

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

1.0 INTRODUCTION

Singda Dam is a multipurpose project which is constructed across the Singda River in Kadangband. It is located at about 19 km West of Imphal in Manipur. The purpose of this dam to cater the needs of drinking water and water supply for irrigation to most part of Imphal city and its nearby surrounding. It is one of the highest earthen dam in India, constructed by National Projects Construction Corporation Limited (NPCCL) and completed in the year 1995. The dam is 490 m long and 60 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 Singda Dam Project – Salient features

The construction of the dam started in the year 1975 and completed in 1995 under the revised project cost of Rs .6814.00 lakh. The main objectives of the dam are to provide drinking water to greater Imphal and a proper irrigation facility to its nearby area. The view of Singda dam is shown in Photo 1. The Chute spillway of Singda dam is shown in Photo 2. The Google image of Singda dam with data logging points is shown in Photo 3.

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

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Photo 1: Singda Dam down-stream side



Photo 2: Spillway of Singda dam

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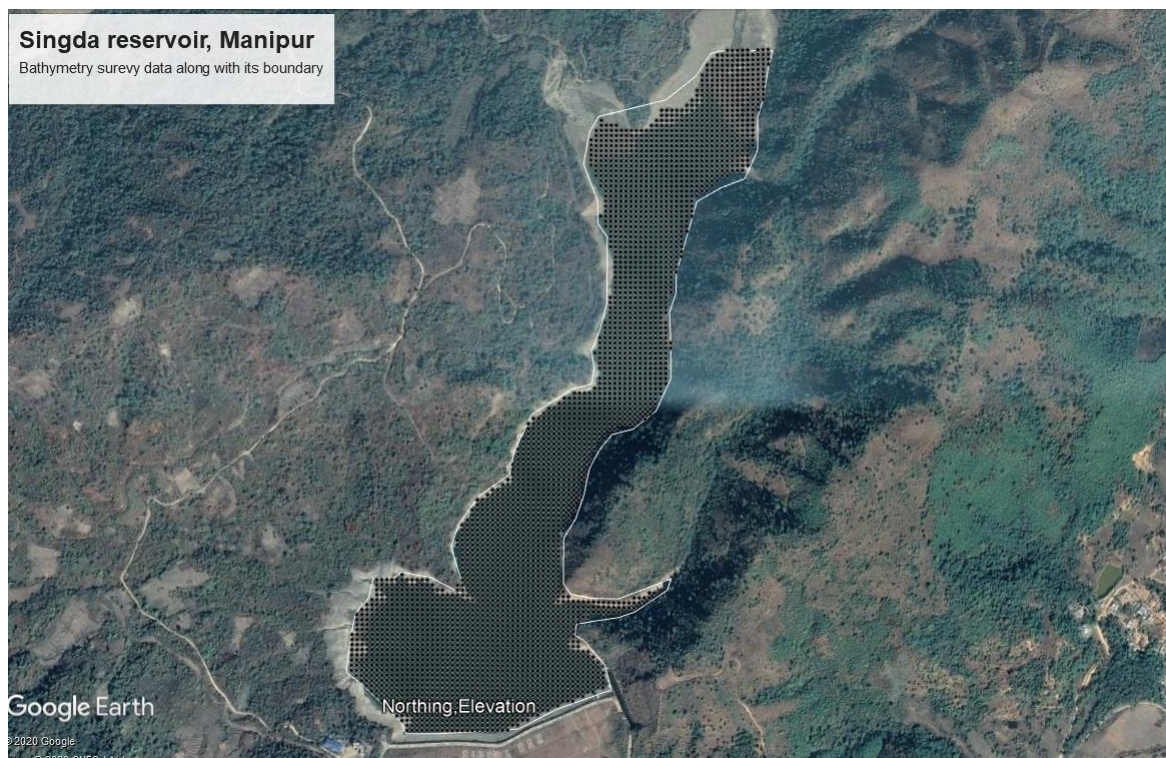


Photo 3: Google image showing the Singda reservoir

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



Photo 4: Upstream view of Singda dam

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Shri Rohit Ahanthem, Superintending Engineer, Irrigation Circle-II, WRD, Govt. of Manipur Shri T. Paokai Haokip, Ex. Engineer, 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 16th to 18th 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 Singda 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.

The purpose of study was 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.

