

APPLICATION OF VERTICAL DATUM FOR EROSION CONTROL AND AMELIORATION IN OJI RIVER LOCAL GOVERNMENT AREA, ENUGU STATE, NIGERIA**M.U. Ezugwu¹, M.N. Ono¹, M.I. Okongwu², and O.L. Godwin-Nwankwo¹**¹Department of Surveying and Geo-Informatics, Nnamdi Azikiwe University, Awka²Department of Building, Nnamdi Azikiwe University, Awka**ABSTRACT**

This study was aimed at the investigation of the application of Vertical Datum for erosion controls and amelioration in Oji River Local Government Area, Enugu State, Nigeria with a view of mapping the area for better gully erosion management. This was achieved through the identification and graphically representation of the most erosion prone areas in Oji River Local Government Area of Enugu State. The methodology was divided into data acquisition, data processing and results presentation and analysis. The primary data which include GPS/GNSS data were collected from the field using Topcon hyper V GNSS on a static mode for the determination of the positions and ellipsoidal heights of the study points, while the secondary data which is the DEM data were acquired from the office of the surveyor general of the federation. The GNSS field data acquisition (Observation) for this project was done on a Static mode for minimum of ten minutes per station. The GNSS Topcon Receiver antenna was set up, centered and leveled on the station marker. The power source and memory requirements were assessed to ensure complete data acquisition; antenna heights measurements and photograph at the start and end of each session of the observation were taken. The data processing was carried out using the magnet office software. The processing was done using the selected station data points. At the end of this work, the table showing the processed results and recorded field data of the station points and their descriptions in the study area were produced also Oji River graphs depicting the location of the 5 Survey stations were produced in accordance to the technical specification that all the receivers was configured to acquire data using logging rate 5secs, elevation mask angle of 15 degree, position dilution of precision (PDOP) less than 4 and number of satellite in view during the observation ranged from 10 to 18 satellites.

Keyword:**Erosion control**, Vertical datum, GNSS, Amelioration and Orthometric Heights.**1.0 INTRODUCTION**

The National Oceanic and Atmospheric Administration [NOAA] (2017) defined geodetic datum as a coordinate system with a reference surface that serves to provide known locations to begin surveys and create maps. Continuing, NOAA (2017) went further to state that there are two types of geodetic datum namely: horizontal datum and vertical datum. Over the years, many different types of vertical datum have been used. “The geoid, quasi-geoid, reference ellipsoid of revolution (normal Earth ellipsoid) are used as a reference surface (datum) for heights in geodesy. In addition, the mean sea surface, which is assumed to coincide to the geoid/quasi-geoid at one point, is also used as a reference surface for heights” (Erol, 2007). Vertical datum is a surface of zero elevation to which heights of various points are referred in order that those heights be in a consistent system. More broadly, a vertical datum is the entire system of the zero-elevation surface and methods of determining heights relative to that surface (NOAA, 2017). This vertical datum is usually employed for different usages including but not limited to erosion control and amelioration in desired locations such as Oji River.

Oji River Local Government Area is affected by different environmental challenges. Water-induced soil erosion is one of the hindrances to finding sustainability to agricultural production and other land use activities. Agriculture is the backbone of the Oji River Local Government’s economy and sustains the livelihood of about 85% of the population (FAO, 2015). Loss of productive soil by erosion has massive environmental and economic impacts to Oji River area. Reports from the Food and Agriculture Organization (FAO, 2015) estimated the annual soil loss in Oji River to about

1.5 billion tons. According to the study by the FAO (2015), about 23 thousand hectares of the land, nearly half of the highland areas in the study area were affected by serious soil erosion. Particularly, in parts of Inyi, Achi, Awlaw and Ugwuoba, half of the agricultural land has soils with a depth of less than 10cm FOA, (2015). This problem has decreased the soil production potential. For example, the annual productivity potential of land in the Oji River highlands is declining by 2.2% per year.

Other researchers such as Onwuka (2008), Officha, Okolie and Onwuemesi (2018) and Ejikeme, Igbokwe, Igbokwe and Aweh (2017) in providing solutions to the erosion menace in erosion prone areas in the southeastern Nigeria have been helpful. Moreover, the Oji River Local Government has also taken some measures to see if the problem could be tackled, by building of retaining walls, construction of drainages and building of culverts.

