BAJOPAS Volume 16 Number 1, June, 2023 **http://dx.doi.org/10.4314/bajopas.v16i1.2**

Bayero Journal of Pure and Applied Sciences, 16(1): 16 - 24
Received: January, 2023
Accepted: April, 2023
ISSN 2006 – 6996

BATHYMETRIC MAPPING AND EVALUATION OF SEDIMENT THICKNESS IN WOJI CREEK, PORT HARCOURT, NIGERIA

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ABSTRACT
Navigational channels have become a useful transportation corridor that has boosted the commerce, tourism, and security needs of people, communities, states, the country, and other nations. Hence, these channels should be safe and navigable at all times. Through bathymetric processes, information about the thickness of underwater sediments can be evaluated. This study is to map the sediment thickness of Woji Creek using the difference from a dual-frequency method. Data was acquired using ELAC (4300) dual frequency echo sounder for depth measurements, Trimble DGPS was used as the positioning system for the project execution, Eiva Navipac (Navigation Software) and total tide prediction data for processing. The echo sounder was interfaced with the GPS for position fixing. The highest and lowest depths around the surveyed section were 8.34m and 2.31m, respectively, while the total length and width of the channel were 1km and 223m, respectively. The sediment thickness computation along the surveyed section of Woji Creek varied between 0.91m to 4.33m. The average sediment thickness of the analysed area was 2.64m. Sea-going vessels may risk grounding in the future if the channel is not monitored. Hence, to improve the efficiency of the creek, dredging activities would need to be carried out.
Keywords: Bathymetric, Evaluation, Sediments, Thickness, Woji Creek

INTRODUCTION

Bathymetry refers to the underwater topography of oceans, seas, and lakes. The word originates from the Greek "βαθύς", deep, and "μέτρον", measure (Benjamin, 2011). Nowadays, bathymetry is mapped using echo sounders, and depending on the later use the collected depth data are in various ways processed and compiled into products such as nautical charts, shaded relief maps, and digital terrain models. Bathymetry is significant for multiple applications in research and society, for example, maritime navigation, ocean circulation modelling, ecosystem monitoring, and marine archaeology. Considerable resources are spent on the collection, management, and preparation of bathymetric data within the research and industry communities as well as at authorities of coastal states.

Bathymetry determines the depth of water, heights, bottom topography, and the location of fixed objects for survey and navigation purposes relative to sea level and a designated datum along a transect line to produce a section. A method of sectioning has to be adopted to obtain a record of undulations of the ground surface along a particular line (Clarke, 1972). This survey involves depth measurement and determination of topographical characteristics of the seabed. The bottoms of these watercourses are composed of granular materials transported as sediments. Sediments are one of the most common pollutants that affect water bodies. When sediments are in excess quantity (very thick), it can reduce the water channel capacity, which can, in turn, pose navigation difficulties to the users of such a water channel. In cases where these sediments are not evacuated over a period of time, it can cause flooding (Ojinnaka, 2007).

Bathymetry studies the underwater depth of lakes and ocean floors (Chukwu and Badejo, 2015). In a bathymetric survey, charts are produced to support the safety of surface or sub-surface navigations, which usually show seafloor relief or terrain as contour lines (depth contours). The chart provides exterior navigational information. The survey sets for the best description of the submarine topographical features may include sound velocity and slope corrections that are more accurate but eliminate the safety bias (Chukwu *et al.,* 2014).

Bathymetric surveys are significant for many purposes, and not limited to 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 determine the dredged volume. It can also be done before pipeline and cable (laying) positioning, fishing, and another geophysical exploration exercise (Chukwu and Badejo 2015).

To produce a bathymetric chart, tidal observation and reduction must be done to reduce the sounding depth of the chart datum (Tata *et al.*, 2018). Tidal observation is conducted prior to and concurrently with the sounding operations period and can be done on an established gauge or temporarily on any selected position where the water level hardly goes below the zero reading of the measuring device (Temporary gauge) (Chukwu and Badejo 2015).