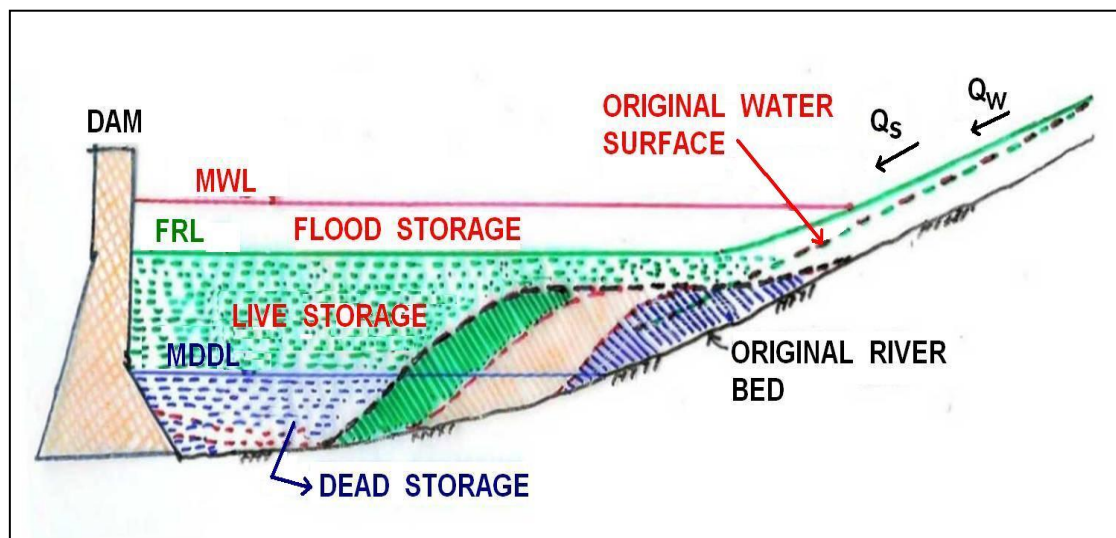


Fig.6: Schematic showing Sedimentation of a Reservoir

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.

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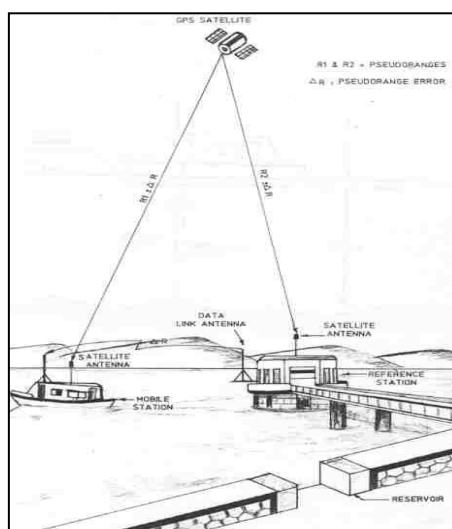


Fig.7: DGPS technique in Survey activity

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

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4.0 INSTRUMENTATION SYSTEM DEPLOYED DURING SURVEY

The survey was done at EL 904.10 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 echosounder (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.

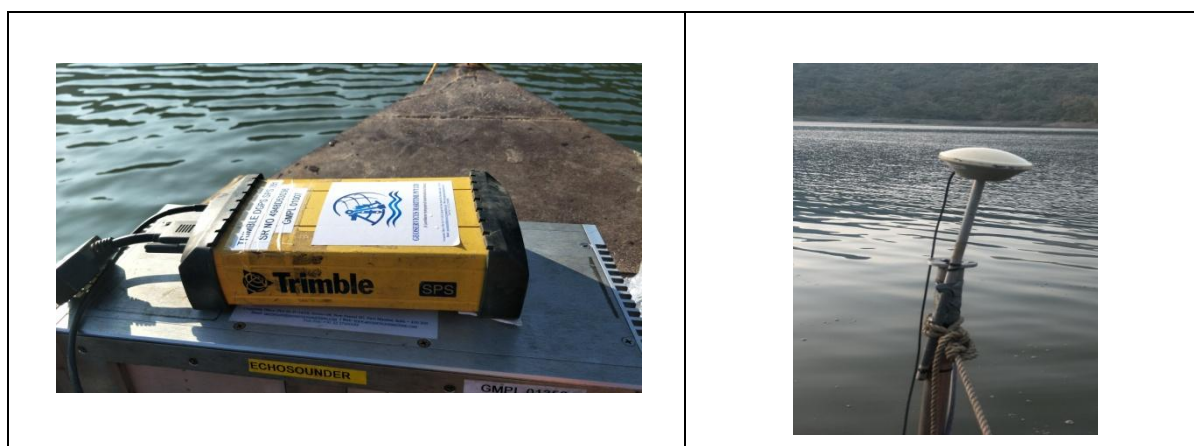


Fig.9: DGPS with antenna

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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 Glonass 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.