Despite this, soil erosion has continued to threaten the livelihood, crop production and land productivity potential and economic growth of Oji River Local Government Area due to improper planning, use of suitable models and lack of good policies. Since it is difficult to address erosion problems at a time, it is important to identify areas that are highly vulnerable to soil erosion for preventive measures in the study area.

Given the shortcomings in the traditional soil erosion risk assessment methods, one needs a more systematic approach to do an effective soil erosion assessment, hence the introduction of vertical datum model. So far, many models for predicting soil erosion have been developed and applied especially in developed countries of the world. The major models include Modified Universal Soil Loss Equation (MUSLE), the Universal Soil Loss Equation (USLE), Morgan-Morgan-Finney (MMF), Agricultural Non-Point Source Model (AGNPS), Erosion Productivity Impact Calculator (EPIC), Water Erosion Prediction Project (WEPP), Soil and Water Assessment Tool (SWAT), and European Soil Erosion Model (EUROSEM). Among these models, the Vertical Datum Model will be the most widely applied empirical model for offering quantitative soil erosion estimation control mapping and conservation planning around the study area and its environs, hence the use in this study.

2.0 LITERATURE REVIEW

2.1 Vertical Datum

NOAA (2015) stated that one way to think about the geoid is to imagine what the Earth's surface would look like if the world's oceans were allowed to flow over the land, without any currents or tides, and conform to gravitational pull. As a result, the water's surface (or geoid) is not a regular, but an irregular smoothly changing surface that is influenced by rock density and the Earth's non-spherical shape. There are three types of height: orthometric, geoid, and ellipsoidal. Orthometric height (H) is the distance from the geoid to a point on the Earth's surface measured along a plumb line to gravitational pull. The reference surface for orthometric height is a level surface that closely coincides with global MSL (the geoid's surface). Orthometric height is what is commonly associated with elevation of a point on the Earth's surface. Geoidal height (N) is the distance along a normal line from the reference ellipsoid to the geoid. In the coterminous United States, values of N (between the GRS80 reference ellipsoid and the geoid) are about -8 meters to about -53 meters. Ellipsoidal height (h) is the distance along a line normal from the reference ellipsoid to a point on the Earth's surface. Calculating H is simply the difference between h and N : $H = h - N$ Height is an important consideration when dealing with data collected via Global Positioning System (GPS). GPS data is considered to be three-dimensional (X , Y , and Z). However, the Z component does not depend upon a direct relation to a gravitational surface. Instead, the X , Y , and Z coordinates are utilized when calculating geodetic latitude, longitude, and h . Then, h can be converted to H so as to be tied into a vertical datum.

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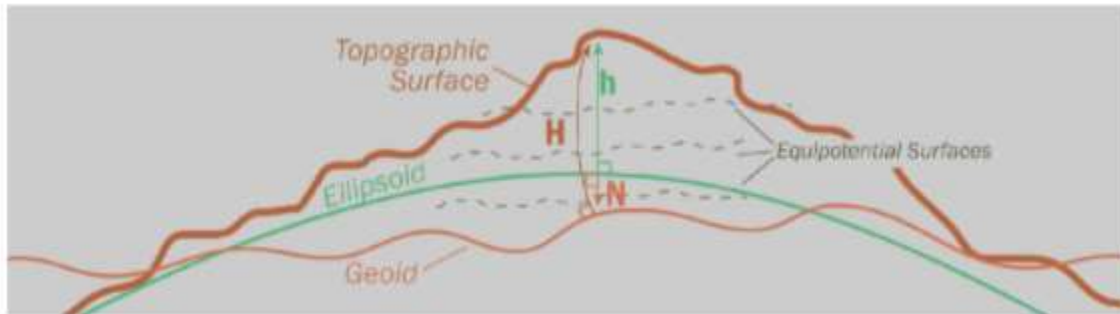


Fig. 2.1: Comparing H , h , and N heights (NOAA 2015).

