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Bathymetric Survey of AMTT-1 and AMTS-1 Access Route and Slot Area at Ogbotobo Oil Field Ogbotobo, Ekeremor Local Government Area, Bayelsa State.

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ABSTRACT

This report presents the results of a detailed bathymetric survey conducted on the AMTT-1 and AMTS-1 access routes and slot area within the Ogbotobo Oil Field, located in Ekeremor Local Government Area, Bayelsa State, Nigeria. The primary goal of the survey was to accurately map the underwater topography to support ongoing and future oil field exploration, development, and maintenance operations. Using advanced single-beam echo sounder technology, high-resolution depth data was collected to create precise bathymetric maps. The survey revealed significant depth variations ranging from 0.45 meters to 2.5 meters, along with key geomorphological features such as submerged ridges and depressions. These findings are crucial for identifying optimal drilling locations, planning pipeline routes, and assessing potential environmental impacts. Additionally, the survey provides important insights into sediment deposition and transport dynamics, enhancing understanding of seabed behavior in the operational area. The results of this study highlight the essential role of bathymetric surveys in ensuring safety, operational efficiency, and environmental responsibility in offshore oil activities. This report serves as a valuable reference for guiding future exploration and infrastructure development within the AMTT-1 and AMTS-1 sectors of the Ogbotobo Oil Field.

1. Introduction

Bathymetry, the science of measuring and mapping underwater topography, is a vital part of hydrography that helps ensure safe navigation, manage aquatic resources, and support environmental conservation. This field has undergone significant changes over the years, mainly driven by technological progress that has improved the accuracy, speed, and detail of underwater terrain mapping. Today, bathymetric surveys are essential tools in areas such as oil and gas exploration, marine ecosystem monitoring, and underwater infrastructure development.

Historically, the origins of bathymetry date back to the early 19th century, when lead line sounding techniques were used to estimate water depths (Smith & Jones, 2020). These involved manually lowering a weighted line from a boat to the seafloor and recording the depths at specific points. While pioneering at the time, these methods were labor-intensive and offered limited spatial coverage and resolution. The development of sonar technology in the early 20th century marked a major breakthrough, enabling more detailed and accurate data collection (Brown & Green, 2018). Sonar systems introduced automated emission of sound waves and reflection measurement, allowing for faster and more consistent mapping.

Modern bathymetric surveys use advanced instruments such as single-beam and multi-beam echo sounders, which are still among the most common technologies today. These systems send acoustic pulses from survey ships to the seafloor and measure the time it takes for the echoes to return, which determines depth (Johnson et al., 2019; O'Brien & Williams, 2021). Multi-beam systems can scan large areas of the seafloor in a single pass, creating high-resolution three-dimensional maps of underwater features.

Alongside sonar-based methods, other advanced technologies have emerged. Light Detection and Ranging (LiDAR) is increasingly used, especially in shallow or coastal waters. LiDAR employs laser pulses to measure distances to underwater surfaces, producing highly accurate depth models over large areas (Thompson et al., 2022). Satellite altimetry is another method, which measures variations in sea surface height from space. These variations reflect gravitational changes caused by underwater features and enable scientists to infer large-scale seafloor topography (Garcia et al., 2020).

Bathymetric data supports many applications. For maritime navigation, bathymetric charts help identify submerged hazards and ensure safe passage through ports, estuaries, and offshore zones (Smith & Jones, 2020; Brown & Green, 2018). In extractive industries, bathymetry helps locate offshore mineral and hydrocarbon deposits and plan infrastructure like pipelines and subsea wells (Johnson et al., 2019). Environmental scientists use bathymetric data to model ocean currents, track sediment transport, and study changes in aquatic habitats, which are vital for conservation efforts (Garcia et al., 2020; Thompson et al., 2022). Civil engineers also rely on detailed underwater topographic maps for designing and installing underwater cables, bridges, and other marine structures (O'Brien & Williams, 2021).

Despite these advances and uses, bathymetric surveying faces challenges. High accuracy demands specialized tools and techniques, and analyzing large data sets can be both time-consuming and complex. Moreover, acquiring and operating bathymetric systems requires significant financial resources and skilled personnel (Johnson et al., 2019; Thompson et al., 2022).

As dependence on marine resources grows and environmental concerns increase, the need for precise bathymetric data becomes even more critical. Future innovations will likely improve the quality and efficiency of underwater surveys, strengthening their role in promoting safe, sustainable, and well-informed decisions in marine and offshore environments.

2. Study Area

The project site is located within the Ogbotobo Oil Field, situated in the Ogbotobo community of Ekeremor Local Government Area, Bayelsa State, Nigeria. Geographically, the area falls within the Niger Delta region, characterized by extensive waterways, mangrove swamps, and diverse ecological features. The surveyed site is defined by the following approximate geographic coordinates:

i. Point 1: Latitude 04°59'39.82"N, Longitude 05°31'05.36"E
ii. Point 2: Latitude 05°00'09.72"N, Longitude 05°31'45.10"E
iii. Point 3: Latitude 04°59'55.02"N, Longitude 05°32'54.48"E

These coordinates encompass the access route and slot area associated with the AMTT-1 and AMTS-1 segments of the oil field. The location is strategically significant for offshore exploration and operational logistics within the lower deltaic environment of southern Nigeria.

