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Bathymetric Survey Of Urban Water Reservoir: Case Study Of Kathauta Jheel,Lucknow, Uttar Pradesh, India

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ABSTRACT

Conducted within Gomtinagar, Lucknow District, Uttar Pradesh, India, the Bathymetry survey encompassed an approximate area of 2.89 square kilometers. This survey aimed to meticulously gauge water depth, achieving a high degree of accuracy measured in centimeters, while also facilitating a comprehensive three-dimensional perspective. The examination of sediment within the reservoir, vital for urban drinking water supply, was conducted through multiple surveys. Moreover, a dynamic map illustrating water depth at 10-centimeter intervals has been meticulously prepared, covering the entire designated segment.

Introduction

The complementary procedure to conducting a LiDAR survey over land surfaces is a bathymetric survey, also known as a Hydrographic Survey. This type of survey is focused on vast bodies of water such as seas, oceans, rivers, canals, lakes, and ponds. Hydrography is a well-developed scientific field used for maritime navigation, marine construction, dredging, offshore oil exploration, and offshore oil drilling. The rules governing hydrographic surveys may vary based on the authorizing body.

Traditionally, these surveys were carried out using ships equipped with sounding lines or echo-sounding technology. In the context of inland waterways, authorities perform surveys on bodies of water within the Indian Territory. This specialized survey helps to comprehend the characteristics of the water column and the underwater terrain.

Contemporary SONAR survey and mapping methods have revolutionized our ability to explore the concealed depths of submerged surfaces, whether they belong to rivers, reservoirs, canals, or interconnected water bodies. This technology is particularly effective in mature water bodies where sediment deposition occurs due to reduced velocity and gradient. Utilizing bathymetric equipment during a hydrographic survey beneath a bridge provides valuable insights into the depth of the riverbed, the submerged course of the river, and various distinctive underwater features.

In the current investigation, a bathymetric survey of Kathauta Jheel in Gomtinagar, Lucknow, Uttar Pradesh, was conducted in response to a request from the Jalkal Vibhag of the Nagar Nigam department. The survey took place during the period of December 16th to 21st, 2020. Throughout the survey, contours were meticulously delineated, and the waterbed's depths were calculated at precise intervals of 25 cm.

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Objectives

The aims of the current endeavor are as follows:
1 Utilizing SONAR equipment to gauge the water depth in Kathauta Jheel.
2 Creating contours that depict the variations in the water column.
3 Generating a comprehensive map illustrating water depth, volume, contours, and a profile view.

Study Area

Kathauta Jheel is located within the Gomti Nagar region of Lucknow city, with geographical coordinates ranging from Latitude 26°52'19.77"N to 26°51'46.36"N and Longitude 81°01'35.07"E to 81°02'5.94"E. The lake's proximity to the city encompasses areas that are integral to Kathauta Jheel's purpose, which is primarily aimed at supplying potable water to the residents of Gomti Nagar and Indira Nagar within Lucknow. This initiative seeks to alleviate the persistent issue of water supply shortages in these localities, an issue that remains unresolved. Notably, approximately 80% of the population in these neighborhoods relies on Kathauta Jheel as their primary source of water, drawing from the Sharda Canal for their drinking water requirements.

Point: A

Situated adjacent to Make Well Hospital & Trauma Centre, in the northern part of the lake, are the coordinates Latitude 26°52'15.820"N and Longitude 81°01'35.400"E.

Point: B

Located approximately 106 meters to the east of point A, the coordinates Latitude 26°52'19.020"N and Longitude 81°01'37.320"E mark a specific position above point A along the eastern perimeter of the lake.

Point: C

Positioned around 150 meters to the east of point B, in close proximity to Lake Hospital, are the coordinates Latitude 26°52'19.680"N and Longitude 81°01'42.000"E, marking a location just below point B along the eastern edge of the lake.

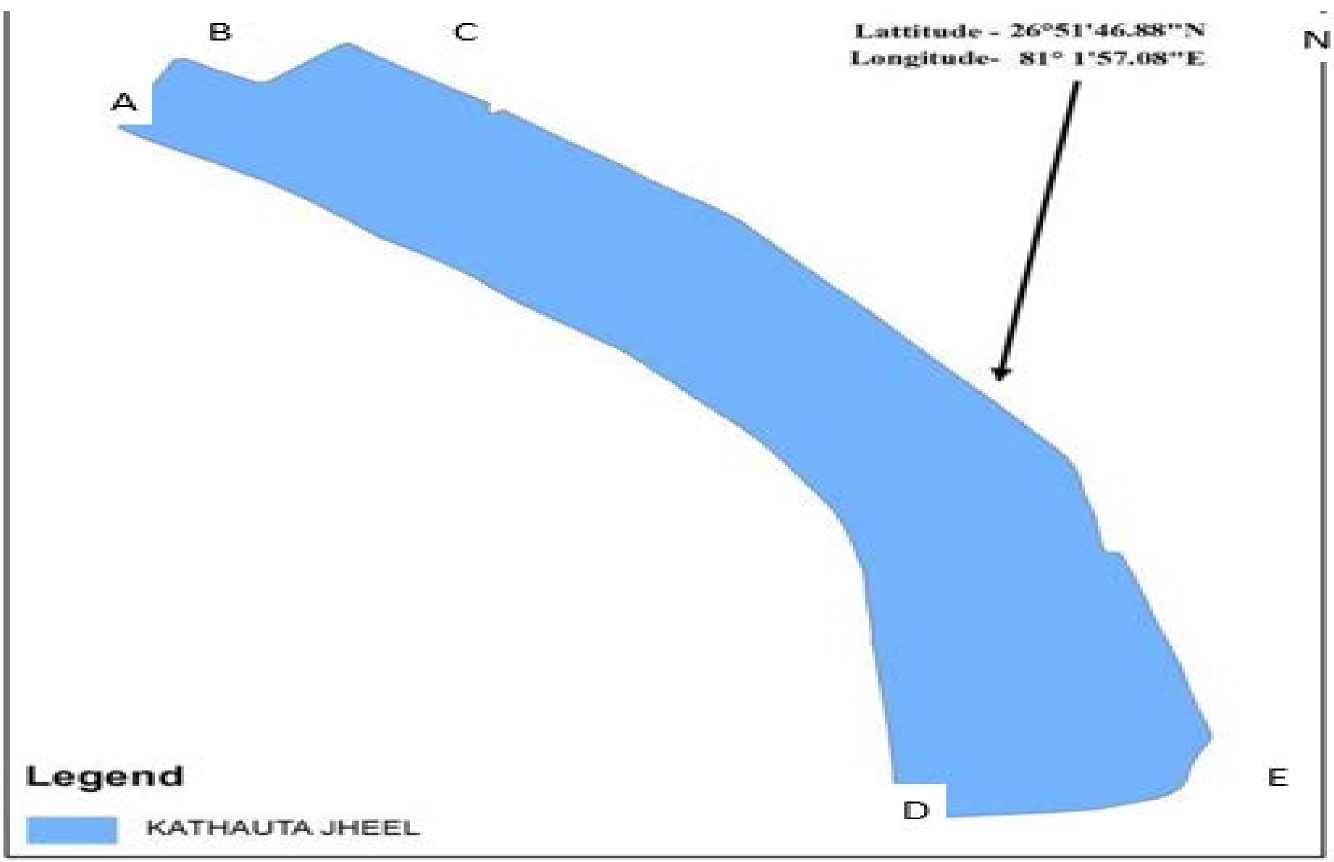
Point: D

Situated in the vicinity of Lucknow Public School and adjacent to the Jal KalVibhag office, where the filtration and distribution of drinking water take place, are the coordinates Latitude 26°51'45.660"N and Longitude 81°01'55.440"E.

Point: E

Positioned close to the UP Fisheries Cooperative Department and within the vicinity of the lake area, these coordinates Latitude 26°51'49.200"N and Longitude 81°02'4.860"E correspond to an area with relatively shallow depths, spanning approximately 0.16 hectares.

On the western side of Kathauta Jheel, you'll find Vastu Khand road, while the eastern side is bordered by Gomti Nagar extension road. The entire expanse of Kathauta Jheel covers an area of 24.27 hectares, with an additional 0.24 square kilometers situated on the northern side of the lake.