Voulgaris *et al.,* (2008) addressed the processes responsible for long-term changes in sea bed morphology. Most authors' sediment thickness analysis and approach are derived from core sediments and remote data from geophysical, geotechnical, and bathymetric surveys (Timothy and Straub *et al.*, 2005). Measuring sedimentation and reservoir capacity levels has significantly challenged dam management (Oke *et al.,* 2019). With the advancement in multi-beam technology, echo sounders have become a significant instrument in bathymetric surveys (Radwan and Tarek, 2016).

Martin *et al.*, (2001) outlined approaches for describing bathymetry and sediment thickness. The approach resulted in the development of a new regional bathymetric model, which improved the description of the depth and morphology of sediments. Seabed classification is facilitated by the acoustic remote sensing of ocean, lake, and river bottoms to characterise the marine floor's physical, geological, and biological properties. Remote sensing is done using almost any sonar, from single-beam echo sounders to sophisticated multi-beam and side-scan imaging sonars.

The prominent factors that caused the changes in the seafloor sediment thickness and topography over a period of time include riverbank erosion and refuse disposal at the river bank. The increased thickness of seafloor sediments in the navigation channel has made navigation difficult and sometimes impossible, except when the channel is being dredged. This has been a challenge over the years, and this challenge can only be eradicated through effective monitoring of the navigation channel; and periodic sediment thickness evaluation of the creek.

Since Woji Creek is a very important and useful transportation corridor that has boosted commerce, tourism, and the security needs of People and Communities within the environment, the creak must be safe at all times for navigation. Safety can be ensured with the knowledge of its sediment thickness, hence the need for this project

This study intends to carry out bathymetric mapping of Woji Creek, Port Harcourt, Nigeria, measuring the depth with a dual-frequency echo-sounding technique to evaluate the sediment thickness and the morphological changes of the creek. The final results could be used to update the existing nautical chart and to create awareness of the need to plan and monitor coastal areas within the Port Harcourt City industrial hub.

METHODOLOGY

3.1.1. Survey Vessel and Sensors Offset Measurements

The vessel offset measurement was carried out to obtain the vessel's shape and to define a centre reference point (CRP) upon which the offsets of the installed sensors (DGPS and Echo sounder) as mounted on the vessel were described. The offset measurement was done using linear tape. This operation was essential because the accuracy of any bathymetric survey is a function of an appropriately measured survey vessel offset. Thus, the offset measurements were done carefully. Figure 1 is a sketch of the vessel offset and the offset of the installed sensors.

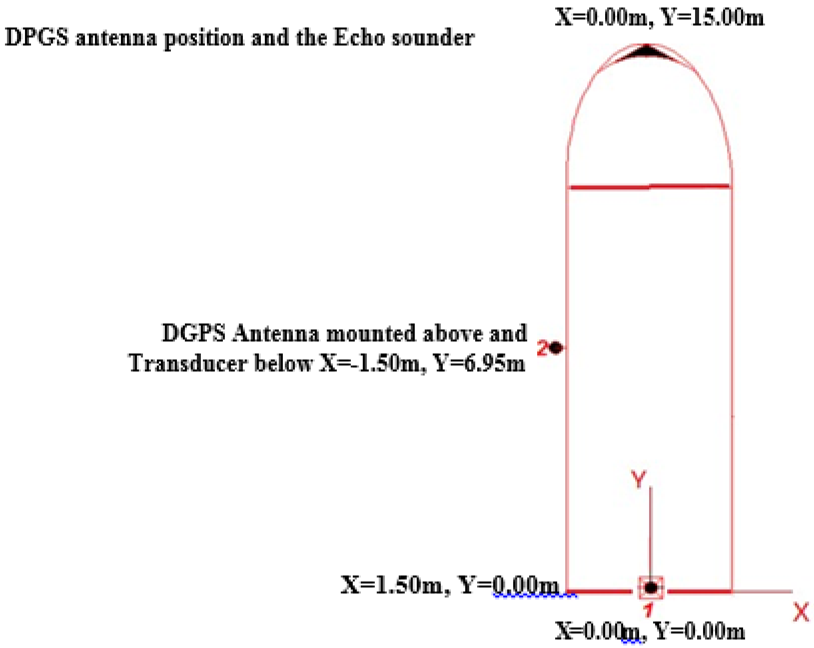


Figure 1: Vessel and Sensors Offsets (Not Drawn To Scale)