2.2 Heights Used in Geodesy and Surveying

To define the 3-D position of points and objects on or above the Earth's surface, different coordinate systems (local/global, natural/model) and coordinate types (Cartesian/curvilinear) are used. In many applications, vertical separations (heights) from an equipotential surface of the Earth's gravity field represented by the mean sea level (geoid) or from model geometry (biaxial geocentric reference ellipsoid) are used. In the former case, we recognize orthometric heights determined traditionally by spirit leveling, in the latter case we refer to *geodetic heights* estimated nowadays by GNSS. Orthometric heights are reckoned along a curved local plumb line of the Earth's gravity field, geodetic heights define a separation of a point above the reference ellipsoid along its straight surface normal. Both heights can be related through the separation of the reference ellipsoid and the geoid called a geoidal height (undulation).

Orthometric heights are based on leveling; however, corrections must be applied to leveled height differences. The corrections are estimated from gravity values observed on the Earth's surface and continued inside topographic masses. Since the computation relies on the mass density of the topographic masses, the orthometric heights cannot rigorously be determined. Depending on the approximation used for their evaluation, orthometric heights get different adjectives such as Helmert or normal orthometric heights. Despite some problems with their estimation, the orthometric heights are still used by many countries, e.g., in Canada and USA.

Recent years saw some significant advances in the theory of orthometric heights and large improvements in availability of data required for their estimation, e.g., (Tenzer *et al.* 2005). In the period after the World War II, important advances in the theory of AMSL heights had been made. To avoid known problems with the estimation of precise orthometric heights (and the geoid), a new theory was introduced by the Russian geodesist Molodensky in 1960. In his theory, orthometric heights were replaced by *normal heights* and the geoid was replaced by the quasi-geoid. The important advantage of this new theory is that no a priori assumptions concerning the topographic mass density must be made. Moreover, no ground gravity data must be collected since the normal heights rely on a model (normal) gravity field generated by the homogeneous reference ellipsoid of the same mass and rotation as the actual Earth. The main advantage of the normal heights is their determinability; their disadvantage is a little bit looser relation to the physical properties of the Earth since they refer to the so-called quasi geoid (or quasi mean sea level). In contrary to orthometric heights, they are reckoned along plumb lines of the normal gravity field that are in practice approximated by ellipsoidal surface normals. Geodetic heights can be then related to normal heights through the separation of the quasi-geoid from the reference ellipsoid called in geodesy a *height anomaly*.

The geoidal height and the height anomaly agree over land areas at the level of 1m with extreme values in high mountains at the level of 1.5 m. The quasi-geoid coincides with the geoid over oceans. Every day surveyors around the world solve the problem of transforming geodetic heights as obtained by GNSS into a regional height system of particular AMSL heights. Not only the type of heights is important, but also an offset of the regional height reference (specific tide gauge) from the adopted international reference must be known. In the following sections, fundamentals from the theory of estimating geoidal heights and height anomalies are given.

3.0 METHODOLOGY

The methodology began with the planning of the survey. During this stage, reconnaissance survey was done through visitation and familiarization of the selected sites in the study area. Office planning was also carried out from the Ministry of the Office of the Surveyor General of the Federation Abuja to obtain the Digital Elevation Model (DEM) and the reference Datum of the Oji River Local Government Area. The *Primary Data* which include GPS/GNSS data were collected from the field using Topcon hyper V GNSS on a static mode for the determination of the positions and ellipsoidal heights of the study points, while the *Secondary Data* which is the DEM data were acquired from the office of the surveyor general of the federation. The above data served as input parameters for the vertical datum model for the selected towns in Oji River Local Government Area.

The hardware components used to execute this research include: Window 13 Dell Laptop with Intel (R) core (TM) i3 CPU B800 at 2.67GHz and RAM size of 4.00GB, SHARP MX – C312PCL6 printer, Topcon GNSS equipment with complete accessories, Tripod, Bipod, Data collector, Handheld GPS, Camera, First Aid box, power surge. The Software Components used to execute this research include: Microsoft word (version 2010), Microsoft excel, Magnet office, Geoid calculator, ArcGIS 10.3.

