TECHNICAL REPORT NO. **September 2020**

Bathymetry Survey of Khoupum Reservoir in Manipur State under National Hydrology Project (NHP)

1.0 INTRODUCTION

Khoupum Dam is constructed across the Manchen Diu River in Western Hill in Manchen in Tamenglong district of Manipur. It is located about 88 km from Imphal city, capital of Manipur. The purpose of the dam is to cater the needs of water supplying for irrigation and drinking water to nearby surrounding villages. It completed in the year 1995. The dam is 530 m long and 17.11 m in height.

The Executive Engineer, Water Resources Department, Govt. of Manipur vide letter no. IFCD/NHP/1-1/2015-16/128 dated 26.07.2019 has requested National Project Monitoring Unit (NPMU), New Delhi for conducting bathymetry survey of three reservoirs Singda, Khuga and Khupum situated in Manipur state under National Hydrology Project (NHP). Subsequently after accepting the proposal by CWPRS, the CWPRS team carried out hydrographic survey during 16-27 January 2020.

1.1 Khoupum Dam Project – An overview

The Khoupum dam project is basically a irrigation project which was started for providing irrigation facility through dam canal to its nearby area beside provide drinking water. This project was inaugurated by then Chief Minister, Yangmasho Shaiza on July 26, 1978 and the Khoupum dam canal project was commissioned by the then Chief Minister, Rishang Keishing in the year 1982-83. The view of Khoupum dam is shown in Photo. 1. The spillway of Khoupum dam is shown in Photo. 2. The Google image of Khoupum dam with is shown in Photo. 3.

The upstream view of Khoupum dam is shown in Photo. 4 at the time of survey at EL 904.5 m.

The salient features of Khoupum dam project are as given in Annexure -1.

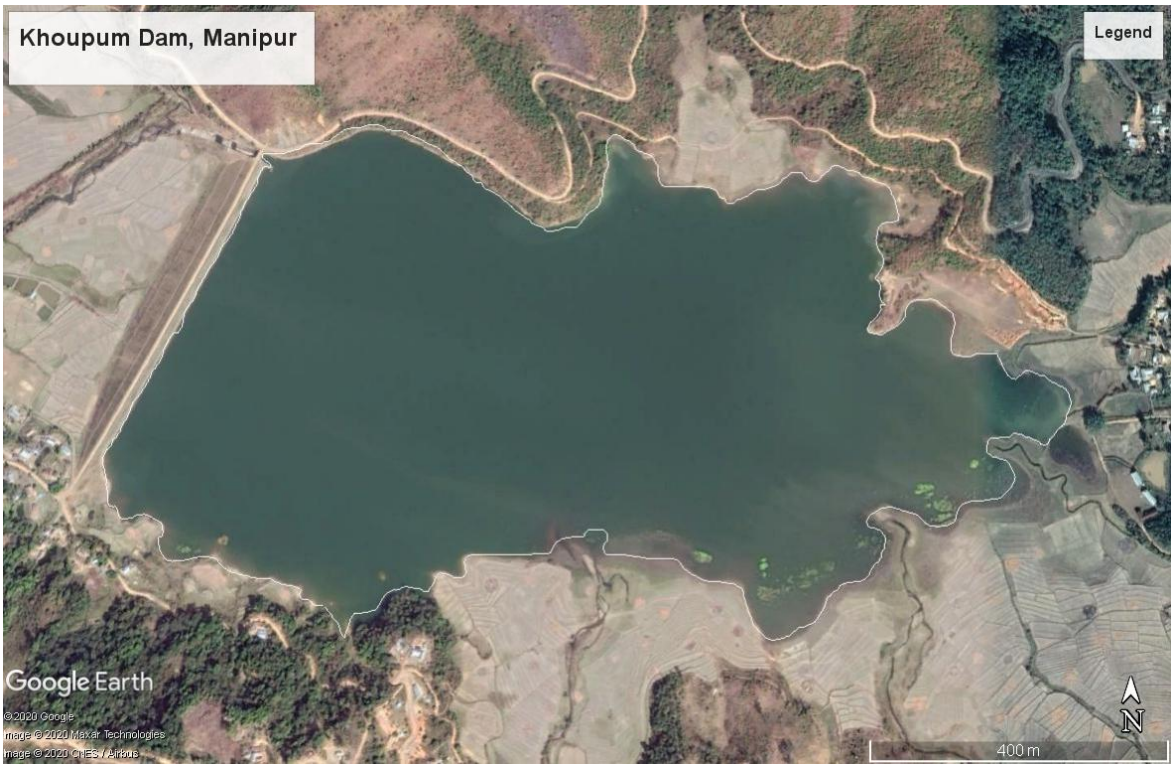


Photo 1: Google image showing the Khoupum reservoir

Photo 2: Khoupum Dam Upstream view

Photo 3: **Khoupum Dam down-stream showing rice cultivation farms**

Photo 4: Spillway of Khoupum dam

Shri T. Paokai Haokip, Ex. Engineer and dam officials took part in the discussions and shared the hydrological data pertaining to the reservoir with CWPRS team at site. After discussion with project authority, it was decided to carry out the actual survey at a closer interval of 10 m grid line so as to measure the volume of water and silt deposited in the reservoir more accurately. The following officials of CWPRS were involved for carrying out bathymetric survey work from 20th to 22nd January, 2020. Shri M. S. Bist, Scientist-C, Shri Ajay Sonavane, A.R.O, Shri Ajit Singh, R.A. and Shri K. Subbarao Murthy, J.E. The CWPRS team with Manipur officials at Singda dam site is shown in photo 5.