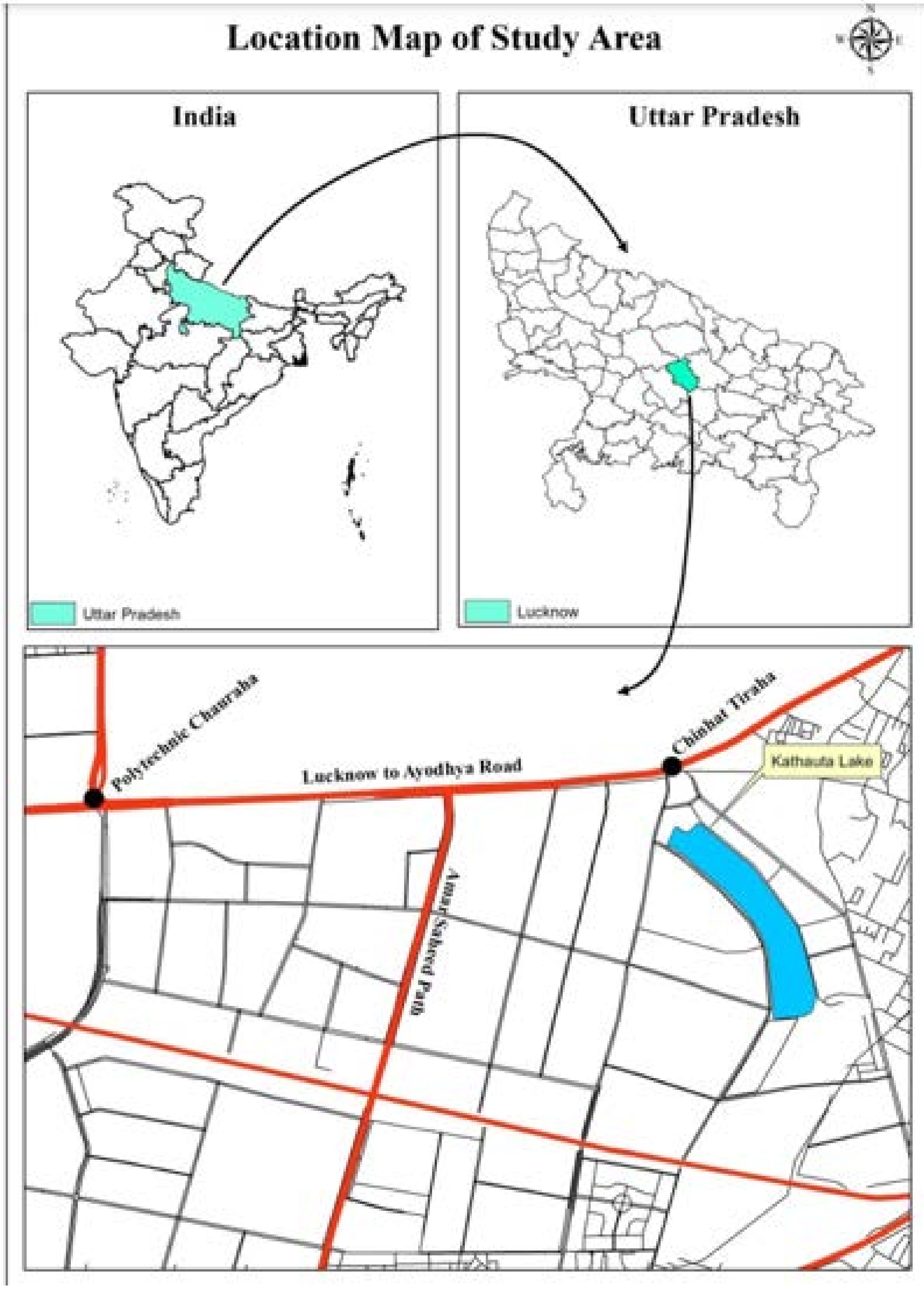


Figure-1 Map showing the study area of KathautaJheel.

History

Kathauta Jheel was meticulously crafted by the Jalkal Vibhag, nestling amidst the Amity University Road region in Gomtinagar, Lucknow. An additional reservoir, named Bharwara Jheel, is reserved to ensure the safety of the water supply during emergencies. This secondary reservoir, Bharwara Jheel, effectively doubles the waterworks' storage capacity. While Kathauta Jheel boasts a storage capability of 800 million liters, Bharwara Jheel can accommodate around 400 million liters.

Remarkably, Kathauta Jheel is equipped to store drinking water for up to 22 days, and it takes approximately six days for the water level to fully recover after being released from the Sharda Sahayak canal. The recently established reservoir adds an extra buffer, capable of sustaining an additional 10 days. When combined, the capacities of both reservoirs enable us to safeguard water for over 30 days, providing

crucial supplementation when the canal undergoes its periodic 35-day closures. The canal, with a depth of four meters and the capacity to hold 80 million liters of water per day, is periodically closed twice a year by the irrigation department for maintenance, which involves cleaning out silt deposits.
The water sourced from the canal plays a pivotal role in meeting drinking water needs. Kathauta Jheel, an integrated reservoir, stretches over a length of 2.89 kilometers.

Methodology

Depending on the nature of the survey and the specific area under examination, various instruments can be employed for conducting a bathymetric survey. Vertical depth measurements can be accomplished using methods such as a hand-held calibrated lead sounding line or a basic echo sounder that produces paper records. However, in the present study, a cutting-edge engineering echo sounder was utilized, equipped with a data logger linked to a position fixer, which operated seamlessly through automated processes facilitated by specialized software.
For precise horizontal positioning, advanced tools were employed, including a differential Global Positioning System (GNSS) along with Z blade technology-equipped instruments affixed onboard a boat. These instruments provide accurate and detailed location data, encompassing latitude, longitude, and altitude information.
The primary objective of this study is to conduct a bathymetric survey and derive insights from the contours formed by analyzing the depth data acquired through sonar pinging.

Bathymetric Technique

The tasks carried out within the reservoir encompassed:
1 Deploying the boat and survey equipment to the designated site.
2 Setting up the complete bathymetry system, along with its integrated subsystems.
3 Executing the bathymetric survey within the designated study area.

Bathymetry Survey Equipments

The equipment employed for the bathymetric survey can be broadly classified into three categories: depth measurement devices, positioning instruments, and water level measurement tools (such as tide or river level gauges). A concise overview of general considerations for utilizing this equipment is provided.

Depth Measurement Equipment

Depth measurement is accomplished through the utilization of Multibeam Echosounders (MBES).

MultibeamEchosounders (MBES)

Employing MBES as a tool for Bathymetry surveys offers significant advantages over Single Beam echo sounders, particularly in its capacity to detect small objects and provide comprehensive bottom coverage. The integration of MBES, alongside vital ancillary equipment such as appropriate motion sensors and gyroscopes, ensures accurate and proper functionality. Corrections are made to account for beam refraction, especially when utilizing wider swath widths, to accurately measure Sound Velocity (SV) profiles throughout the water column. It is crucial to conduct regular and precise calibration of the MBES.
The enhanced level of detail and expansive coverage afforded by MBES enables the identification of errors linked to inaccuracies in survey boat offsets, Sound Velocity, or excessive boat motion. Such errors should be factored into the calculation of the overall accuracy assessment accompanying the dataset.
A Bathyswath system's essential elements consist of sonar transducers, a Transducer Interface Unit (TIU), and a software package. This software package encompasses real-time functionalities for data acquisition, processing functions to handle the collected data, and quality assurance mechanisms to ensure survey accuracy. The integration of this system into a comprehensive survey suite enables the acquisition of pertinent position, orientation, and environmental data, ultimately facilitating precise survey results.
Within the scope of the present study, the setup involves installing the system on a specially designed motorized boat crafted from marine-grade aluminum. This configuration guarantees precise measurement readings and enables the real-time collection of survey data, ensuring a notable degree of accuracy.

Positioning System Equipment

The core technique employed for establishing the position of the survey boat during the Bathymetry survey is Differential GPS. To enhance accuracy, the source of differential corrections is validated by comparing it against a known mark using a local base station. A GPS receiver is set up to provide position output within the WGS84 datum, complete with corresponding quality indicators. Vigilant oversight of position accuracy during sounding operations is maintained through continuous assessment of factors such as the number of tracked satellites and PDOP (Position Dilution of Precision), or by performing real-time comparisons with a secondary system.

