ISSN 2229-5518

Bathymetric Investigation of Seabed Topographical Changes of Woji Creek

Akwaowo Ekpa[1], Imo Abasiekong[1]
[1]Department of Geoinformatics and Surveying, University of Uyo, Akwa Ibom State, Nigeria.

Abstract— Seabed changes refer to changes in the structure, elevation and composition of the bottom surface of the water body. There are range of human activities on Woji Creek in Rivers State, Nigeria, which have led to changes of the seabed. These include exploitation of sand and gravel from the seabed, marine littering or disturbing sediment, dredging, land reclamation and effluent discharge. The paper investigates the extent of topographical changes and possible causes. The data used were bathymetry dataset of 2012 and 2018, Google Earth imageries of same years, and tidal data. The methodology involved processing the Google Earth Imagery of the area with ArcMap 10.2 to create a database, sorting and processing the bathymetric dataset with HYPACK 2008 software before being exported into ArcMap to produce charts, and Digital Elevation Models (DEM) for both years. Histogram charts and graphs were used to analyze the seabed changes. The queries analyses from GIS tool revealed that the net sediment mass was 401725448.38952kg, while the net dredged mass was 306305126.437316kg. The result indicated that significant net sedimentation and dredging occurred in the Woji Creek within these periods. These results prompt the need to further investigate the impacts of human activities within the creek on the environment, through impact assessment studies for the sustainability of the environment as well as safety of lives and properties.

Index Terms— Bathymetry, Chart, Database, Digital Elevation Model, Seabed, sounded depths, topography, Woji Creek.

1 Introduction

Bathymetry is the science of measuring the depths of the oceans, seas, etc. and charting the shape and topography of the ocean floor [7]. The instruments conventionally used for this type of survey are echo sounders and swath sounding systems. In this method, propagated acoustic waves are used to access the target, and the time interval between the transmitted and received wave signals gives a measure of the depth.

Seafloor mapping (bathymetry) is one of the oldest professions known to humankind. Mariners have measured the depths under their vessels for thousands of years, primarily for safe navigation. Striking the rocky ocean floor would imperil the ship, threaten loss of life, and jeopardize the livelihood of those aboard [8]. Initially, charts derived from seafloor mapping were primarily for military purposes - naval warfare and information were kept as closely guarded national secrets. Today, national governments, militaries, telecommunication companies, petroleum corporations, and academic institutions map the seafloor for many applications [8]. In addition, fishing activities need detailed chart in order to avoid loss of fishing gear and fishing vessels to undetected or poorly identified obstructions. Fishermen also needed charts to identify areas where fishing was limited or prohibited [5]. Bathymetry goes a long way to enhance the identification of possible features on the seabed such as elevation changes, rock outcrop, wreckages, sunken vessels (where any exist), pipeline, or any other obstructions that could cause hazard to navigators. Others include sedimentation purposes to check for accretion or erosion, pre and post dredging bathymetry, that is to determine the existing status of the water body or to ascertain the dredged volume. It can also be done prior to pipeline and cable (laying) positioning, fishing and other geophysical exploration exercise [2], for improving navigational safety, and for national security protection [3].

Seabed changes refer to changes in the structure, elevation and composition of the bottom surface of the waterbody. Because these activities (or changes) differ in terms of their extent, degree of impact, or affected habitat types and associated communities, the overall magnitude of their impact differs. Physical loss and damage to the seabed has widespread effects on biodiversity, ecosystems, food web dynamics and marine habitats [9]. Thus, understanding seafloor morphology and its evolution is critical to scientific investigations of boundary layer processes.

This study aimed at investigating seabed topographical changes of Woji Creek in Port Harcourt, Rivers State, Nigeria. There are range of human activities which have led to possible changes to the seabed. These include scraping away the seabed (during anchoring or vessel grounding), exploitation of sand and gravel from the seabed, marine littering or disturbing sediment, dredging, land reclamation and effluence discharge. In addition, natural occurences such as flooding and ebbing, aquatic flora and fauna induced sediments also contribute to these changes over time. Woji Creek has served as major vessel navigation channel, flora and fauna habitat, and source of eceonomic livelihood to the inhabitants of the surrounding communities. It is on this premise that this study justifies need to investigate the extent of possible changes of seabed for the purpose of monitoring, controlling, and managing the activities within this region, optimally to sustain this resource and also to avert imminent dengers.

2 Study Area

Woji Creek is an estuarine tidal water located between longitude 6^0 55^0 E and 7^0 05^0 E and latitudes 4^0 48^0 N and 4^0 57^0 N, in Port Harcourt, Rivers State, Nigeria. The extent of the study area, which is a carved out portion of Woji Creek, Rivers State

ISSN 2229-5518

covers over 100,000sqm; with a length and breadth of approximately 1,000m and 100m respectively.

