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Analysis Of The Displacement Patterns Of Obajana And Environs Using Precise Point Positioning Solution.

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Abstract: *This paper describes the displacement pattern of Obajana and environs. Displacement is the shift recorded in the easting, northing and zenith direction of a point of observation. The aim of this study was to analyze the displacement pattern in the 3 directions. A Hi-Target GNSS V30 receiver was used on static mode to acquire satellite signal of receiver locations which of course were the observation stations. The duration for at every observation station was averagely 60 minutes. The observations were carried out in 3 months interval for 1 year. The raw GNSS data was downloaded and further converted into a RINEX data for compatibility analysis in online Precise Point Positioning (PPP) solutions. The RINEX data were uploaded to CSRS-PPP, a Canadian online PPP solution for post-processing of the GNSS results. After this, the peak horizontal displacement formula was used to determine the horizontal displacement. The height differencing method was used to determine the vertical displacement values. Analysis were done with graphs and charts for easy understanding. The results were actually in centimeter and millimeter range. It is recommended the PPP solutions can be reliable in terms of geodetic monitoring because of its weighted least square algorithm.*

Keywords: Displacement, GNSS, RINEX, PPP.

1.0 INTRODUCTION

Displacements could be horizontal or vertical. This study will show the displacement pattern of points observed in Obajana and environs. The points were observed to detect some traces of displacements. Horizontal displacements are shifts in the direction of Eastings and Northings of any point. While the Vertical displacement is a shift in the direction of the zenith of any point. Displacement can be caused by different factors such as increased human activities according to Yasuko, *et al.,* (2014). Also, Grapethin *et al.,* (2018) and Walker (1998) wrote that extraterrestrial impacts, explosions, storm waves hitting the shore, tidal effects and rock or limestone mining and blasting are responsible for inducing movements on the earth's surface. These displacements if not monitored could erupt into hazards.

According to Guma, (2021), Nigeria in the year 1999, had its first earth tremor occurrence and due to dearth of monitoring campaign prior to that time to detect its imminence, the occurrences in recent times, have terrified the Nigerian people. Some places that have experienced this tremor in Nigeria are; Kwoi in Kaduna State, Mpape in Abuja, Ijebu-Ode in Ogun State, Shaki in Oyo State, Igbogene in Bayelsa State and Maitama in Abuja. Nigeria National Space Research and Development Agency (NASDRA) (2018) reported that in two towns of Abuja, Nigeria (Mpape and Maitama) alone, the causes of these earth tremors that occurred recently were due to excessive borehole drilling activities in and around these towns.

For this reason credited to NASDRA, this idea for this was research was birthed. It was birthed to monitor the displacement of the surface of the terrain in Obajana and environs because lots of mining operations go on there. In Obajana is located the largest Cement manufacturing factory in the whole of West African region. It is called Dangote Cement PLC. In Obajana incessant mining activities have been ongoing since 1992 when it was Obajana cement Plc, the impact of mining activities needs to be monitored and controlled. There is need for monitoring of dynamism in order to have knowledge of the rate of displacements in the study area and environs (Guma, 2021).

The Concept of the Canadian Spatial Reference System (CSRS).

Tetreault, Kouba, Heroux and Legree, (2005) wrote that CSRS-PPP (CSRS - Precise Point Positioning) authorizes GPS users in and outside of Canada to realize accurate positioning by accepting GPS observations from a single receiver over the Internet. The result of data submitted to CSRS-PPP is equivalent to the ones anyone can obtain with phase-differential GPS without the need to access or process data collected concurrently at a base station that are properly referenced. CSRS-PPP can process GPS observations from single or dual-frequency GPS receivers operating in static or kinematic mode. Depending on user equipment, receiver dynamics and duration of the observing session; this application can improve positioning results by a factor of 2 to 100 in comparison to uncorrected point positioning using broadcast GPS orbits.

According to Tetreault *et al*, (2006) explained further that, the key to the success of this CSRS-PPP approach is that, it uses of precise GPS orbit and clock products generated through international collaboration which are typically 100 times better than those contained in the GPS broadcast navigation message. While the service estimates user positions based on satellite orbits established in the International Terrestrial Reference Frame (ITRF), transformation parameters to NAD83 (CSRS) are applied internally to link the user directly to the CSRS. NAD83 (CSRS) is being increasingly adopted as the standard of reference for positioning in Canada. Positioning with respect to recognized standards greatly facilitates sharing and integrating geo-referenced datasets to ensure their long-term spatial compatibility at the highest precision, permitting interoperability of related applications.

RELATED LITERATURE

Ogutcu, (2020), agreed that Network-based real-time kinematic (NRTK) GNSS is a commonly used surveying technique used to generate reliable error models that can mitigate dispersive (e.g. ionospheric delay) and non-dispersive (e.g. tropospheric delay and orbit bias) errors. Ogutcu, (2020) researched on the performance of NRTK positioning for deformation and landslide monitoring using a simulation apparatus. The methodology was that observation was carried out on 24 hour bases while NRTK data was acquired with 1-s sampling intervals. Ogutcu, (2020) explained that, the 24-h NRTK data have to be subdivided into 12-, 6-, 3- and 1-h to investigate the effect of observation time on monitoring displacement performance.

In their processing, two filtering methods were deployed and that is, the averaging of the raw observations and the averaging of the observations derived from Kalman filtering. This was done for every session of GNSS observation. The displacements obtained from the filtered NRTK observations are compared to what was known to be the simulated (true) displacements.

Again, experiment was carried out using first-order low-pass and moving-average filters. The results of the experiments indicate that 1-sigma horizontal and vertical Root Mean Square errors (RMSEs) of displacements between the filtered NRTK data and true displacements are determined to be 1.5 and 5.4 mm, respectively, using 24-h data.

Ogutcu, (2020), inferred that for detecting displacements in real time, the minimum magnitude of displacements needs to be 7 mm and 10 mm for the horizontal and vertical components, respectively, to distinguish the displacements from the noise. In this review, no gap was discovered.

Segina *et al*, (2020), introduced a prototype of low-cost GNSS monitoring system which was installed under field conditions. The detected surface displacements were evaluated through a comparison with the network of classic geodetic measurements. The results of a nine-month monitoring period using seven GNSS stations provided a landslide surface movements. The displacement data were correlated with precipitation measurements.

Kistler (2016) shows the results of the time series analysis with displacements from 1933 to 2015 as well as comparison with the displacement rates from the SAR analysis. Furthermore, the following GNSS survey points. The comparison of the displacement rates showed that the result obtained were identical. The GNSS measurements show slightly higher rates with 7 to 8mm/year in comparison to the SAR rates with 5 mm/year.

Yuwono and Prasetyo (2019) used Global Navigation Satellite Systems (GNSS) in deformation monitoring and estimating infrastructure and motion of crustal plate. Yuwono and Prasetyo (2019) monitored displacement on a dam structure using GNSS survey and terrestrial survey base on Total Station. The standard deviations of the observations showed that both instruments are capable of monitoring displacements.

Yuwono and Prasetyo (2019) explained that, some factors such as erosion and stability problems could be responsible for deformations in embakment and dams etc. Yuwono and Prasetyo (2019) adviced that in order to preserve the safety of dams or structures, monitoring of structural and dam behavior before and after construction process is very important.

Yuwono and Prasetyo (2019) agreed that, there are numerous techniques for measuring the deformations for early warning signs and they can be grouped mainly into; geodetic and non-geodetic techniques.

Kistler (2016) inferred also that, SAR interferometry datasets have been used to determine the terrain displacements.

RESEARCH DIRECTION

This study tends to monitor the displacement pattern of points and so, both peak displacement method and the vertical displacement method deployed by Guma, (2021) was used. They are;

Horizontal peak displacement will be computed for using;

$$H_p = \sqrt{\Delta E^2 + \Delta N^2} \qquad 1.1$$

The vertical displacement estimation formula will be;

$$\Delta \text{h} = h_{t+1} - h_{t-1} \qquad 1.2$$

METHODOLOGY

Locations for monitoring stations were chosen for their suitability for GPS observations. Before the Monumentation, the following characteristics were well thought of;

i. No obstructions above the 15° cutoff angle around the location of the control stations.
ii. No reflecting surfaces that could cause multipath.
iii. The location is safe and away from traffic and passersby. So that the receivers may be left unattended to for some time.
iv. No powerful transmitters (radio, TV antennas, etc.) in the vicinity.

Hi-Target V30 GNSS Single Receiver and its accessories were used to acquire data from the satellite. The receiver was used to acquire Satellite data in quasi static mode. An average of 60 minutes was spent on each station. The observations for data acquisition were made on **Static** mode with Hi-Target single frequency receiver. The single receiver occupied each of the stations for one (1) hour on 3 months interval. The time of the first phase of observation was February, 2020. Before observation at each observation station, a temporary adjustment was usually carried out. This include; the setting up of the GPS receiver on the observation point. Centring with optical plummet to focus on the intersection that defines the middle of the ground point. Then, the foot screws attached with the tribrach were turned simultaneously to bring the spirit bubble to the centre of its run. After this, the height of instrument would be taken by measuring from the tip of the iron rod on the ground point to the Trunnion axis as identified on the receiver head. The data logger would be put on and the connection between the receiver and data logger would be made through their inbuilt Bluetooth system.

The acquisition of the secondary data aspect of this work involve the manipulation and simulation of the primary data acquired from the static observations into more useful form by using appropriate software. The acquired satellite data on static mode, were downloaded from the receiver to the laptop computer.

The software known as Hi-Target Geomatics Office was used to convert the ".GNS" files to PPP compatible files which is the RINEX format. The RINEX data were uploaded to CSRS-PPP online solution. After some little time, the results were sent back via email. Because this study is going to be limited to horizontal and vertical displacements, only the corresponding results will be discussed.