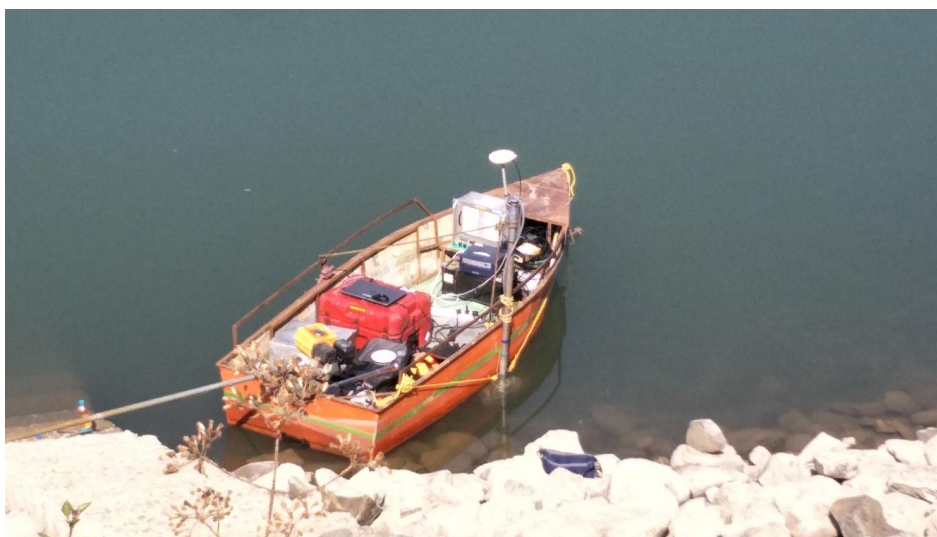


Fig.10: Survey Boat with GPS Antenna with Mechanical Fixture for GPS

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.

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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

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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.

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



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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 4.796 MCM and corresponding area is 0.325 sq .km and at FRL of 909.5 m with help of triangular interpolation the volume is 6.429 MCM. The Table 1 shows the volume and area correspond to different elevation.

Table 1

Sr. No.	Elevation (in m)	Volume (In M.cum)	Area (In Sq Km)
1	872.5	0.0000	0
2	873.5	0.0043	0.005
3	874.5	0.0150	0.0212
4	875.5	0.0412	0.0308
5	876.5	0.0760	0.0388
6	877.5	0.1176	0.0444
7	878.5	0.1645	0.0494
8	879.5	0.2163	0.05437
9	880.5	0.2733	0.05797
10	881.5	0.3366	0.0672
11	882.5	0.4091	0.0776
12	883.5	0.4911	0.0862
13	884.5	0.5828	0.0955
14	885.5	0.6820	0.1053
15	886.5	0.7919	0.1143
16	887.5	0.9110	0.1234
17	888.5	1.0390	0.1335
18	889.5	1.1780	0.1424
19	890.5	1.3250	0.1515
20	891.5	1.4840	0.1627
21	892.5	1.6540	0.1742
22	893.5	1.837	0.186
23	894.5	2.033	0.1984
24	895.5	2.243	0.2115
25	896.5	2.468	0.2244
26	897.5	2.7070	0.2369
27	898.5	2.960	0.2492
28	899.5	3.230	0.2624
29	900.5	3.516	0.2771
30	901.5	3.823	0.2899
31	902.5	4.144	0.2995
32	903.5	4.470	0.316
33	904.5 (During Survey)	4.796	0.325



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After necessary interpolation of the data the different graphs have been plotted, Volume - Elevation and Area -Elevation curve, are shown in Figs. 13 and 14.