Woji Creek is a one of the major inland waterways in Nigeria; it opens to the Bonny Estuary, which houses the Onne Port. It originates from Okpoka River channel (bifurcation) and drains into Bonny River. It also traverses through many communities including Oginigba, Woji Azubiae, Okujagu, Okuru-Ama, Abuloma, Ojimba, Oba, Kalio-Ama and Okrika.

The occupation of the people around Woji Creek include fishing, farming, and maritime transportation. Its environs have witness tremendous developments over the past decade in terms of residential and industrial structures, land reclamation, construction of barriers, dredging, security outposts.

Figs 1 and 2 show the goggle earth imageries of Woji Creek for year 2012 and 2018 respectively.

Fig 1: Google Earth imagery of Woji Creek at 2012

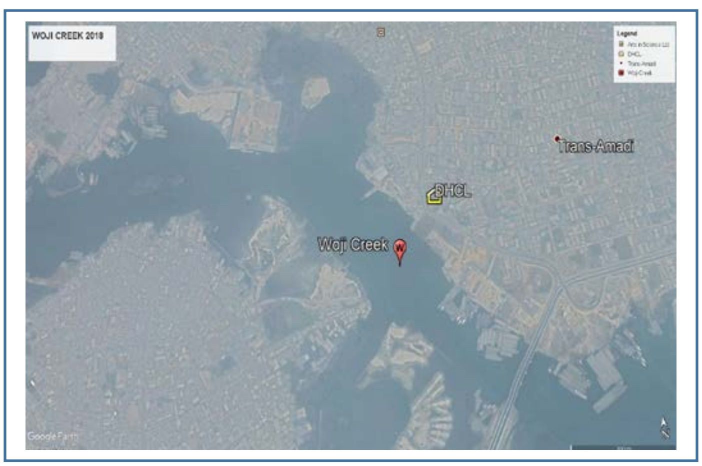

Fig 2: Google Earth imagery of Woji Creek at 2018

3 METHODOLGY

The workflow adopted for this study is as illustrated in fig 3. The stages involved are data acquisition, data processing and analysis, and finally, data presentation.

3.1 Data Acquisition

The bathymetry dataset of 2012 and 2018 were obtained for the study. To check for integrity, the data was exported in kml file format to load on Google Earth, and both datasets plotted on AutoCAD to ascertain the extent of overlay as well as to confirm that it fitted into the study area. The obtained data was imported to HYPACK and matrixed in a 25x25 square interval. A Google Earth imagery of the project area downloaded at maximum resolution and saved in Joint Photographic Expert Group (JPEG) format was used as the base map of the project. Google Earth Pro was able to provide the states of Woji Creek as at 2012 and 2018 respectively using the time slider (fig 1 and 2).