Kinematic GPS provides enhanced accuracy for horizontal positioning, especially when the dimensions of the echo sounder's footprint are comparable.

Equipment Used: Utilizing the Trimble SPS 461 Dual Antenna DGPS Receiver as a rover.

Motion Sensor Equipment

Motion sensing equipment commonly falls under the category of accelerometers, offering varying levels of complexity and precision. Ensuring accurate installation and proper alignment within the survey boat's reference framework is crucial. In forthcoming surveys, the incorporation of Kinematic GPS for survey boat motion corrections alongside accelerometer-based motion sensors is anticipated.

For both types of motion sensors, users will diligently verify their accurate functioning, ideally through a form of ground truthing. This may involve quantifying motion error residuals in data gathered over a well-known flat surface, thereby establishing a reliable measure of motion accuracy.

Survey boat – Equipment Offsets

The precise location of the different sensors on the survey boat is meticulously determined in relation to a shared reference point, and this information is accurately integrated into the survey acquisition software.

River Gauge Equipment

To align collected soundings with Chart Datum, River Gauge measurements involving both height and time are essential. Furthermore, these measurements serve to establish Mean Sea Level over extended periods. River Gauge data is commonly gathered through automated recording gauges. Additionally, information is obtained through alternate means such as manual tide pole readings, which are referenced against a recognized datum (typically chart datum). An alternative approach involves the use of Kinematic GPS with centimeter-level precision in the vertical dimension, which provides comprehensive height measurements, encompassing the Gauge component as well.

A Real-Time Kinematic (RTK) The foundational configuration is employed to transmit corrections through a UHF-Radio link. Subsequent to calibration, automated gauges come into play. The precision of water level measurements, which are utilized to adjust soundings, significantly influences the overall accuracy of the survey.

Survey Process

The process of conducting the Bathymetry survey is structured into five primary stages (as depicted in Table 1), and each stage is further segmented into several sets of instructions or procedures. These encompass comprehensive directives relevant to each phase of the survey.

***Table 1*–The Survey Process**

S.N.	Stage	Group	Instructions or Procedure
1	Preparation	Planning	Extract current survey data from existing sources and plan observations
		Calibration	Elimination of systematic errors from survey instruments prior to observations
2	Data Collection	Verification	Configuration of equipment to ensure instruments are collecting data to the correct standard during survey operations
		Observation	Data collection, including those observations necessary for ongoing validation
		Data Logging	Ensure appropriate data is logged to correct parameters
3	Data Processing	Data Cleaning	Removal of invalid data
		Data Selection	Selection of valid data for further processing/rendering
		Data Storage	Storing of selected processed data in appropriate formats

4	Data Analysis	Quality	Determine the quality of surveyed data via proven methods and compare with required standards
		Coverage	Determine if sufficient valid data has been collected
5	Data Rendering	Reports	To document the survey process and results to provide adequate transparency
		Plots	To render data as the client as required
		Digital Data	To render/archive digital data
		Field Records	To render/archive field records

Survey Team

Covering an approximate area of 3 kilometers within Kathauta Jheel, Gomtinagar, Lucknow, the Bathymetry Survey was undertaken by RSAC-UP. The survey team comprised all project scientists and additional project personnel who took part in the endeavor.

The Bathyswath System was installed on a survey boat provided by RSAC-UP, accompanied by personnel from the Provincial Armed Constabulary (P.A.C) responsible for rowing the boat. The team was adequately equipped with all essential safety gear.

Discussions and Results

The Bathymetry survey of Kathauta Jheel was carried out within the urban expanse of Gomtinagar, Lucknow, Uttar Pradesh, encompassing an area spanning 2.89 square kilometers. The survey achieved depth measurements up to 5.25 meters, ensuring precision at the centimeter level, while also offering a three-dimensional perspective within a GIS environment. The calculated volume of Kathauta Jheel stands at approximately 914,776.46 cubic meters.

The Bathymetry survey conducted in Kathauta Jheel distinctly reveals the characteristics of the underwater environment and the sediment deposition pattern. Notably, illustrative maps featuring a contour interval of 1 meter for water column depth have been meticulously crafted. These maps vividly illustrate significant details, including the peak water column depth, ranging from 4 to 5 meters in proximity to the southern boat dock ramp. Conversely, the minimum water column depth falls within the range of 0.5 to 2.5 meters near the intake point of the Jheel. Meanwhile, the overall average depth of the lake registers between 4 to 5 meters, as depicted in Figure 2.

The contour lines representing the water column in the surveyed sections of Kathauta Jheel exhibit variations of 1.5 meters, following a 1-meter interval. These contour lines extend in a northwest-to-southeast direction across the northern region of the lake and a north-to-south direction in the southern region. Notably, the contour lines illustrate a distinct pattern of silt deposition predominantly concentrated in the southern portion of the lake.

Using specialized software, a representative slope map of Kathauta Jheel has been generated. This slope map has been categorized into five distinct ranges: 0-2.30, 2.30-5.50, 5.50-11.10, 11.10-18.10, and 18.10-31.10 (as depicted in Figure 5). The map derived from the bathymetry survey has been categorized into three distinct groups based on water column depths: <2.5m, 2.5-4m, and >4m. This classification takes into consideration the necessity of desolation efforts within Kathauta Jheel, aimed at enhancing its water storage capacity, as illustrated in Figure 4.

The 3D point cloud data served as the foundation for constructing the underwater topography. Cross-sectional profiles of Kathauta Jheel were established across 12 distinct sections, outlined as follows.

Section A - A' represents the southernmost cross-sectional profile, oriented along a strike of 1890, 90. The highest depth of 4.4 meters is recorded at coordinates 81° 1' 56.913" E 26° 51' 46.677" N, while the shallowest depth of 0.4 meters is found at coordinates 81° 2' 1.335" E 26° 51' 46.838" N. This decrease in depth is attributed to significant sand deposition.

Section B - B' corresponds to the southern profile cross-section, aligned with a strike of 1880, 80. The greatest depth of 4.5 meters is observed at coordinates 81° 1' 56.769" E 26° 51' 47.814" N, while the minimum depth of 1.5 meters is noted at coordinates 81° 2' 1.335" E 26° 51' 48.301" N due to the presence of deposited sand.

Section C - C' denotes the southern profile cross-section oriented along a strike of 1950, 150. The highest depth of 4.2 meters is identified at coordinates 81° 2' 0.575" E 26° 51' 52.201" N, while the shallowest depth of 3.3 meters is recorded at coordinates 81° 1' 56.045" E 26° 51' 52.528" N.

Section D - D' represents the southern profile cross-section aligned with a strike of 2000, 200. The maximum depth of 4.6 meters is observed at coordinates 81° 2' 2.135" E 26° 51' 55.614" N, and the minimum depth of 3.9 meters is documented at coordinates 81° 2' 0.069" E 26° 51' 55.679" N.

Section E - E' corresponds to the southern profile cross-section oriented with a strike of 2050, 250. The peak depth of 4.5 meters is noted at coordinates 81° 1' 56.083" E 26° 51' 57.273" N, while the shallowest depth of 3.7 meters is identified at coordinates 81° 1' 57.931" E 26° 51' 57.663" N.

Section F - F' represents the mid-area profile cross-section with a strike of 2150, 350. The maximum depth of 4.6 meters is documented at coordinates 81° 1' 56.881" E 26° 52' 1.498" N, while the shallowest depth of 2.8 meters is observed at coordinates 81° 1' 59.636" E 26° 52' 2.310" N.

Section G - G' corresponds to the mid-area profile cross-section oriented along a strike of 2200, 400. The highest depth of 4.2 meters is noted at coordinates 81° 1' 56.012" E 26° 52' 3.709" N, and the minimum depth of 3.2 meters is found at coordinates 81° 1' 57.716" E 26° 52' 4.684" N.