Photo 5: CWPRS team with Manipur officials at Khoupum dam site

1.2 SCOPE OF STUDIES

The scope of the studies was to carry out sedimentation survey of Singda reservoir for assessment of silt and to find out the present storage capacity of reservoir. For bathymetry survey a motorized fiber boat arranged by project authority was used. The eco-sounder sensor with special fixture was fitted on one side of the boat and the GPS antenna was mounted on the same axis to collect the DGPS locations precisely. The echo sounder used during survey was single beam dual-frequency eco-sounder (210 Khz, 33 Khz) Knudsen make and the GPS was Trimble make.

It was aimed to provide the present reservoir storage capacity and to estimate the silt deposited in the reservoir.

1.3 OBJECTIVE OF SURVEY

The purpose of the bathymetric survey is to find the present storage capacity and silt deposited in the reservoir. This will help the dam authority for utmost utilization and proper planning of distribution of water supply for irrigation and drinking purpose. It also includes finding out the possible methods to enhance the dam water storage capacity by means of siltation removal from the reservoir.

2.0 RESERVOIR SEDIMENTATION PROCESS

Sedimentation surveys are important in the reservoir for optimum reservoir operation based on realistic assessment of available storage. Reduction in the storage capacity beyond a limit prevents the reservoir from fulfillment of different purposes. Figure 6 shows the process of sedimentation in a reservoir. Periodical capacity surveys of reservoir help in assessing the rate of sedimentation and reduction in storage capacity. This helps for efficient management of reservoir and also helps in taking decision about treatment of catchment area, if the rate of siltation is excessive.

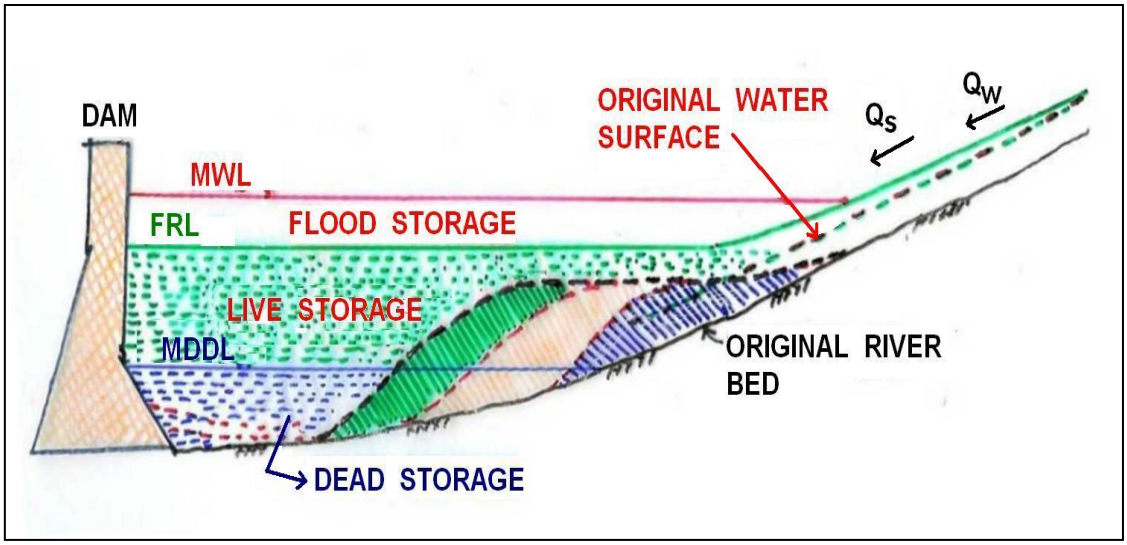


Fig.6: Schematic showing Sedimentation of a Reservoir

Among many methods, boat mounted DGPS based Bathymetry Survey is the most accurate. This report is based on the Integrated bathymetry survey system used in data collection along with processing the data. This reservoir was designed with a gross storage capacity of 9.71 MCM at FRL 909.50 m.

3.0 METHODS OF ESTIMATING THE RESERVOIR CAPACITY

The various methods for calculating the reservoir capacity are mentioned below.

1) Conventional Bathymetry Method
2) Satellite Remote Sensing (SRS) Technique
3) Modern Bathymetric Technique using eco-sounder and DGPS

Nowadays, the widely accepted IBS method for obtaining depth data by using a Single-Beam Echo-sounder (SBES) / Multi beam echo-sounder with position provided by electronic ranging equipment. Subsequently, positioning measurement has been made more accurately and easier with the advent of DGPS and RTK.

In the subsequent chapter, IBS bathymetry system is described in detail which was used during this survey.

3.1 MODERN BATHYMETRIC TECHNIQUE USING ECO-SOUNDER AND DGPS

The system consists of the hi-tech equipment components are :

i) Positioning system which includes Transponder or DGPS units
ii) Depth Measuring Units consisting of single beam echo-sounder and Transducers
iii) Data Processing software in a computer system

This survey is carried out in a rapid and efficient manner. A boat equipped with the bathymetric equipment, the GPS system mounted on board and a lap-top computer is used of bathymetric survey while its reference station is positioned on a known geographical benchmark. The survey software enables fixing of grid lines and interfacing of bathymetry and DGPS, taking x, y, and z values at required interval/grid. Boat navigation is also controlled by the software, so that boat tracks the grid line accurately. The surveys can also be carried out at random mode. The data collected is then processed and analyzed using specially developed software to obtain the results in various forms e.g. point plots, contour and three dimensional maps of reservoir bed, area capacity elevation tables and cross-sections of reservoir. Fig. 7 shows the DGPS technique in Survey activity.