The topography of the seabed within the study area is generally undulating, with depth variations influenced by natural sedimentation processes and tidal movements typical of deltaic environments. Climatically, the area experiences a tropical monsoon climate, marked by two distinct seasons—a wet season extending typically from March to October, and a dry season occurring from November to March, though seasonal transitions may vary slightly from year to year. The region is generally humid, with a mean annual temperature of approximately 28.64 °C, which is about 0.82% lower than the national average for Nigeria. These climatic conditions, combined with the region's ecological complexity, significantly influence the hydrodynamic behavior and sediment transport processes within the project site.

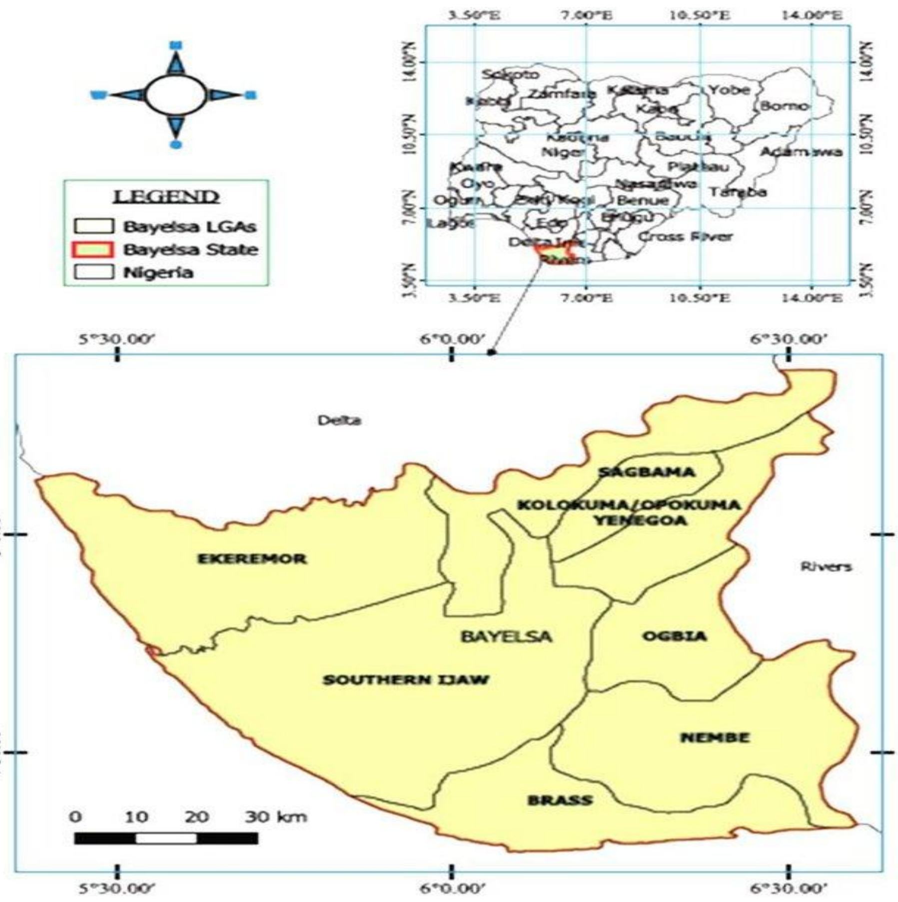


Fig 1. Study Area.

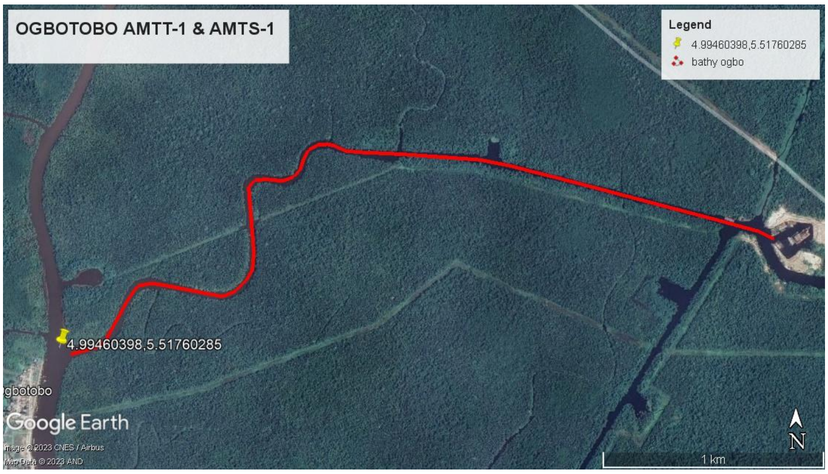


Fig 2.1. Google imagery of Study Area

3. Materials and Methods

3.1 Materials Used

INSTRUMENTS USED

i. South SDE 28S Echo-Sounder (Single Beam
ii. Hi-Target GPS (Dual Frequency Receivers).
iii. Sokkia automatic level, leveling staff & tripod
iv. HP computer.
v. Tide gauge and linen measuring tape
vi. Bar Check Plate with graduated rope,
vii. Batteries and other accessories
viii. Safety Boots, Hard Hats & Life Jackets

SOFTWARES USED

1. Notepad
2. Microsoft Excel 2010
3. South SDE-28
4. Autodesk Civil 3D 2019
5. Power Navigation
6. Surfer-10

3.2 Methods

The methodology encompasses both the field and office procedures adopted in executing the bathymetric survey project. The methods employed were rooted in the fundamental surveying principle of "working from whole to part," which ensures the reliability and accuracy of acquired data for subsequent analysis and map/chart production. The procedure adopted followed a systematic workflow where each stage logically progressed into the next, thereby ensuring efficiency and successful realization of the project objectives.

