ASSESSING RESERVOIR CAPACITY USING ADVANCED HYDROGRAPHIC SURVEY TECHNIQUES

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ABSTRACT

Sedimentation of reservoirs is a matter of serious concern to water resources planners and engineers since storage capacity is rapidly depleting. Sedimentation not only occurs in the dead storage as intended but also starts in the upstream reached of reservoir encroaching into the live storage capacity. This impairs the planned functions and benefit of the reservoir. Assessing the storage capacity of the reservoir at periodical intervals is of vital importance, since it is observed that the rate of sedimentation in many reservoirs is higher than the rate considered during the planning stage. Bathymetric survey is a direct method for assessment of sediment deposition and its distribution in the reservoir of the dam. Various techniques can be used for bathymetric surveys using advanced position fixing equipments, multi-beam and single beam echo sounders and sub-bottom profilers.

The present paper discusses the bathymetric surveys carried out for one of the largest storage reservoirs in India. The survey was conducted using both single beam and multi-beam sonar depth sounder. Since the reservoir has huge storage capacity, single beam echo sounder was used along the predefined transect to measure the depth. The updated storage capacity of the reservoir was computed based on the measured data. The mapping of sediment deposition in the vicinity of dam and intake is very important. Hence, the multi-beam sonar that gives the detailed floor bed below the water surface was used along the main river and near the intake.

Keywords *: hydrographic survey, multi-beam, Single beam, reservoir capacity, reservoir sedimentation*

1. INTRODUCTION

Dam construction breaks the sediment balance in a natural river, creating an impounded river reach. As the water level rises, the flow speed decreases, and so does the sediment transport capacity. Therefore, the reservoir will gather sediment and lose capacity until a balance is once again achieved, normally after the sediment fills up the impoundment (Morris & Fan, 1998). The worldwide loss of storage caused by sedimentation each year is greater than the increased capacity from newly built reservoirs. Continual sedimentation can no longer assure reservoir capacity, flood control, power generation, irrigation, and other benefits related to the storage capacity. Regarding power generation, when the reservoir sedimentation reaches a high level, the energy production will decrease. An estimated value of 0.5–1% of the global reservoir storage is lost each year, while the sedimentation rate varies between 0.1% and 2.3%. In India, it is observed that the rate of sedimentation in the reservoirs constructed in the west flowing rivers upto Narmada is about 0.861 mm/ year (6.51 Ha. m. /100 Sq km /year) (CWC, 2015).

Hydrographic surveys are the most accurate method to measure the distribution pattern of sediment and the loss in storage capacity.

Zhong-Luan Yan explained the advantages of using Multi Beam Survey (MBS) in determining the loss in storage capacity after major earthquake. The bathymetric survey is conducted in the Zpingpu reservoir on the river Min. It was observed that Multi Beam Survey was able to capture the changes in bathymetry in detailed aiding in assessing in loss of reservoir capacity (Zhong-Laun et al., 2018).

Sheng explored the possibility of combined survey approach of getting aerial survey for topographic data above the water surface level and Multi Beam Survey to obtained the bathymetric data. The survey was performed for Tongjiqiao reservoir of Zhejiang Province in China. The novel approach in survey will help in reducing the survey time considerably (NAN S. et al. 2015).

Benjamin used spatially referenced hydro acoustic depth data to assess the survey resolution required to obtained accurate volume measurements. The study showed that the survey conducted with 50m transact was about 99% accurate compared to modelled volume. This accuracy is reduced by about 4.2% when survey is conducted at 300m transact

with near shore transact. The study provides some guidelines in finalizing the transact spacing in Single Beam Survey (SBS).

The present paper describe the hydrographic survey conducted for Indira Sagar Project, Madhya Pradesh using both SBS and MBS

2. INDIRA SAGAR PROJECT

The Indira Sagar project is a multipurpose project on Narmada river in the district of Khandwa, Madhya Pradesh. The project includes 92 m high and 653 m long concrete gravity dam, with a surface Power House of 1000 MW installed capacity and 249 km long canal to provide irrigation in 1.23 lakh hectares of Cultural Command Area (CCA) in the districts of Khandwa and Khargone. The gross storage capacity of the reservoir is 12211 (Mm3) at FRL 262.13 m. The water spread area at FRL is about 913.48 Sq km. The dead storage capacity of the Reservoir is 2467 (Mm3) at Minimum Draw Down Level (MDDL) 243.23 m. Filling of Indira Sagar dam started in the year 2003 and project was commissioned in 2005 (CWPRS, 2016). The location of the project in the Google image is shown in the Figure 1a and Figure 1b shows the view of project from the upstream.