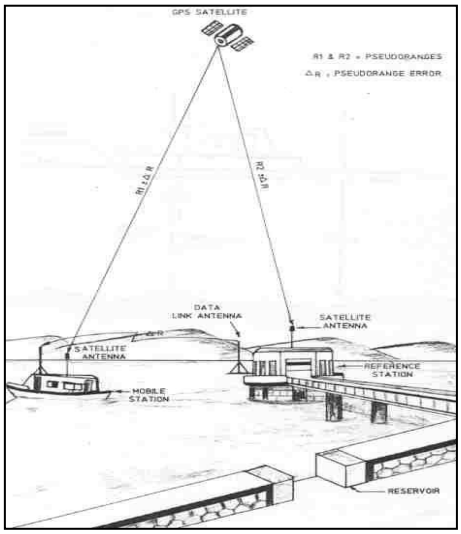


Fig.7: DGPS technique in Survey activity

DGPS hydrographic surveying allows faster data acquisition with better accuracy than any previous hydrographic survey technique. The line of sight from the base station to the boat is not necessary. The base station is set up only once per survey, instead of the usual once per cross section. A DGPS survey can be completed between control points (even on opposite side of a mountain) without having to traverse or even to see the other point. Other advantages are the ability to achieve centimeter accuracy and the ability to efficiently collect large amount of data. The photo of eco-sounder with data logging system is shown in Fig 8.

Fig.8 : Echo-sounder with Laptop for logging real-time data acquisition-IBS Equipment

4.0 INSTRUMENTATION SYSTEM DEPLOYED DURING SURVEY

The survey was done at EL 724.22 m and the Integrated Bathymetric system (IBS) used during this survey consists of modern sophisticated electronic equipment consisting of GPS, Echo sounder, Discus antenna, sensor along with the fixture to hold the sensor. The echo sounder used during survey was single beam dual-frequency eco-sounder (210 Khz, 33 Khz) Knudsen make and the GPS was Trimble make. Data collection, processing and calculations are done by means of Hypack software. With the use of this advanced Integrated Bathymetry system the results are more accurate.

The components of IBS used are given below.

4.1 Differential Global Positioning System (DGPS)

The Positioning system which includes Transponder or DGPS units is one such highly reliable, accurate, state of art device to get position by observing satellite. It can also track up to 12 satellites to achieve maximum positional accuracy. The GPS receiver receives error correction from reference station and combines them with the received satellite signals to compute much more accurate self-position. The Trimble make GPS display interfacing unit, Echo sounder sensor, and antenna used during surveys is shown in Fig 9.

Fig.9: DGPS with antenna

The mobile antenna logs the instantaneous position data from the available GPS satellites and corrects the satellite introduced errors with the help of beacon correction. The Trimble DGPS with beacon correction (Beacon station name: Sagar Island) was used during this survey, by which GPS and Glonoss data were received. This way we have logged the position with few cms level of accuracy during the total survey.

Since the present area of survey was near to coastal zone, which received the Beacon Station correction data from Sagar Island. The integrated bathymetric system with GPS was compact and could be accommodated in smaller boats. Figure 11 shows the actual boat used during survey. This Integrated Bathymetric Survey (IBS Equipment) consists of echo-sounder with Laptop and DGPS interfacing for online data collection is shown in Fig 10.

Fig.10: Survey Boat with Equipments

4.2 ECHO-SOUNDER

The Knudsen make single beam dual frequency echo sounder as shown in Fig. 11 is used for depth measuring having following specification. Range -0.2 to 200 m and Accuracy of 0.01 m +/- 0.1% of depth @ 210 kHz and 0.10 m +/- 0.1% of depth @ 33

kHz. This dual frequency echo-sounder is specified to distinguish between top depth and the consolidated bottom. The high frequency (210 KHz) is used to detect the top of the mud/sediment. Under favorable conditions the low frequency signal (33 KHz) can penetrate into the bottom and reveal information about the bottom structure. This system has controls to set the energy levels of the beams being transmitted under water. The velocity of sound is an important parameter, which is set at 1500 m/s based on the sound velocity calibrator readings. The same was cross checked with knudsen echo sensor.

Fig.11: Echo sounder sensor with sensor

The data collection was done with dual frequency mode throughout the survey on the predefined survey lines.

4.3 LAPTOP WITH NAVIGATION SOFTWARE

The real time position and depth data acquired are stored in the laptop through the Hypack navigation software as shown in Fig. 12 below.

Fig.12: Data logging through Hypack navigation software in laptop

4.4 DATA COLLECTION SYSTEM

The Data Collection System consists of a Laptop loaded with Hypack survey software. The Hypack survey module collects the depth data from the echo- sounder which is linked with the position data. This is collected at every 10 meters interval and logged as ".RAW" format data for further analysis. This software is used to plan and collect the data for data processing, which runs in the laptop and through USB serial port.

5.0 METHODOLOGY OF SURVEY

The survey was carried out with a boat equipped with the ultrasonic dual frequency echo sounder, Mobile GPS system with Beacon correction data mounted on board and a lap-top computer. The Hypack survey software is used for fixing of grid lines and interfacing of bathymetry equipment and GPS by taking x, y, and z (depth 1 and 2) values at 10 m grid interval/grid. Boat navigation is also controlled by the software, so that boat tracks the grid line accurately.