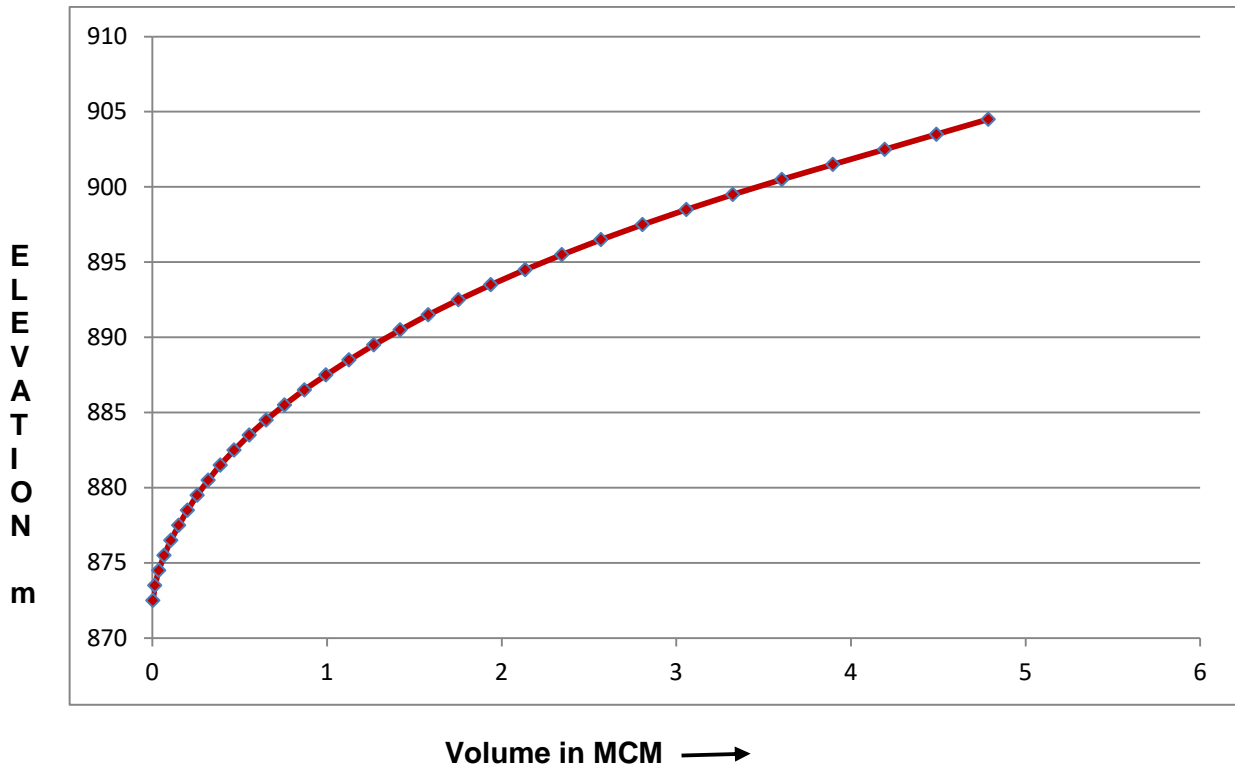


Fig. 13: Elevation- Capacity curve of Singda reservoir

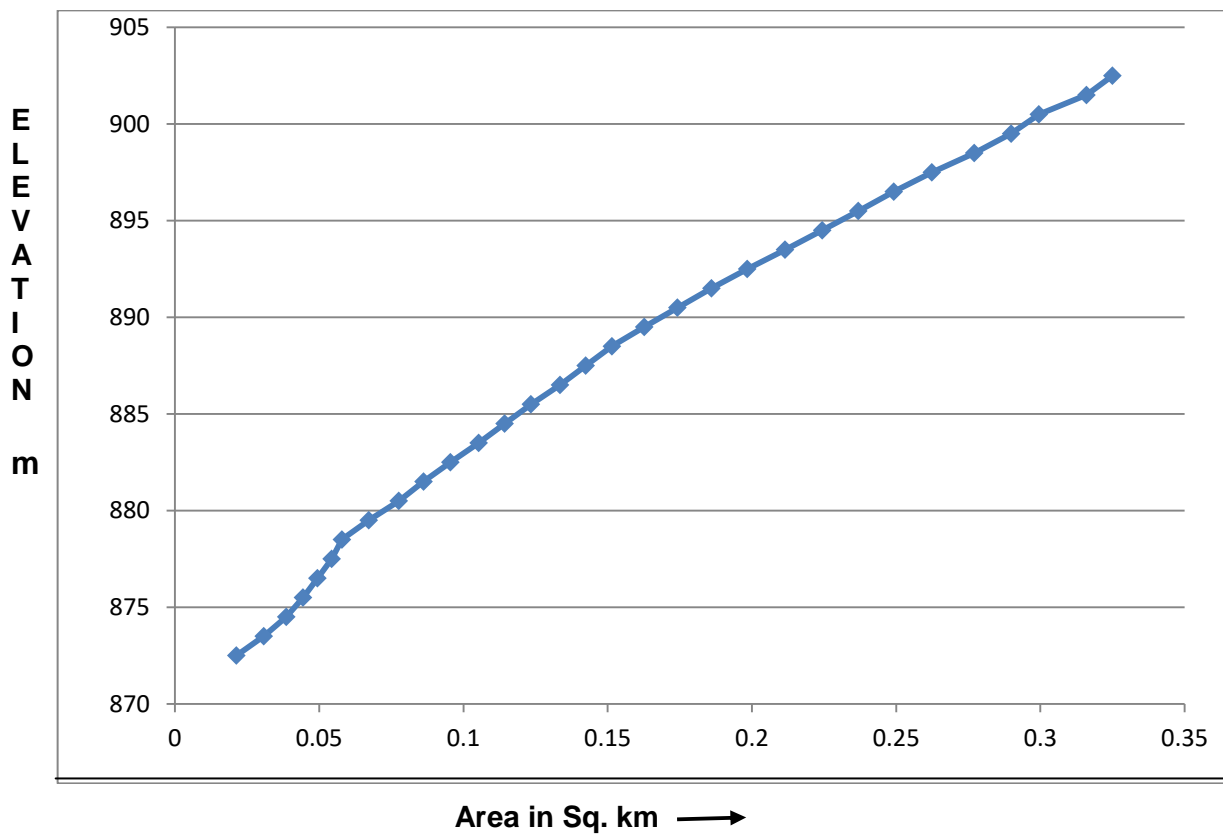


Fig. 14: Elevation- Area curve of Singda reservoir



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The Area-Capacity curve of Singda reservoir is shown in Fig. 15.