The stages involved in the execution of this project were:

Reconnaissance → Data Acquisition → Data Downloading and Processing → Data Analysis → Information Presentation

3.2.1 Reconnaissance

Office Reconnaissance and Field Reconnaissance

Office reconnaissance formed the foundation of the project and was carried out before the commencement of fieldwork. It involved thorough planning and review of relevant information to ensure that field operations would proceed smoothly and within expected accuracy standards. Key activities undertaken during this phase included:

i. Understanding the purpose and scope of the survey from the client's brief and project instructions

ii. Reviewing the specifications for accuracy and choosing an appropriate working scale

iii. Determining the most suitable measurement techniques for data acquisition

iv. Selecting appropriate survey instruments for the project, such as GPS and echo sounders

v. Ensuring full team preparedness and role allocation for field operations

Additionally, the client provided a list of boundary coordinates for the Ogbotobo AMTT-1 and AMTS-1 Access Route and Location Box, which covered the area proposed for sounding and dredging. These coordinates enabled the team to understand the extent of the survey coverage, facilitating effective planning for logistics and data acquisition.

Field reconnaissance was conducted after the office planning stage. This involved visiting the project site to gain a comprehensive overview of the physical environment. The reconnaissance aimed at:

i. Identifying and confirming control points to be used at the start and end of the survey route

ii. Selecting appropriate instrument stations along the access route

iii. Walking through the entire survey stretch to examine terrain conditions and determine the best approach for chainage staking and data collection

This on-site evaluation resulted in the creation of a reconnaissance (recce) diagram depicting the general layout and plan of the project area. Although not drawn to scale, this diagram was instrumental in guiding field activities and station setup.

The data acquisition stage involved the actual field measurements and observations. The focus was on collecting accurate position and depth data, which are the essential parameters in bathymetric surveys.

The equipment and procedure employed were as follows:

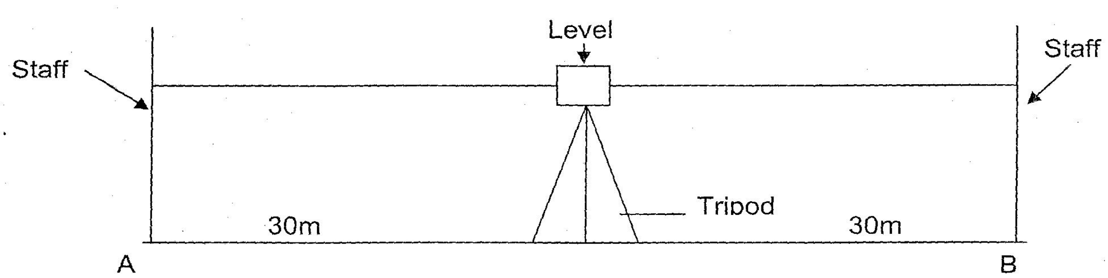
- **Hi-Target GNSS Receiver:** Used for position fixing to determine the X and Y coordinates of each sounding point
- **Echo Sounder:** Used to measure depth (Z-values) by transmitting acoustic pulses and recording their return from the seabed

The integration of GNSS and echo sounder data ensured the capture of three-dimensional positional information (X, Y, Z), which is critical for generating bathymetric maps and assessing the underwater terrain for dredging suitability.

Instrument Testing and two-Peg Test (Level Instrument Calibration)

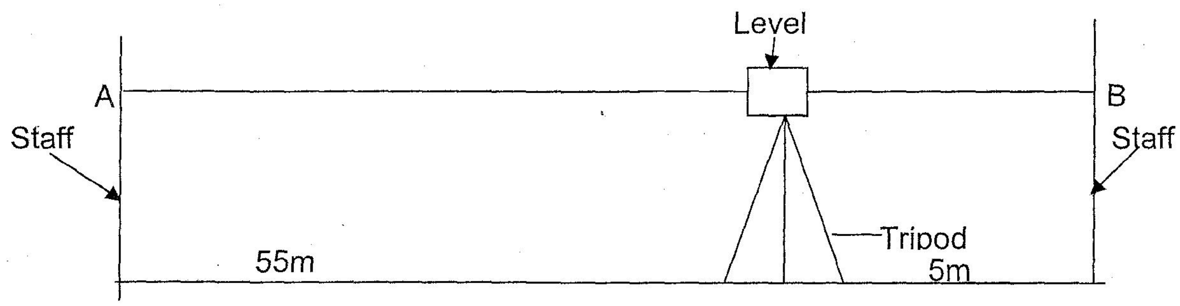
Before the commencement of field operations, all survey instruments were subjected to calibration and functional checks. This standard procedure ensures that all equipment is in proper working condition and capable of delivering accurate and reliable results.