The GNSS field data acquisition (Observation) for this project was done on a Static mode for minimum of ten minutes per station. The GNSS Topcon Receiver antenna was set up, centered and leveled on the station marker. The power source and memory requirements were assessed to ensure complete data acquisition; antenna heights measurements and photograph at the start and end of each session of the observation were taken. The data processing was carried out using the magnet office software. The processing was done using the selected station data points. The orthometric heights of the selected stations were computed with geoid calculator software using the geodetic longitude, latitude and ellipsoidal height as the input parameters. The results of the methodology was presented using TABLES and GRAPHS which showed the processed geodetic coordinates and observed ellipsoidal heights (h), processed orthometric heights (H) and processed Geoidal undulation (N) in 3D in each of the towns.

4.0 RESULTS ANALYSIS

4.1 GNSS/GPS Observed Field Data

The data in Table 4.1 shows the processed results and recorded field data of the station points and their descriptions in the study area. (Appendix 4 shows the observed field book data)

Table 4.1: The computed data from the field work

N (dcm)	E (dcm)	Ellipsoidal height (m)	Geoid height(m)	orthometric height (m)	point name	Town Name
6.13612	7.29307	185.768	21.283	164.485	reference point	Inyi
6.111781	7.302794	192.12	21.256	170.864	point 1	Inyi
6.122536	7.296242	177.27	21.265	156.005	point 2	Inyi
6.125603	7.293642	171.51	21.266	150.244	point 3	Inyi
6.077714	7.311369	235.75	21.244	214.506	point 4	Inyi
6.183922	7.233394	82.42	21.252	61.168	point 5	Inyi
6.152222	7.271156	108.78	21.273	87.507	point 6	Inyi
6.156158	7.270814	119.69	21.278	98.412	point 7	Inyi
6.181108	7.31005	194.24	21.381	172.859	point 8	Achi
6.182622	7.317236	203.93	21.394	182.536	point 9	Achi
6.181508	7.326692	188.18	21.406	166.774	point 10	Achi
6.162742	7.337933	254.24	21.392	232.848	point 11	Achi
6.161978	7.338811	257.87	21.392	236.478	point 12	Achi

6.138858	7.321764	253.03	21.33	231.7	point 13	Achi
6.265058	7.210606	53.3	21.315	31.985	point 14	Ugwuoba
6.264025	7.152072	46.6	21.184	25.416	point 15	Ugwuoba
6.250625	7.160564	76.6	21.187	55.413	point 16	Ugwuoba
6.251183	7.233486	64.84	21.344	43.496	point 17	Ugwuoba
6.257019	7.196883	48.78	21.276	27.504	point 18	Ugwuoba
6.067353	7.350119	207.57	21.238	186.332	point 19	Awlaw
6.055789	7.356631	159.09	21.222	137.868	point 20	Awlaw
6.079814	7.262372	209.39	21.135	188.255	point 21	Awlaw
6.076522	7.298369	177.87	21.186	156.684	point 22	Awlaw
6.060861	7.297486	126.96	21.156	105.804	point 23	Awlaw
6.132667	7.223742	73.93	21.154	52.776	point 24	Akpugoeze
6.1589	7.224744	84.54	21.198	63.342	point 25	Akpugoeze
6.121869	7.223122	85.45	21.135	64.315	point 26	Akpugoeze
6.134639	7.230442	97.27	21.17	76.1	point 27	Akpugoeze
6.131494	7.240086	105.75	21.184	84.566	point 28	Akpugoeze

4.1.4 Elevation Profile Data Presentation and Analysis

Graphical presentation of elevation profiles of the selected towns in Oji River Local Government Area.
The graphs showing the elevation profiles of the towns were all referenced from the reference pillar stationed at Inyi. The horizontal and vertical units of the graphs are in meters. Again, the study map of the area in appendix 2 is helpful in knowing the drainage pattern and how some of the areas will be affected by erosion flow direction due to difference in elevations.