The surveys can also be carried out at random mode without survey lines. The data collected is then processed and analyzed using specially developed software (Hypack) to obtain the results in various forms e.g. point plots, contour and three dimensional maps of reservoir bed, area capacity elevation tables and cross-sections of reservoir. DGPS hydrographic surveying allows faster data acquisition with better accuracy than any previous hydrographic survey technique. The line of sight from the base station to the boat is not necessary. A DGPS survey can be completed between control points (even on opposite side of a mountain) without having to traverse or even to see the other point. Other advantages are the ability to achieve centimeter accuracy and the ability to efficiently collect large amount of data. However, the present area of survey is near to coastal zone, which receives the Beacon Station correction data from Sagar island. The data collected system with GPS is compact and can be accommodated in smaller boats.

The Khoupum dam spillway is shown in Photo 13. The intake structure for canal discharge is shown in Photo 14 and the locked gates for regulating the discharge is shown in Photo 15.

Photo 13: Crest of spillway with Water level marking

Fig.14: Intake structure showing outlet gates for water discharge for irrigation

Fig.15: Locked gates for regulating the discharge to canals

6.0 DATA ANALYSIS AND INTERPOLATION

The data collected at dam site was analyzed using various processing software such as Hypack, Surfer, AUTOCAD at CWPRS. The uneven data has been brought to a regular grid form by applying krigging method for elimination of noisy spikes for getting the useful data samples (depth values). Special filters were used to clear the spikes in the bathy data. Mostly the noises attribute to the boat movement, under water vegetation, engine and the surface wave noise. The processed data was used for further analysis in SURFER software. The depth data was processed initially for preparing grid files. These grid files are used to prepare contour plots, surface plots and for the estimation of volume as well as surface area by standard formulae such as Trapezoidal rule, 1/3 Simpson's Rule and Simpson's 3/8 Rule together. The survey was carried out on water level of

904.10 m. The results were based on the interpolation of the depth data acquired by the echosounder in dual frequency mode. This data is interpolated by krigging method for the zone lying in between two survey lines. This generates the grid data set, which was used for the data analysis. For the volume estimation, we used Trapezoidal Rule, Simpson's Rule and Simpson's 3/8 Rule jointly. Volume found using bathymetry survey at EL 904.5 channel 1 depth (210 khz) was 4.787 MCM and corresponding area is 0.3957 sq .km and at FRL of 909.5 m with help of triangular interpolation the volume is 6.271 MCM.

The volume and area of Khoupum dam corresponding to different elevation is shown in Table 1.

TABLE: 1

Sr. No.	Elevation (in m)	Volume (In M.cum)	Area (In Sq Km)
1	714.22	0.000005	0.0003
2	715.22	0.0150	0.0322
3	716.22	0.0791	0.0963
4	717.22	0.2066	0.1578
5	718.22	0.3904	0.2132
6	719.22	0.6328	0.2733
7	720.22	0.9365	0.3325
8	721.22	1.2971	0.3833
9	722.22	1.7141	0.4416
10	723.22	2.1936	0.4954
11	724.22 **FRL (During Survey)**	2.7252	0.5177

- By using IBS system, the reservoir gross storage capacity at El 724.22 m during survey is calculated 2.7252 M.CM for a water spread area of 0.5177 sq. km.

After necessary interpolation of the data the different graphs have been plotted, Volume - Elevation and Area -Elevation curve, are shown in Figs. 16 and 17.