The results for CSRS-PPP for the observations were obtained for February, 2020, May 2020, August 2020, November 2020 and finally, February 2021. They results are displayed in tabular form;

Table 1.1: The PPP results for February, 2020

S/N		20-Feb		
	STN ID	EASTING (m)	NORTHING (m)	ELLIP HGT
1	PHD 001	252506.448	872471.814	74.902
2	PHD 006	252670.394	868382.856	79.449
3	PHD 007	249303.245	862100.665	81.823
4	PHD 008	251812.304	864381.901	66.794
5	PHD 010	250094.703	868113.602	84.301
6	PHD 011	241153.682	843998.099	87.632
7	PHD 016	217416.604	881042.205	232.363
8	PHD 017	218015.872	883422.256	268.713
9	PHD 018	217698.872	882087.851	249.117

10	PHD 021	246109.945	864605.587	114.687
11	PHD 023	240464.990	863692.444	151.738
12	PHD 024	239193.685	864424.162	136.961
13	KGY 021	250995.696	867315.777	91.540
14	LM 130	245327.140	863497.840	91.337

Table 1.2. PPP results for May, 2020 observations

STN ID	EASTING (m)	NORTHING (M)	ELLIP HGT
PHD 001	252506.500	872471.818	74.841
PHD 006	252670.429	868382.900	79.548
PHD 007	249303.341	862100.666	81.931
PHD 008	251812.355	864381.902	66.803
PHD 010	250094.610	868113.512	82.899
PHD 011	241153.697	843998.110	87.602
PHD 016	217416.595	881042.204	232.207
PHD 017	218015.895	883422.271	268.665
PHD 018	217698.913	882087.849	249.181
PHD 021	246110.011	864605.575	114.827
PHD 023	240464.954	863692.458	151.678
PHD 024	239193.764	864424.171	137.090
KGY 021	250995.692	867315.747	90.037
LM 130	245327.122	863497.837	91.291

Table 1.3: PPP results for August, 2020

STN ID	**EASTING (m)**	**NORTHING (M)**	**ELLIP HT**
PHD 001	**252506.427**	**872471.801**	**74.817**
PHD 006	**252670.474**	**868382.868**	**79.381**
PHD 007	**249303.389**	**862100.641**	**81.825**
PHD 008	**251812.36**	**864381.924**	**66.768**
PHD 010	**250094.588**	**868113.487**	**82.512**
PHD 011	**241153.692**	**843998.096**	**87.615**
PHD 016	**217416.572**	**881042.209**	**232.304**
PHD 017	**218015.821**	**883422.243**	**268.682**
PHD 018	**217698.854**	**882087.861**	**249.125**
PHD 021	**246109.978**	**864605.597**	**114.733**
PHD 023	**240464.769**	**863692.356**	**151.439**
PHD 024	**239193.741**	**864424.172**	**137.111**
KGY 021	**250995.656**	**867315.711**	**89.988**
LM 130	**245327.16**	**863497.828**	**91.311**

Table 1.4: November, 2020 SPP observation

POINT 1D	EASTING(M)	NORTHING (M)	EL HT
PHD 001	252506.472	872471.807	74.865
PHD 006	252670.543	868382.914	79.393
PHD 007	249303.395	862100.631	81.893
PHD 008	251812.385	864381.919	66.796
PHD 010	250094.604	868113.536	82.627
PHD 011	241153.684	843998.102	87.609
PHD 016	217416.643	881042.211	232.291
PHD 017	218015.938	883422.253	268.699
PHD 018	217698.88	882087.882	249.133
PHD 021	246109.958	864605.592	114.735
PHD 023	240464.93	863692.447	151.654
PHD 024	239193.77	864424.189	137.072
KGY 021	250995.703	867315.76	90.117
LM 130	245327.133	863497.842	91.218

Table 1.5: PPP result for February, 2021 SPP Observations.

S/N	STN ID	**FEB 20**	MAY 20	**AUG 20**	NOV 20	FEB 21
1	PHD 001	**74.902**	74.841	**74.817**	74.865	74.842
2	PHD 006	**79.449**	79.548	**79.381**	79.393	79.384
3	PHD 007	**81.823**	81.931	**81.825**	81.893	81.883
4	PHD 008	**66.794**	66.803	**66.768**	66.796	66.761
5	PHD 010	**84.301**	82.899	**82.512**	82.627	
6	PHD 011	**87.632**	87.602	**87.615**	87.609	87.725
7	PHD 016	**232.363**	232.207	**232.304**	232.291	232.336
8	PHD 017	**268.713**	268.665	**268.682**	268.699	268.714
9	PHD 018	**249.117**	249.181	**249.125**	249.133	249.143
10	PHD 021	**114.687**	114.827	**114.733**	114.735	114.703
11	PHD 023	**151.738**	151.678	**151.439**	151.654	151.789
12	PHD 024	**136.961**	137.090	**137.111**	137.072	137.136
13	KGY 021	**91.540**	90.037	**89.988**	90.117	89.994
14	LM 130	**91.337**	91.291	**91.311**	91.218	91.259

Processing of Horizontal Displacement

Horizontal peak displacement is computed for using;

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$H_{pd}=\sqrt{\Delta E^2 + \Delta N^2}$ 1.3

The co-seismic displacement as estimated are between February, 2020 and February, 2021. The results are presented in table 1.6. The ΔE and ΔN are obtained from the differencing of February, 2020 and February, 2021 coordinates. Therefore, to determine the displacement that may have occurred between February 2020 and February 2021, we have;

For point PHD 001 between February 2020 and February 2021, we have;

ΔE = 0.043

ΔN =0.009

$D_p = \sqrt{0.043^2 + 0.009^2}$ = 0.043931m

The same procedure was carried out to determine the displacements for every other points.

Table 1.6: Displacement results for all points.

STN ID	ΔE(m)	ΔN(m)	PEAK DISPLACEMENT(m) $D_p = \sqrt{\Delta E^2 + \Delta N^2}$
PHD 001	0.043	0.009	0.043931
PHD 006	0.111	0.035	0.116387
PHD 007	0.080	-0.039	0.089
PHD 008	0.03	-0.002	0.03
PHD 011	-0.02	0.031	0.03689
PHD 016	0.002	-0.001	0.002
PHD 017	0.027	-0.008	0.00563
PHD 018	0.023	-0.007	0.024
PHD 021	0.004	-0.019	0.003883
PHD 023	-0.072	-0.005	0.07217
PHD 024	0.078	0.024	0.081605
KGY 021	0.038	-0.045	0.0588982
LM 130	0.00	-0.012	0.012
**PHD 010	-0.099	-0.066	0.118983

**PHD 010 was estimated for 9 months interval because the point was destroyed as a result of construction work ongoing around the point area and so there was no observation in February 2021 there.

Processing of Vertical displacement

The Ellipsoidal heights were part of the data obtained from the CRSC-PPP online post processing results of points observed. The online Geoid Height Calculator was used to generate the geoidal undulations (N) and the orthometric heights (H). Table 1.7 and table 1.8 shows the various heights obtained for February 2021.

Table 1.7: Orthometric, Geoid and Ellipsoidal heights of February, 2021.

STN ID	Ellipsoidal Height (m)	Geoidal Undulation(m)	Orthometric Height (m)
PHD 001	74.842	23.274	51.568
PHD 006	79.384	23.220	56.164
PHD 007	81.883	23.135	58.748
PHD 008	66.761	23.164	43.597
PHD 011	87.725	22.948	64.777
PHD 016	232.336	23.295	209.041
PHD 017	268.714	23.289	245.425
PHD 018	249.143	23.293	225.85
PHD 021	114.703	23.167	91.536

PHD 023	151.789	23.164	128.625
PHD 024	137.136	23.172	113.964
KGY 021	89.994	23.203	66.791
LM 130	91.259	23.156	68.103

Table 1.8: Heights for PHD 010 in November, 2020.

STN ID	ELLIPSOID (m)	GEOID HEIGHT (m)	ORTHOMETRIC (m)
PHD 010	82.627	23.211	59.416

Table 1.9 contain heights obtained for February, 2020 observation. The heights were obtained from online Geoid Height Calculator.

Table 1.9: Heights for February, 2020.

STN ID	Ellipsoidal Height (m)	Geoidal Undulation(m)	Orthometric Height (m)
PHD 001	74.902	23.274	51.628
PHD 006	79.449	23.220	56.229
PHD 007	81.823	23.135	58.688
PHD 008	66.794	23.164	43.630
**PHD 010	84.301	23.211	61.090
PHD 011	87.632	22.948	64.684
PHD 016	232.363	23.295	209.068
PHD 017	268.713	23.289	245.424
PHD 018	249.117	23.293	225.824
PHD 021	114.687	23.167	91.520
PHD 023	151.738	23.164	128.574
PHD 024	136.961	23.172	113.789
KGY 021	91.540	23.203	68.337
LM 130	91.337	23.156	68.181

The vertical displacements for each point were computed for. The point PHD 001 was computed as thus;

$h_{2021} - h_{2020}$ where h_{2021} is the orthometric height for PHD 001 on February, 2021 and it is 51.568m. h_{2020} is the orthometric height obtained in February, 2020 which is 51.628m.

$$h_{2021} - h_{2020} = 51.568 - 51.628 = \mathbf{-0.06m}$$

The same procedure was followed to determine for displacement on other observation points as can be seen in table 1.10.

Table 1.10: Vertical displacement results for each station point.