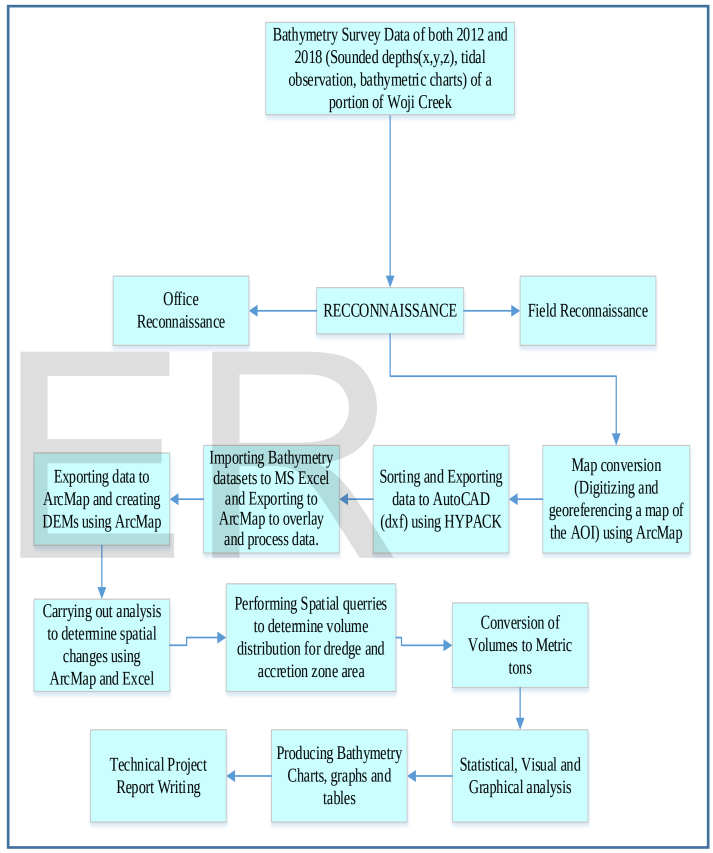

Fig 3: Workflow of the Study

3.2 Reconnaissance

Reconnaissance was conducted in both the office and field to ascertain the condition of equipment, available data of both years for the area under investigation. Enquiries were made about the activities (ongoing) and condition of the Woji Creek. A visit to Woji Creek was made to have an overview of the area. Some prominent features such as barges and boathouses parked along the creek shore were seen, and increased debris deposition at the mid-east border of the area of interest, which were not identified on the google earth imagery, were also observed.

ISSN 2229-5518

3.3 Map Conversion and Database Creation

The obtained Google Earth Imagery (raster data) [4] of the project area was processed using ArcMap 10.2. This included definition of spatial reference, georeferencing, database creation, digitizing of area of interest, and identification of relevant features. All the available data were referenced to WGS 1984 (UTM Zone 32N). Georeferencing was performed with 2nd order polynomial georeferencing using six (6) pairs of coordinates. A geo-database was optimized to store and query data that represents objects defined in a geometric space primarily as points, lines and polygons as well as their attributes.

Geographic feature layers were created with the aid of the ArcCatalog by specifying names, feature types and spatial reference (fig 4). The layers created were the project boundary and location ID.

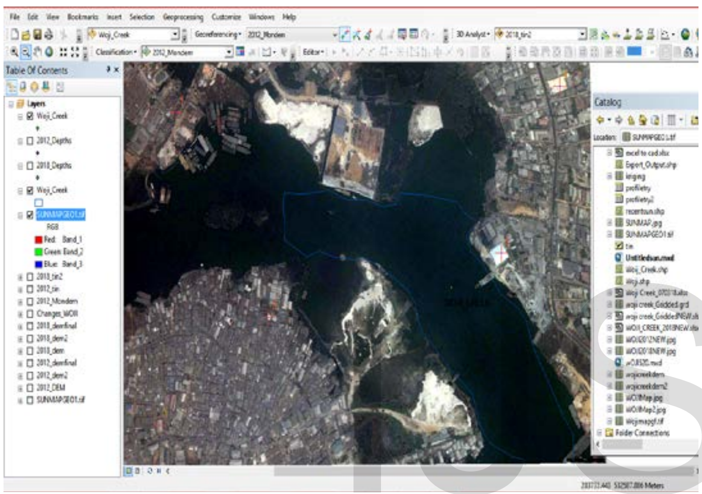

Fig 4: Screenshot of the Database of the Study Area.

4 RESULTS AND ANALYSES

4.1 XYZ Conversion and Sorting

From the HYPACK software, specific settings were chosen to enhance accurate plotting of sounding points. The XYZ to MTX method was adopted for filling matrices as they interpolated data to cover areas where data was sparse or nonexistent. This created a fully filled, and accurate HYPACK matrix file to guide further analysis by further converting MXT file to TIN model. Both 2012 and 2018 bathymetry data were imported to the HYPACK software and the above procedure was performed to sort the data as well as export it to AutoCAD readable format (dxf) as shown in figure 5.

4.2 Generation of DEM

Bathymetry data (x, y, z) of both years available in MS Excel file format were imported into ArcMap 10.2, and converted into ArcMap table and processed to display series of sounded depths positions. From the converted sounded depths in ArcMap, a Digital Elevation Model (DEM) was generated using the kriging interpolation method. The advantage kriging method has over inverse distance weighted and other deterministic methods is easy production of prediction maps, like prediction errors and probabilities. In other words, kriging supplies the precision associated to each estimate. The DEM for 2012 and 2018 are as shown in figs 6 and 7 respectively.

