Bathymetric Mapping to Support Ecological Restoration and Management of the Korle Lagoon

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Key words: Korle Lagoon, bathymetric map, instantaneous depth, topographical pattern, dredging, Digital Elevation Model (DEM)

SUMMARY

One of the most polluted lagoons in the city of Accra is the Korle Lagoon. The Korle lagoon is located between Chorkor and James Town in the Accra Metropolitan Assembly (AMA) of the Greater Accra Region, Ghana. The increasing industrial activities and consumption of the population of Accra generate a large amount of waste which is transported through major uncovered drains into the Korle Lagoon. Debris and sediments are also carried by runoff water during the rainy seasons into the lagoon causing flooding in its catchment area. The Hydrological Depart under the Ministry of Works and Housing undertook phase II of the Korle Lagoon Ecological Restoration project in November 2000. One of the main activities was clearing and dredging the Korle Lagoon to remove silts and prevent flooding in the area. A similar project was carried out in April 2022 with funding from the World Bank. This study was conducted to produce a bathymetric map to show the bottom configuration and the depth of the dredged Korle Lagoon for effective management. Data acquisition was performed using a dual frequency echo sounder for depth sounding, positions were determined using Vector sensor GNSS receivers, and tidal observation and reduction were also done using a level instrument and tide gauge. Bathymetric data processing including cleaning, tidal reduction and correction on instantaneous depth was carried out in QPS Qinsy software. Further processing and generation of the Digital Elevation Model (DEM) were performed using surfer 11.0 software and ArcGIS 10.7 software to create maps and the lagoon capacity computation. The processed depths were analysed and presented in form of models and tables. The deepest spot was -4.37m while the shallowest spot was -0.20m respectively. The study determined the Korle lagoon bed topographical pattern and the maximum capacity of the lagoon at the time of the survey was determined to be 800,136.62 m3.

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1. INTRODUCTION

For analyses and prudent decision-making, it is crucial to be aware of the depth of lakes, lagoons, and ocean bottoms (Lister, 2010). Charts are created in bathymetric surveys to support the safety of surface or subsurface navigations, and these charts provide information for surface navigation by showing the relief or terrain of the seabed as contour lines and Digital Elevation Models (DEM) (Chukwu et al, 2014). Bathymetric surveys are essential for a variety of marine applications, including dredging, sedimentation and siltation analysis, and other reasons. Prior to positioning pipelines and cables, fishing, and other geophysical exploration exercises, bathymetry is also carried out (Arzu et al, 2004). Tidal observation and reduction are essential for computing sounding depth to the chart datum when creating a bathymetric map. (Arzu et al, 2004). By capturing both inorganic sediments and organic matter, the Korle lagoon serves as a sink for matter and serves as a nursery for a diversity of aquatic fishes and invertebrates. The main basin into which the majority of Accra's flood waters flow before flowing into the sea is the Korle Lagoon. Water for the lagoon is drawn from a 400 km^2 catchment region (Biney and Amuzu, 1995). The Odaw River, as well as two significant drains in its eastern and western portions, are its three principal discharge sources. The Korle lagoon has lost its fishery escapades due to heavy pollution sedimentation and siltation. The main causes of pollution include waste spills and industrial effluent. The wastes come from homes, businesses, places of recreation, offices, and organisations like hospitals and schools. In addition to paper, batteries, glass, plastics, textiles, and excreta, aerosol cans, they also include food refuse (Mensah, 1976). The lagoon's environmental effect assessment revealed the extent of nature and human interference, particularly with regard to coastal waters (Mensah, 1976). This paper seeks to provide to provide an up-to-date bathymetric map to support restoration and effective management of the Korle Lagoon. For the purpose of understanding the Korle Lagoon's physical state and developing suitable research and monitoring plans that can help with more sustainable management, it is crucial to conduct a bathymetric survey of the lagoon.