Installation of Transducer and the GPS Antenna
The echo sounder transducer was installed firmly by the side of the survey vessel to facilitate depth measurements. A set of fabricated metal supports and clamps aided the installation of the transducer. It was ensured that the transducer was standing vertically to avoid false depth measurements. The GPS antenna was mounted on the echo sounder transducer pole (Figure 2) so that the depth (z) and position (x, y) of points can be measured synchronously.

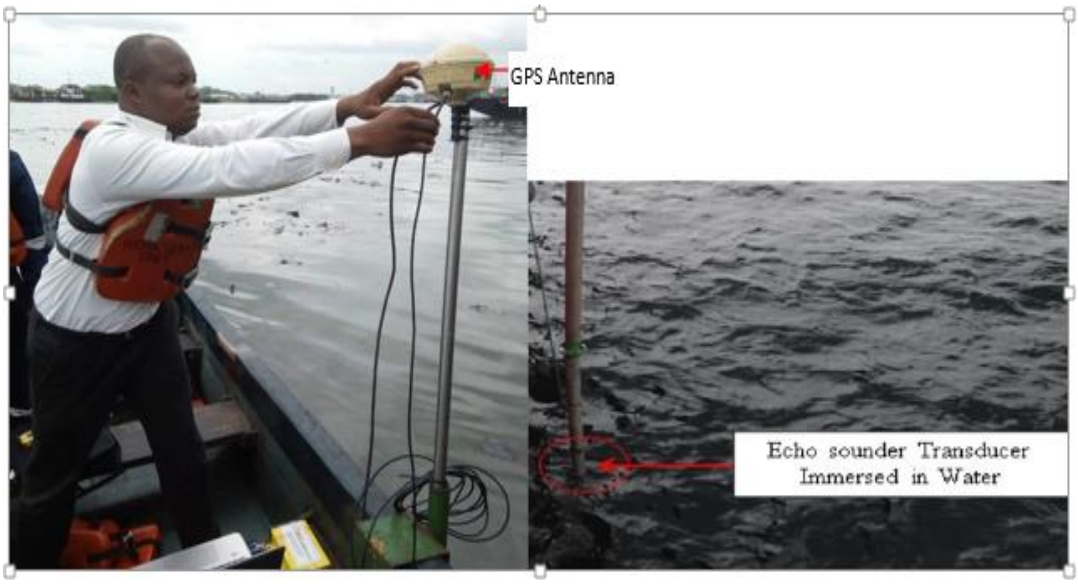


***Figure 2: Installation of Echo Sounder Transducer and GPS Antenna** (Author, 2021)*

System Set-up and Configuration
This project phase involved setting up and configuring the personal navigation computer and other equipment required for the survey. The equipment set-up included a 12vots car battery for power supply, UPS, Elac Hydrostar 4300 dual frequency Single Beam Echo sounder, Trimble DGPS receiver, and Moxa communication ports device for interfacing all the survey equipment with the navigation software. After the setting-up and confirming that all the instruments were working perfectly well, a general system configuration was carried out, during which the echo sounder, Gyro and DGPS data acquisition formats were configured. Also, geodetic parameters already inputted into the navigation software were double-checked to ensure they were intact. Figure 3 shows the personnel during set-up and configuration.