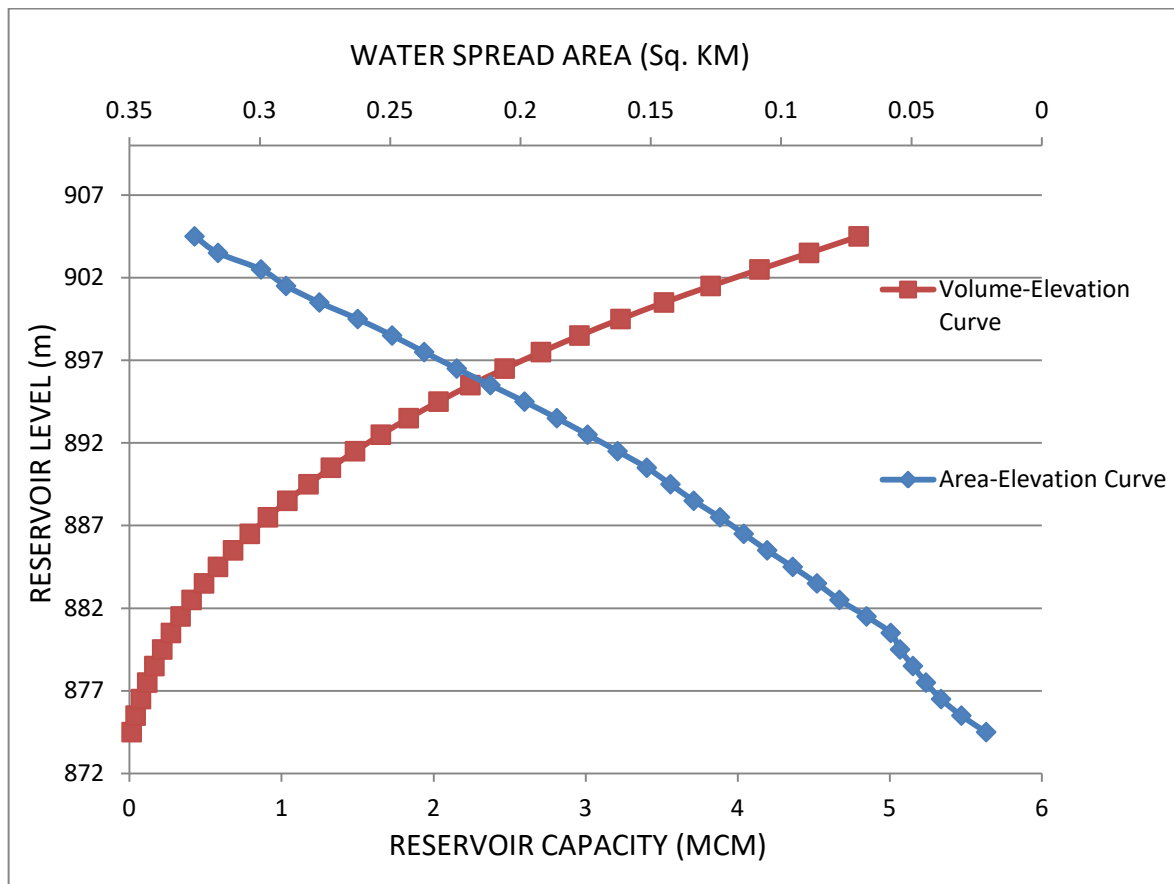


Fig. 15: Area-Capacity curve of Singda reservoir

The Surface map is shown in Fig. 16. The Elevation- Contour map is shown in Fig. 17. The contour plot is enclosed in Annexure 2 and depth profile plot is enclosed in Annexure 3.

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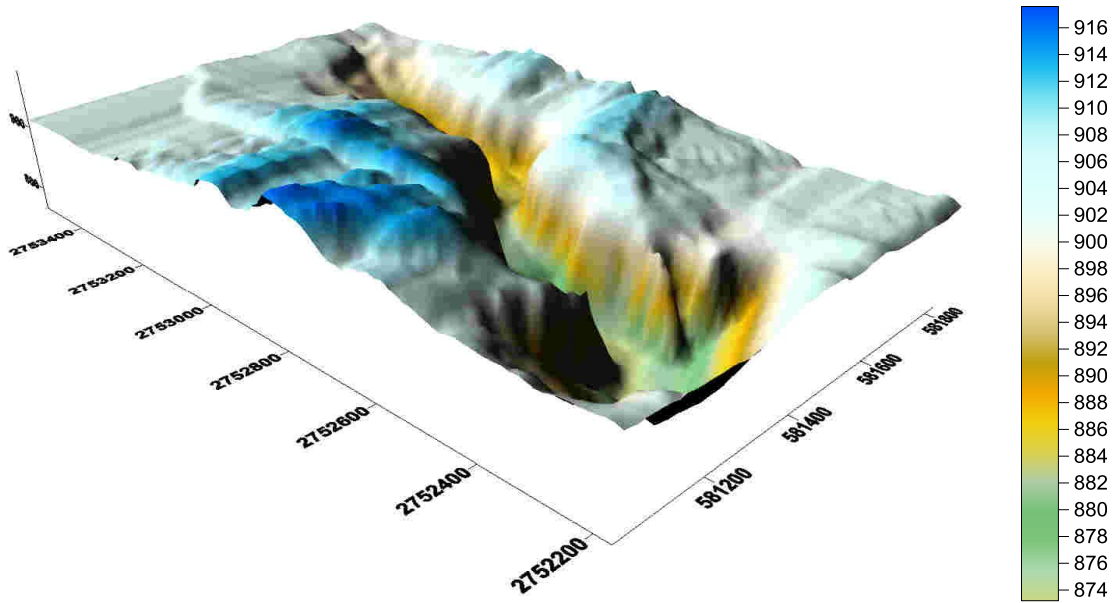