2. MATERIALS AND METHODS

2.1 Study Area

The Korle lagoon is in James Town, Accra Metropolitan Assembly (AMA) in the Greater Accra Region, between latitude 005° 31’ 52’’ N and 005° 32’ 14’’ N and longitude 000° 13’

16’’ W and 000° 13’ 10’’ W respectively. The main basin into which most of the Accra's floodwaters flow before hitting the sea is the Korle lagoon. One of the world's most polluted water bodies is the Odaw-Korle basin, which generates significant amounts of solid refuse and acts as a cesspool for most Accra's industrial and municipal wastes. Water for the lagoon is drawn from a 400 km2 catchment region. According to the Accra Metropolitan Assembly, there are over 65 out of the 82 officially identified slums and shanty towns within the immediate environment of the Odaw-Korle catchment/basin.

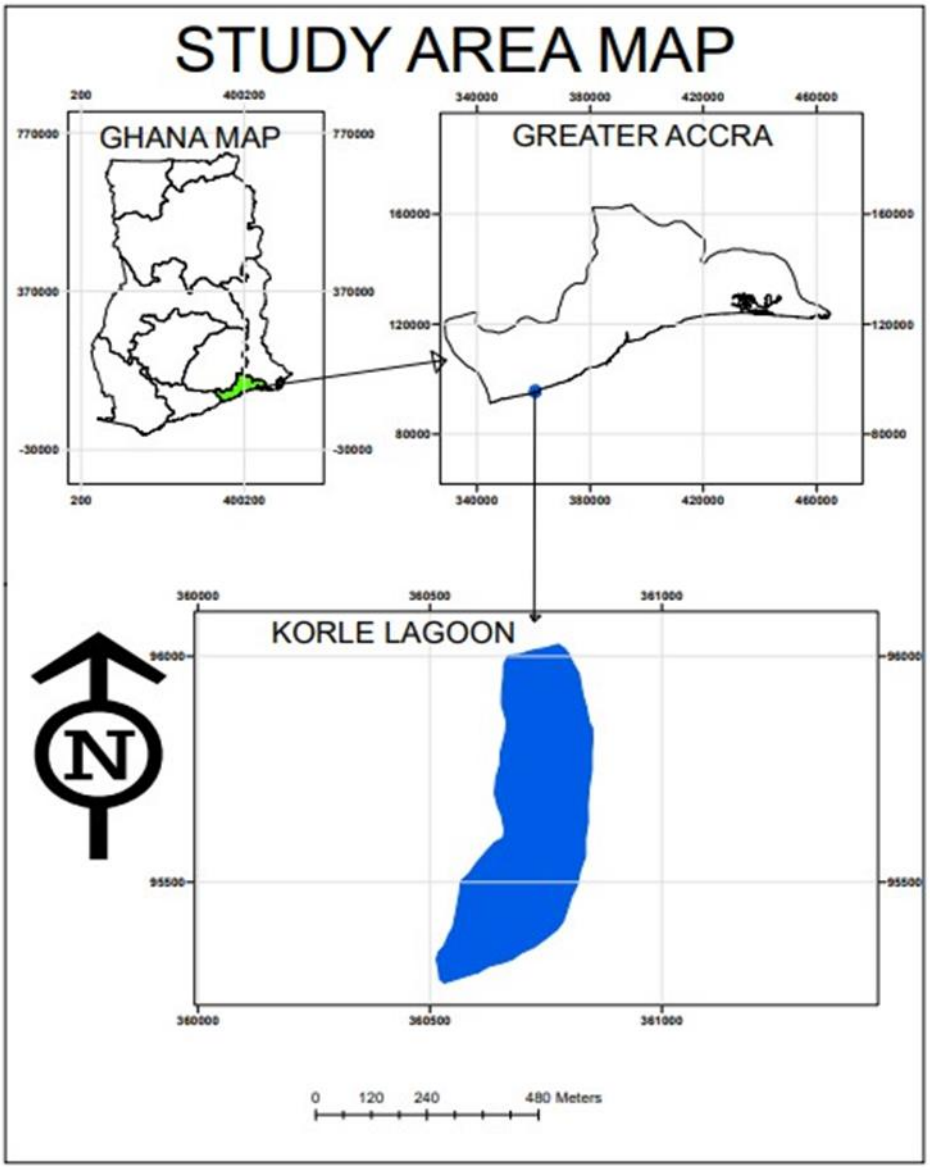

Figure 1. Study Area

2.2 Survey Method

The survey was performed on a silver boat equipped with Kongsberg EA440SP high performance hydrographic wide band single beam echo sounder (shallow to medium depth waters), transducer of 30/200 kHz, Three Vector sensor GNSS receivers and an outboard engine Yamaha 2.0 HP. Bathymetric information was recorded through boat speed of 3 knots with the sounder frequency adjusted to 200 kHz, and programmed to automatically log the data each 5 s. The survey was performed for about 2 hours through a grid approach (25 × 25 m) slightly following its intersections at a perpendicular direction regarding the Gulf of Guinea coast position. Throughout the navigation into the lagoon, extra data were recorded outside the grid and borderlines. Sound velocity was determined using sound Valeport SWiFT SVP in the deeper part of the lagoon (1375-1480m/s) and Tidal observations were made with a levelling staff at 5 minutes interval before the sounding commenced. The data collected was processed using QPS Qinsy software.