STN ID	h_2 orthometric Height (m) Feb, 2021	h_1 Orthometrc Height (m) feb, 2020	V.d= $h_2 - h_1$ (m)
PHD 001	51.568	51.628	-0.06
PHD 006	56.164	56.229	-0.065
PHD 007	58.748	58.688	0.06
PHD 008	43.597	43.630	-0.033

PHD 010	*59.416*	61.090	-1.674
PHD 011	64.777	64.684	0.093
PHD 016	209.041	209.068	-0.027
PHD 017	245.425	245.424	0.001
PHD 018	225.850	225.824	0.026
PHD 021	91.536	91.520	0.016
PHD 023	128.625	128.574	0.051
PHD 024	113.964	113.789	0.175
KGY 021	66.791	68.337	-1.546
LM 130	68.103	68.181	-0.078

Analysis of the Horizontal displacements on points

The displacement is going to be analysed graphically from February, May, August, November 2020 and February, 2021. The vertical axis represent North coordinate and the Horizontal represent the Easting coordinates. The scale were generated by the Microsoft word software and they are in millimeters in both axes.

The displacement increased a little. There was decline between May to August, 2020 which clearly agrees that there were almost no vehicular activities there owing to covid-19 restrictions in Kogi State. There seemed to be gradual shift from that August to November and then, to February 2021 because activities increased. The figure 4.1b clearly interpreted the activities of Banda area through those times of observation.

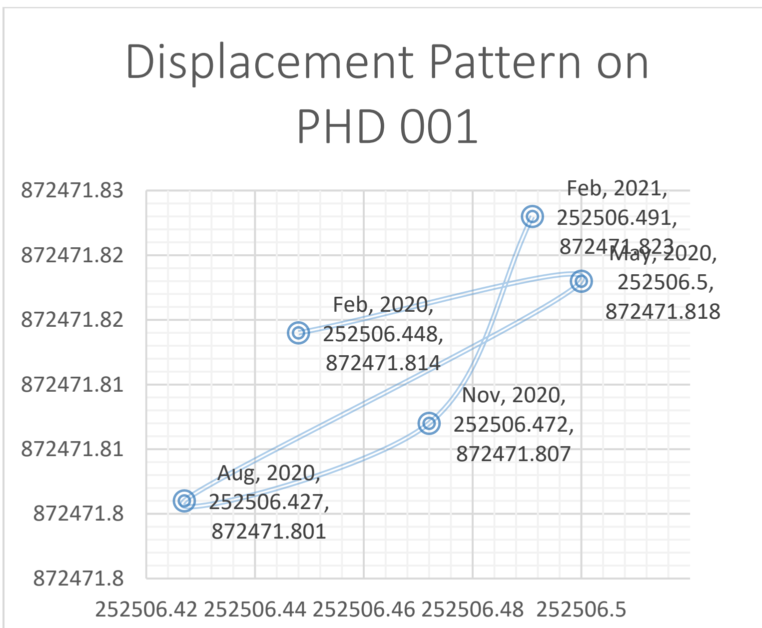

Fig 4.1b: The displacement pattern on station PHD 001.

Table 1.11: the displacement values of PHD 001 as represented in the fig 4.1.

	FEB 20-MAY 20 (m)	MAY 20- AUG 20 (m)	AUG 20 – NOV 20 (m)	NOV 20 – FEB 21 (m)
ΔE	0.052	-0.073	0.045	0.019
ΔN	0.004	-0.017	0.006	0.016

As observed and deduced from observation on PHD 001, the displacement that occurred between May and February 2020 are 0.052m and 0.004m in the Easting and Northing direction respectively. Between May and August 2020, the shift were negative, that is, -0.073m and -0.017m in the Easting and Northing direction. There happened to be virtually no displacement between November and August, 2020 (0.00 in the Easting and 0.006 in the Northing direction). In between February 2021 and November 2020, the displacement in Easting and Northing are, 0.019m and 0.016m respectively.

Between May and August of 2020, the little displacement could be attributed to covid-19 lockdowns that restricted movements. After activities commenced, it showed in the results in figure 4.2 between November 2020 and February 2021 as there were increase.

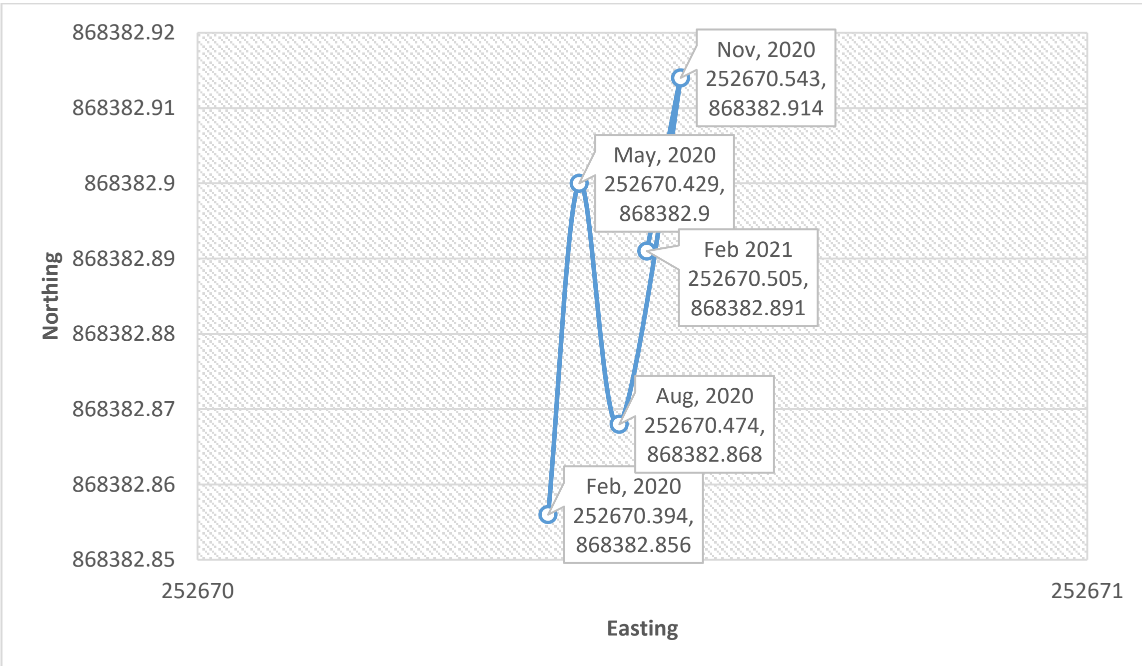

Fig 4.2: Displacement pattern on PHD 006.

Table 1.12: the displacement values of PHD 006 as represented in the fig 4.2.

	FEB 20-MAY 20 (m)	MAY 20- AUG 20 (m)	AUG 20 – NOV 20 (m)	NOV 20 – FEB 21 (m)
ΔE	0.035	0.045	0.069	-0.038
ΔN	0.044	-0.032	0.046	-0.023

Between February 2020 and May 2020, there were 0.035m and 0.044m displacement in the E and N components, between May 2020 and August 2020 there were 0.045m and -0.032m, between August 2020 and November 2020 there were 0.069m and 0.046m displacement in E and N directions. While between November 2020 and February 2021, the displacement were -0.038m and -0.023m in the E and N directions respectively.

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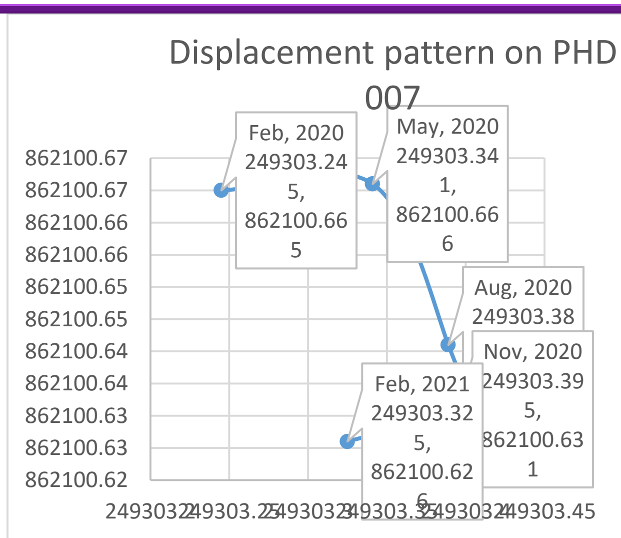

Fig 4.3: Displacement pattern of PHD 007

There were 0.096m and 0.001m shift between Feb 2020 and May 2020 in the E and N component and from the Table 1.13, there are 0.048m and -0.025m shift from May 2020 to Aug 2020. 0.006m and -0.01m could be seen in the Easting and Northing directions and -0.07m and -0.005m between Nov 2020 and Feb 2021.

Table 1.13: The displacements through the 1 year of observation on PHD 007

	FEB 20-MAY 20 (m)	MAY 20- AUG 20 (m)	AUG 20 – NOV 20 (m)	NOV 20 – FEB 21 (m)
ΔE	0.096	0.048	0.006	-0.07
ΔN	0.001	-0.025	-0.01	-0.005

Displacement on PHD 008 is shown in figure 4.4. There were indeed little displacements the table 1.14 also shows it for better understanding.