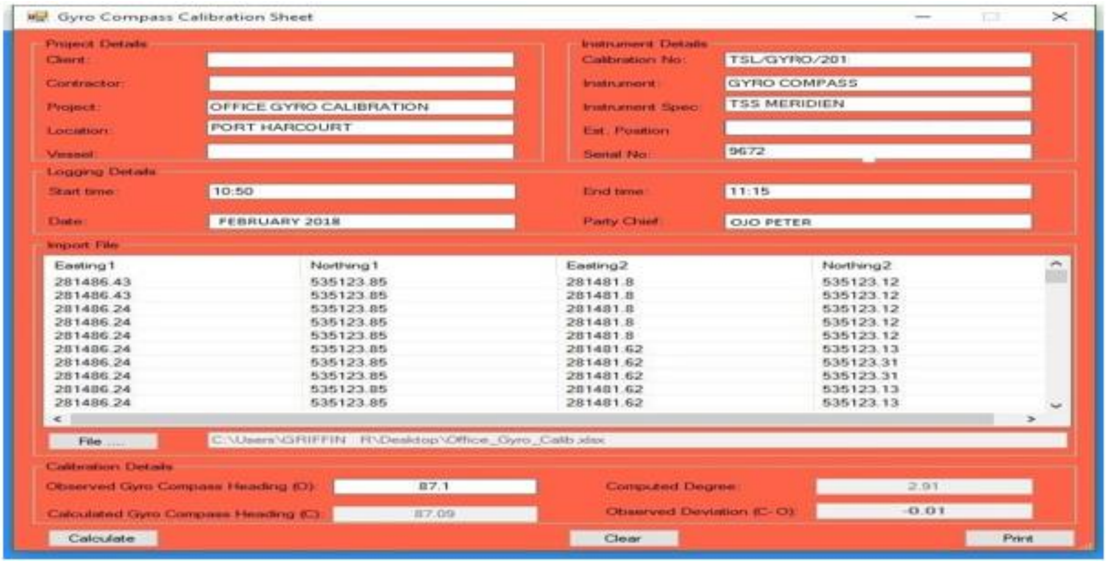
Figure 3: Author Carrying Out Equipment Set-up and Configuration *(Author, 2021)*

Bar Check on the Echo Sounder

The Echo Sounder was calibrated at the survey location before the commencement of survey work. The result from the calibration indicated that the transducer was functional. Bar checks were carried out to calibrate the echo sounder to correct index errors. The index errors were found to be less than 0.02m. To clear the errors, the draft setting on the echo sounder was adjusted to bring the reading to par with that measured in the bar check. The single beam Echo sounder was checked to have unhindered communication with the navigation system. The SVP was used to determine the speed of sound in seawater. Velocity readings obtained were also used to calibrate the Echo Sounder.

Gyro Heading Calibration

Calibrating the equipment before deploying it for this study was very important. Based on this, calibration was carried out on the Gyroscope before engaging it for field operations. The Gyroscope was calibrated using two DGPS alignment methods. This procedure was carried out by aligning the Gyro compass against a straight line in the office and the two DGPS receivers placed at both ends of the line. GPS data was logged for about 30 minutes for the two DGPS, respectively. The GPS data were used to compute for bearing, which was compared with the Gyro heading reading; the result obtained was within the manufacturer's tolerance limit, which is ±0.020º, and the difference was input into the software for corrections. Figure 4 shows the Gyrocompass calibration result.



Gyro Compass Calibration Sheet

Project Details
Client:
Contractor:
Project: OFFICE GYRO CALIBRATION
Location: PORT HARCOURT
Vessel:

Instrument Details
Calibration No: TSL/GYRO/201
Instrument: GYRO COMPASS
Instrument Spec: TSS MERIDIEN
Est. Position:
Serial No: 9672

Logging Details
Start time: 10:50
End time: 11:15
Date: FEBRUARY 2018
Party Chief: OJO PETER