The processed bathymetric data was exported and saved as csv file in Microsoft Excel with column attributes of northings, eastings and depths and subsequently imported in to the suffer software for analysis. Both 2D and 3D models were generated from the analysis done. Cross sectional profile was also determined to analyse the changes in depths across the lagoon. The bathymetric map was produce using ArcGIS 10.7 software. Figure 2 shows the boat mobilizations and calibrations (left), the Kongsberg EA440SP echosounder used (top) and data collection (right).

Figure 2. mobilizations and calibrations (left), the Kongsberg EA440SP echosounder used (top) and data collection (right)

3. RESULTS AND DISCUSSIONS

The northings and eastings coordinates define the horizontal positions of each sounding point. The higher negative values indicate points of higher depths, and the low negative values indicate points of shallow depths. The actual depths were computed in the quinsy software using the mathematical formulae below.
Depth = Velocity x Time/2
The actual depth was obtained by adding the draft to the depth. i.e
Actual depth = draft + depth
The draft is the distance from the bottom of the boat to the transducer. It was measured with a tape. This draft was input into the qinsy software to automatically generate the actual depths. The draft was measured to be 1 foot which is equivalent to 0.3048 m.

Figure 3 presents the contour representation of the lagoon showing lines connecting points of equal depths (isobaths). The positive contour values show the heights of points at the banks of the lagoon and the negative contour values show the depths of points inside the lagoon. Again, the colour scale shows the different colours, representing varying depths and heights. i.e., colours ranging from -3.2 to -4.0 indicate the deepest part of the lagoon and 7.2 to 8.0 indicate places of higher heights at the banks.