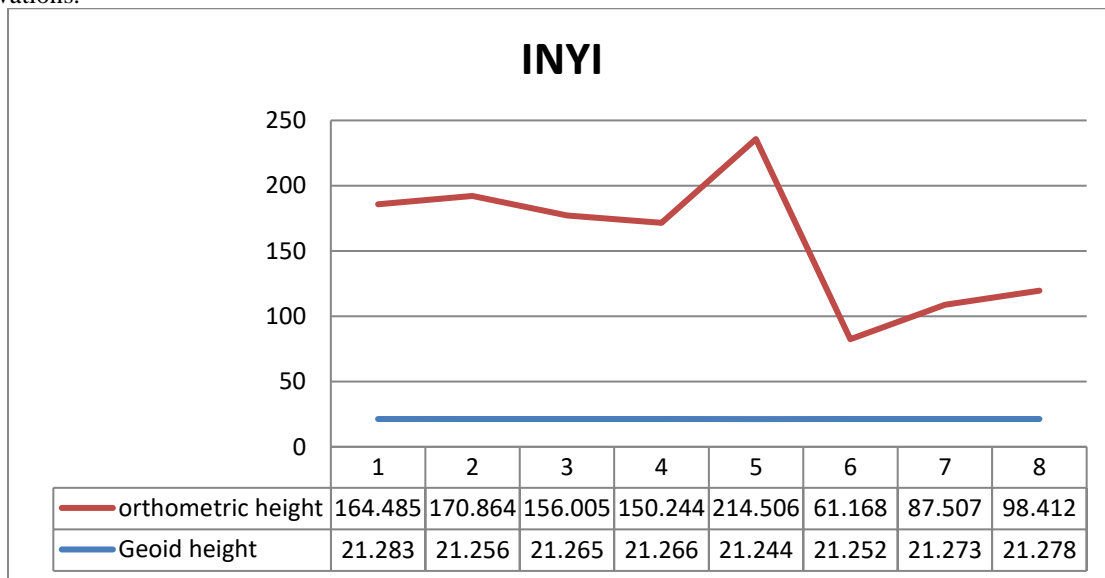


Fig. 4.2: Graphical presentation of the elevation profile of Inyi Town

Figure 4.2 shows the graphical presentation of the erosion profile of Inyi Town as was processed with Microsoft excel software using the geodetic latitudes and longitudes, orthometric heights and geoid heights of Inyi Town station points as input parameters. The graph shows the profiling of the elevation of Inyi and how the seepage flow direction of erosion could affect the environment of the underlain area. The graph shows that some parts of the Inyi Town are highly prone to erosion menace if not properly and technically managed. For example, at the erosion points 4 and 6 with orthometric heights of 150.244m and 61.168m respectively, the level of damage of rill erosion is turning into a V-Shaped gully sites whose lengths are above 100m each from its head and the widths are less than 3 meters while the depths are 0.5 and 0.6 meters respectively. With reference to the study area map, Inyi town has relatively good drainage system but the steep nature of the area makes life activities in the area so vulnerable to erosion menace. Based on the results, the greater the angle of the flow is in relation to the direction of gravity; the occurrence and continuation of erosion takes place in higher gradients. The result also shows that with the use of the DEM (appendix 3) and the determination and computation of the orthometric heights of Inyi town, government and its agencies will be able to know the elevation and flow direction of rain water in the area. This will help them to know the drainage pattern that is required to control, ameliorate and manage the menace of erosion in Inyi town and other erosion areas in Oji River Local Government Area.