Fig. 16: Elevation- Surface map

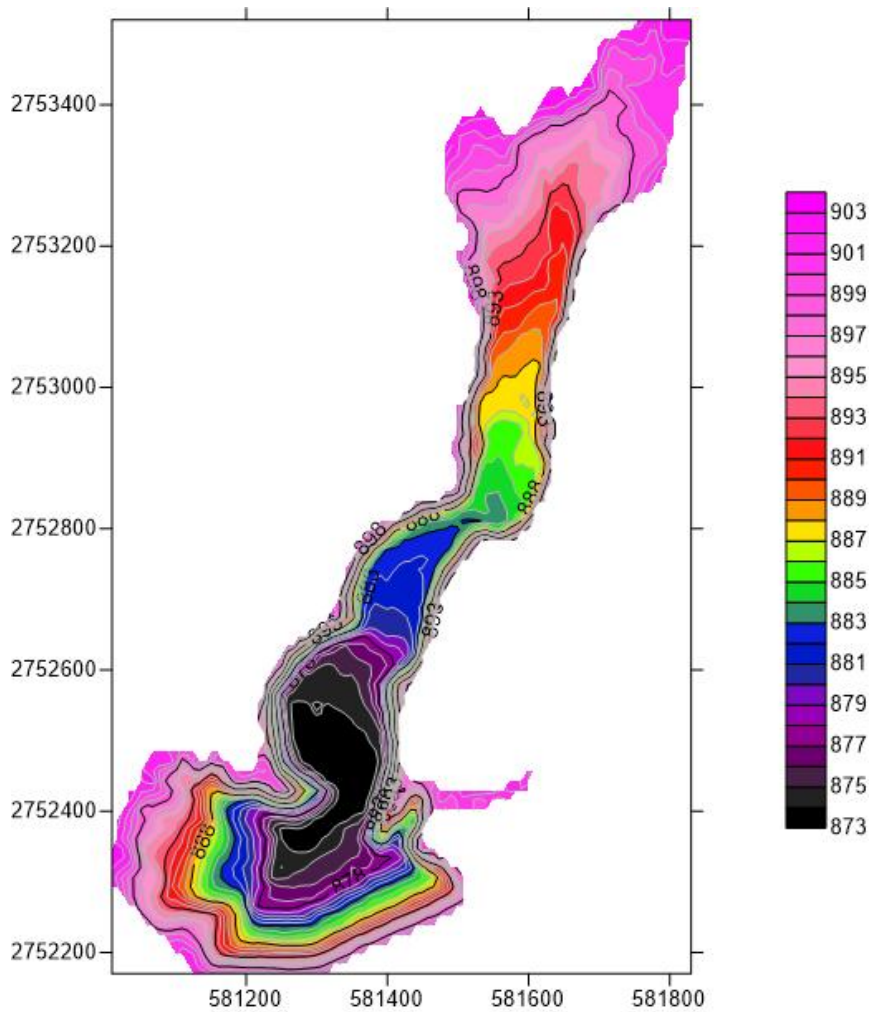


Fig. 17: Elevation- Contour map

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It was observed that on river left bank bank, in some area of hill there is large soil erosion which is shown in Fig. 18. This is contributing substantial sediment in the reservoir.



Fig. 18: Soil erosion at river left bank hill.

- By using IBS system, the reservoir gross storage capacity at El 904.50 m during survey is calculated 4.796 M.CM for a water spread area of 0.325 sq. km.

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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	904.50 m (During CWPRS survey)	4.796	0.325	7.243	34

With the help of extrapolation method and iteration methods, It is estimated, that the reservoir live storage capacity at FRL 909.5m is 6.43 MCM at a water spread area of 0.439 sq.km.

When compared with original gross storage design data which was 9.71 MCM, there is a reduction of 3.28 MCM i.e. 34 % in the gross storage capacity of the reservoir at FRL 909.50 m.

When compared with original live storage which was 8.51 MCM, there is a reduction of 2.13 MCM i.e. 25 % in the live storage capacity of the reservoir at FRL 909.50 m. There is an average annual loss in the live storage capacity of 1% over a period of 25 years from the date of impounding of the dam i.e. 1998 year.

Hence, the amount of silt deposited is 3.28 MCM as compared with gross storage capacity. During the first survey conducted by CWPRS after the construction of Singda dam, it was observed that there is a substantial loss in gross storage capacity during a span of 25 years. From the above observations, it is suggested to de-silt the reservoir in order to restore the dam's original storage capacity. This will increase the life span of dam and will cater the need for which it was constructed.

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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.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 has extended their support in providing all necessary arrangements required for carrying out the hydrographic survey. We are also thankful to M/s Geoservice Maritime limited, Navi Mumbai for sparing the latest bathymetric equipment for this survey work.



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Annexure: 1

I Location of Dam

Dam site	:	Across Singda river about 19 km from Imphal
State	:	Manipur
River	:	Singda
Longitude	:	93° 48' 24" East
Latitude	:	24° 52' 30" North

II HYDROLOGY

Catchment area upto dam site	:	25.30 sq.km
Average annual rainfall	:	1600 mm/63 inches
75 % dependable max discharge	:	7.08 m ³ / sec
Run off factor	:	51.58 %

III Reservoir

Gross storage capacity (at EL 909.50 m)	:	9.71 MCM
Live Storage Capacity	:	8.51 MCM
Dead storage capacity (at EL 876.00 m)	:	1.21 MCM
F.R.L.	:	909.50 m
M.W.L.	:	912.18 m

IV Main Dam

Type	:	Zoned earth fill dam
Total length of earth dam	:	490 m
Max. Height of dam	:	60 m
Top of dam	:	EL 914.50 m