To check for collimation error in the leveling instrument, the **two-peg test** method was employed. Two points (designated as A and B) spaced 100 meters apart on a relatively flat terrain were selected. A leveling staff was held vertically on each point. The level instrument was then positioned midway between the two points, and temporary adjustments were made. Readings were subsequently recorded on both staffs to detect any angular deviation or misalignment in the instrument's line of sight.



Staff Reading on A	=	1.742m
Staff Reading on B	=	1.137m
Difference	=	0.605m

The level was then moved to 75m towards staff B for the second set up. The same operation carried out in the first set-up was carried out in the second set-up.



Staff Reading on A	=	1.803
Staff Reading on B	=	1.196
Difference		0.607

The difference between staff readings in fig 3 and fig 4 above were computed to be 0.002m. Therefore the collimation error of 0.002/2=0.001m is within tolerance limit. It shows that the level was in good working condition.

GPS Instrument Test and Control Check

The Hi-Target GPS was configured in Real-Time Kinematic (RTK) mode and tested using known control points to verify accuracy.

Procedure:

i. Control Pillar GBO 35 was used as the base station. (refer to Table 3.1 below)

ii. The base receiver was set up over GBO 35, and its antenna height and datum parameters were input using the controller unit.

iii. Another GPS receiver was configured as a rover and set up on Pillar GBO 34.

iv. Real-time correction signals were transmitted via radio from the base to the rover.

v. The rover computed and displayed corrected coordinates, which were compared against known values.

Result:

The coordinate comparison between the base and rover remained within acceptable tolerance levels, confirming that the instrument was functioning optimally.

	GIVEN COORDINATE		**Achieved with RTK GPS**		**DIFFERENCE**	
STATION	**N (w. belt)**	**E (w. belt)**	**N (w. belt)**	**E (w. belt)**	▲N	▲E
GBO 34	347088.460	110552.910	347088.428	110552.885	0.032	0.028
GBO 35	347161.130	110534.520	347161.130	110534.520	0	0
GBO 36	347136.560	110437.610	347136.522	110437.627	0.038	-0.017

Table 3.1. Control beacons and coordinates

Bar-Check Calibration of Echo Sounder

Bar-check calibration was performed at both the beginning and end of the bathymetric sounding operation. A metal bar affixed to a calibrated rope (up to 10 meters) was used for the test.

Procedure:

i. The metal bar was submerged to depths of 1m, 2m, and 3m in water.

ii. The corresponding depth readings displayed by the echo sounder were compared with the actual calibrated depths on the rope.

iii. Minimal discrepancies confirmed that the echo sounder was accurately measuring water depths.

Tidal Observations and Water Level Establishment

Height Transfer

A leveling instrument was used to transfer elevation from the known control point (GBO 35) to a peg placed at the current water level. Staff readings were taken at both the control point and the water peg, with the time of observation carefully recorded.

Tide Gauge Installation and Observation

A tide gauge was employed to monitor water level fluctuations at 10-minute intervals.

i. Observation began at 4:05 PM and ended at 6:12 PM (local time).
ii. These tidal readings were recorded throughout the bathymetric survey duration and later used to reduce observed echo sounder depths to true depths.

Point ID	B.S (m)	I.S (m)	F.S (m)	H.I (m)	R.L (m)	TIME	Re-Mark
GBO35	1.279			3.779	**2.500**		Pillar
Peg	1.530		2.798	2.511	**0.981**	**10:35am**	**Water surface**
GBO 36			0.693		**1.818**		Pillar

Table 3.2. Tidal readings

Sensor Interface with Navigational Software

The DGPS and echo sounder were interfaced with the navigation software PowerNav using serial communication ports.

Procedure:

i. The sensors were physically connected to the ports on the echo sounder.
ii. PowerNav was launched, and sensor configuration was completed, including selection of the coordinate system (WGS 84 and NTM Mid-Belt).
iii. A test was run within the software to ensure data logging commenced properly and that real-time positional data and depths were being correctly displayed and recorded.

Echo Sounding: Depth Measurement and Position Fixing

The Digital Echo Sounder (SOUTH SDE-28S) was used to capture depth data along planned survey lines.

Methodology:

i. The survey boat was fitted with a 3-meter draft.
ii. The echo sounder transducer was mounted 0.2m below water surface at one end of the draft, while the DGPS antenna was fixed at the other end above the water surface, ensuring zero offset.
iii. The DGPS and echo sounder were powered and allowed time to initialize.
iv. Key settings included:
    i. Projection Datum: NTM (West Belt)
    ii. Draft: 0.2 meters
    iii. Fix Interval: 10 meters
    iv. Time/Date/Velocity: Confirmed and synchronized

The PowerNav software was synchronized with the echo sounder via dongle connection. Upon successful setup, automatic data logging commenced. The survey was conducted line-by-line, with:

i. Four (4) lines within the location box area, and
ii. Three (3) lines along the access route, recording depths at 10-meter intervals.