Import File

Easting1	Northing1	Easting2	Northing2
281486.43	535123.85	281481.8	535123.12
281486.43	535123.85	281481.8	535123.12
281486.24	535123.85	281481.8	535123.12
281486.24	535123.85	281481.8	535123.12
281486.24	535123.85	281481.8	535123.12
281486.24	535123.85	281481.62	535123.13
281486.24	535123.85	281481.62	535123.31
281486.24	535123.85	281481.62	535123.31
281486.24	535123.85	281481.62	535123.13
281486.24	535123.85	281481.62	535123.13

File .... C:\Users\GRIFFIN R\Desktop\Office_Gyro_Calib.xlsx

Calibration Details
Observed Gyro Compass Heading (O): 87.1
Computed Degree: 2.91
Calculated Gyro Compass Heading (C): 87.09
Observed Deviation (C- O): -0.01

Calculate Clear Print

Figure 4. Gyro compass calibration sheet *(Author, 2021)*

Survey Line Plan
The survey lines were designed based on the outline of the project location obtained from Google Earth. The design was facilitated by AutoCAD and was further loaded on the navigation software. There was a need to increase the survey lines' density for better detection of the seabed topography. The creek was relatively small; as such, the run lines were 25m apart, while the cross lines were 100m apart. The 25m x 100m line plan was adopted due to the small size of the creek. The survey was also carried out along the cross sections, running perpendicular to the channel, as shown in Figure 5.

Figure 5: Survey Lines Plan (Author, 2021)

Data Acquisition
This stage of the project was centred on the acquisition of field data. The field data were acquired using Eiva NaviPac (Navigation software package), Echo Sounder, DGPS and the Survey Boat. Below is a brief description of these instruments. Eiva NaviPac Is a very reliable navigation software suite used for navigation and facilitates the interfacing of the echo sounder and GPS. Trimble DGPS was used as the positioning system for the project execution. The echo sounder was interfaced with the GPS for position fixing. Trimble DGPS is a differential Global Navigation Satellite System (GNSS) solution for accurate positioning. It is very rugged with reliable accuracy and has functions such as Superior interference suppression (both in-band & out-band) and multipath mitigation.

ELAC (4300**)** dual-frequency echo sounder was used for depth measurements. The bathymetric survey was carried out along the run lines and cross lines. The run lines were 10m intervals apart, while the cross lines were 100m interval spacing. The run lines were made 10m apart to enhance sufficient data acquisition because the creek is relatively small.

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SG Brown Meridian Surveyor gyro was used as the heading sensor for the project execution. The unit utilises a dry dynamically tuned gyroscope (DTG) Gyro element, providing exceptional performance with excellent accuracy. The Meridian Surveyor gyro boasts a wide range of interfaces to enable use on any marine vessel. And those do not require routine maintenance, which is common with conventional spinning mass Gyrocompasses.

During data acquisition, the GPS has a minimum of 15 satellites. The HDOP, VDOP and PDOP were **0.6**, **0.9** and **1.1,** respectively. The survey vessel maintained a navigation speed of **3.5**knots during the survey operations; while being monitored to ensure that the data were acquired along the planned lines**.**

Computation of Reduced Depths
The depths acquired by the echo sounder were referenced to the Lowest Astronomical Tide (LAT). Thus, all measured depths were reduced using predicted tidal values obtained from Admiralty
The total Tide Prediction Table for Port Harcourt is presented in Table 1

Table 1. Predicted Tidal Values (Extracted sample data from 2018) ***(Author, 2021)***

3664 Port Harcourt

4°46'N 7°00'E Nigeria Wednesday, March 07, 2018 System

Data Area 10. South Atlantic & Indian Ocean (Southern Part) Version 13

Date: 3/7/2018

Time			Tidal Values		
6:00 AM	11:50 AM	5:40 PM	1.5 m	1.2 m	1.8 m
6:10 AM	12:00 PM	5:50 PM	1.5 m	1.2 m	1.9 m
6:20 AM	12:10 PM	6:00 PM	1.6 m	1.1 m	1.9 m
6:30 AM	12:20 PM	6:10 PM	1.7 m	1.0 m	2.0 m
6:40 AM	12:30 PM	6:20 PM	1.8 m	1.0 m	2.0 m
6:50 AM	12:40 PM	6:30 PM	1.8 m	0.9 m	2.1 m
7:00 AM	12:50 PM	6:40 PM	1.9 m	0.8 m	2.1 m
7:10 AM	1:00 PM	6:50 PM	1.9 m	0.8 m	2.1 m