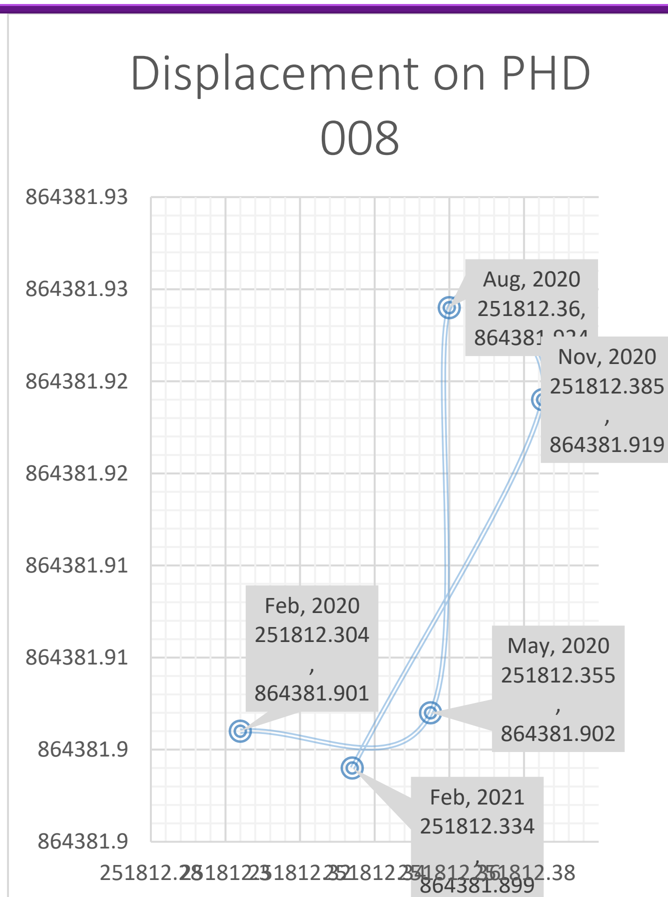

Fig 4.4: Displacement pattern of PHD 008

In the E and N component between Feb 2020 and May 2020, the shifts were 0.051m and 0.001m. While, between the intervals of May 2020 to Aug 2020, it was 0.005m and 0.022m, in between Aug 2020 and Nov 2020, the results were 0.025m and -0.005m. Lastly, between Nov 2020 and Feb 2021, the results were -0.051m and -0.02m.

Table 1.14: Displacement on PHD 008

	FEB 20-MAY 20 (m)	MAY 20- AUG 20 (m)	AUG 20 – NOV 20 (m)	NOV 20 – FEB 21 (m)
ΔE	0.051	0.005	0.025	-0.051
ΔN	0.001	0.022	-0.005	-0.02

Analysis of point PHD 010 is in both the figure 4.4 and table 1.14 as well. The figure 4.4 shows the displacement pattern every 3 month interval.

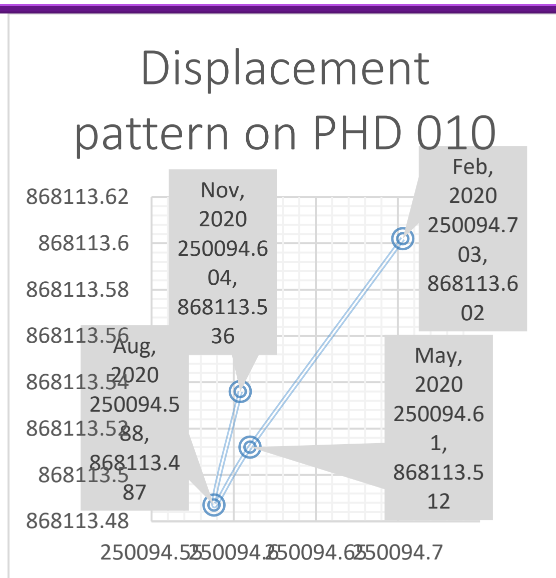

Fig 4.5: Displacement on PHD 010

In the E and N component between Feb 2020 and May 2020, the shifts were 0.096m and 0.001m. While, between the intervals of May 2020 to Aug 2020, it was 0.048m and -0.025m, in between Aug 2020 and Nov 2020, the results were 0.006m and -0.01m. Lastly, between Nov 2020 and Feb 2021, the results were -0.07m and -0.005m.

Table 1.15: Displacement on PHD 010

	FEB 20-MAY 20 (m)	MAY 20- AUG 20 (m)	AUG 20 – NOV 20 (m)	NOV 20 – FEB 21 (m)
ΔE	0.096	0.048	0.006	-0.07
ΔN	0.001	-0.025	-0.01	-0.005

The displacement pattern on Point PHD 001 is shown in Figure 4.6 as well as in Table 1.16.

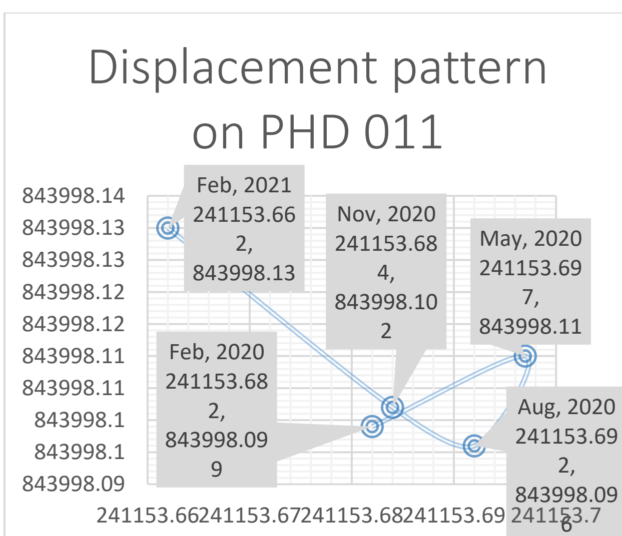

Figure 4.6: Displacement on PHD 011.

In the E and N component between Feb 2020 and May 2020, the shifts were 0.015m and 0.011m. While, between the intervals of May 2020 to Aug 2020, it was -0.005m and -0.014m, in between Aug 2020 and Nov 2020, the results were -0.008m and 0.006m. Lastly, between Nov 2020 and Feb 2021, the results were -0.022m and 0.028m.

Table 1.16: displacement on PHD 011

	FEB 20-MAY 20 (m)	MAY 20- AUG 20 (m)	AUG 20 – NOV 20 (m)	NOV 20 – FEB 21 (m)
ΔE	0.015	-0.005	-0.008	-0.022
ΔN	0.011	-0.014	0.006	0.028

The displacement analysis on PHD 016 for the one year observation of 3 months interval is as presented in Fig 4.7 and Table 1.17 respectively.

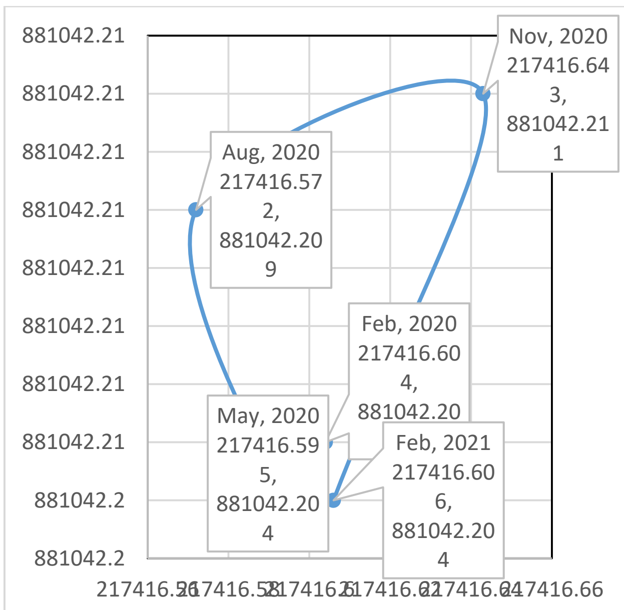

Fig 4.7: Displacement pattern on PHD 016

In the E and N component between Feb 2020 and May 2020, the shifts were -0.009m and -0.001m. While, between the intervals of May 2020 to Aug 2020, -0.023m and 0.005m, in between Aug 2020 and Nov 2020, the results were 0.071m and 0.002m. Lastly, between Nov 2020 and Feb 2021, the results were -0.037m and -0.007m.

Table 1.17: Displacements on PHD 016

	FEB 20-MAY 20 (m)	MAY 20- AUG 20 (m)	AUG 20 – NOV 20 (m)	NOV 20 – FEB 21 (m)
ΔE	-0.009	-0.023	0.071	-0.037
ΔN	-0.001	0.005	0.002	-0.007

The displacement analysis on PHD 017 for the one year observation of 3 months interval is as presented in Fig 4.8 and Table 1.18 respectively.