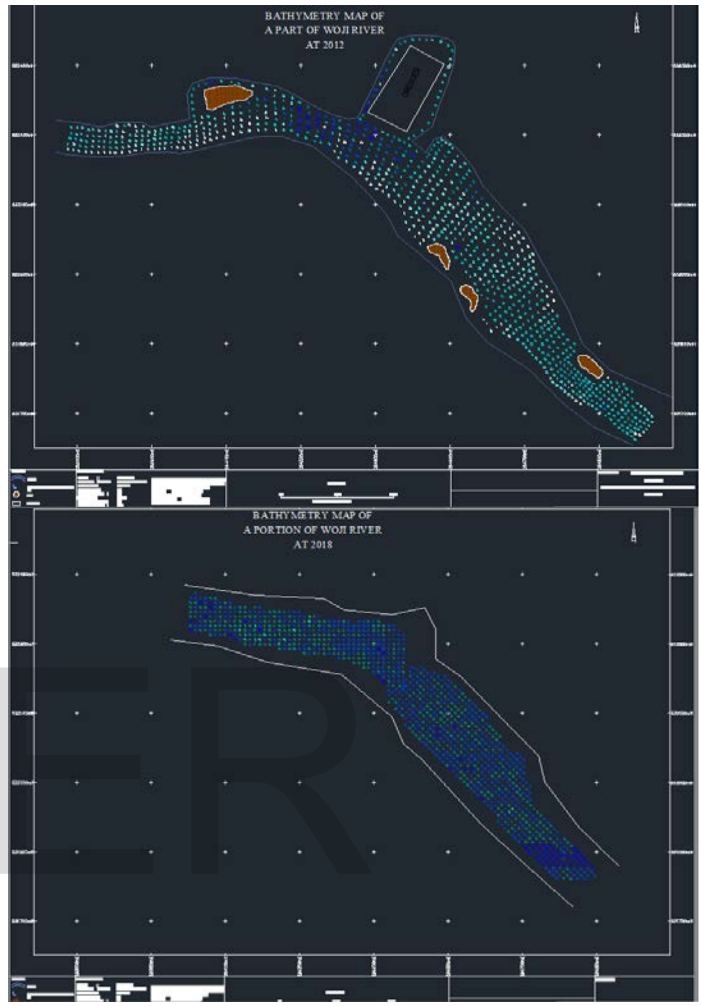

Fig 5: Plotted Sounded Depths for 2012 and 2018

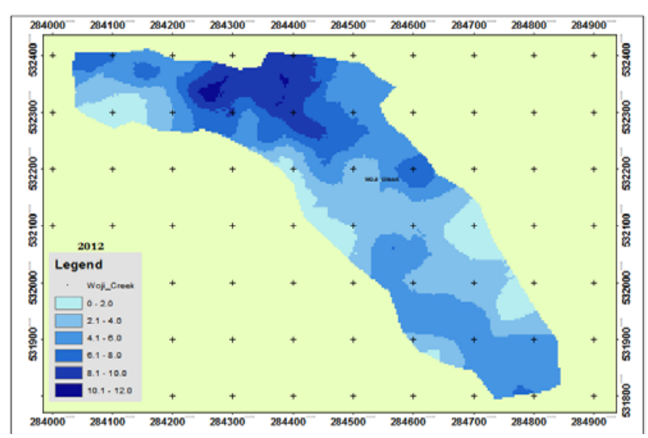

Fig 6: DEM of the Seabed of Woji Creek in 2012

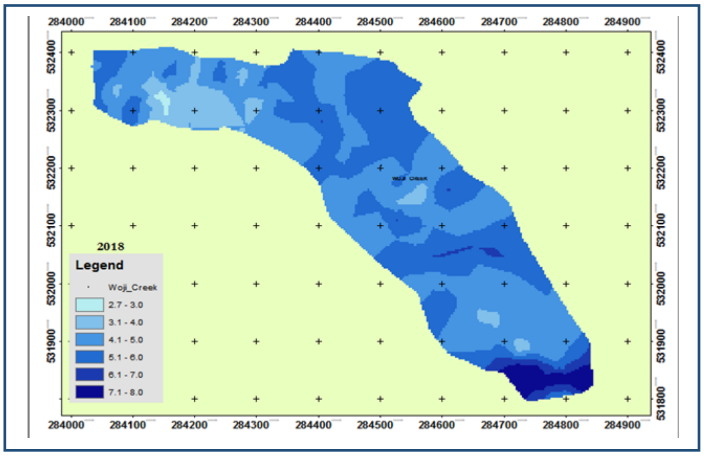

Fig 7: DEM of the Seabed of Woji Creek in 2018

4.3 Histograms Analyses of Bathymetric Datasets

Histogram plots of the bathymetric datasets for 2012 and 2018 were plotted to show the depths distribution of the same portion of Woji Creek respectively as shown in figs 8 and 9.