Sediment Thickness Measurement

Sediment thickness was measured using the reduced depths obtained from Channel-1 and Channel-2 frequencies of the echo sounder. Channel-1 depths are low frequency (LF) acoustic signals with relatively weak penetration strength defining the topmost layer of the seafloor, while the depth obtained from the high frequency (HF) acoustic signal with stronger penetration strength depicted the depth below the sea bed sediment layer. The two depths of information were used for the sediment thickness analysis.

Computation of the Sediment Thickness

The sediment thickness computation was done using depth obtained from both the low-frequency acoustic signal (LF) defining the top layer of the mud and the depth obtained from the high-frequency acoustic signal (HF) depicting the seafloor below the sediment. Based on the two sets of depths {low-frequency depths (LFD) and high-frequency depths (HFD)} information, the sediment thickness was computed as expressed below.

SD = HFD - LFD

Where;

SD = Sediment thickness, LFD = Low Frequency Depth, HDF = High Frequency Depth

RESULTS AND DISCUSSION

The processed bathymetric survey data was plotted electronically using CAD (Computer Aided Design) technology to produce a Bathymetry map and sediment evaluation profile chart, as shown in Figure 5. The contour map was plotted using Surfer software (a digital cartographic tool) to generate the contours. The contours were plotted at 0.2m contour intervals, as shown in Figure 5, while Figure 6 shows the sediment thickness profile, depicting the seabed's true nature.

Table 2. Observed Sediment Thickness on the Investigated Seabed Area of Woji Creek (extracted sample data) *(Author, 2021)*

A S/N	B Eastings (m)	C Northings (m)	D Measured Depth (LFD 38khz)	E Measured Depth (HFD 200khz)	F Obs Tide	G=(D-F) LFD Tide Corr. (FLD 38KHz)	H=(E-F) HFD Tide Corr. (FLD 200KHz)	I =(G-H) Obs Thickness
1	284439.78	532240.26	7.58	7.30	1.8	5.78	5.50	0.28
2	284451.11	532339.61	6.58	7.42	1.8	4.78	5.62	-0.84
3	284349.69	532326.71	6.84	6.64	1.8	5.04	4.84	0.20
4	284245.66	532332.10	6.81	7.10	1.8	5.01	5.30	-0.29
5	284148.45	532353.76	6.58	6.87	1.8	4.78	5.07	-0.29
6	284057.06	532388.87	6.55	6.43	1.8	4.75	4.63	0.12
7	283852.92	532335.75	6.29	6.72	1.8	4.49	4.92	-0.43
8	283786.56	532388.17	4.64	5.80	1.8	2.84	4.00	-1.16
9	283751.92	532369.16	5.67	5.89	1.8	3.87	4.09	-0.22
10	283748.75	532303.68	5.31	5.46	1.8	3.51	3.66	-0.15