V Spillway

Type	:	Chute spillway
Length	:	330.00 m
Capacity	:	557.84 m ³

VI Intake

Intake level	:	902 m, 892 m, 878 m
Intake capacity	:	70 cusecs



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VII Irrigation Distribution system

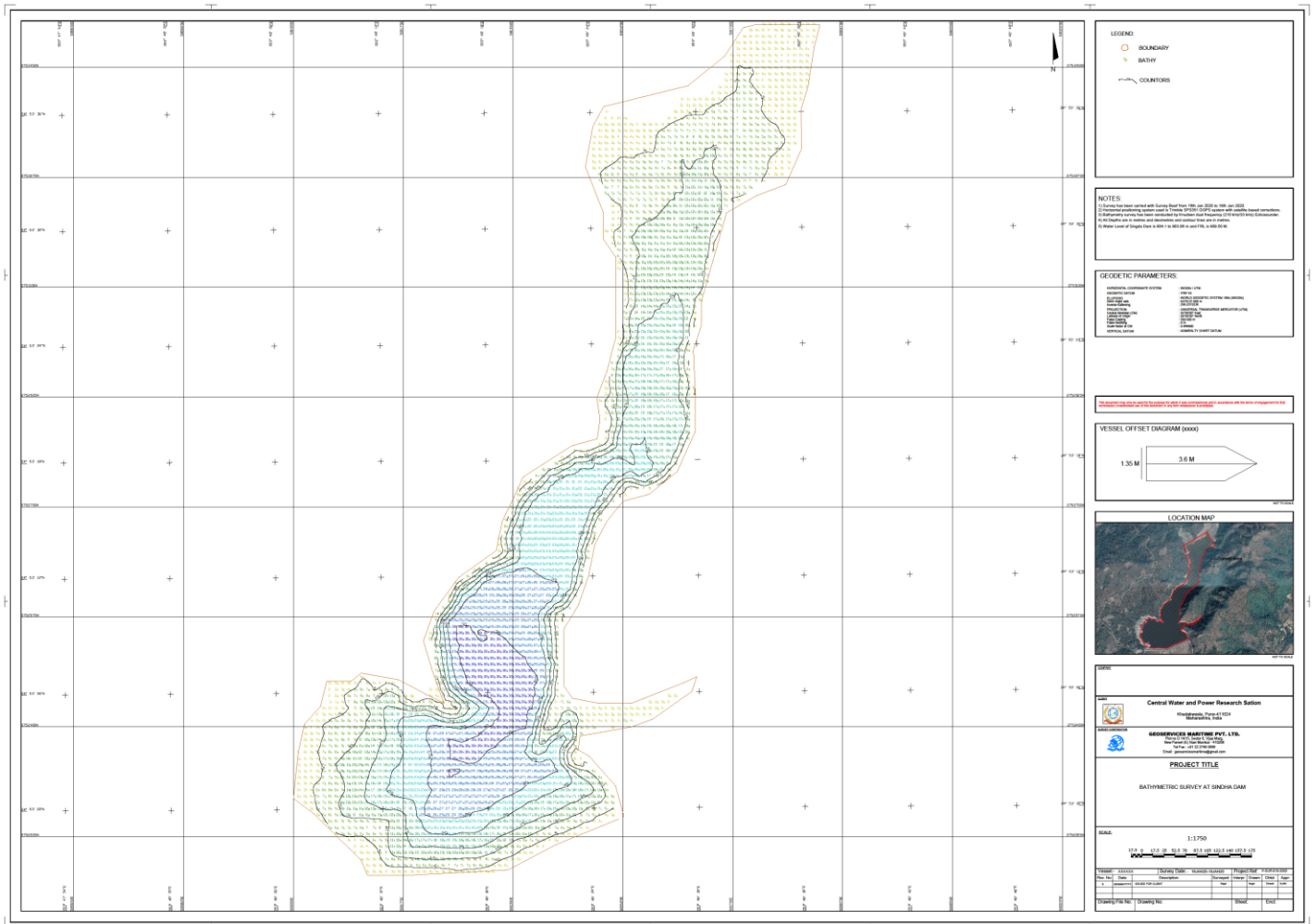
Gross command area	:	14000 Acre
Cultural command area	:	6000 Acre

Annual irrigation	:	10250 Acre
Intensity of irrigation	:	171 %



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Annexure: 2



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

Annexure: 3