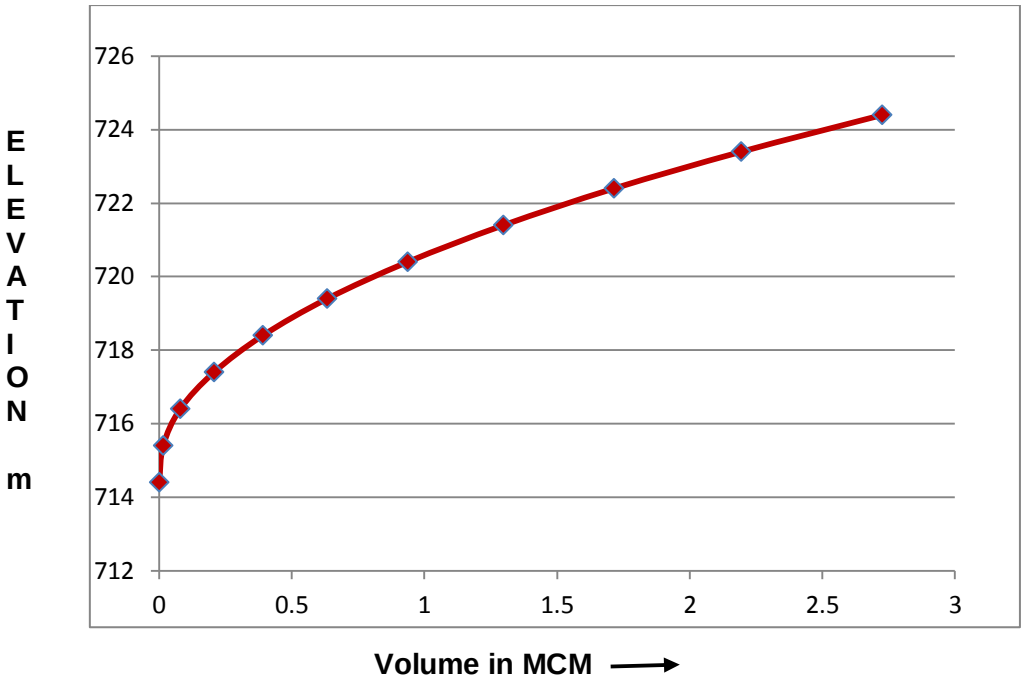


Fig. 16: Elevation- Capacity curve of Singda reservoir

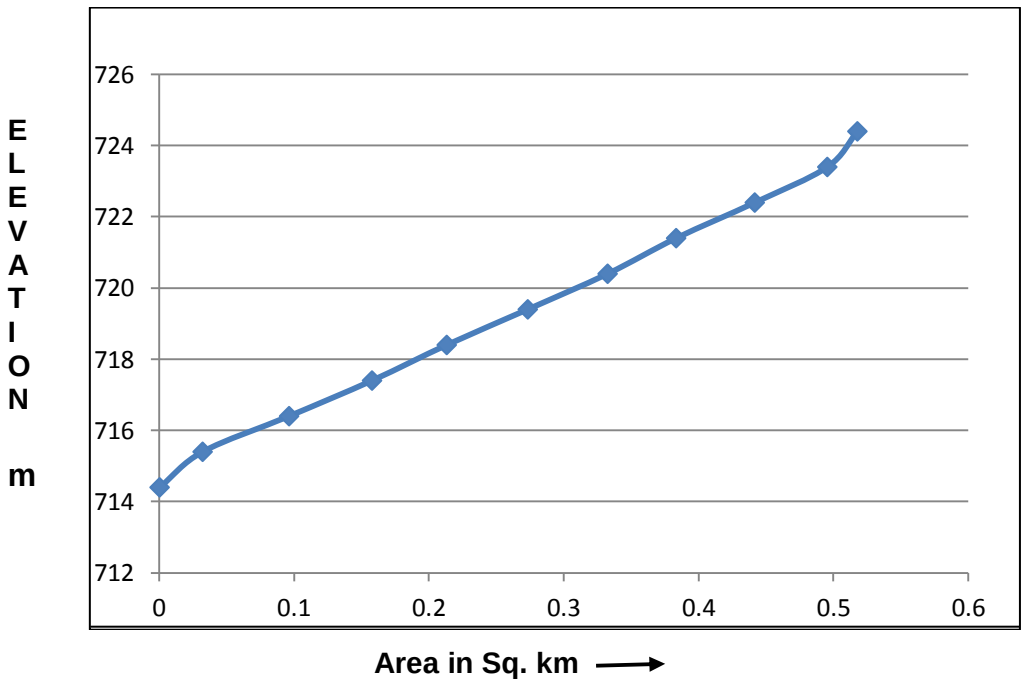


Fig. 17: Elevation- Area curve of Singda reservoir

The Area-Capacity curve of Khoupum reservoir is shown in Fig. 18.

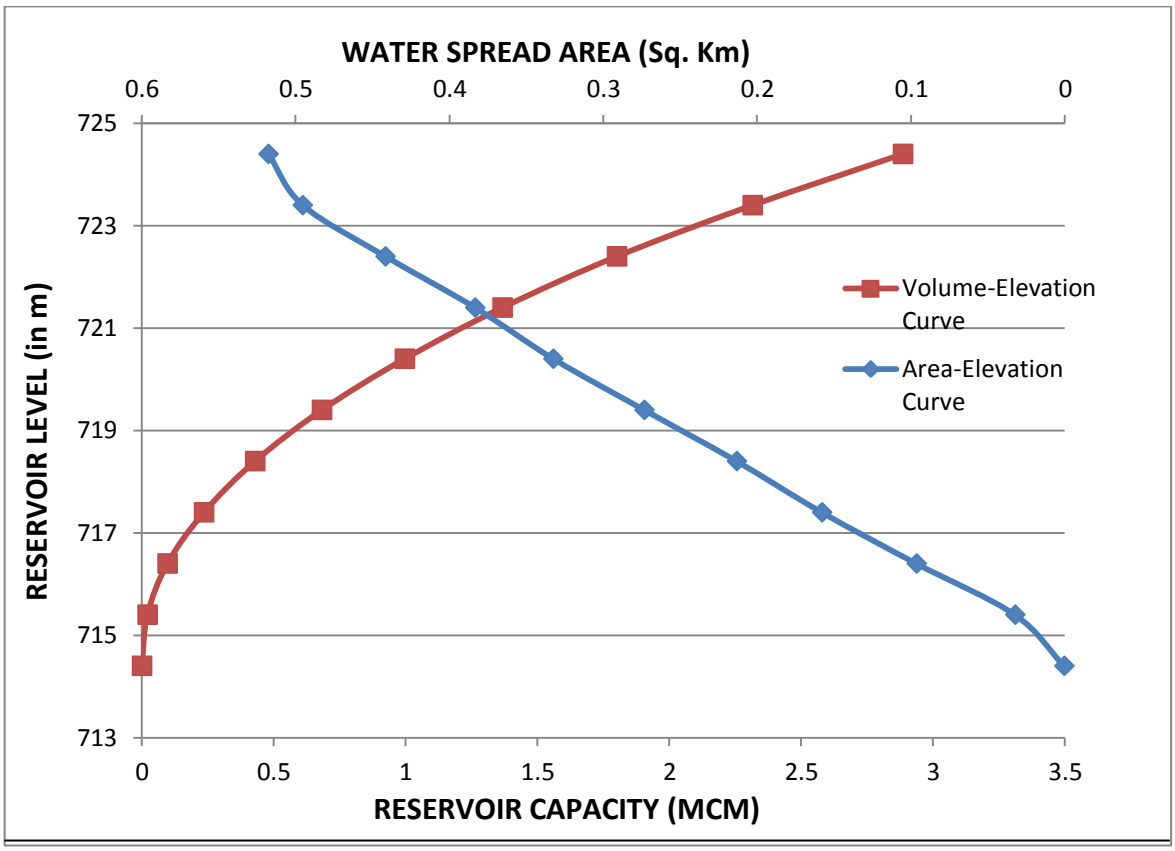


Fig. 15: Area-Capacity curve of Singda reservoir

The Surface map and contour elevation is shown in Fig. 19 and Fig. 20 respectively. The contour plot is enclosed in Annexure 2 and depth profile plot is enclosed in Annexure 3.