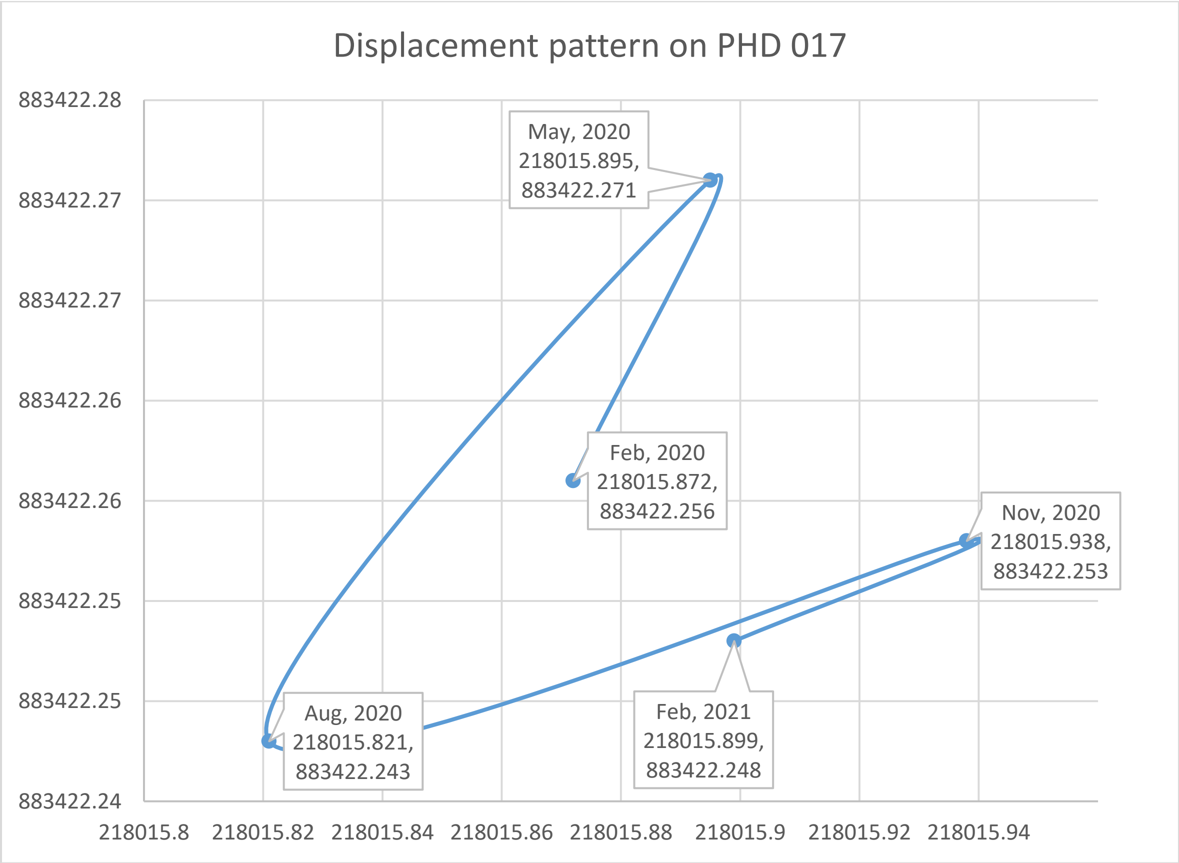

Fig 4.8: Displacement on PHD 017

In the E and N component between Feb 2020 and May 2020, the shifts were 0.023m and 0.015m. While, between the intervals of May 2020 to Aug 2020, it was -0.074m and -0.028m, in between Aug 2020 and Nov 2020, the results were 0.117m and 0.01m. Lastly, between Nov 2020 and Feb 2021, the results are -0.039m and -0.005m.

Table 1.18: Displacement on PHD 017

	FEB 20-MAY 20 (m)	MAY 20- AUG 20(m)	AUG 20 – NOV 20(m)	NOV 20 – FEB 21(m)
ΔE	0.023	-0.074	0.117	-0.039
ΔN	0.015	-0.028	0.01	-0.005

The displacement analysis on PHD 018 for the one year observation of 3 months interval is as presented in Fig 4.9 and Table 1.19 respectively.

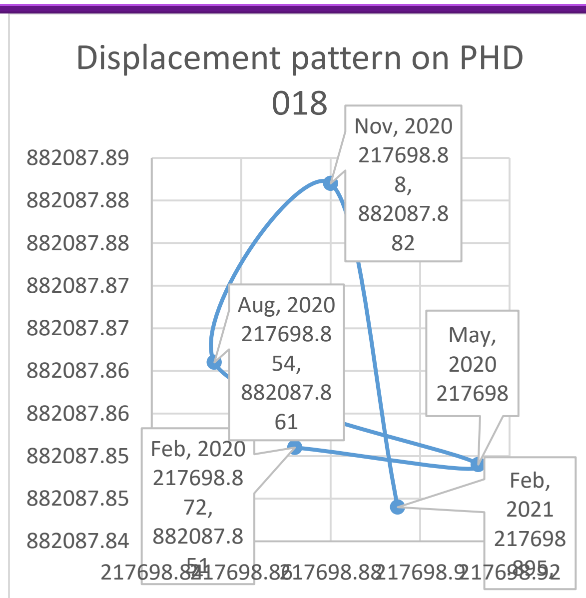

Fig 4.9: Displacement on PHD 018

In the E and N component between Feb 2020 and May 2020, the shifts were 0.041m and -0.002m. While, between the intervals of May 2020 to Aug 2020, 0.005m and 0.012m, in between Aug 2020 and Nov 2020, the results were 0.026m and 0.021m. Lastly, between Nov 2020 and Feb 2021, the results were 0.013m and -0.038m.

Table 1.19: Displacement on PHD 018

	FEB 20-MAY 20(m)	MAY 20- AUG 20(m)	AUG 20 – NOV 20(m)	NOV 20 – FEB 21(m)
ΔE	0.041	0.005	0.026	0.013
ΔN	-0.002	0.012	0.021	-0.038

The displacement analysis on PHD 021 for the one year observation of 3 months interval is as presented in Fig 4.10 and Table 4.10 respectively.

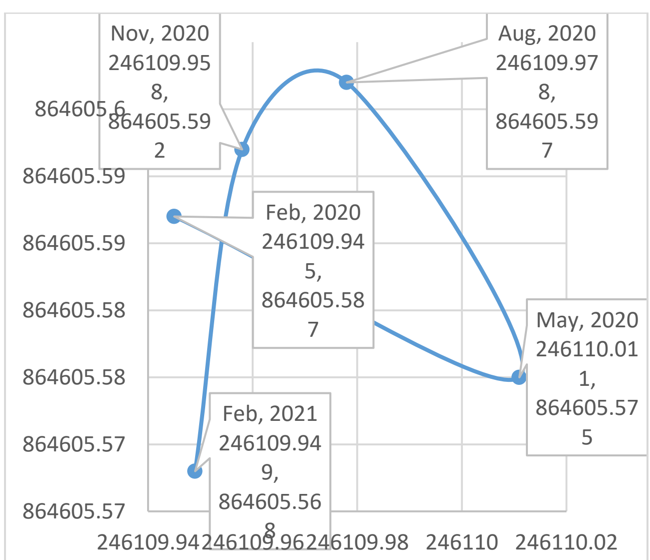

Fig 4.10: Displacements on PHD 021

In the E and N component between Feb 2020 and May 2020, the shifts were -0.066m and -0.012m. While, between the intervals of May 2020 to Aug 2020, -0.033m and 0.022m, in between Aug 2020 and Nov 2020, the results were -0.02m and -0.005m. Lastly, between Nov 2020 and Feb 2021, the results were -0.009m and -0.024m.

Table 1.20: Displacement on PHD 021

	FEB 20-MAY 20 (m)	MAY 20- AUG 20 (m)	AUG 20 – NOV 20 (m)	NOV 20 – FEB 21 (m)
ΔE	-0.066	-0.033	-0.02	-0.009
ΔN	-0.012	0.022	-0.005	-0.024

The displacement analysis on PHD 023 for the one year observation of 3 months interval is as presented in Fig 4.11 and Table 1.21 respectively.

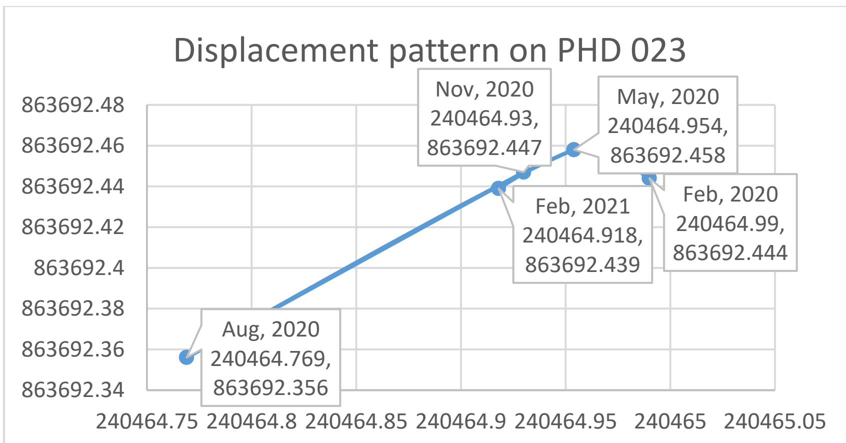

Fig 4.21: Displacements on PHD 023

In the E and N component between Feb 2020 and May 2020, the shifts were -0.036m and 0.014m. While, between the intervals of May 2020 to Aug 2020, -0.185m and -0.102m, in between Aug 2020 and Nov 2020, the results were 0.161m and 0.091m. Lastly, between Nov 2020 and Feb 2021, the results were -0.012m and -0.008m.

Table 1.21: Displacement on PHD 023

	FEB 20-MAY 20 (m)	MAY 20- AUG 20 (m)	AUG 20 – NOV 20 (m)	NOV 20 – FEB 21(m)
ΔE	-0.036	-0.185	0.161	-0.012
ΔN	0.014	-0.102	0.091	-0.008

The displacement analysis on PHD 024 for the one year observation of 3 months interval is as presented in Fig 4.12 and Table 1.22 respectively.

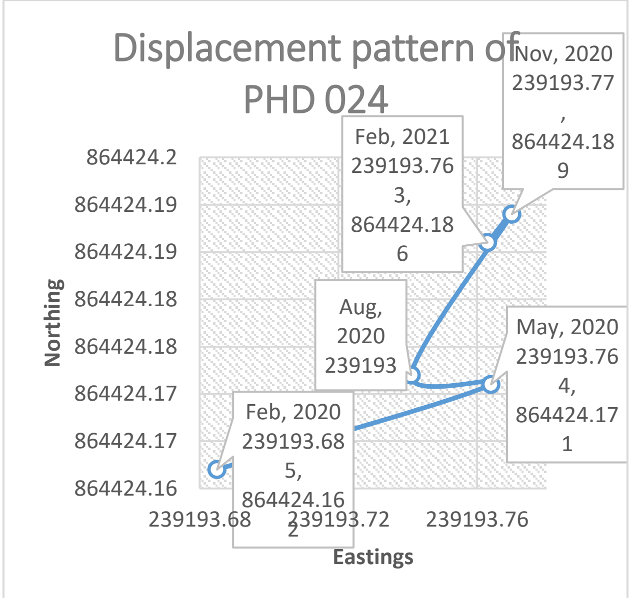

Fig 4.12: Displacements on PHD 024

In the E and N component between Feb 2020 and May 2020, the shifts were 0.079m and 0.009m. While, between the intervals of May 2020 to Aug 2020, -0.023m and 0.001m, in between Aug 2020 and Nov 2020, the results were 0.029m and 0.017m. Lastly, between Nov 2020 and Feb 2021, the results were -0.007m and -0.003m.

