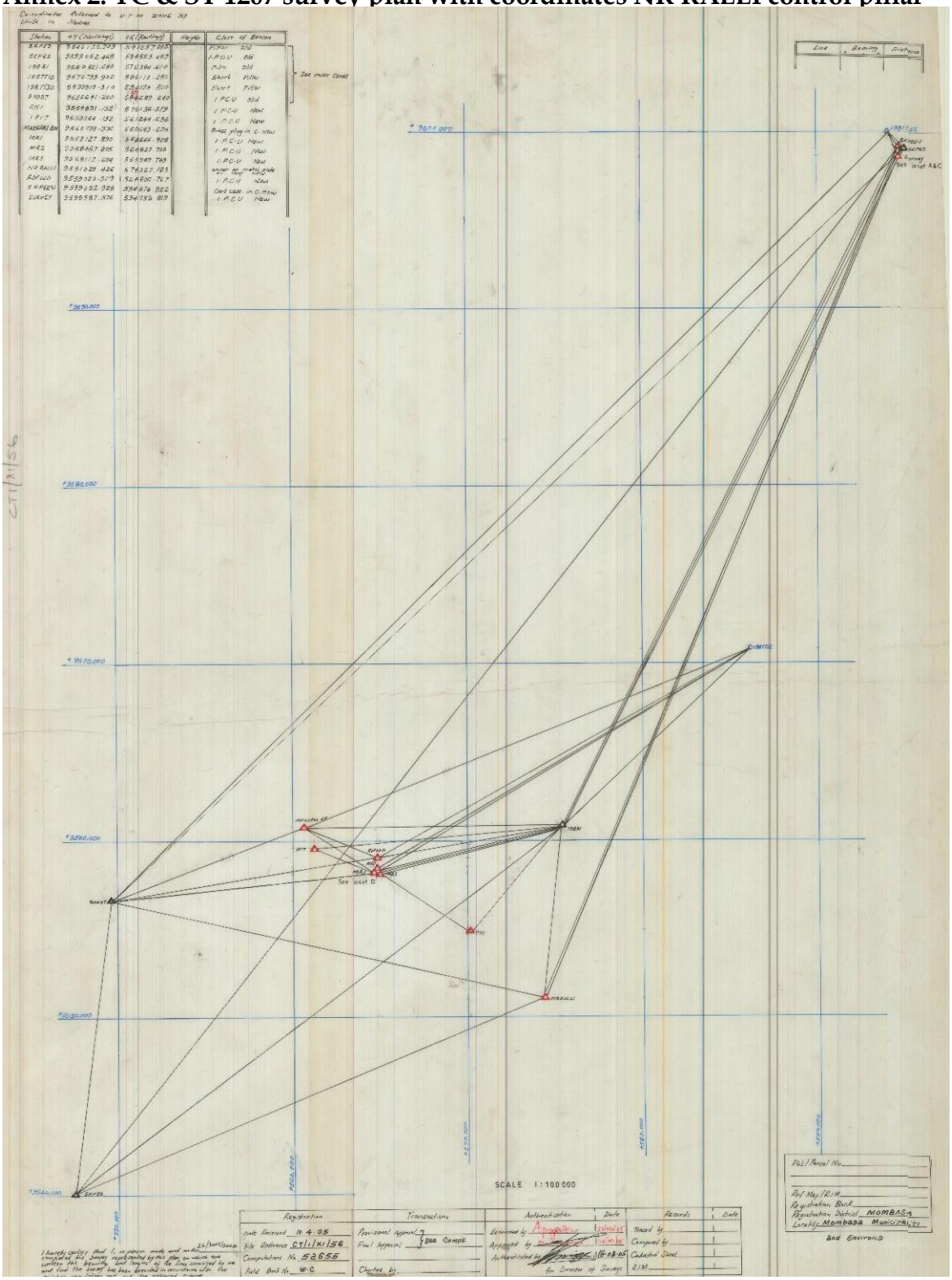
Abstract Nº 78 — T.C. Nº — Comps Nº 9

Comps. 123/1, 138/1

Co-ords. N	Co-ords. E	Height (Feet)
9 540 130.909	547 557.042	~~1481.3~~ ~~1489.5~~ 1489.9

To Station:	(t-T)	Projection Bearing	Distance mtrs
SKP. 58		218° 30' 27.75"	38656.342
SKP. 54		245° 47' 29.85"	81966.901
SKP. 55		292° 35' 42.95"	57958.116
SKP. 56		321° 22' 16.61"	55009.951
SKP. 60		36° 55' 34.00"	45093.584
198.S.11	-3.1	33° 30' 45.5"	25636.75
200.S.7	- 2.1	07° 21' 36.1"	16647.46

Annex 2: TC & ST 1207 survey plan with coordinates NR RALLI control pillar



Annex 3: Static GNSS Survey Field Observation Log sheet

<table>
<tr><td colspan="2">PROJECT NAME:</td><td>Extension of Horizontal Controls</td></tr>
<tr><td colspan="2">PROJECT LOCATION:</td><td>Kwale and Mombasa Counties</td></tr>
<tr><td colspan="2">PHYSICAL LOCATION:</td><td>At Kwale KWS gate</td></tr>
<tr><td colspan="2">DATE: 14th May, 2019</td><td>OBSERVER: Samson Odhiambo and David Adhola</td></tr>
<tr><td colspan="3">GEOGRAPHIC LOCATION: (FROM TRIG. INDEX CARD)</td></tr>
<tr><td colspan="2">NORTHING (M)</td><td>EASTING (M)</td></tr>
<tr><td colspan="2">9540130.909</td><td>547557.042</td></tr>
<tr><td colspan="2">POINT INFORMATION:</td><td rowspan="8">PHOTO:  </td></tr>
<tr><td>POINT ID:</td><td>SKP. 59</td></tr>
<tr><td>START TIME:</td><td>11.39AM</td></tr>
<tr><td>END TIME:</td><td>17.52PM</td></tr>
<tr><td>SLANT HEIGHT:</td><td>0.4730 metres</td></tr>
<tr><td>RECEIVER MODEL:</td><td>Trimble 5700</td></tr>
<tr><td>RECEIVER S/NUMBER</td><td>0220329256</td></tr>
<tr><td colspan="2">Remarks: it is a Ist order SOK control pillar in good condition.</td></tr>
</table>

Annex 4: GNSS observations

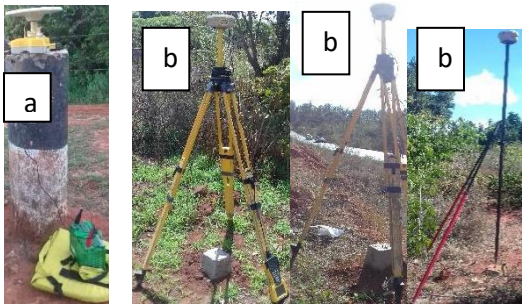


Plate 3.2: (a) Trimble receiver set over SKP 59 and (b) set over new pillars