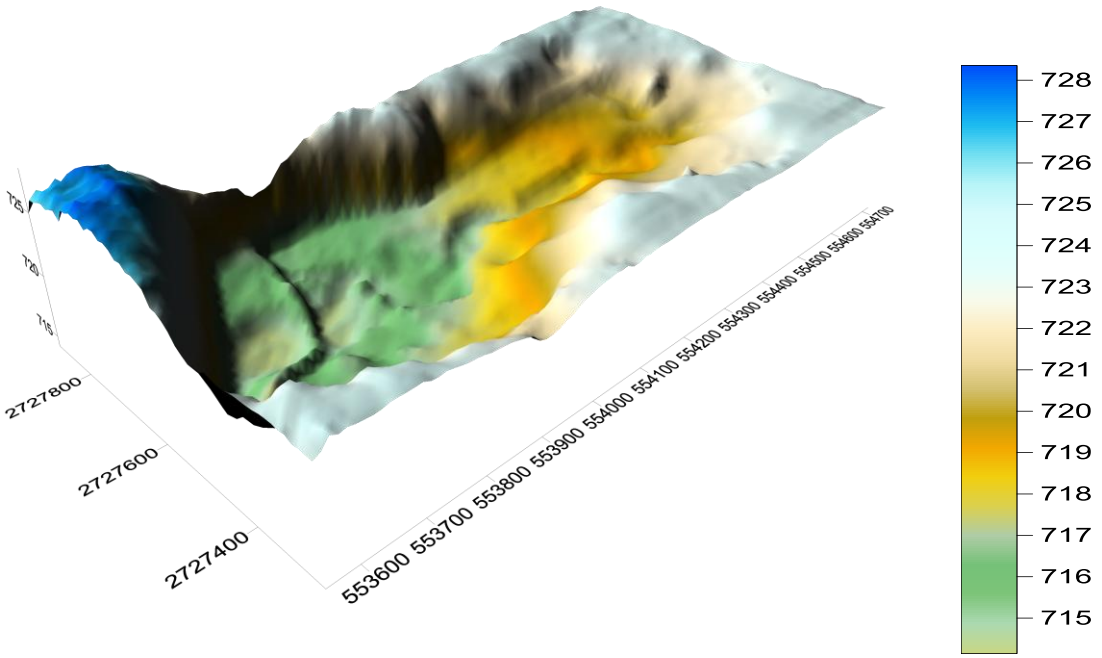


Fig. 19: Elevation- Surface map

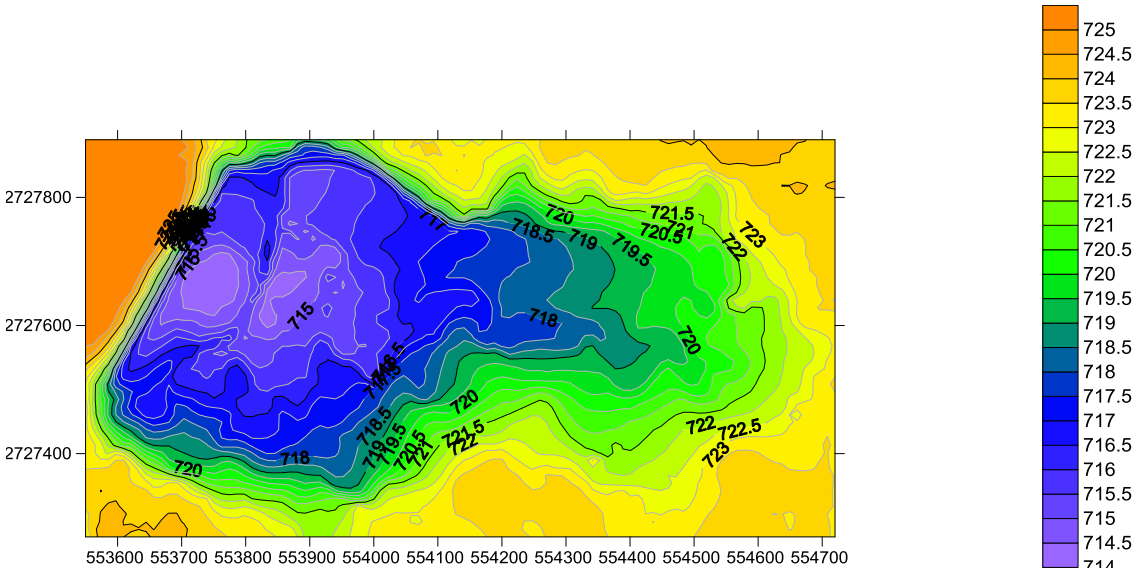


Fig. 20: Contour map

7.0 RESULTS & CONCLUSIONS

The bathymetric survey result is tabulated in Table 2.