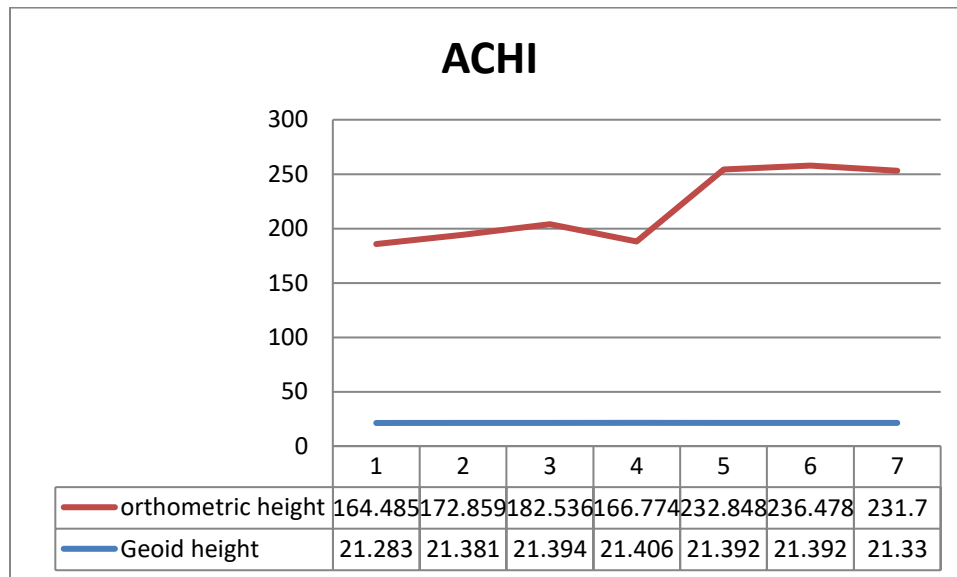


Fig. 4.3: Graphical presentation of the elevation profile of Achi Town

Figure 4.3 shows the graphical presentation of the profile of Achi Town as was processed with Microsoft excel software using the geodetic latitudes and longitudes, orthometric heights and geoid heights of Achi Town station points as input parameters. The graph shows the profiling of the elevation of Achi and how the seepage flow direction of erosion could affect the environment of the underlain area. Relating the study area map to the above table, it shows that Achi Town has high elevation points and still suffers more than any other town in Oji River Local Government Area from erosion menace due to poor drainage system which is a signal that erosion can easily affect agricultural productivity and economic life of the environment. The plate 1 as indicated in statement of problem was example of a road constructed without any drainage system. For example, at the erosion points 4 and 6 with orthometric heights of 166.774m and 236.478m respectively, the level of damage of rill erosion is turning into a U-Shaped gully sites whose lengths are above 100m each from its head and the widths are less than 5 meters while the depths are 2.6 and 3.2 meters respectively. The geology of Achi is mainly sandy soil which makes it more prone to soil weathering. The use of the orthometric heights determination and the DEM of the area will aid the government and its agencies to have clearer view of the flow direction and the drainage system that is required for possible control and amelioration of erosion in the area.