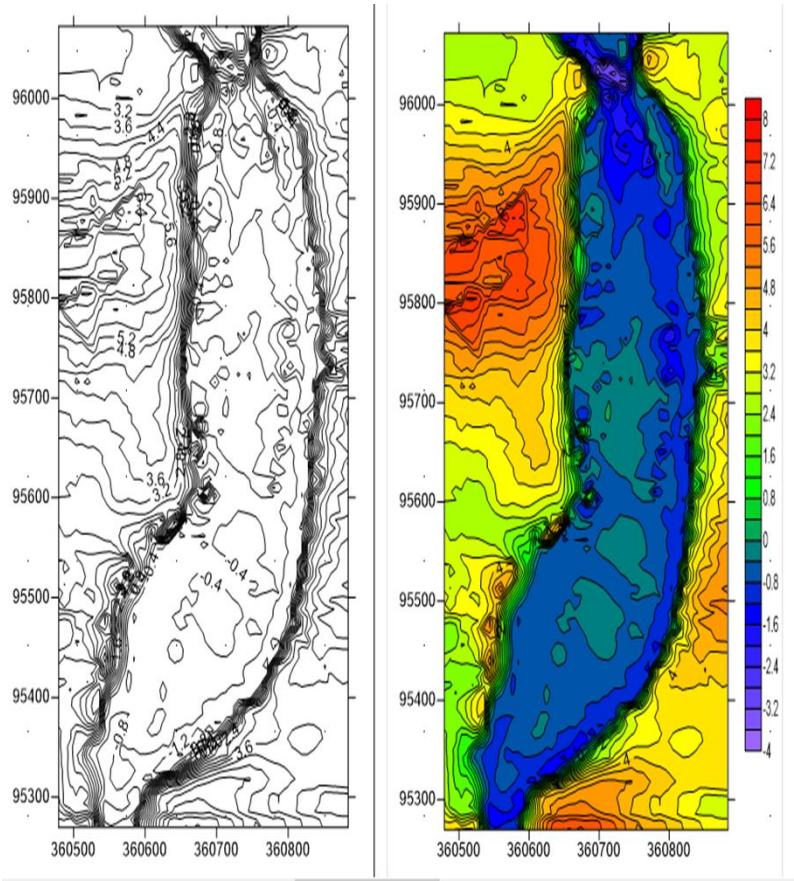

Figure 3. contour representation of the lagoon showing isobaths

Figure 4 shows the 3D representation (left) and the capacity (right) of the lagoon depicting the impression of depth in real scene, to better appreciate the terrain. The capacity of the lagoon at the time of the survey was determined using ArcGIS software with the surface volume tool. The surface volume tool was lunched following a series of operations ranging from Arc toolbox, 3D analyst tool, Functional surface and then Surface volume. The maximum water level of the lagoon was determined to be 2.733 m using a level instrument. This value was input into the surface volume tool to determine the maximum capacity of the lagoon. The capacity of the lagoon at the time of the survey was determined to be 543102.923 m^3.

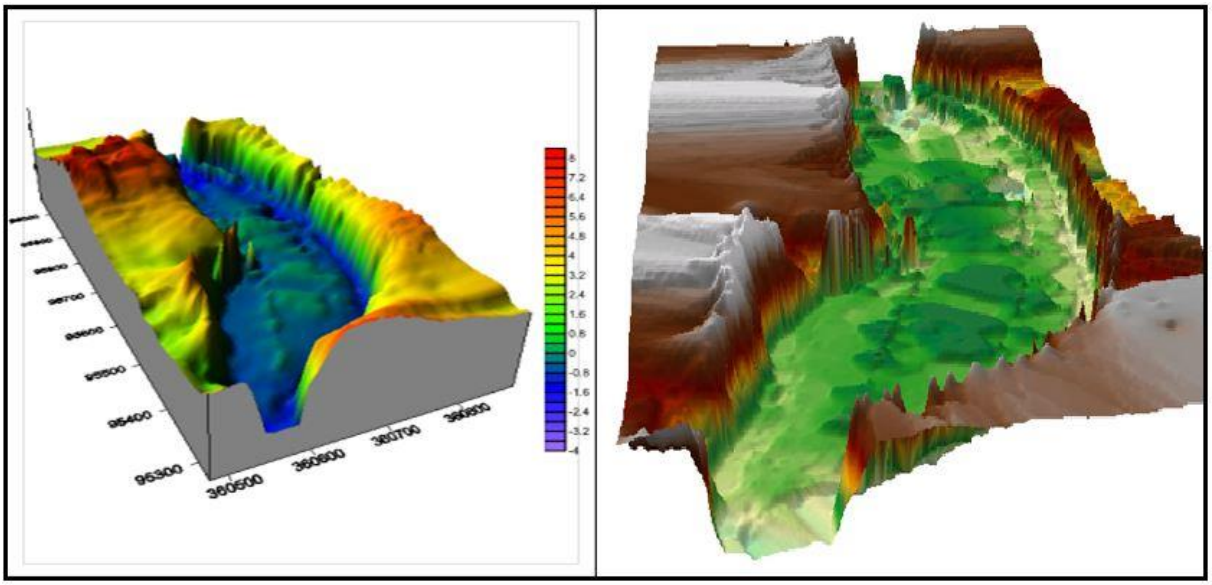

Figure 4. 3D representation (left) and the capacity (right) of the lagoon

The horizontal (left) and vertical (right) cross sections depict the undulating nature of some part of the lagoon when moving from west to east, north to south and vice versa (Figure 5). The distance scale shows the interval at which the bottom nature varies along the line.