TABLE 2: Data Analysis Results

Sl. No	Elevation (m)	Gross Storage Capacity (M.CM)	Water Spread Area (Sq.km)	Original gross capacity (M.CM)	Capacity loss (in %)
1	724.24 m	2.725	0.5178	2.78	2 %

When compared with original gross storage design data which was 2.78 MCM, there is a reduction of 0.055 MCM i.e. 2 % in the gross storage capacity of the reservoir at FRL 724.24 m. The amount of silt deposited is 0.055 MCM.

During the period of survey, it was observed that the lock gates (2 nos.) used for regulating the water supply to the canal were non- functional and got stuck at one position due to which there was a constant discharge in the canal.

It is suggested to carry out repairs and servicing of lock gates and make them operative for smooth operation of the gates so that varying discharge in the canal can be maintained.

8.0 ACKNOWLEDGEMENT

We acknowledged Shri A.K. Agrawal Director, CW&PRS, Dr. Prabhat Chandra, Scientist-E and Dr. L. R Ranganath Scientist-D (TC) who have provided necessary support during preparation of this report.

Our sincere thanks due to Shri Rohit Ahanthem, Superintending Engineer, Irrigation Circle-II, WRD, Govt. of Manipur and his team of officials, Shri Irom Royal, Ex. Engineer, Shri Petlad K Haokip , E.E. and others in Irrigation division of Singda Dam project, Manipur who have extended their support in providing all necessary arrangements required for carrying out the hydrographic survey. We are also thankful to M/s Geoservice , Maritime ltd., Navi Mumbai for sparing the latest bathymetric equipment for this survey work.

Annexure: 1

I Location of Dam

Dam site	:	Across Manchen Diu river about 88 km from Imphal
State	:	Manipur
River	:	Manchen Diu
Longitude	:	24º 39' 41.82" East
Latitude	:	93º 32' 0.62" North

II Hydrology

Catchment area at dam site	:	18.88 Sq.km
Average annual rainfall	:	1800 mm
Annual yield at dam site	:	2000Ac.ft

III Elevation

Maximum Water Level	:	726.65 m
Full reservoir level	:	724.22 m
Lowest water level	:	711.38 m
Dead storage/intake level	:	716.75 m
Irrigation water level	:	715.99 m
Water spresd level	:	0.84 Sq.Km

IV Reservoir

Gross storage capacity (FRL- 724.22 m)	:	2.78 MCM
Live Storage Capacity	:	2.50 MCM
Dead storage capacity (El 716.75 m)	:	1.21 MCM
F.R.L.	:	724.22 m
M.W.L.	:	726.65 m

V Main Dam

Type	:	Zoned earth fill dam
Total length of earth dam	:	530 m
Max. height of dam	:	17.11 m

VI Spillway

Type	:	Chute spillway
Length	:	330.00 m
Width	:	10 m
Capacity	:	0.43 cumec
Type of Control	:	locked gate