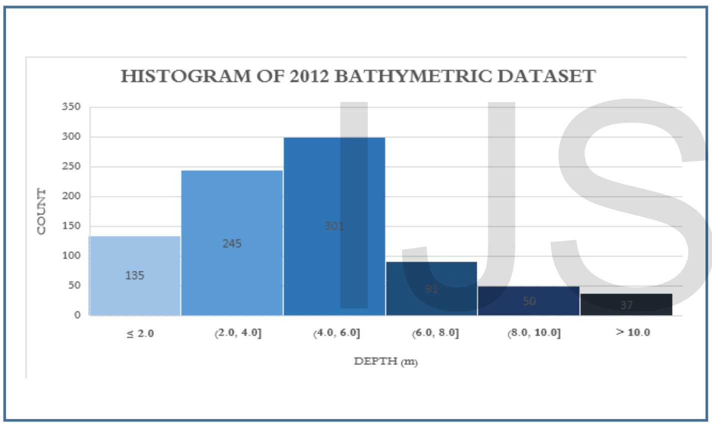

Fig 8: Depth Range Distribution of 2012 Bathymetric Dataset

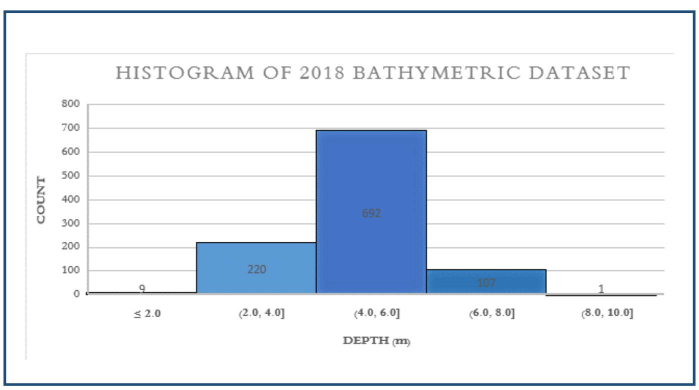

Fig 9: Depth Range Distribution of 2018 Bathymetric Dataset

In order to investigate seabed morphological changes, histogram was used in classification of depth range and determining the change in depths distribution.

The histogram plots for 2012 and 2018 reveal that there were (morphological changes) due to possible actions of dredging/sand mining and accretion/siltation taking place on the bottom of the creek. The results have indicated that there was population growth for depth between between 4.0 – 6.0m; whereas, decease of depths were observed between < 2.0m, 2.0 – 4.0m, 6.0 – 8.0m, and 8.0 -10.0m. Whereas, water depth ranges rather increase.

4.4 Routes Profile Generation and Analyses

Profiles were generated from three (3) 3D line feature(s) drawn over the DEM surface at left, center and right flanks (profiles 1, 2, and 3) of the Woji Creek. Conversely, to detect depth change over time on the Woji Creek topography, three routes were designed and the depth values for the two dataset (2012 and 2018) were plotted against distances drawn along a given profile at an interval of 50m. The plotted route profiles using dataset of 2012 DEM are shown in fig 11.

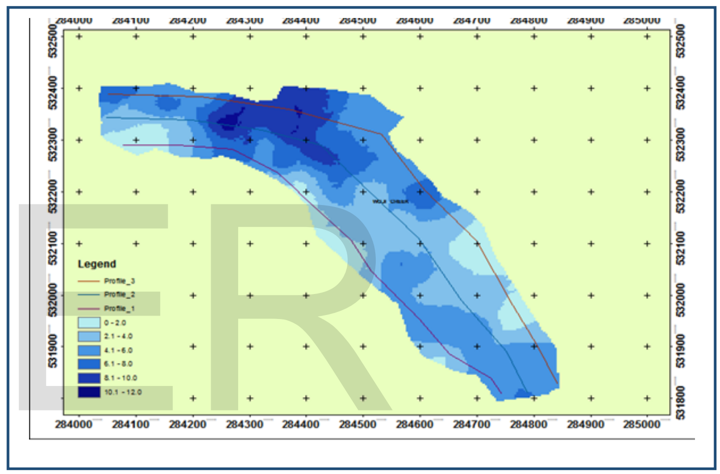

Figure 11: Plotted Route Profile 1, 2 and 3 using 2012 DEM

The three graphs were taken at interval of 50 m on a profile along the three routes; line 1 (left flank), line 2 (centre flank) and line 3 (right flank) respectively as shown in figs 12, 13 and 14. The three route profiles graphs revealed that the seabed had changes between 2012 and 2018. (It is pertinent to note that the x-axis of the graphs was inverted to depict the depth from water surface).