Figure 1a : Google Image of Indira Sagar reservoir

Figure 1b : Indira Sagar dam view from upstream

3. DATA ACQUISITION TECHNIQUES

Single Beam Echo Sounding Technique: The idea here is to use various echo-sounding frequencies from the single Echo-sounder. Lower the frequency, the better the impulses penetrate the surface. Consequently, the impulse from a 210 kHz sounder is reflected by sediment density of 1.2 kg/l, whereas the impulse from a 33 kHz sounder is reflected by a density of 1.4 kg/l. It is thus possible, by varying the frequency, to obtain a return spectrum, which can in turn be used to characterize the various layers of sediment as shown in Figure 2.

(i) Multi beam Echo Sounding Technique: A Multi beam Echo Sounder is a type of sonar that is used to map the river/ reservoir. Like other sonar systems, Multi-beam systems emit sound waves in a fan shape. The amount of time it takes for the sound waves to bounce off the river/reservoir bed and return to a receiver is used to determine water depth. Unlike other sonars, multi-beam systems use beam forming to extract directional information from the returning sound waves, producing a swath of depth readings from a single ping.

(ii) DGPS: Differential positioning is the technique or method used to position one point relative to another. DGPS requires two or more GPS receivers to be recording measurements simultaneously. Differential positioning is more concerned with the relative difference in position between two users, who are simultaneously observing the same satellite, than with the absolute position of the individual user.

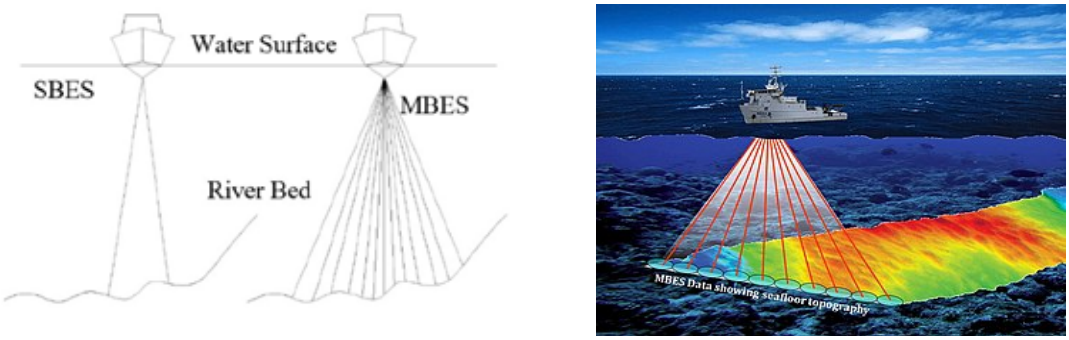

Figure 2 : Single beam and multi beam hydrographic survey techniques

4. METHODOLOGY

The studies pertaining to loss in the reservoir capacity was carried out using bathymetric survey. Single beam dual frequency echo sounding technique was used to determine the different bed levels in the reservoir. This echo sounder was attached to the boat which was moving along the known grid intervals of 200m across entire reservoir, shown in Figure 3. DGPS system (Fig. 4) was also attached to the boat with the help of which real time positioning was established. The depth for corresponding points was obtained by Single beam echo sounder. With the help of this Single beam dual frequency Echo Sounding technique, the point data (Long, Lat & depth) was collected on the established grid for the entire reservoir area. The analysis of the data was carried out to generate the contour map and digital elevation model of the reservoir. Reservoir capacity at various elevations was then computed. The capacity of the reservoir at the time of impoundment was computed based on the bench mark survey (original survey) and from the above two capacities, the losses in the storage was estimated.