Table 1.22: Displacement on PHD 024

	FEB 20-MAY 20 (m)	MAY 20- AUG 20 (m)	AUG 20 – NOV 20 (m)	NOV 20 – FEB 21(m)
ΔE	0.079	-0.023	0.029	-0.007
ΔN	0.009	0.001	0.017	-0.003

The displacement analysis on KGY 021 for the one year observation of 3 months interval is as presented in Fig 4.13 and Table 1.23 respectively.

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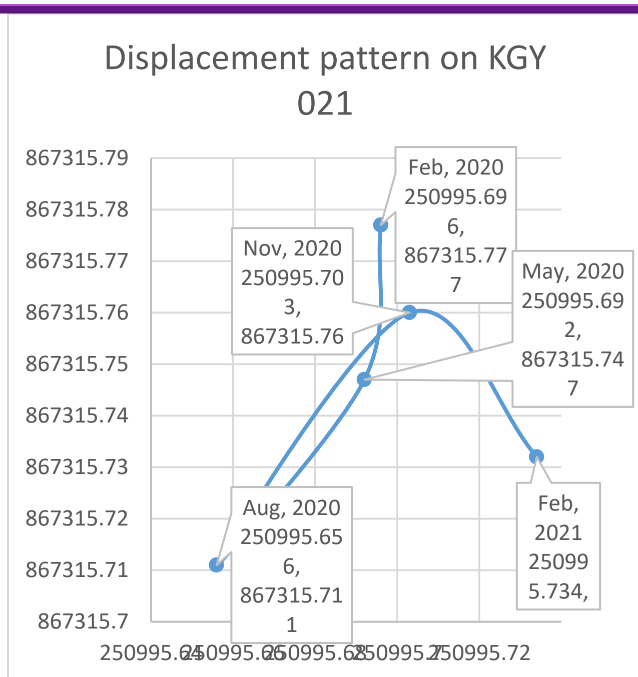

Fig 4.13: Displacements on KGY 021

In the E and N component between Feb 2020 and May 2020, the shifts were -0.004m and -0.03m. While, between the intervals of May 2020 to Aug 2020, -0.036m and -0.036m, in between Aug 2020 and Nov 2020, the results were 0.047m and 0.0491m. Lastly, between Nov 2020 and Feb 2021, the results were 0.031m and -0.028m.

Table 1.23: Displacements on KGY 021

	FEB 20-MAY 20 (m)	MAY 20- AUG 20 (m)	AUG 20 – NOV 20 (m)	NOV 20 – FEB 21 (m)
ΔE	-0.004	-0.036	0.047	0.031
ΔN	-0.03	-0.036	0.049	-0.028

The displacement analysis on LM 130 for the one year observation of 3 months interval is as presented in Fig 4.14 and Table 1.24 respectively.

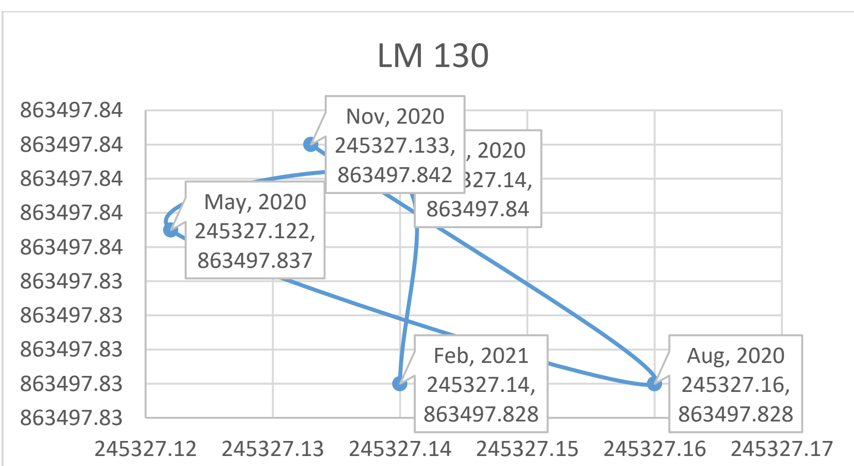

Fig 4.14: Displacements on LM 130.

In the E and N component between Feb 2020 and May 2020, the shifts were -0.018m and -0.003m. While, between the intervals of May 2020 to Aug 2020, 0.038m and -0.009m, in between Aug 2020 and Nov 2020, the results were -0.027m and 0.014m. Lastly, between Nov 2020 and Feb 2021, the results were 0.007m and -0.014m.

Table 1.24: Displacement on LM130

	FEB 20-MAY 20 (m)	MAY 20- AUG 20 (m)	AUG 20 – NOV 20 (m)	NOV 20 – FEB 21 (m)
ΔE	-0.018	0.038	-0.027	0.007
ΔN	-0.003	-0.009	0.014	-0.014

Analysis of Vertical displacement.

The vertical displacement pattern on the observation station in Obajana and environs can be best understood in graphically. The graph beginning from figure 5.1 to figure 5.14 displays them all.

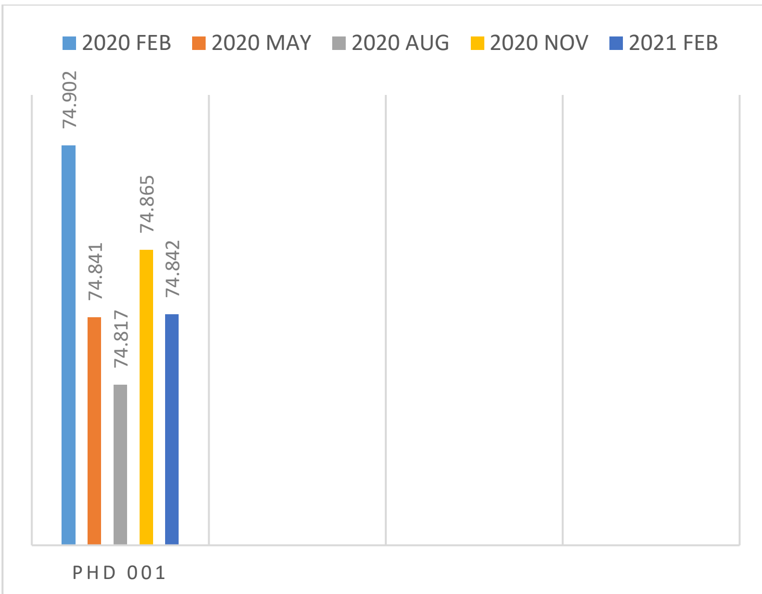

Fig 5.1: Vertical Displacement on Station PHD 001.