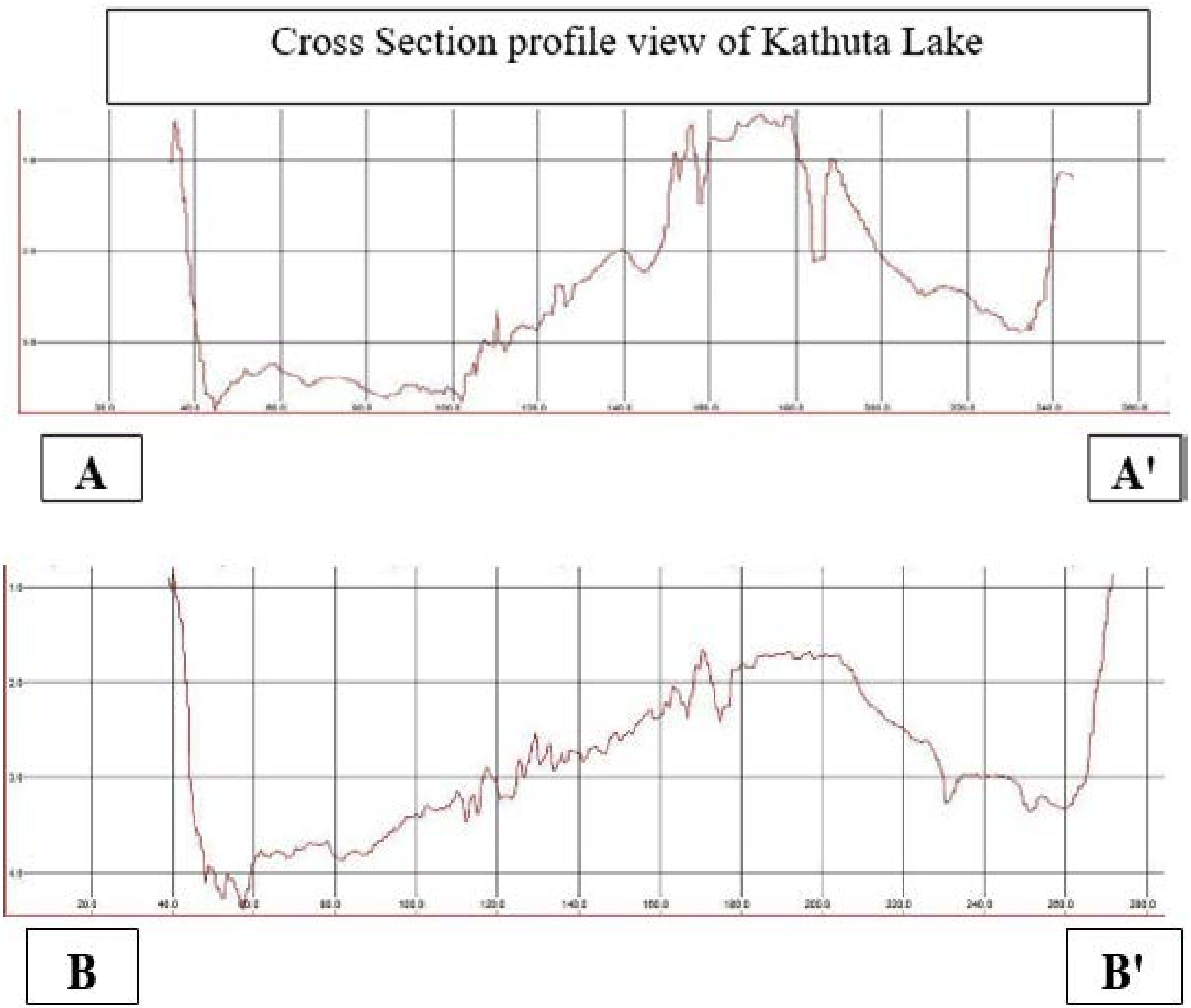
Section H - H' signifies the northern profile cross-section with a strike of 2210, 410. The maximum depth of 4.2 meters is observed at coordinates 81° 1' 52.136" E 26° 52' 9.528" N, and the minimum depth of 3.2 meters is recorded at coordinates 81° 1' 50.613" E 26° 52' 8.813" N.

Section I - I' represents the northern profile cross-section oriented with a strike of 2300, 500. The peak depth of 4.2 meters is identified at coordinates 81° 1' 49.056" E 26° 52' 12.681" N, while the shallowest depth of 2.9 meters is observed at coordinates 81° 1' 49.998" E 26° 52' 13.234" N.

Section J - J' corresponds to the northern profile cross-section aligned with a strike of 2320, 520. The highest depth of 4.7 meters is recorded at coordinates 81° 1' 45.106" E 26° 52' 14.762" N, while the minimum depth of 2.6 meters is noted at coordinates 81° 1' 46.628" E 26° 52' 15.900" N.

Section K - K' depicts the northern profile cross-section oriented along a strike of 2330, 530. The maximum depth of 4.8 meters is documented at coordinates 81° 1' 42.822" E 26° 52' 13.235" N, while the shallowest depth of 3.1 meters is observed at coordinates 81° 1' 45.541" E 26° 52' 16.452" N.

Section L - L' corresponds to the northernmost profile cross-section with a strike of 2350, 550. The peak depth of 4.2 meters is noted at coordinates 81° 1' 40.213" E 26° 52' 15.348" N, and the minimum depth of 2.7 meters is recorded at coordinates 81° 1' 42.534" E 26° 52' 19.118" N.



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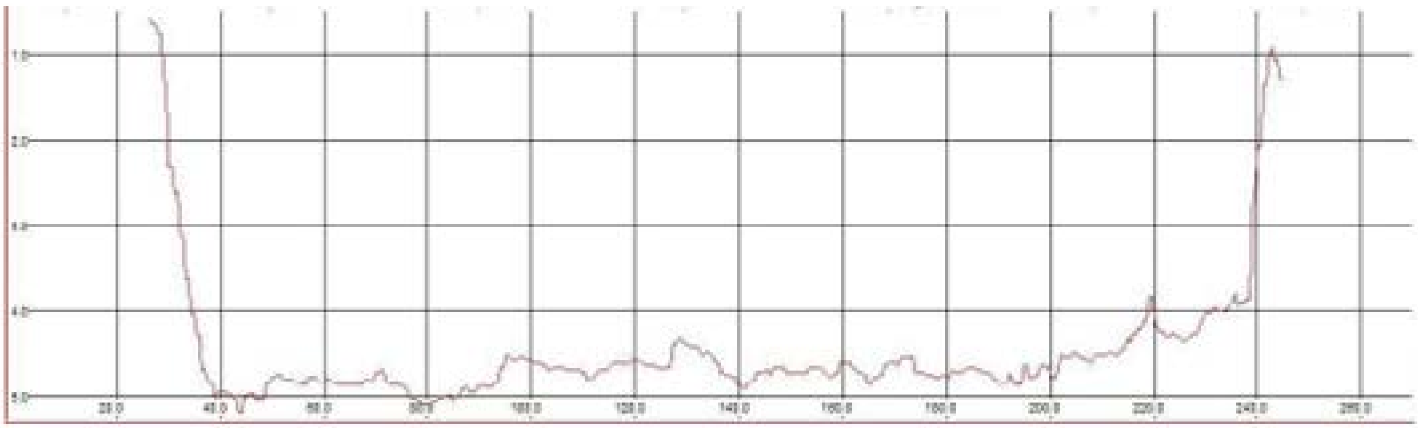

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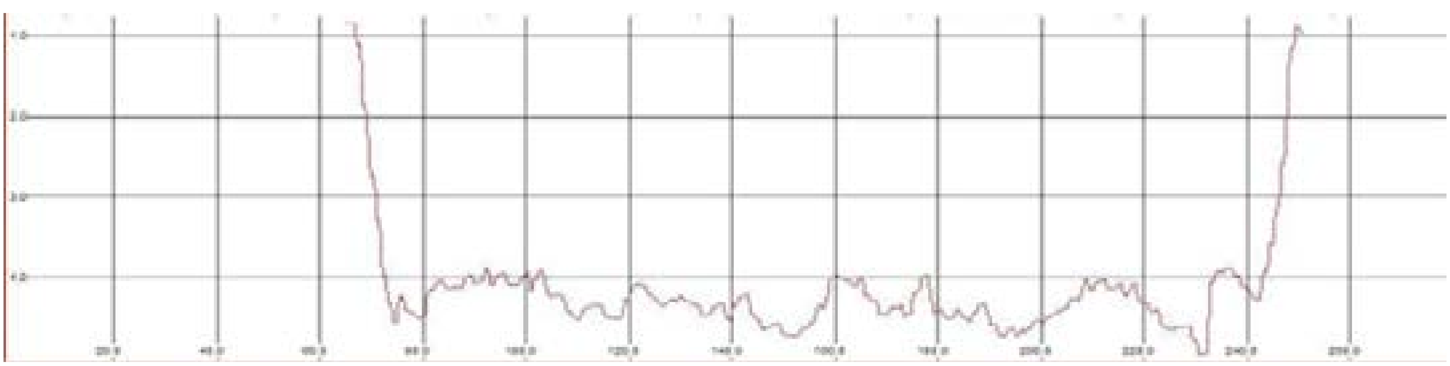