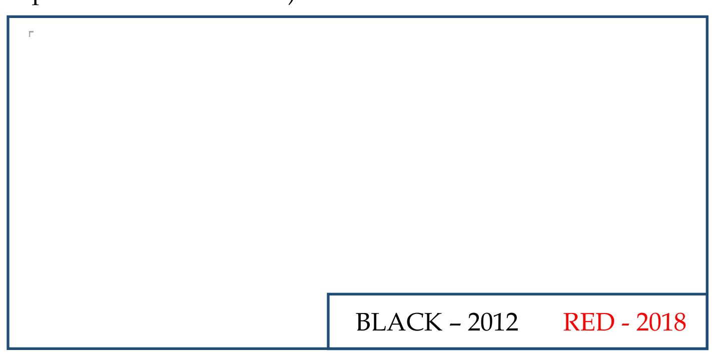

Fig 12: Left Flank Profile (1) of a portion of Woji Creek

BLACK – 2012 RED - 2018

Fig 13: Centre Flank Profile (2) of a portion of Woji Creek

BLACK – 2012 RED - 2018

Fig 14: Right Flank Profile (3) of a portion of Woji Creek

4.5 Raster Surfaces (DEMs) Analyses of 2012 and 2018

The 'Cut Fill tool' was used to create a map based on two input surfaces—before and after—displaying the areas and volumes of surface materials that have been modified by the removal or addition of surface material. Both year's input raster surfaces were coincident. For accurate results, the z-units were the same as the x,y ground units to ensure that the resulting volumes were in cubic meters. The attribute table of the output raster presented the changes in the surface volumes following the cut fill operation. Positive values for the volume difference indicate regions of the before raster surface that have been cut (material removed). Negative values indicated areas that have been filled (material added). When the cut/fill operation was performed a specialized renderer drew areas that have been cut in blue, and areas that have been filled in red. Areas that have not changed were displayed in grey (see fig 15).

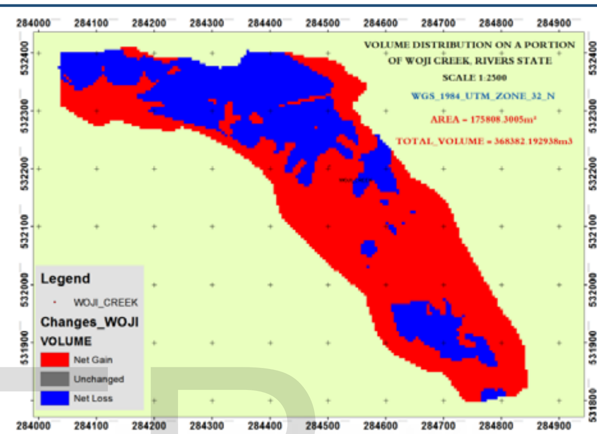

Fig 15: Spatial Changes between 2012 and 2018

Table 1: Sample Water Depths difference between 2012 and 2018.

S/N	Eastings	Northings	2012_Depths	2018_Depths	Depth Difference
1	284740.542	531828.108	5.0	6.7	-1.7
2	284790.542	531828.108	5.8	6.5	-0.8
3	284840.542	531828.108	5.7	6.6	-0.9
4	284640.542	531878.108	1.9	4.8	-2.9
5	284690.542	531878.108	4.7	5.4	-0.7
6	284740.542	531878.108	5.0	4.5	0.5
7	284790.542	531878.108	5.1	4.5	0.5
8	284840.542	531878.108	5.3	5.9	-0.6
9	284590.542	531928.108	4.7	5.2	-0.5
10	284640.542	531928.108	5.7	4.5	1.2
11	284690.542	531928.108	5.1	3.9	1.2
12	284740.542	531928.108	2.7	4.6	-1.9
13	284790.542	531928.108	2.6	4.4	-1.7
14	284590.542	531978.108	4.3	4.9	-0.6
15	284640.542	531978.108	4.1	4.4	-0.3
16	284690.542	531978.108	3.7	4.6	-0.9
17	284740.542	531978.108	2.1	4.5	-2.4
18	284540.542	532028.108	4.5	5.2	-0.7
19	284590.542	532028.108	4.2	5.0	-0.9
20	284640.542	532028.108	3.4	5.1	-1.6
21	284690.542	532028.108	2.6	5.0	-2.3
22	284740.542	532028.108	2.2	5.3	-3.1

ISSN 2229-5518

Similarly, comparing depths diferences, the table 1 above shows the differences in depths of sample points (x,y) for both 2012 and 2018 bathymetry dataset, extracted at 50m x 50m apart. Negative difference indicates increase in sounded depth meaning dredging or mining occurred at those areas. Whereas, Positive depth difference indicates that sedimentation occured at such points.