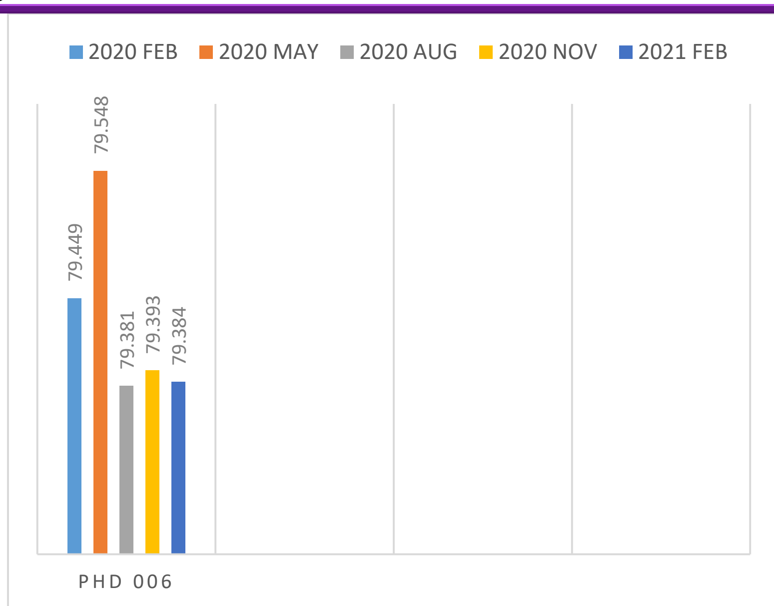

Table 5.1: Vertical Displacement on Station PHD 006

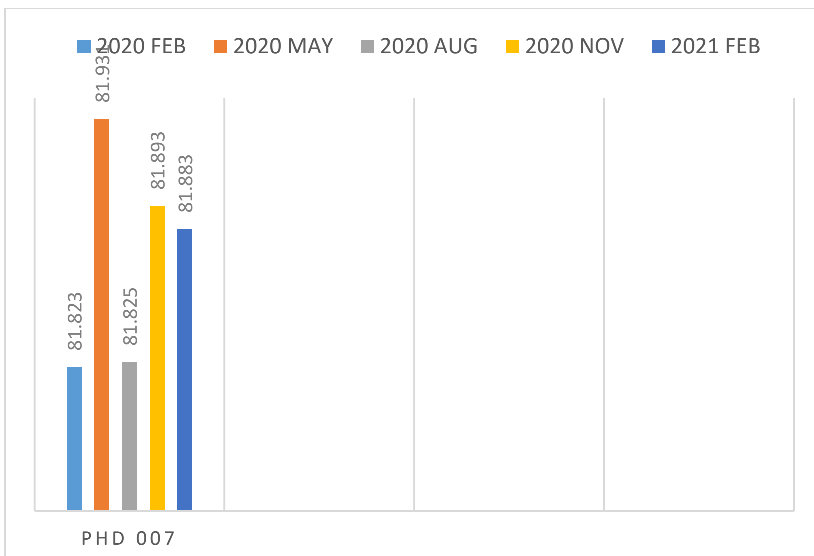

Table 5.3: Vertical displacement pattern on station PHD 007

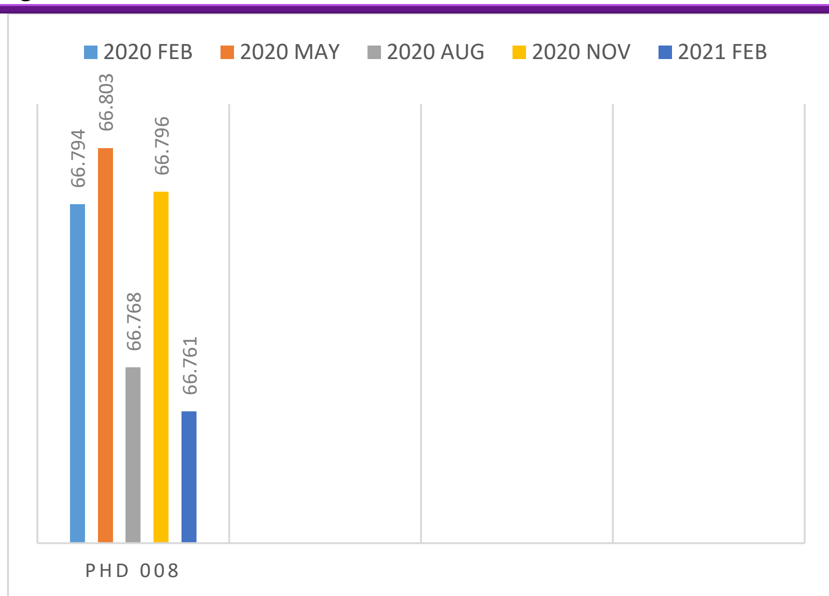

Table 5.4: Vertical displacement pattern on station PHD 008.