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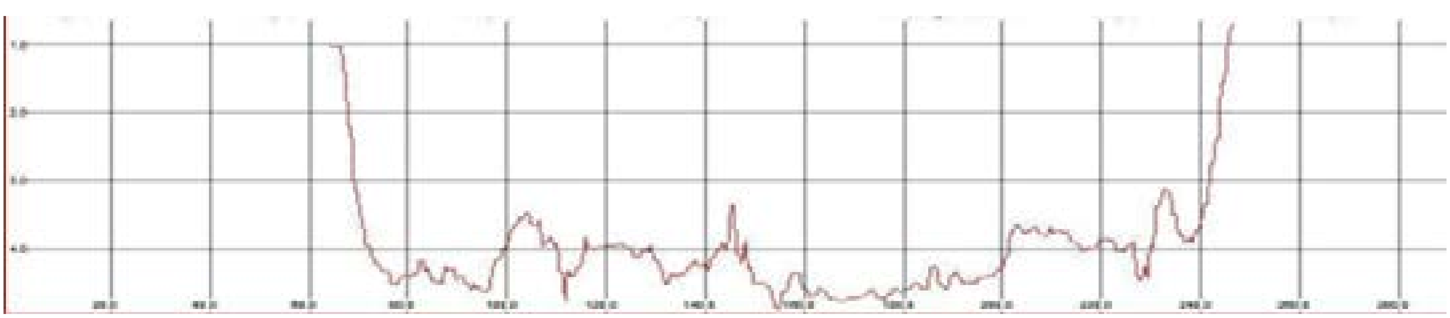

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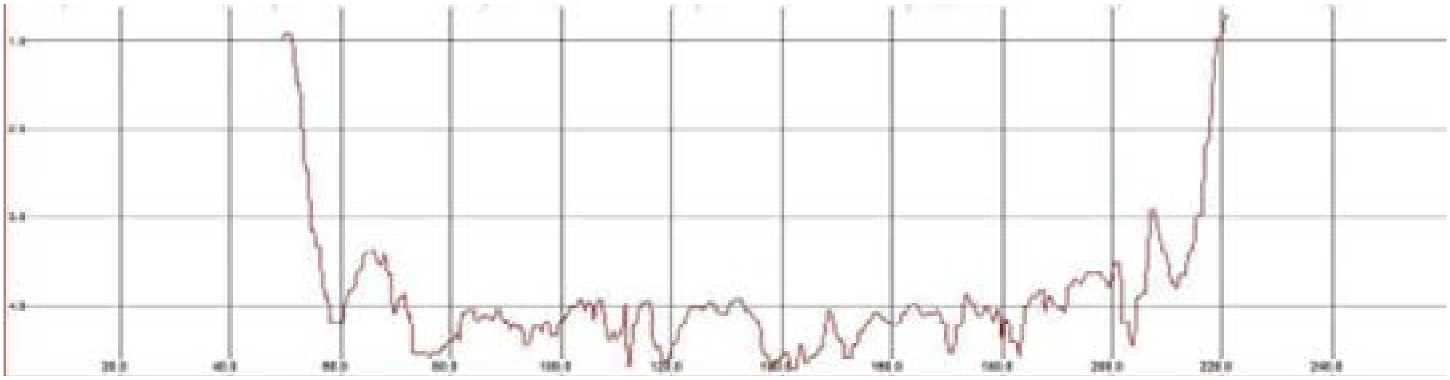

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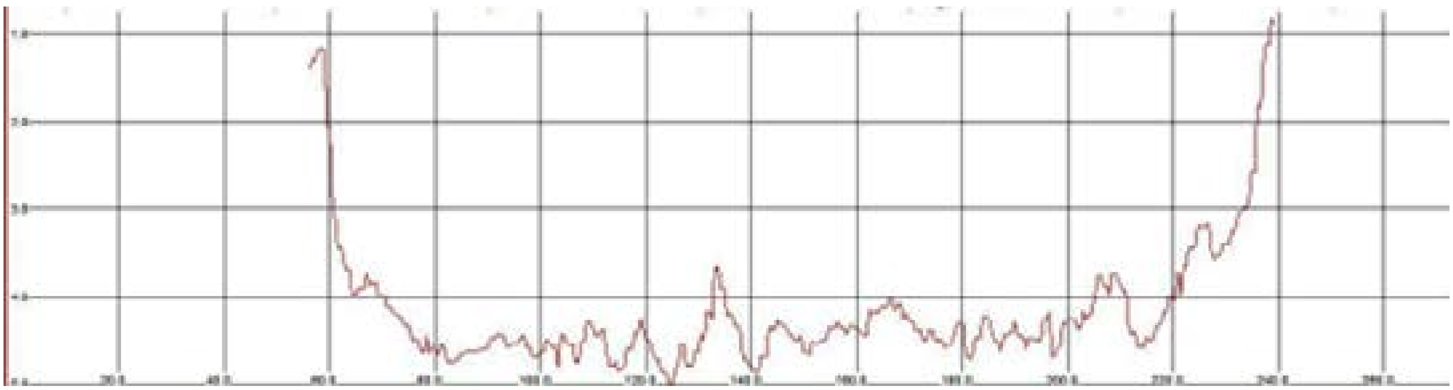

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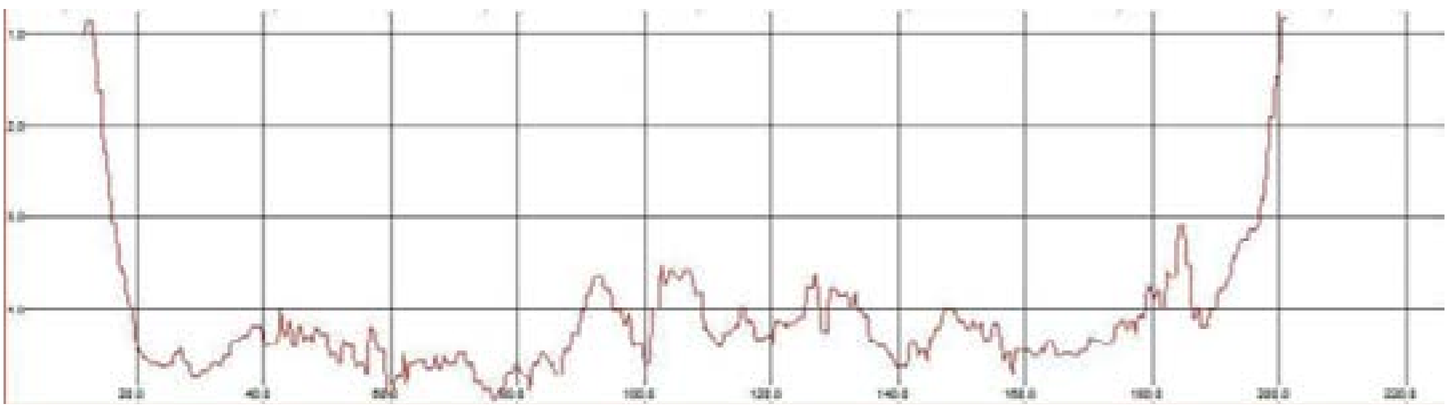