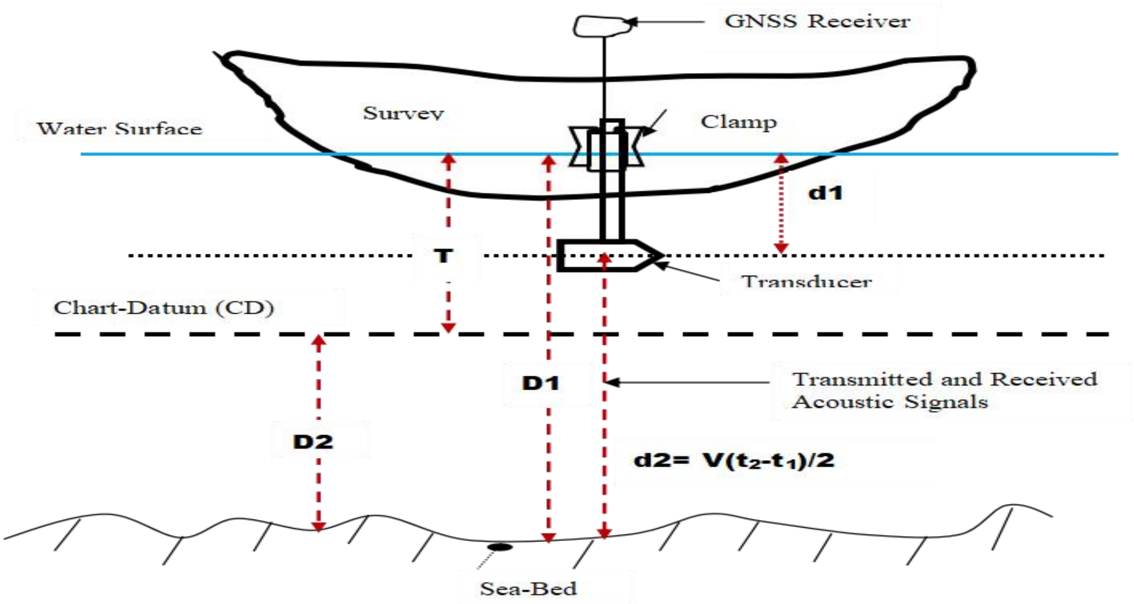


Fig 3.1. Schematic Diagram of Single-Beam Echo Sounder Setup for Bathymetric Surveying

4. Results and Analysis

The data acquired during the bathymetric survey of the AMTT-1 and AMTS-1 Access Route and Slot Area at Ogbotobo Oil Field were systematically processed and analyzed using Microsoft Excel and Autodesk Civil 3D 2019 software. The process was executed in several stages to ensure accuracy, consistency, and suitability of the final outputs for engineering and planning applications.

Data Visualization and Charting

Following tidal correction and data cleaning, the validated data set was imported into Autodesk Civil 3D 2019 for detailed visualization and charting. A bathymetric chart was produced using the Nigeria Transverse Mercator (NTM) coordinate system – West Belt, which is suitable for engineering and hydrographic surveys in this region of Nigeria.

An AutoCAD drawing was generated at a scale of 1:2000, which appropriately balances detail and spatial coverage. The bathymetric map illustrates:

i. The shoreline boundary in relation to the surveyed area.

ii. Sounded depth values plotted at 10-meter longitudinal intervals.

iii. A consistent grid layout with longitudinal lines spaced at 10-meter intervals for easy interpretation and spatial referencing.

These charts provide a clear spatial representation of the seabed's topography, essential for navigation, engineering design, and dredging operations.