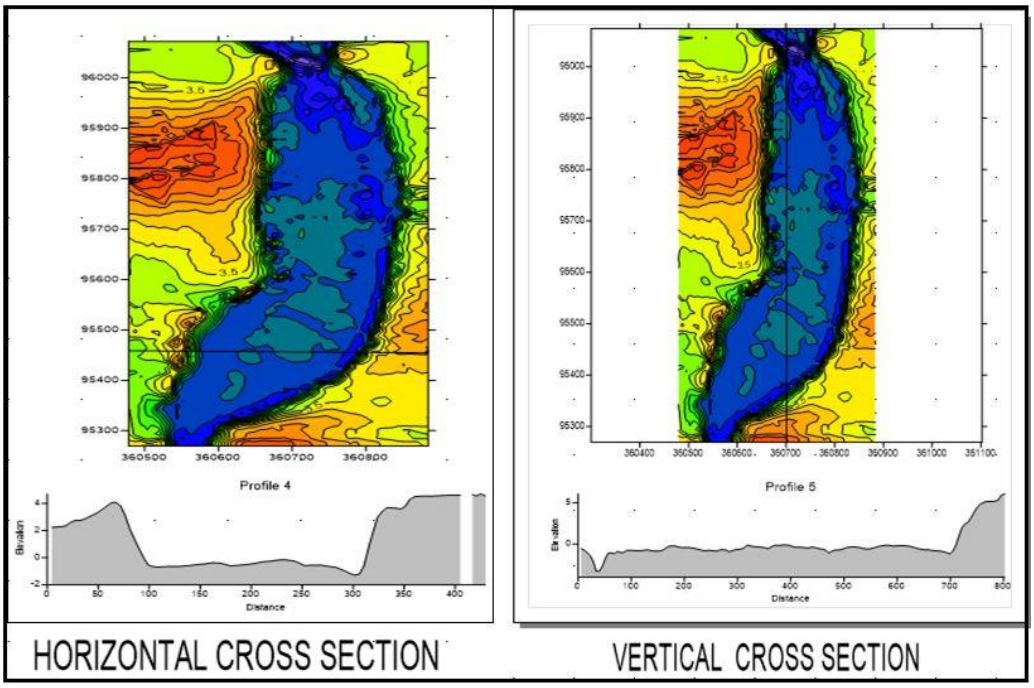

Figure 5. Horizontal (left) and vertical (right) cross sections of the lagoon

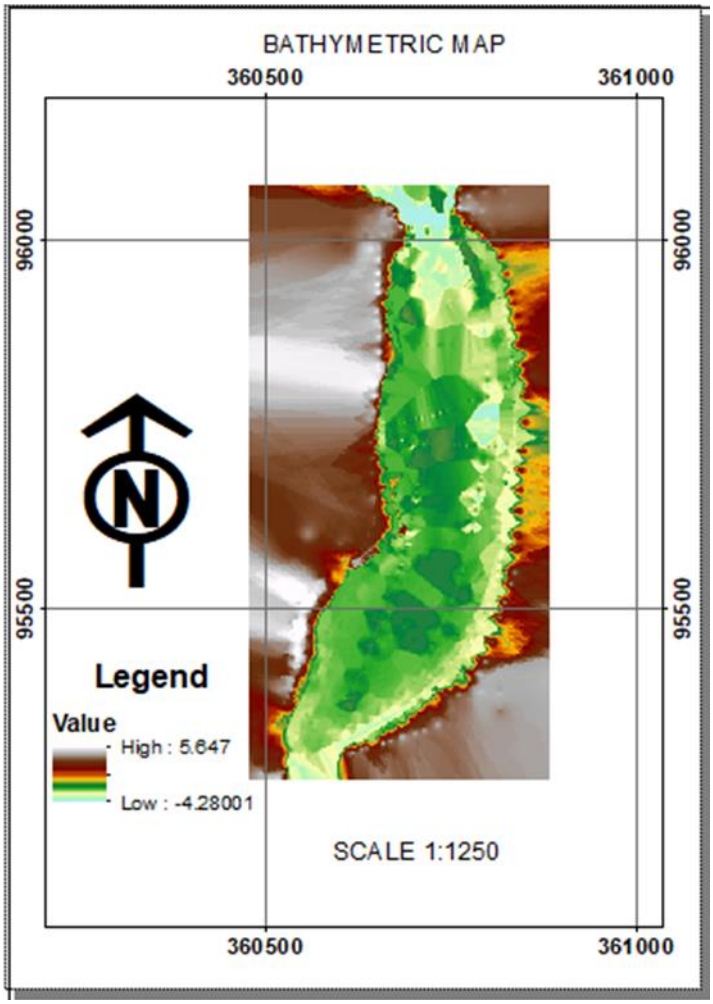

Figure 6. Bathymetric map of Korle Lagoon showing topographical pattern of the lagoon bottom.

4. CONCLUSION AND RECOMMENDATIONS

The study determined the Korle lagoon bed topographical pattern. The analysis performed on the acquired data revealed the topography of the lagoon bed with the deepest depth to be -4.28 m and the shallowest depth to be -0.20 m. From the study, the measured depth was determined using echo sounder which worked with the principles of sound waves travelling at a given time. The average time taken for the sound wave to travel to the lagoon bed and back, multiplied by the sound velocity gave the measured depth. The actual depth was obtained by adding the draft to the measured depth.

The capacity of the lagoon at the time of the survey was determined to be 543102.923 m3 using ArcGIS software with the surface volume tool. It is clear that any quantity of water

greater than 543102.923 m3 will cause the water level to rise above the maximum level (2.733 m) and the water would start to spill and may result in flooding.

It is recommended that subsequent bathymetric surveys should be conducted periodically to determine the rate of sedimentation. To completely cover the lagoon bottom, it is advised that a multi beam echo sounder be used.

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BIOGRAPHICAL NOTES