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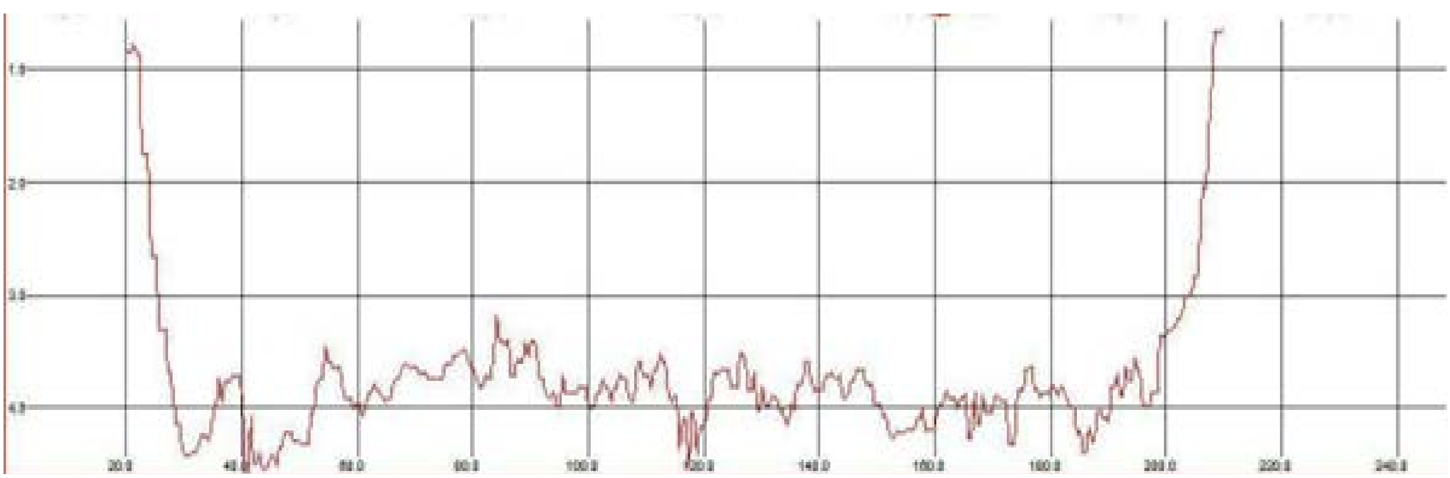

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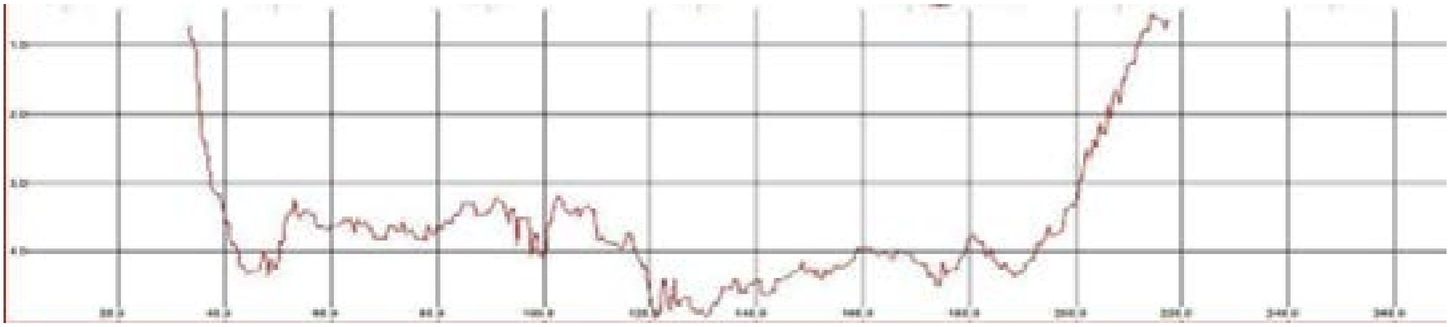

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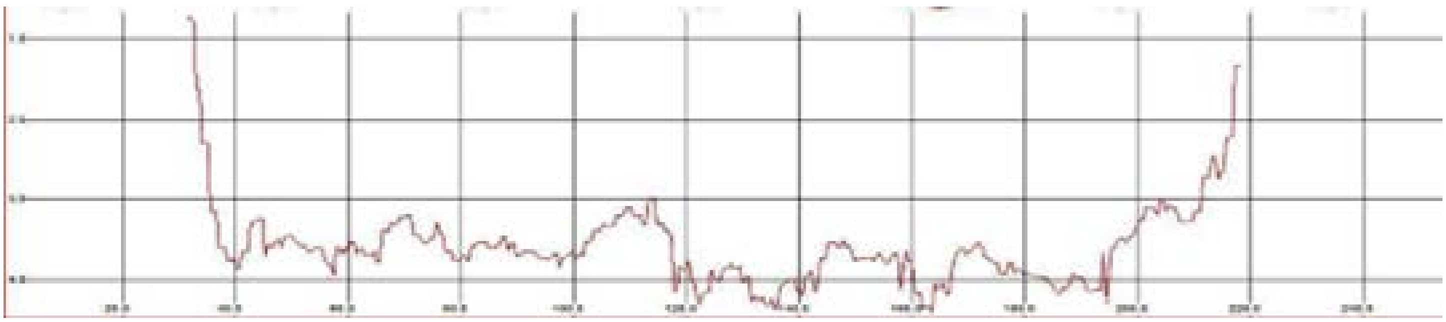

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Cross Section profile view of Kathuta Lake