Bathymetric Survey Map Interpretation

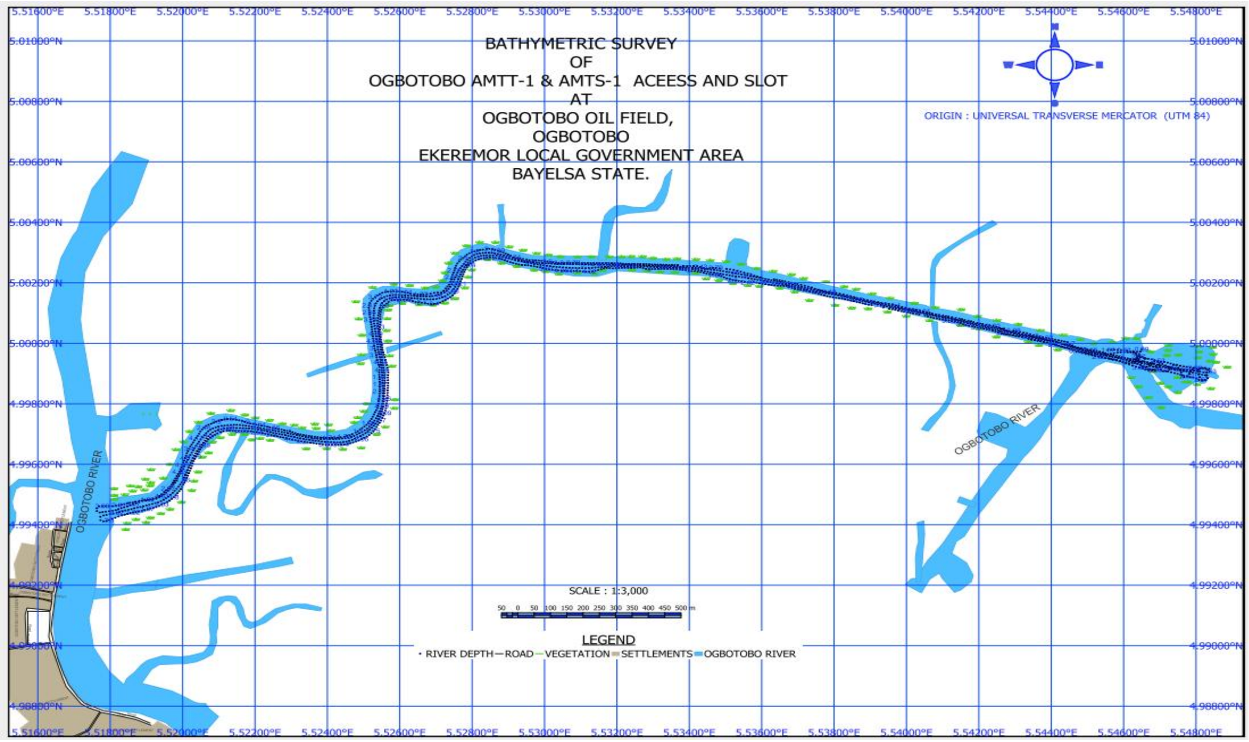


Fig 4.1. Bathymetric Sail Lines and Survey Route Map

The image above illustrates the planimetric representation of the bathymetric survey of AMTT-1 and AMTS-1 Access Route and Slot Area at Ogbotobo Oil Field, situated in Ogbotobo, Ekeremor LGA, Bayelsa State. This map provides a top-down spatial context of the hydrographic features, bathymetric tracklines, surrounding vegetation, roads, and local settlements along the Ogbotobo River.

Key Observations:

i. **Survey Route:**

The bathymetric track follows the winding route of the Ogbotobo River, from the western end of the access channel through the slot area to the eastern terminal, covering about 5 km. This path is essential for marine logistics, barge movement, and maintenance dredging planning within the oil field operations (IHO, 2020).

ii. **Bathymetric Track lines and Coverage:**

Numerous evenly spaced survey lines are visible, indicating a systematic bathymetric data collection method, likely using a single-beam or dual-frequency echo sounder. These tracklines run along the river centerline, ensuring full bottom coverage, especially along the proposed access and slot paths.

iii. **Topographic and Hydrographic Features:**

The map displays river channels, nearby vegetation, and settlement areas, providing context for land-water interactions. The spatial layout highlights the terrain's complexity, especially regarding sediment movement, erosion areas, and navigational hazards along the watercourse (Yao et al., 2020).

iv. **Coordinate System and Scale:**

The map adopts the Universal Transverse Mercator (UTM Zone 32N) projection based on WGS 84, enabling integration with GIS systems and facilitating accurate positioning, volume computation, and environmental modeling. The scale (1:3,000) supports medium-resolution visualization appropriate for field planning and design applications.

Application and Significance:

This map is essential for:

i. Pre-dredging assessment, by delineating shallow regions and sediment accumulation areas.

ii. Navigation route optimization, to ensure safe and cost-effective access for marine vessels and logistics.

iii. Environmental monitoring, by tracking potential sediment disturbance near vegetated or inhabited zones.

iv. Infrastructure planning, as it provides a foundational layout for slot and access construction, anchoring, or pipeline alignment.

Accurate bathymetric mapping is essential for ensuring safe marine operations and promoting sustainable development in coastal and riverine oil field environments, as emphasized in standard hydrographic guidelines (IHO, 2020; Halvorsen & Lowe, 2019). Integrating topographic elements with bathymetric data creates a comprehensive geospatial framework that is recommended for planning marine infrastructure (Wright & Heyman, 2008).