4.6 Volumes Determination

The data for this computation was initially stored in grid raster format (DEM) having arrays of square cells structures. For any given depth difference input, the volumes for dredged mass and accretion on the topography could be determined. The cells in the image were scaled using an orderly manner in assigning value; from the upper-right corner, a sequential value is given to each unique edge - connected area of accretion (or net gain), dredged (or net loss), or unchanged. Determining the volume, the area was first calculated. This is simply the number of cells in the region (Count) multiplied by the cell size of the raster and was obtained to be 175808.3005 square meters. With the calculated area, the volume was calculated using the representation below.

$$\text{Volume} = (\mathit{cell\_area}) * \Delta Z$$

where $\Delta Z = Z_{2012} - Z_{2018}$

Therefore,

$$\text{Volume} = 368382.192938 \text{ m}^3$$

From the formula, for areas where dredging occurred, the volume was positive, whereas, areas where accretion occurred, the volume was negative. Dredged portions were depicted with blue colour, while red depicted accretion area (as shown in figure 15).

4.7 Query using GIS Tool

ArcMap is a veritable tool which offers the capability of extracting meaningful information; through querying of feature class data, use of spatial analyst for extraction of useful information relating to spatial distributed data. Spatial analyst uses image statistics to estimate volume from image data. These images were initially converted to Raster format in the same bit, so the partitioning was uniquely done to obtain the area. The brightness value was a function of depth, and the difference from the two images yielded the change in depth, which was used in determining the volume through mathematical multiplication.

Queries for accretion and its statistical distribution revealed that the total volume of deposited sediment was the sum of component volume shown in the statistical portion. From calculation, the result was 209014.28116m^3 (fig 16). While, figure 17 represents query for dredged/mined volumes and its statistical distribution. The total dredged volume was the sum of component volume shown in the statistical portion; and was added to be 159367.911778m^3 (fig 17).

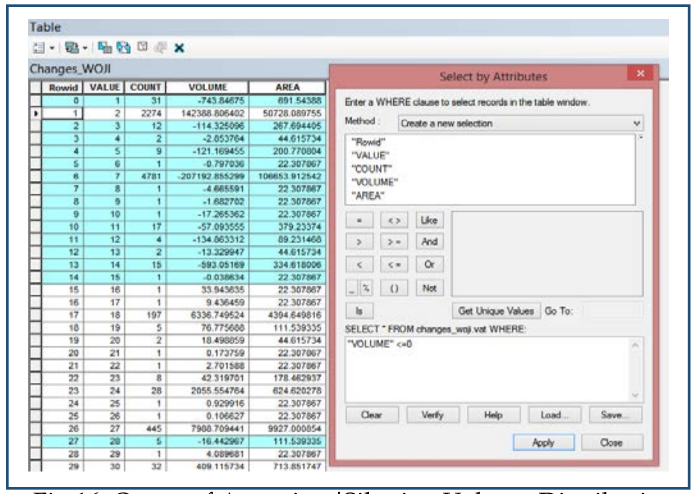

Fig 16: Query of Accretion/Siltation Volume Distribution

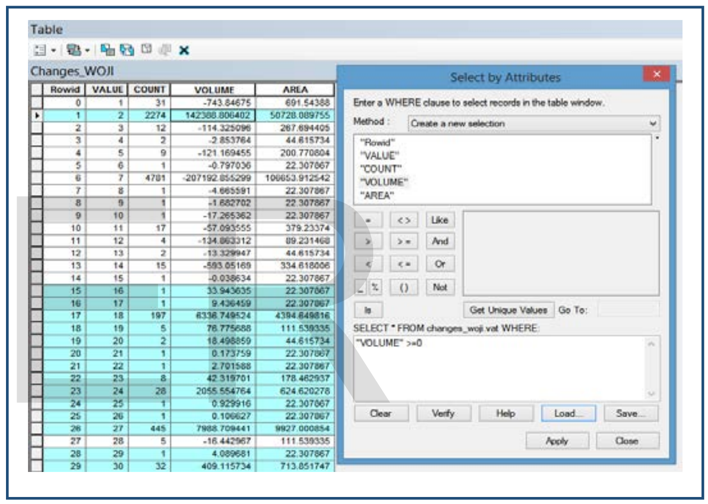

Fig 17: Query of Dredged/Mined Volume Distribution

4.8 Volume Conversion to Metric Ton

With reference to the above section (4.7), volumes for accretion/siltation and dredged/sand mining material were calculated as 209014.28116m^3 and 159367.911778m^3 respectively. The total volume within the project area was calculated as 368382.192938m^3.

From the calculated volumes, it simply reveals that sediment deposited mass was greater than the mass of material dredged from the creek. Converting these volumes to weight, we have that;

$$\text{Density (D)} = \text{Mass/ Volume.}$$

(The density for wet sand is 1922 kg/m^3).

$$\text{Mass (kg)} = \text{Density x Volume}$$

Therefore, for Sediment mass (kg):

$$= 209014.28116\text{m}^3 \times 1922 \text{ kg/m}^3$$

Net Gain (or Sediment) mass (kg) = 401725448.38952kg

Similarly, for Dredged mass (kg)
= 159367.911778m^3 x 1922 kg/m^3

Net Loss (or Dredged) mass (kg) = 306305126.437316kg

Determining the number of tons, we have that:
1000kg is equivalent to 1 metric ton.