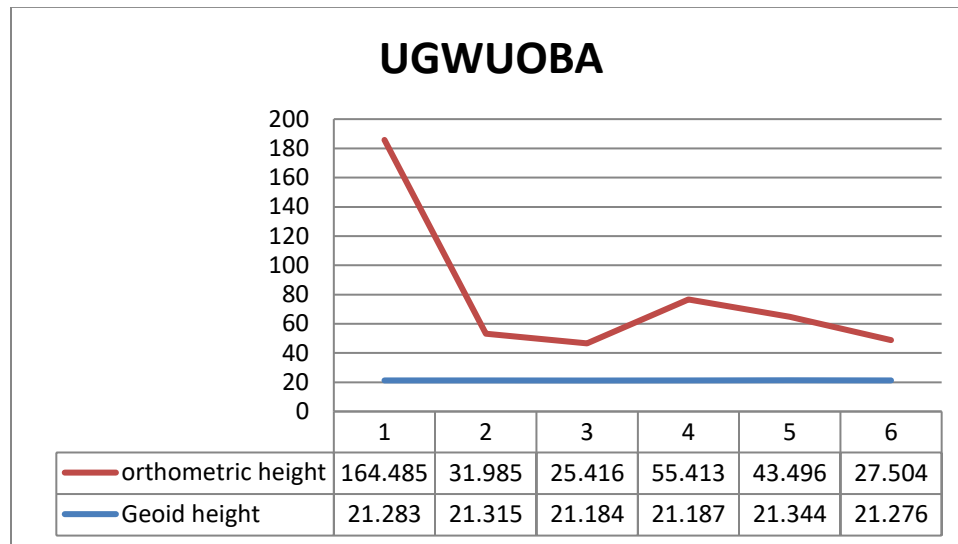


Fig. 4.4: Graphical presentation of the elevation profile of Ugwuoba Town

Figure 4.4 shows the graphical presentation of the profile of Ugwuoba Town as was processed with Microsoft excel software using the geodetic latitudes and longitudes, orthometric heights and geoid heights of Ugwuoba Town station points as input parameters. The graph shows the profiling of the elevation of Ugwuoba and how the erosion runoff could affect the environment of the steep parts of the underlain area. The produced study map shows that Ugwuoba Town has good drainage system. The impact of erosion in this study area is felt due to improper town planning. For example, at the erosion points 3 and 6 with orthometric heights of 25.416m and 27.504m respectively, the level of damage of rill erosion is turning into a V-Shaped gully sites whose lengths are above 100m each from its head and the widths are less than 3 meters while the depths are 0.3 and 0.4 meters respectively. The result also shows that with the use of the DEM (appendix 3) and the determination and computation of the orthometric heights of Ugwuoba town, government and its agencies will be able to know the elevation and flow direction of rain water in the area. This will help them to know the drainage pattern that is required to control, ameliorate and manage the menace of erosion in Ugwuoba town.

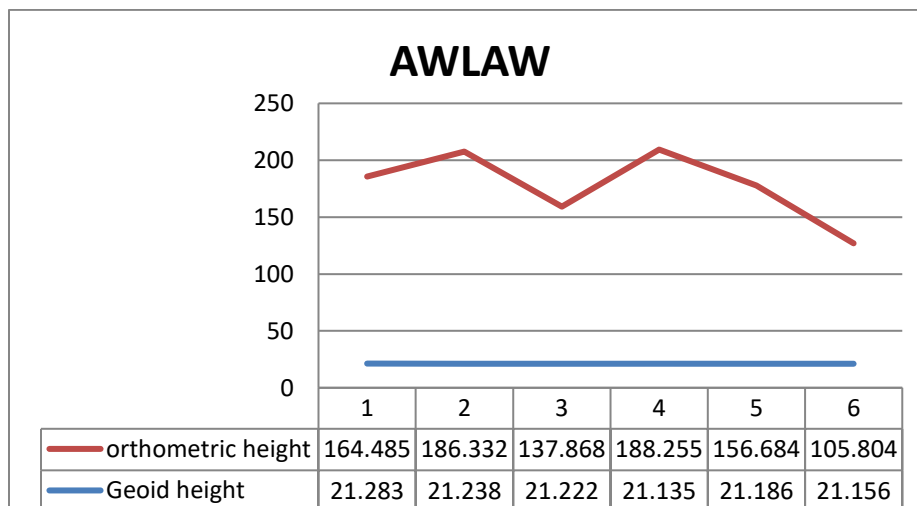


Fig. 4.5: Graphical presentation of the elevation profile of Awlaw Town

Figure 4.5 shows the graphical presentation of the profile of Awlaw Town as was processed with Microsoft excel software using the geodetic latitudes and longitudes, orthometric heights and geoid heights of Awlaw Town station points input parameters. The graph shows the profiling of the elevation of Awlaw and how the seepage flow direction of erosion could affect the environment of the steep parts of the underlain area. The graph shows that Awlaw Town has moderately high elevation with poor drainage system. For example, at the erosion points 3 and 6 with orthometric heights of 137.868m and 105.804m respectively, the level of damage of rill erosion is turning into a V-Shaped gully sites whose lengths are above 100m each from its head and the widths are less than 3meters while the depths are 0.4 and 0.7 meters respectively. There is high impact of erosion runoff in some parts of the area especially those living in the lower elevation of the area. The result also shows that with the use of the DEM (appendix 3) and the determination and computation of the orthometric heights of Awlaw town, government and its agencies will be able to know the elevation and flow direction of rain water in the area. This will help them to know the drainage pattern that is required to control, ameliorate and manage the menace of erosion in Awlaw town.