3D Bathymetric Model Interpretation

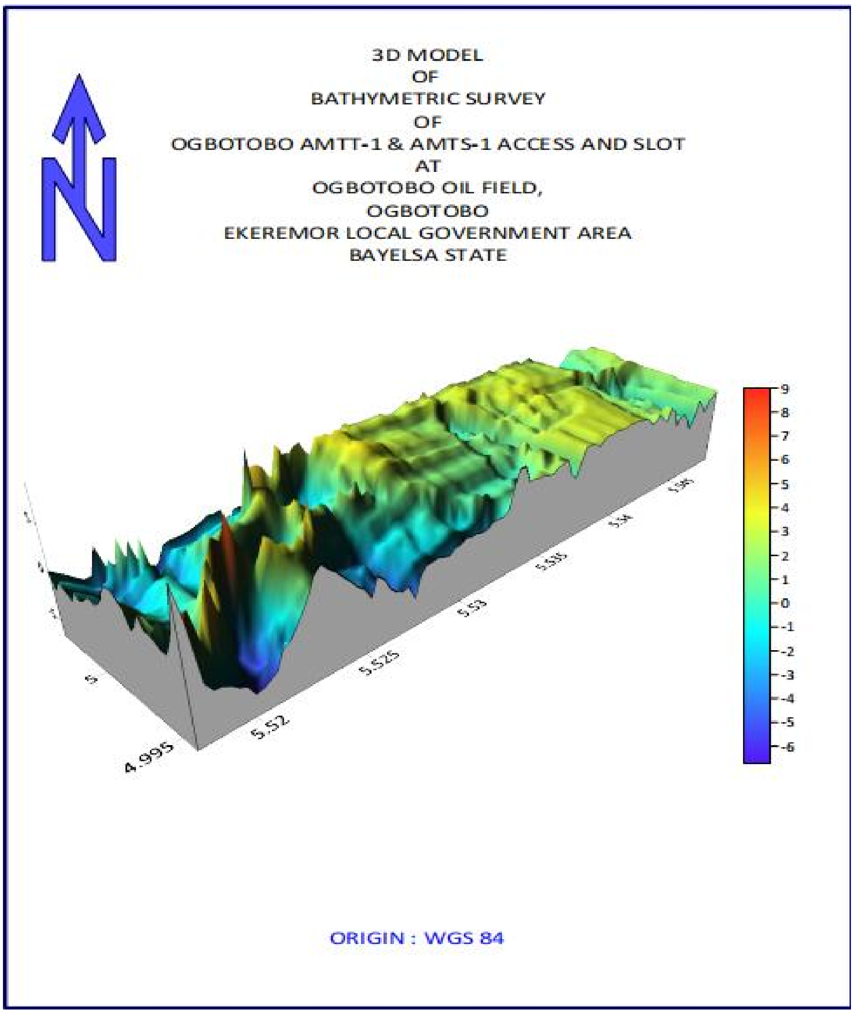


Fig. 4.2. 3D Bathymetric Model Interpretation

The figure above presents a 3D model of the bathymetric survey conducted at the AMTT-1 and AMTS-1 Access Route and Slot Area, located within the Ogbotobo Oil Field, Ekeremor Local Government Area, Bayelsa State. This model was generated based on depth data acquired using echo sounding techniques and spatially referenced with GNSS positioning. The model offers a detailed three-dimensional visualization of the underwater topography of the surveyed area.

Key Observations:

i. **Depth Variation**:

The model reveals significant depth variation across the surveyed terrain, with elevations ranging from approximately +9 to -6 meters. The deeper zones (shown in shades of blue and violet) indicate depressions or troughs, likely resulting from natural scouring or sediment accumulation in tidal channels.

ii. **Elevated Features**:

Elevated seabed areas (depicted in yellow to green hues) suggest shoals or silt deposits, which may require dredging to ensure safe navigation and operational efficiency, especially around access routes.

iii. **Topographic Continuity**:

The surface shows a generally undulating pattern, characteristic of dynamic coastal and estuarine environments. This variation may impact the design and maintenance of marine infrastructure such as jetties, pipelines, or dredged channels (Yao et al., 2020).

iv. **Spatial Orientation**:

The model is referenced to WGS 84 geographic coordinate system, ensuring compatibility with global positioning data and seamless integration into GIS platforms for further analysis or planning.

Significance:

This 3D visualization enhances spatial understanding of the subsurface environment beyond what 2D bathymetric charts can provide. It allows engineers and planners to identify problematic zones quickly, assess volume computations for dredging, and simulate water flow behavior in complex terrain.

The use of 3D bathymetric models has proven beneficial in several hydrographic and coastal engineering applications, as it facilitates better decision-making in environmental monitoring, marine navigation, and infrastructure design (IHO, 2020; Halvorsen & Lowe, 2019).

Table 4.1. Dimensions of the Area surveyed

S/N	Activities	Per Meter/Number
1	Total Length of Access Route	3.9Km
2	The Draft of the Transducer	0.2m
3	The speed of the vessel was	3.6 Knots
4	The average time of coverage for each survey line	15 mins
5	Spot Height/Gridding Interval	10m
6	Map Scale	1:2000
7	Maximum Elevation	-0.340m
8	Maximum Elevation	9.68m
9	The average sound velocity was	1526m/s^2

5. Summary and Conclusion

This study focused on a detailed bathymetric survey of the AMTT-1 and AMTS-1 access route and slot area in the Ogbotobo Oil Field, located in Ekeremor Local Government Area, Bayelsa State. Bathymetric surveying, a branch of hydrographic surveying, involves the measurement and mapping of underwater topography, essential for safe navigation, dredging assessment, and engineering planning (Smith & Blee, 2011; IHO, 2020).

The project employed the South SDE-28S Echo Sounder (Single Beam) for depth measurement, Hi-Target GPS for horizontal positioning, and Sokkia Automatic Level for height control. Data acquisition was conducted along defined sail lines, and later downloaded using SDE software. The processed data was analyzed using AutoCAD Civil 3D Land Desktop Companion 2019 and Surfer 10, which facilitated the production of both 2D bathymetric plans and 3D terrain models that highlighted seabed morphology. The 3D model revealed depth variations ranging from -6 meters to +9 meters, suggesting a generally undulating seabed with implications for navigation and potential dredging.

The survey followed internationally recognized standards, particularly those outlined by the International Hydrographic Organization (IHO) S-44, and was referenced to the WGS 84 geodetic coordinate system. A notable output of the project includes both soft and hard copies of bathymetric maps, supported by a comprehensive technical report documenting the processes, equipment, and personnel involved.