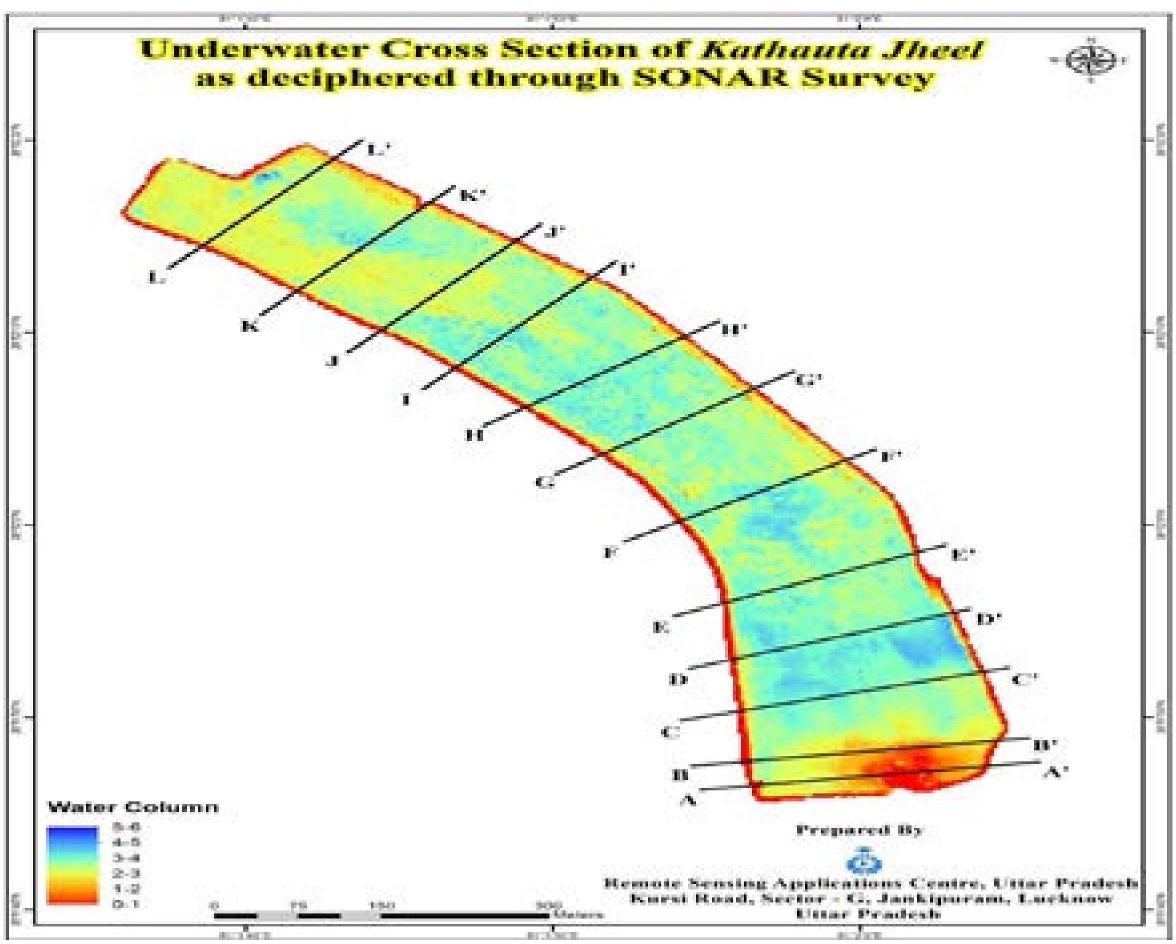


Figure: 2 Map showing underwater Cross section of Kathauta Jheel

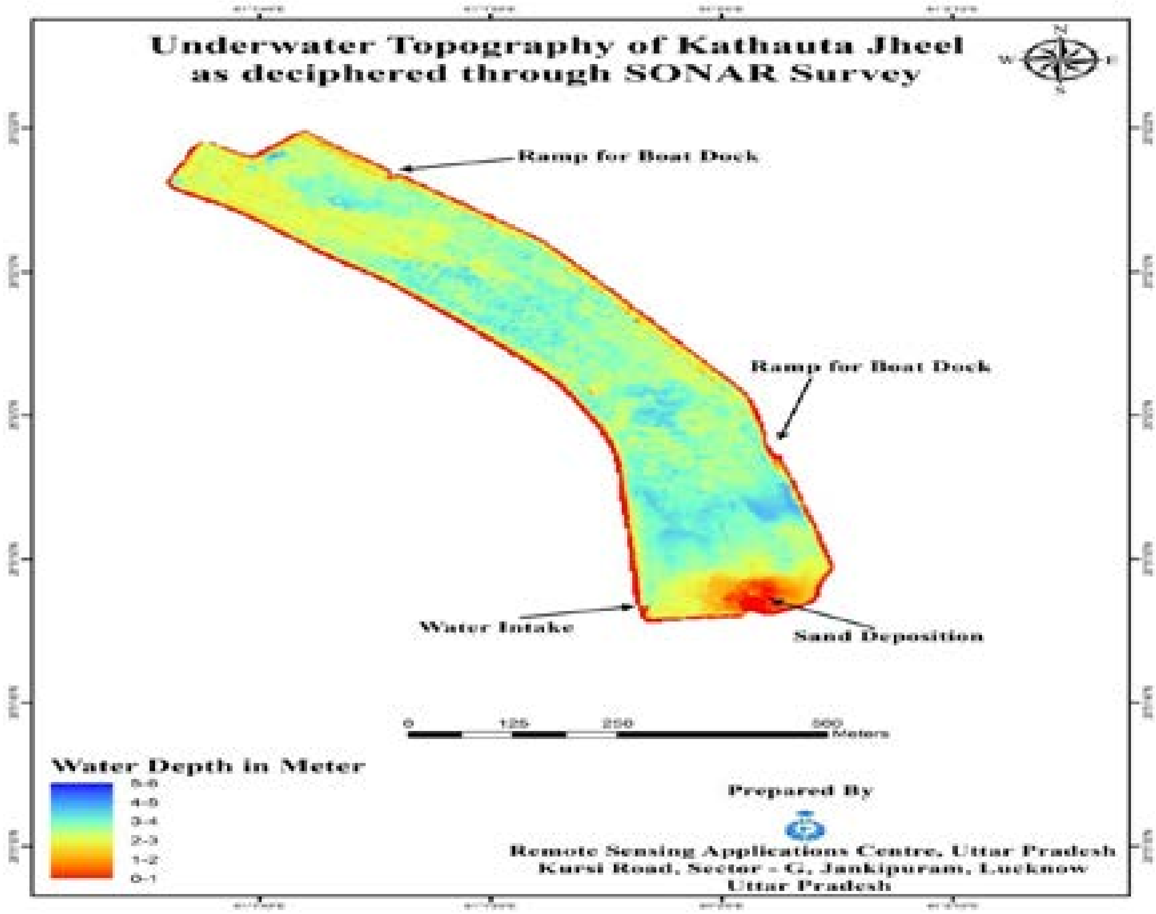


Figure:3 Map showing the Underwater Topography of KathutaJheel

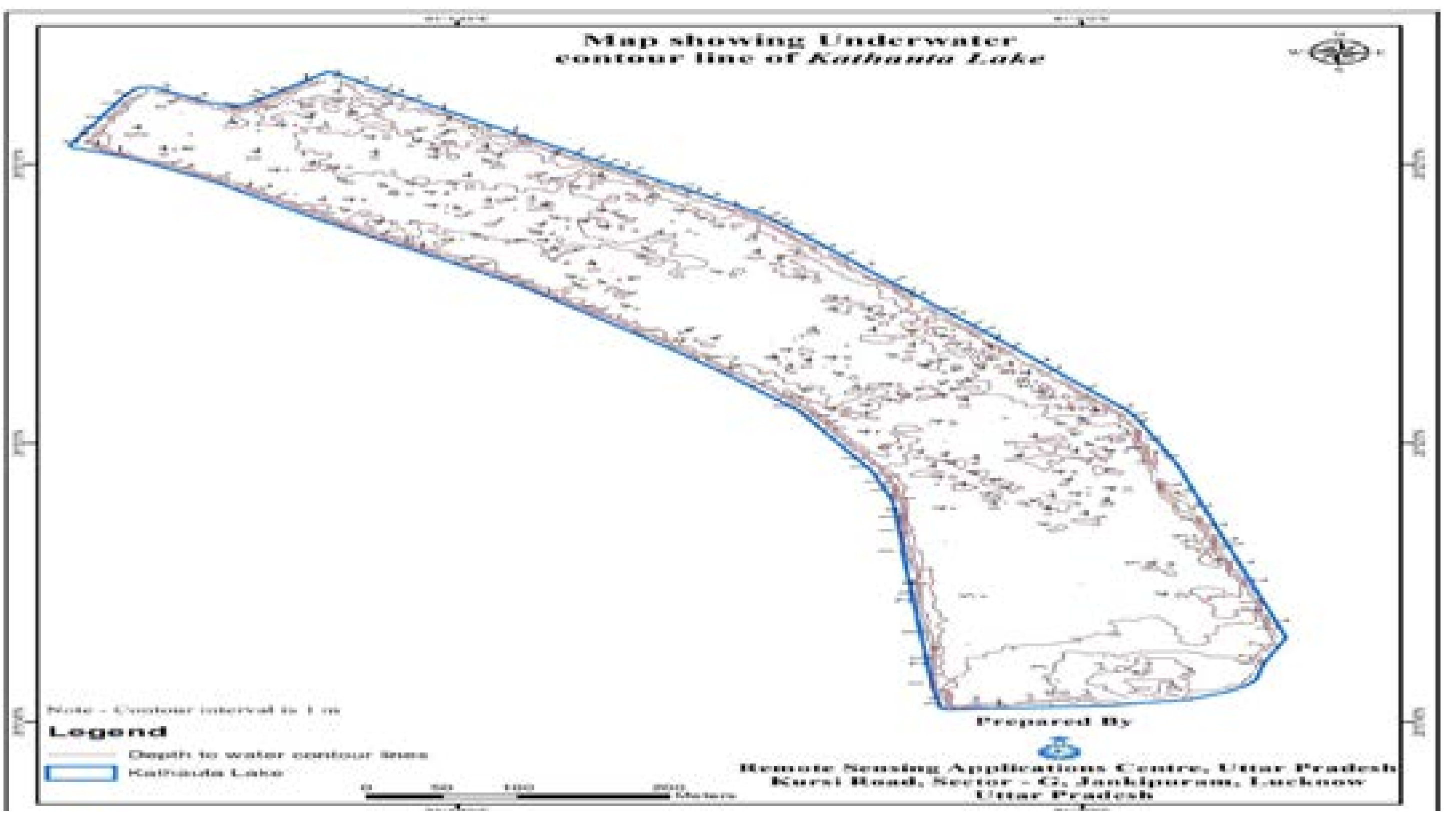


Figure:4 Map showing the Underwater Contour of KathutaJheel

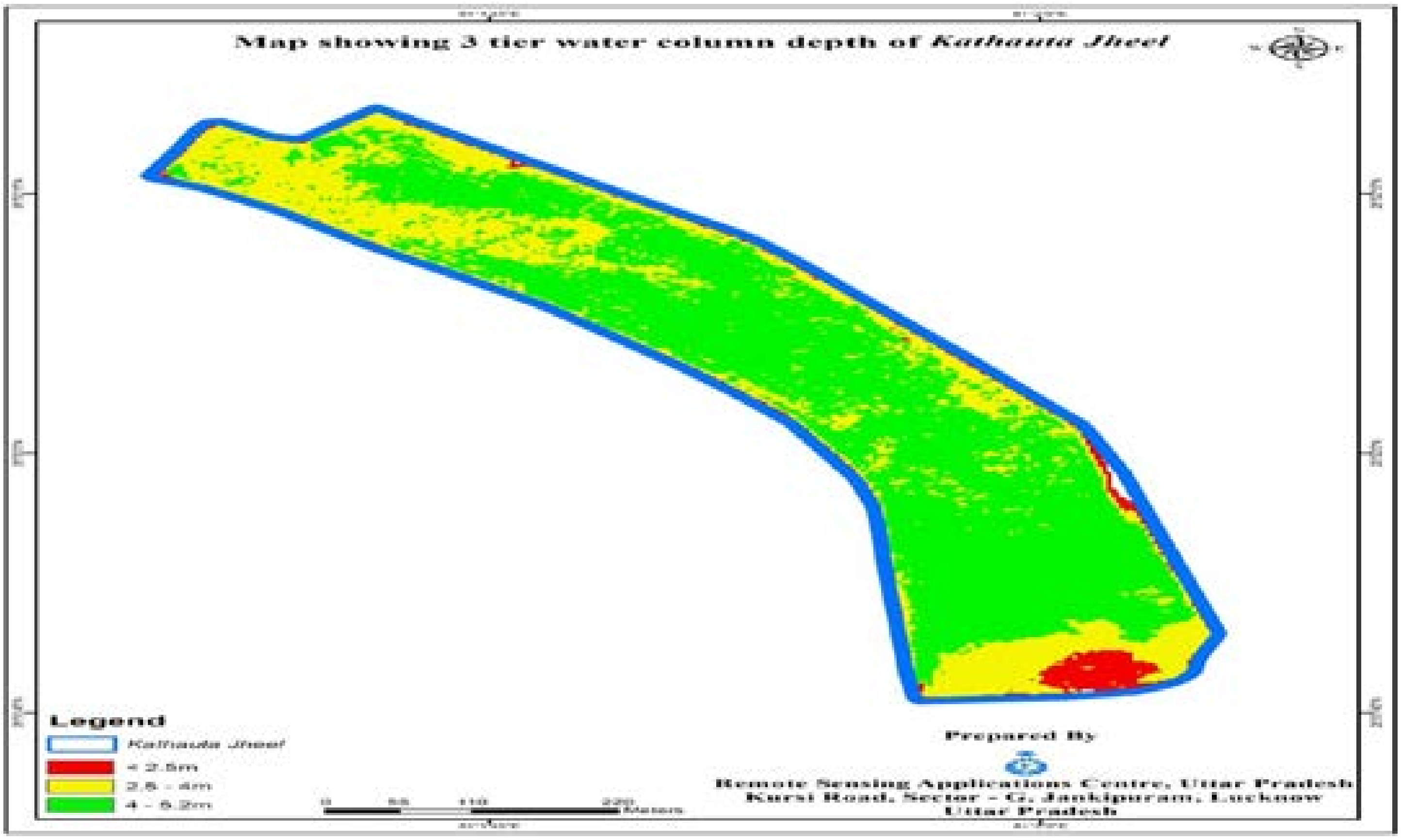
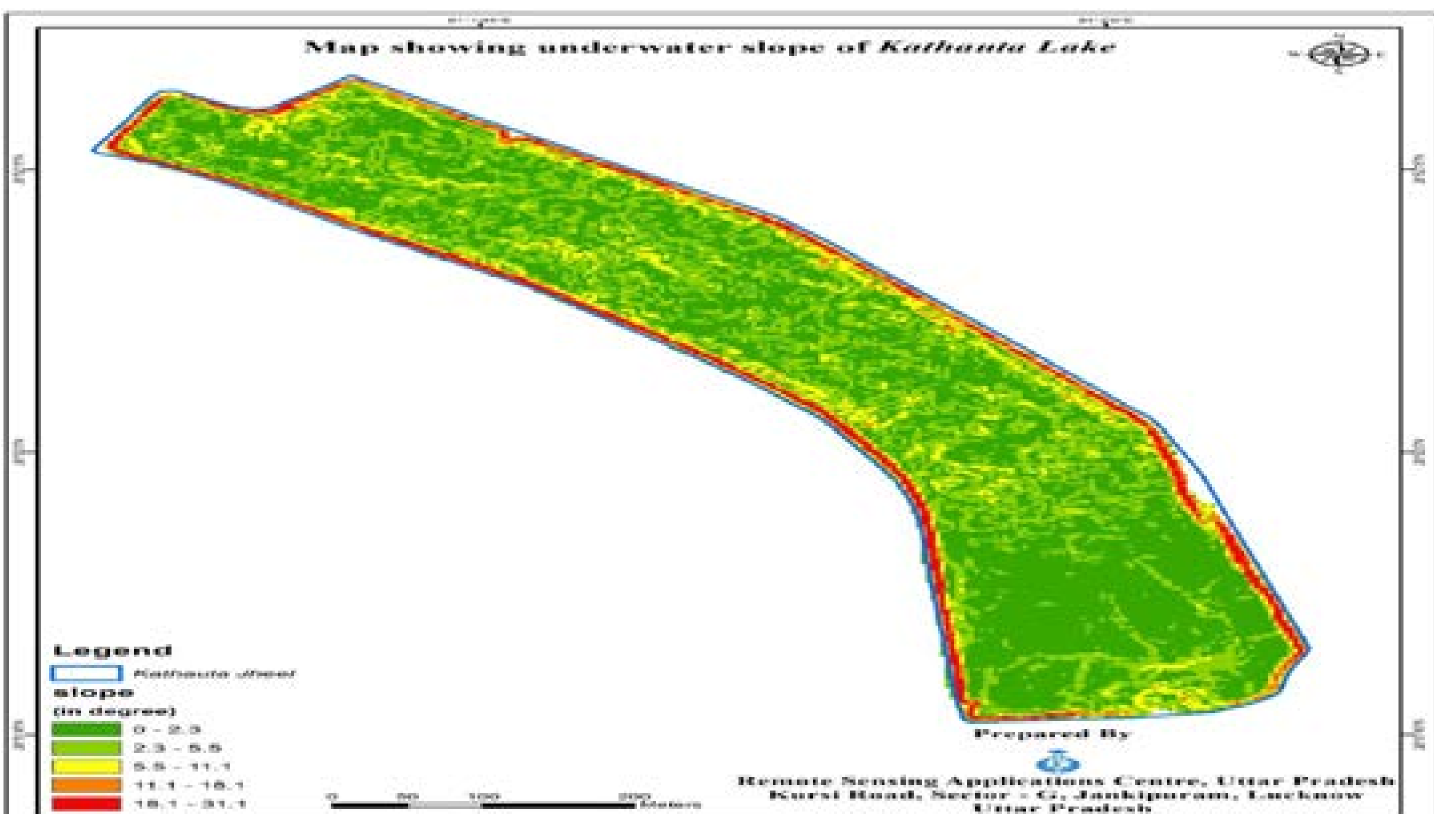


Figure: 5 Map showing 3 tier water column depth of KathutaJheel

Figure: 6 Map showing the Underwater Slope of KathutaJheel



Conclusions

Modern advancements in Sonar survey and mapping have opened up avenues to explore submerged terrains such as canals, rivers, and water bodies. The Bathymetric instrument leverages Sonar technology to precisely gauge the water column from the surface, delivering an accuracy of 1 meter along with precise coordinate data. In December 2020, RSAC-UP undertook underwater surveys within Kathauta Jheel, situated in Lucknow district, Uttar Pradesh. Subsequently, the collected data underwent processing, culminating in the creation of contour maps with 1-meter intervals for enhanced visualization.

This survey methodology proves invaluable in identifying potential obstructions, offering a preliminary insight necessary prior to commencing dredging operations. The insights within this report can be harnessed by the Irrigation department to strategically plan dredging endeavors, targeting specific locations to optimize cost efficiency while bolstering water body capacity. Additionally, the study holds significance in route planning and facilitating water sports activities. The report's applicability extends to various stakeholders, including the Irrigation Department, Central Water Commission, Inland Waterland Authority of India, and sports authorities in Uttar Pradesh.