VII Intake

Intake level	:	716.75 m
Intake capacity	:	0.43 cumec

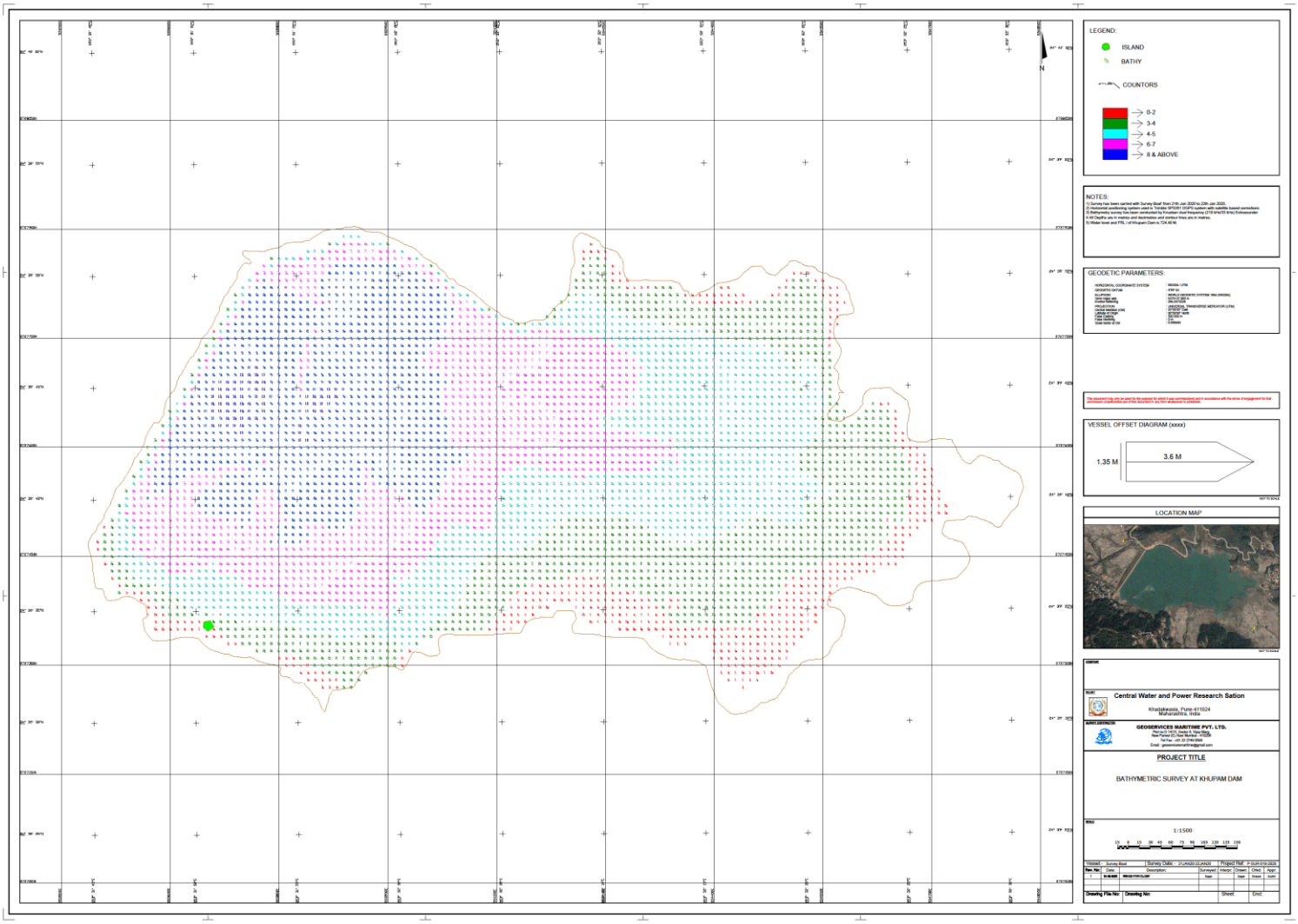
VIII Irrigation Distribution system

Gross command area	:	3500 acres
Cultivable command area	:	1500 Ha
Annual irrigation	:	1000 Ha
Intensity of irrigation	:	193 %
Irrigation DURING Rabi	:	900 acres

IX Length of Main Canal

Right	:	10 Km
Left	:	5 Km

Annexure: 2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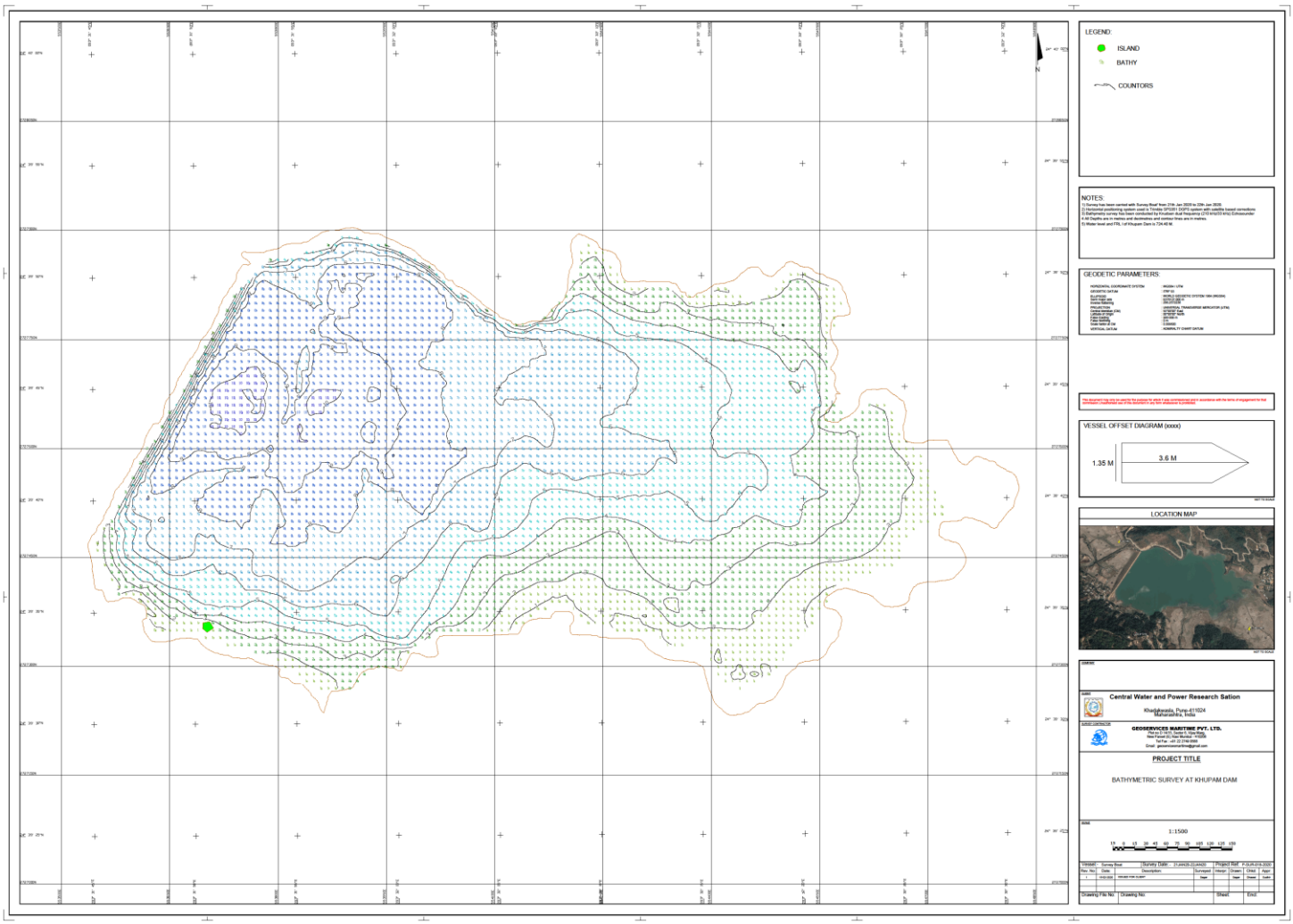
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Khadakwasla, Pune-411024
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