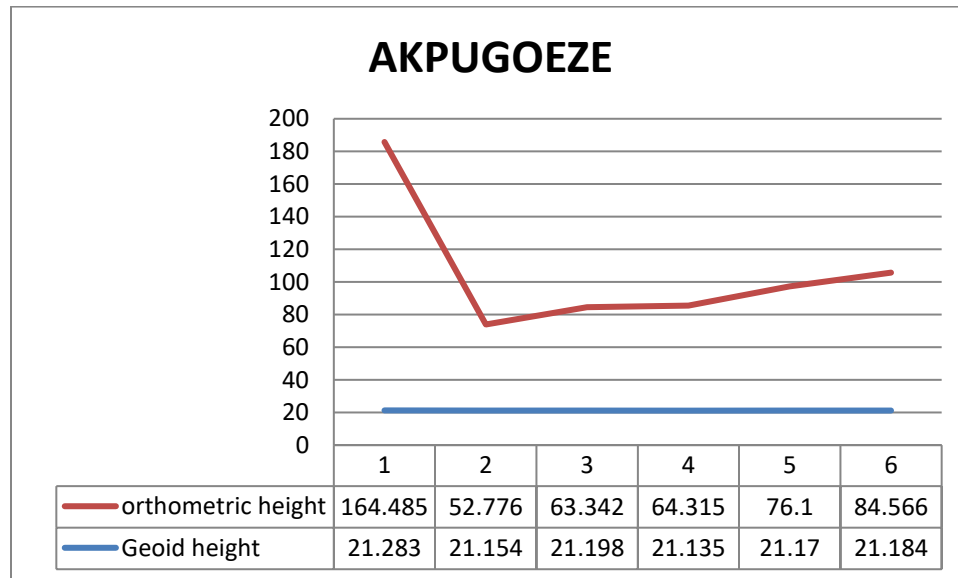


Fig. 4.6: Graphical presentation of the elevation profile of Akpugoeze Town

Figure 4.6 shows the graphical presentation of the profile of Akpugoeze Town as was processed with Microsoft excel software using the geodetic latitudes and longitudes, orthometric heights and geoid heights of Akpugoeze Town station points input parameters. The graph shows the profiling of the elevation of Akpugoeze and how the seepage flow direction of erosion could affect the environment of the steep parts of the underlain area. The graph shows that Akpugoeze Town has relatively plain elevation with good drainage system. For example, at the erosion points 2 and 4 with orthometric heights of 52.776m and 64.315m respectively, the level of damage of rill erosion is turning into a V-Shaped gully sites whose lengths are above 100m each from its head and the widths are less than 3 meters while the depths are 0.6 and 0.4 meters respectively. The impact of erosion in the area is felt because of lack proper town planning. The result also shows that with the use of the DEM (appendix 3) and the determination and computation of the orthometric heights of Akpugoeze town, government and its agencies will be able to know the elevation and flow direction of rain water in the area. This will help them to know the drainage pattern that is required to control, ameliorate and manage the menace of erosion in Akpugoeze town.

CONCLUSION

Vertical datum model is a veritable tool for possible amelioration and control of erosion. It is a predictive tool for future control and amelioration of soil erosion prone areas. The DEM was sourced from the Office of the Surveyor General of the Federation, Abuja and it was used for the determination of the orthometric heights of the area and the

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data were computed to show the flow direction of erosion in the study area. It also shows that vertical datum as a model can be reliable with the use of vertical heights to control and ameliorate erosion prone areas.

Nevertheless, the technique has some limitations, the method of acquiring GNSS data from the affected areas were labor-intensive which requires significant care by the instrument observer. Also the GPS instrument requires adequate power supply to cover a reasonable distance during observation.

RECOMMENDATIONS

After a thorough analysis and investigation of this study in Oji Rive Local Government Area of Enugu State, the study recommends:

1. The findings of this study showed that the vertical datum model can serve as a yardstick and reference point for surveyors in erosion prone areas.
2. It will help to educate the government by creating awareness on the usefulness of vertical datum as a model in mapping and assessing soil erosion sites.
3. It will also benefit the Urban and Regional Planners in planning and designing an area for residential, commercial, urban and semi-urban purposes.
4. It serves as a guide for policy makers in making policy against illegal over stressing of lands.
5. The findings will also help the Structural and Civil Engineers in designing and executing their jobs.

COMPETING INTERESTS

Authors have declared that no competing interests exist

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