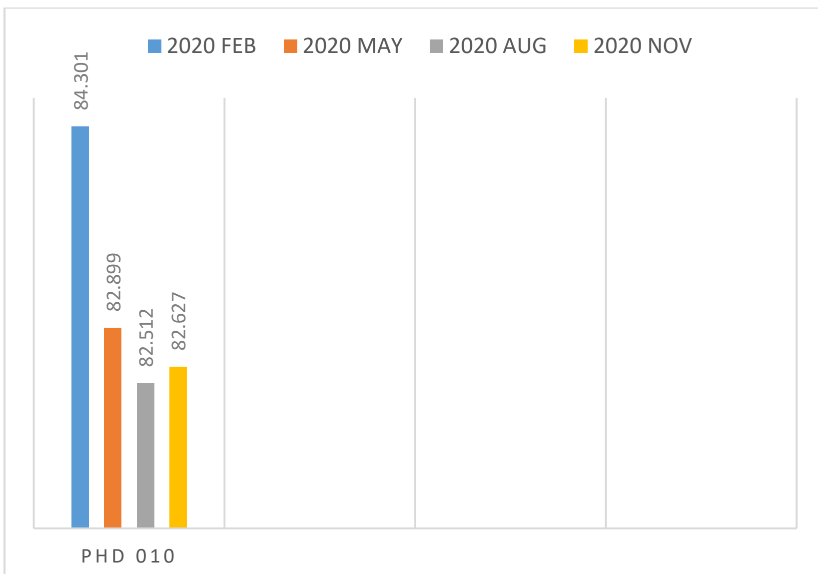

Figure 5.5: Vertical displacement pattern on station PHD 010

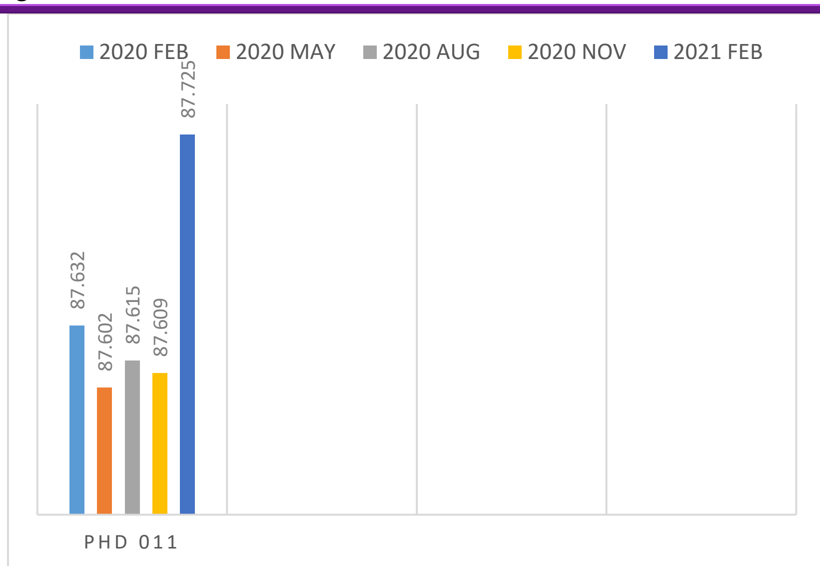

Figure 5.6: Vertical displacement pattern on station PHD 011

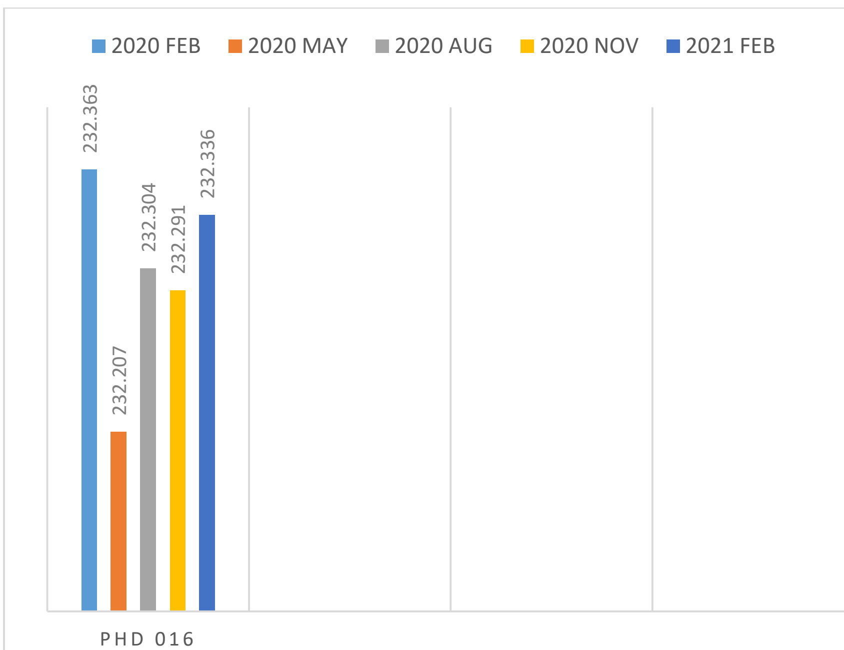

Figure 5.7: Vertical displacement pattern on station PHD 016

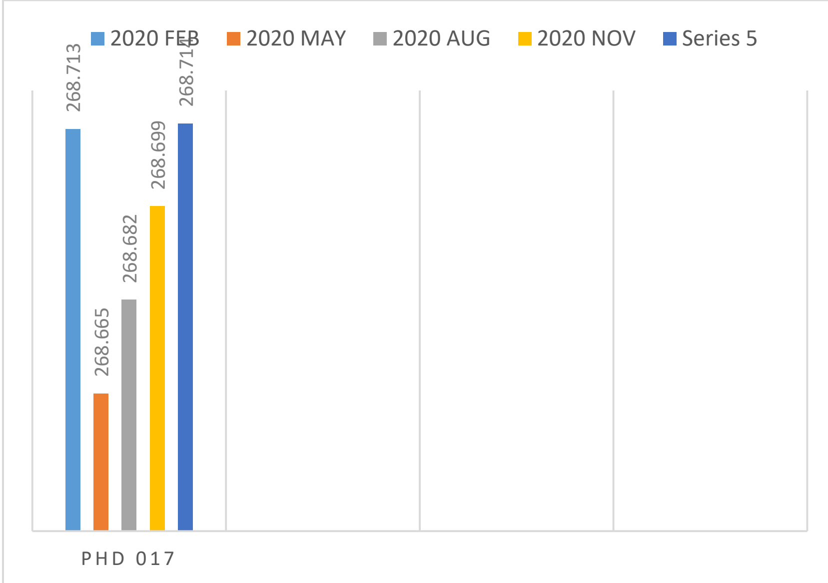

Figure 5.8: Vertical displacement pattern on station PHD 017

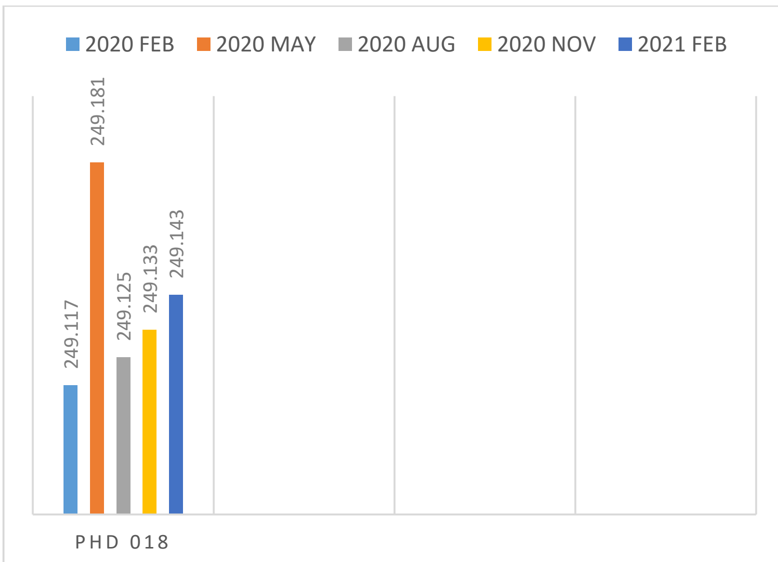

Figure 5.9: Vertical displacement pattern on station PHD 018

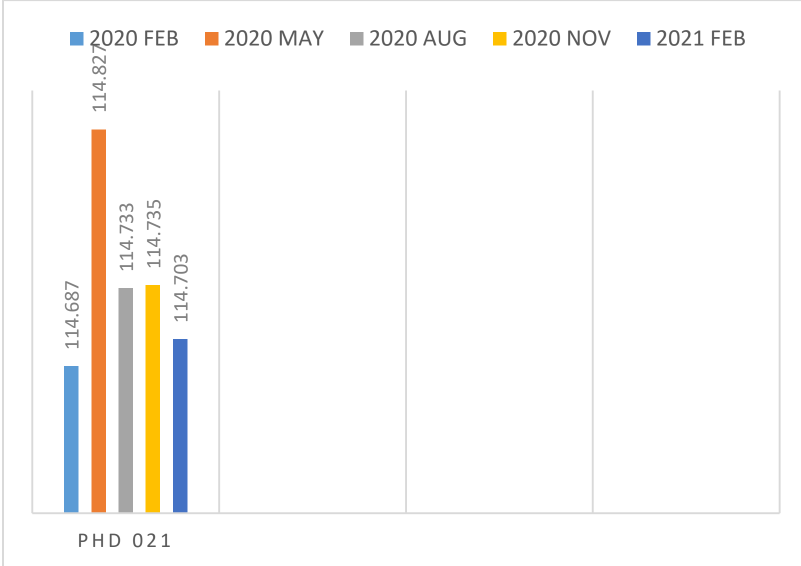

Figure 5.10: Vertical displacement pattern on station PHD 021

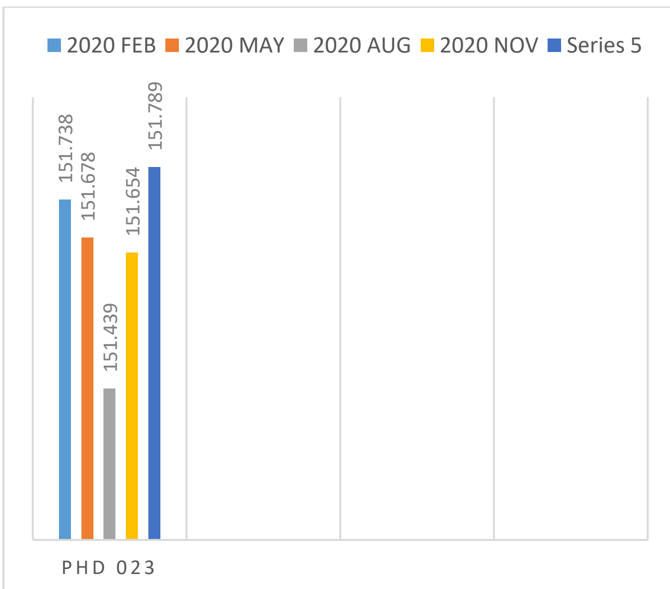

Figure 5.11: Vertical displacement pattern on station PHD 023

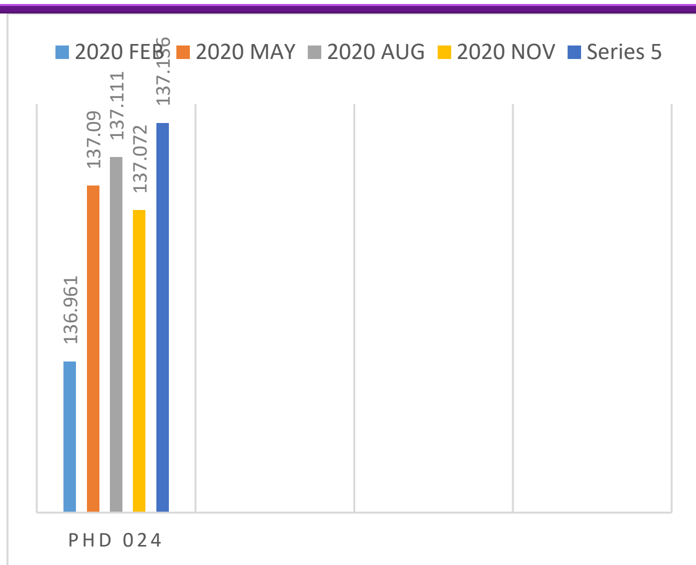

Figure 5.12: Vertical displacement pattern on station PHD 024

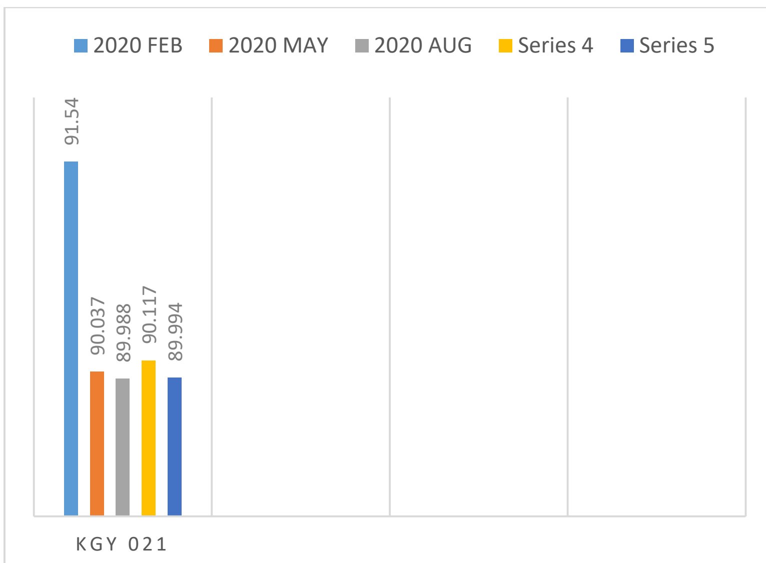

Figure 5.13: Vertical displacement pattern on station KGY 021

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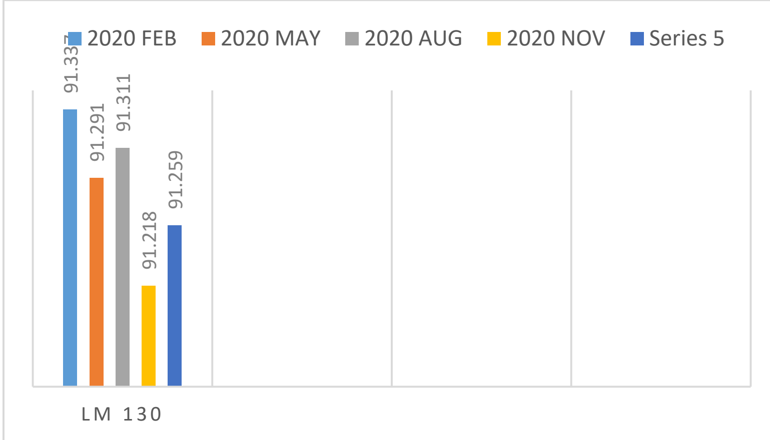

Figure 5.14: Vertical displacement pattern on station LM 130

Discussion of Result of vertical displacement pattern of points

The displacement vertically were in millimeter and centimeter range.

Table 1.25: The vertical coordinates of the various phases of observation.

S/N	STN ID	**FEB 20**	MAY 20	**AUG 20**	NOV 20	FEB 21
1	PHD 001	**74.902**	74.841	**74.817**	74.865	74.842
2	PHD 006	**79.449**	79.548	**79.381**	79.393	79.384
3	PHD 007	**81.823**	81.931	**81.825**	81.893	81.883
4	PHD 008	**66.794**	66.803	**66.768**	66.796	66.761
5	PHD 010	**84.301**	82.899	**82.512**	82.627	
6	PHD 011	**87.632**	87.602	**87.615**	87.609	87.725
7	PHD 016	**232.363**	232.207	**232.304**	232.291	232.336
8	PHD 017	**268.713**	268.665	**268.682**	268.699	268.714
9	PHD 018	**249.117**	249.181	**249.125**	249.133	249.143
10	PHD 021	**114.687**	114.827	**114.733**	114.735	114.703
11	PHD 023	**151.738**	151.678	**151.439**	151.654	151.789
12	PHD 024	**136.961**	137.090	**137.111**	137.072	137.136

13	KGY 021	**91.540**	90.037	**89.988**	90.117	89.994
14	LM 130	**91.337**	91.291	**91.311**	91.218	91.259

The only station where a remarkable vertical shift was observed was on PHD 010. The reason was because, erosion began its menace around the point and immediately, the government deployed construction equipment to the area and that affected the existence of the observation point. It could be noticed that observation for February 2021 was never carried out there.

CONCLUSION

The pattern of horizontal and vertical displacement were depicted graphically and the shifts in values were generally, in centimeter and millimeter range. Aside from PHD 010, every other point of observation were virtually intact. The little shifts experienced, explained the dynamism of the areas of observation. The horizontal movements though, were in millimeter level, still explained also some level of vibration in the areas. Further research should be conducted to investigate the vibration level of points in all the observation points. The vertical displacement results showed some up and down shifts in millimeter and centimeter level too. Therefore, this work is open for vibration analysis of the various points

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