Therefore, the mass (tons) for both dredged material and sediment materials are as below:

Sediment mass (Metric Ton) = 401725.44839t
Dredged mass (Metric Ton) = 306305.12644t

From the above estimates, it shows that more than average of the above metric tons of sediment (sand) is being dredged (or mined) from this portion of the creek and a little less than average is deposited.

Schaffer et al. [1], showed that estuary was being predominately controlled by physical processes, where the primary sediment structures of the bed were laminations, and the majority of the physical sediment disturbance occurred on a scale of weeks to months. And it was found that sediment deposition and eroded mass peaked at low-passed tidal range. For this study, sedimentation or accretion in this area were possibly caused by a number of factors such as;

i. Deposition of waste products from the Slaughter Market and accompanying residential layout (e.g. Golden Estate) as well as closely situated companies releasing effluents discharge directly into the Creek.
ii. Land reclamation activities and barrier/jetty construction/fortification caused the Creek to be exposed to sediments.
iii. Wreckages – barges and boathouses sunken within the creek were left to submerged for years, thereby obstructing the topography of the Creek.
iv. In addition, natural actions of erosion and tidal current were primary sources of sediment deposition to the Creek, as particles are moved from adjourning waterbodies either upstream/downstream in to the Creek.

Howbeit, there is need to investigate the impact of dredging/sand mining and or siltation/accretion on the environment through Environmental Impact Assessment (EIA) in oder to obtain accurate analysis and evaluation. Similarly, (Pye and Van Der Wal [6] asserted that in many regions worldwide, estuaries especially are being heavily surveyed due to their direct impact on human health, recreation, and industry.

5. Conclusion

The paper employed bathymetric datasets of 2012 and 2018 to investigated Woji Creek seabed topographical changes. The results of the study suggested that significant net sedimentation and dredging occurred within the creek between the span of six years. The used of GIS tool has proved to be effective in determining the net sediment mass as 401725448.38952kg, and the net dredged mass as 306305126.437316kg. This implied that extensive human activities are witnessed within this section of Woji Creek under study. Therefore, further studies are recommended on remaining parts of the creek to possibly ascertain the source of mass deposit to the creek. Futhermore, there is need to assess the impacts of these human activities within the creek on the neighbouring environment, through impact assessment studies for the sustainability of the environment as well as safety of lives and properties.

Finally, detailed bathymetric studies are needed to elucidate the changes associated with the entire Woji River to reduce uncertainties in depth estimates with individual bathymetric soundings for the purpose of safe navigation.

References

[1] B. O. Schaffer, and R. Christopher, O. Sherwood and O. C. Jonathan, "Sediments, Morphology and Sedimentary Processes on Continental Shelves: Advances in Technologies, Research and Applications," Special Publication 44 of the International Sedimentologists, available at https://www.wiley.com/, pp. 432, 2012.
[2] F. Chukwu and O. T. Badejo, "Bathymetric Survey Investigation for Lagos Lagoon Seabed Topographical Changes," Journal of Geosciences and Geomatics, 3(2), pp. 37-43, 2015.
[3] J. Hardisty, "Estuaries: Monitoring and Modelling the Physical System," Journal of Coastal Research. Blackwell Publishers, Vol. 27(3), pp. 604-604, 2007.
[4] Google Earth Pro, available at http://www.earth.google.com, 2018.
[5] J. Maxtone-Graham, "The Greatest Ocean Liner of Our Time," Bulfinch Press, Time Warner Group Book, New York, pp. 130, 2004.
[6] K. Pye, S. Blott and D. Van Der Wal "Long Term Estuary Processes and Morphological Change," Department of Geology, Royal Holloway, University of London, pp. 249-266, available at https://www.estuary-guide.net/PDFs/, 2003.
[7] N. Panigrahi, Computing in Geographic Information Systems. Boca Raton: CRC Press, 2014.
[8] T. A. Kearns and J. Bremen, "Bathymetry - The Art and Science of Seafloor Modelling for Modern Applications. Ocean Globe, ESRI Press, Redlands, 2010
[9] WISE Marine, "Physical Loss and Damage Affect Sea Floor Integrity," Marine Information System for Europe, available at https://water.europa.eu/marine/topics/pressures/physical-loss-and-damage, 2018.