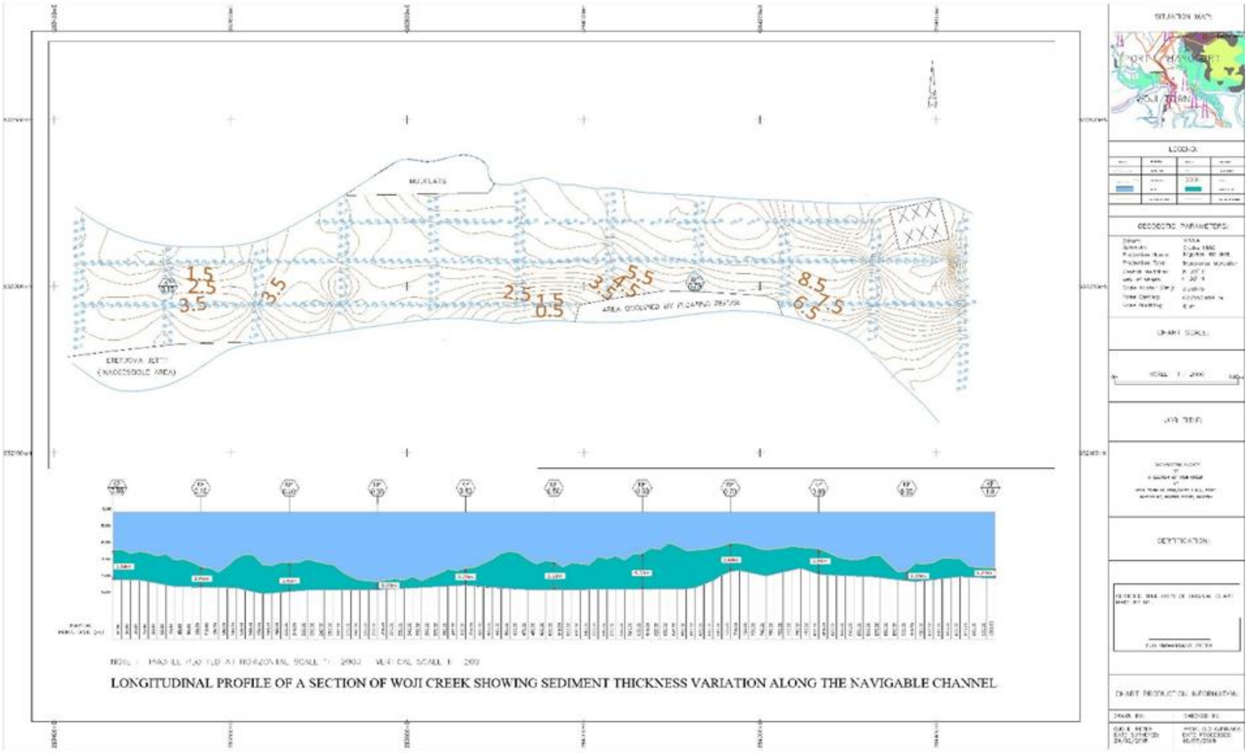

Figure 5: Bathymetry + Contour + Sediment Evaluation Profile Chart *(Author, 2021)*