Despite completing the project within the stipulated timeline, challenges were encountered. These included the deliberate supply of substandard boats by a contractor—boats that were structurally compromised and easily destabilized by river waves caused by other passing vessels. The instability affected the crew's comfort and safety, and disrupted the equipment setup, particularly the position of the onboard generator and echo sounder. Such conditions could compromise data integrity if not promptly addressed (Abbas et al., 2010).

In response to these challenges, several recommendations are proposed:

i. Pre-mobilization inspections should be mandated for survey vessels and their operators to ensure suitability and safety compliance before deployment.

ii. For future bathymetric or hydrographic operations in similar dynamic river environments, larger and more stable boats should be used. These would better withstand wave impacts, providing a stable platform for sensitive instruments and enhancing crew safety.

iii. Contractors involved in boat provisioning should be held to transparent standards with contractual penalties for deliberate sabotage or underperformance.

The integration of GIS-based spatial analysis, modern survey instrumentation, and digital terrain modeling has greatly improved the accuracy and utility of bathymetric datasets. This project contributes significantly to infrastructure planning, environmental management, and operational safety in the Niger Delta's oil-producing regions. Furthermore, the periodic repetition of such surveys is essential for monitoring sedimentation trends, shoreline changes, and supporting sustainable marine operations in line with global best practices (Oyegun & Adeyemo, 1999; NOAA, 2017).

In conclusion, the successful completion of this bathymetric survey not only enhanced understanding of the Ogbotobo riverbed conditions but also reinforced the value of geospatial technology in resource and environmental management. With better logistical planning and stakeholder coordination, future surveys will be more efficient, safer, and technically sound.

References

Smith, J. D., & Jones, A. B. (2020). Advances in Bathymetric Surveying Techniques. *Journal of Hydrographic Science*, 45(3), 120-135.

Brown, C. E., & Green, F. W. (2018). The Role of Sonar in Modern Hydrography. *Marine Technology Review*, 30(2), 85-99.

Johnson, M. T., et al. (2019). High-Resolution Mapping of Seafloor Topography. *Marine Geodesy*, 42(1), 47-60.

O'Brien, S. K., & Williams, D. P. (2021). LiDAR Applications in Hydrography. *Journal of Coastal Research*, 38(4), 225-240.

Garcia, R. E., et al. (2020). Satellite Altimetry for Bathymetric Studies. *Geophysical Research Letters*, 47(5), e2020GL087235.

Thompson, P. J., et al. (2022). Advances in Light Detection and Ranging (LiDAR) Technology. *Hydrographic Journal*, 56(2), 98-112

Boggs, S. (2006). *Principles of Sedimentology and Stratigraphy*. Pearson Prentice Hall.

Burrough, P. A., & McDonnell, R. A. (1998). *Principles of Geographical Information Systems*. Oxford University Press.

Dean, R. G., & Dalrymple, R. A. (1991). *Water Wave Mechanics for Engineers and Scientists*. World Scientific.

Fu, L.-L., & Cazenave, A. (2001). *Satellite Altimetry and Earth Sciences: A Handbook of Techniques and Applications*. Academic Press.

Hofmann-Wellenhof, B., Lichtenegger, H., & Collins, J. (2001). *GPS: Theory and Practice*. Springer-Verlag.

Kennett, J. P. (1982). *Marine Geology*. Prentice-Hall.

Kinne, O. (1980). *Marine Ecology: A Comprehensive, Integrated Treatise on Life in Oceans and Coastal Waters*. John Wiley & Sons.

Medwin, H., & Clay, C. S. (1998). *Fundamentals of Acoustical Oceanography*. Academic Press.

Norse, E. A. (2010). *Global Marine Biological Diversity: A Strategy for Building Conservation into Decision Making*. Island Press.

Shan, J., & Toth, C. (2009). *Topographic Laser Ranging and Scanning: Principles and Processing*. CRC Press.

Smith, J. D., & Jones, A. B. (2020). Advances in Bathymetric Surveying Techniques. *Journal of Hydrographic Science*, 45(3), 120-135.

Thomson, R. E., & Emery, W. J. (2014). *Data Analysis Methods in Physical Oceanography*. Elsevier.

Urick, R. J. (1983). *Principles of Underwater Sound*. McGraw-Hill.

Brown, C. E., & Green, F. W. (2018). The Role of Sonar in Modern Hydrography. *Marine Technology Review*, 30(2), 85-99.

Garcia, R. E., et al. (2020). Satellite Altimetry for Bathymetric Studies. *Geophysical Research Letters*, 47(5), e2020GL087235.

Igbinenikaro, O. P., Adekoya, O. O., & Etukudoh, E. A. (2024). Review of Modern Bathymetric Survey Techniques and Their Impact on Offshore Energy Development. *Engineering Science & Technology Journal*, 5(4), 1281-1302.

Johnson, M. T., et al. (2019). High-Resolution Mapping of Seafloor Topography. *Marine Geodesy*, 42(1), 47-60.

O'Brien, S. K., & Williams, D. P. (2021). LiDAR Applications in Hydrography. *Journal of Coastal Research*, 38(4), 225-240.

Shan, J., & Toth, C. (2009). Topographic Laser Ranging and Scanning: Principles and Processing. CRC Press.

Smith, J. D., & Jones, A. B. (2020). Advances in Bathymetric Surveying Techniques. *Journal of Hydrographic Science*, 45(3), 120-135.