Sebastian Botsyo is the officer in charge of hydrography at the Survey and Mapping Division, Lands Commission – Ghana and a lecturer in hydrographic surveying, land surveying principles and remote sensing at the Ghana School Surveying and Mapping. A resourceful person with a technical background in Geomatic Engineering, Hydrography, and GIS and have the potential for world-leading research and teaching in any aspect of Land Surveying,

Hydrography, Ocean, and Geospatial Engineering. Sebastian have more than 15 years of experience in the collection and analysis of coastal morphological (coastal erosion and protection), coastal sediment transport processes and hydrographic data. My academic research has resulted in peer-reviewed international journal articles and conference papers, technical reports, invited lectures, workshops and seminars. In addition to academic research, He has conducted several consultancy projects.
Mr. Botsyo obtained MSc in Hydrography (Cat A) at the University of Plymouth, UK in November 2022. Prior to his study in hydrography, he obtained MPhil in GIS (2019) and BSc in Geomatics Engineering (2016) all from the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. He also studied Surveying and Mapping at the Ghana School of Surveying and Mapping (GSSM) in Accra (2006) and pursued Geo-Informatics (GIS Operations) at, the University of Twente, Netherlands (2012). He studied basic education at St. Francis Teacher Training College in Hohoe from 1999 to 2002 to obtain Teachers Certificate 'A'.
He is a professional member of the Ghana Institution of Surveyors (GhIS), American Geophysical Union (AGU), Hydrographic Society UK – Student/New Graduate member, Young Surveyors Network, FIG. Also a student member of RICS, IES, CICES and IMarEST.

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