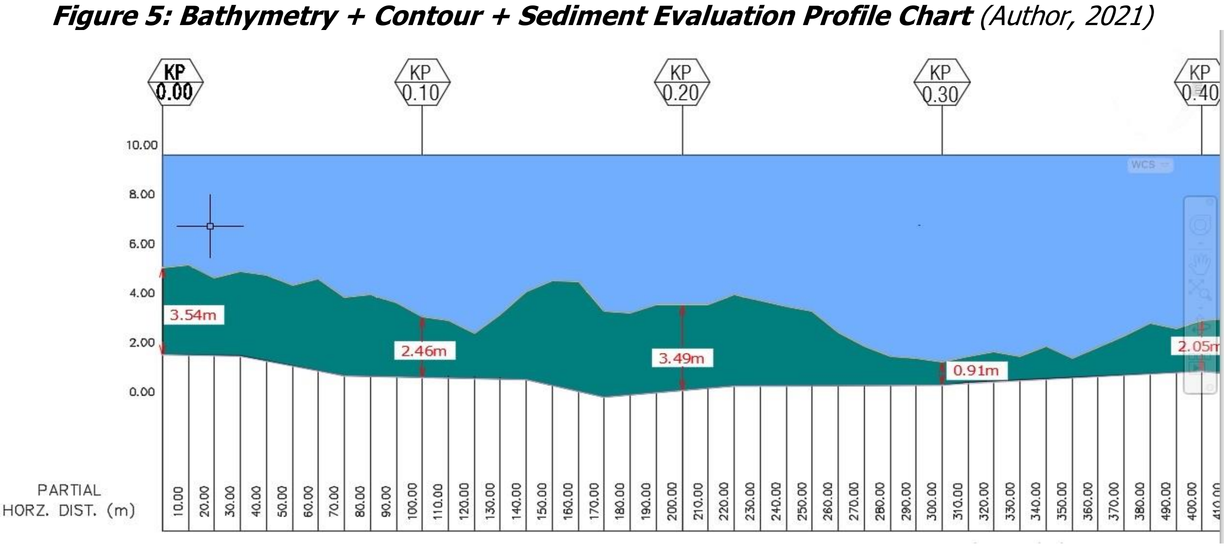

Figure 6: Sediment Thickness Profile *(Author, 2021)*

Table 3: Sediment Thickness Variation *(Author, 2021)*

Sediment Thickness Variation		
From	**To**	**Range (m)**
KP 0.00	KP 0.10	3.54 - 2.46
KP 0.10	KP 0.20	2.46 - 3.49
KP 020	KP 0.30	3.49 - 0.91
KP 0.30	KP 0.40	0.91 - 2.05
KP 0.40	KP 0.50	2.05 - 3.22
KP 0.50	KP 0.60	3.32 - 4.33
KP 0.60	KP 0.70	4.33 - 3.44
KP 0.70	KP 0.80	3.44 - 3.08
KP 0.80	KP 0.90	3.08 - 1.20
KP 0.90	KP 1.00	1.20 - 1.24

DISCUSSION OF RESULT

The bathymetric survey revealed a wreck suspected to be a vessel at coordinate (282439.25mE, 532375.23mN) around the ALCON company jetty of the creek. The highest and lowest depths around the surveyed section were 8.34m and 2.31m, respectively (sound data). It can be seen that there is a directly proportional relationship between the depth of the creek and the thickness of the bottom sediment.

The average sediment thickness of the surveyed section was 2.64m (thickness variation table). The region with higher depth has smaller sediments, while the regions with low depth have thicker sediments. Hence, the results obtained from the sea floor profile revealed the presence of sediments suspected to have occurred as a result of erosion, dumping of refuse and shoaling activities at the river banks around the surveyed section.

Sea-going vessels may risk grounding in the future if the channel is not monitored. To improve the efficiency of the creek, dredging activities would need to be carried out. This information is useful for carrying out visibility studies of a water body and obtaining necessary information about the seabed, which will form the foundation for further studies. Sediment thickness is classified based on the thickness variation. The sediment thickness along the surveyed section of Woji Creek varied between 0.91m to 4.33m, as shown in Table 2. The sediment thickness variation is shown in the table below, a section of the sediment chart. More details are contained in the graphs produced. The sediment thickness table was based on the 1-kilometre point (KP) sectioned into ten of one hundred meters.

From Table 3 above, it can be seen that there is no relationship between the sediment thickness and the depth of the riverbed. However, the sediment thickness is lowest at KP 0.30 and highest at KP 0.6. There are no unique characteristics of the activities going on at the river's surface at these Kilometer points to which the variation in sediment thickness can be attributed. So, the thickness of the sediments along the river bed can be said to be a result of the bed materials being transported.

CONCLUSION

The study carried out bathymetric mapping and evaluating sediment thickness in Woji Creek, Port Harcourt, Nigeria. This evaluation of sediment thickness is important knowledge for safe navigation and further planning and development of the creek. The project has shown the importance of understanding the depth of the seabed as well as its thickness. These two morphological characteristics of the sea are fundamental in planning navigational routes and dredging activities: charts of thickness and depth variation serve as a pictorial guide for quick access to important information. The highest and lowest depths around the surveyed section were 8.34m and 2.31m, respectively (sound data). The sediment thickness along the surveyed section of Woji Creek varied between 0.91m to 4.33m. The study has also demonstrated the unlimited use of GIS in bathymetric survey processing, from its acquisition stage to the production of charts

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