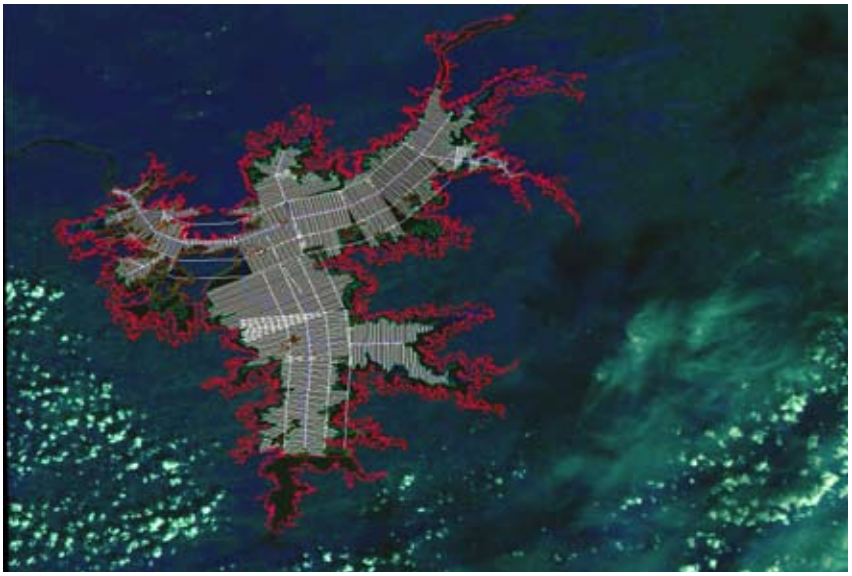

Figure 3 : Grid prepared over entire reservoir of Indira Sagar Project

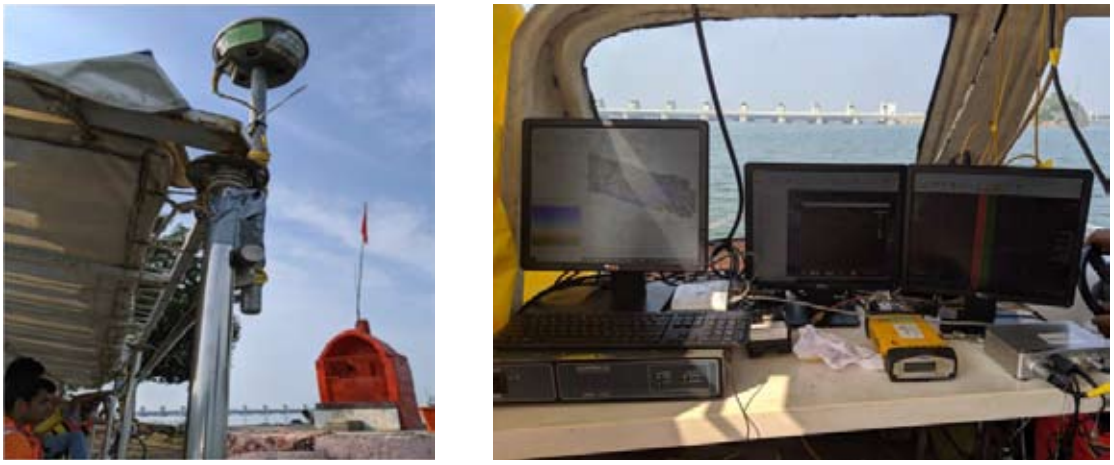

Figure 4 : DGPS and other Survey equipments

Hydrographic survey with Multi beam was also conducted near the dam and intake for 1:1 mapping of the reach as this area is crucial from sediment deposition point of view. Before the actual survey work, the sensor of multi beam echo-sounder was calibrated with respect to (i) Sun's Azimuth (ii) Angle of Vessel with respect to Northing and Easting (iii) Depth is calibrated with the help of plate test and single beam echo-sounder. In the present study, Norbit Multi Beam Survey system was used for bathymetric survey.

5. RESULT AND DISCUSSION

The data acquired from the single beam was analysed in the GIS software to prepare the detailed contours and digital model to assess the losses in the capacity. .The longitudinal profile of the pre-impounding and 2019 survey is shown in Figure 5.

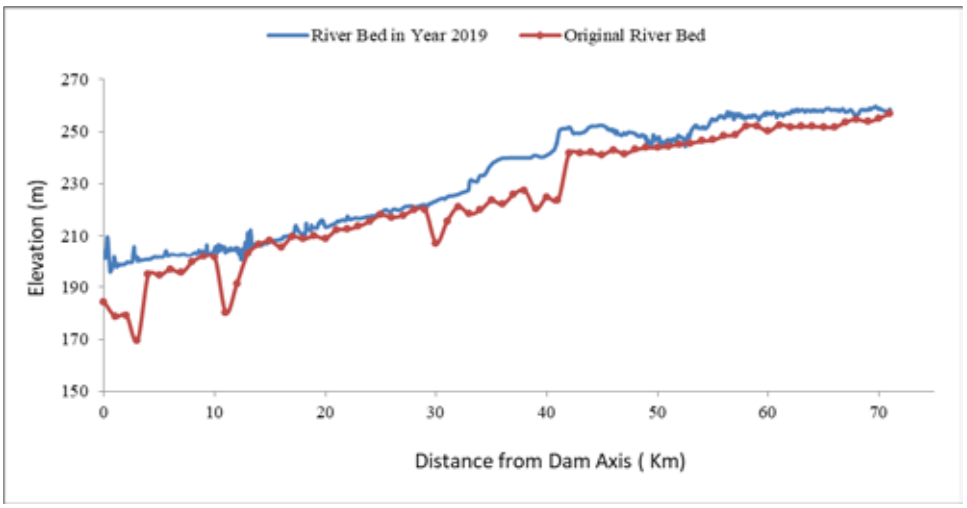

Figure 5 : Comparison between original and bed profile of 2019

The results indicate the delta front of deposition has advanced to a distance of 35 km from dam axis. The depth of sediment deposit at this location is about 14 m. The data acquired using Multi beam survey was analysed in GIS software and 1:1 mapping of the area near the dam structure is shown in Figure 6. The Digital Elevation Model (DEM) of the complete reservoir area is shown in the Figure7 and three-dimensional view depicting the bathymetry of river Narmada near the dam area is shown in Figure 8.

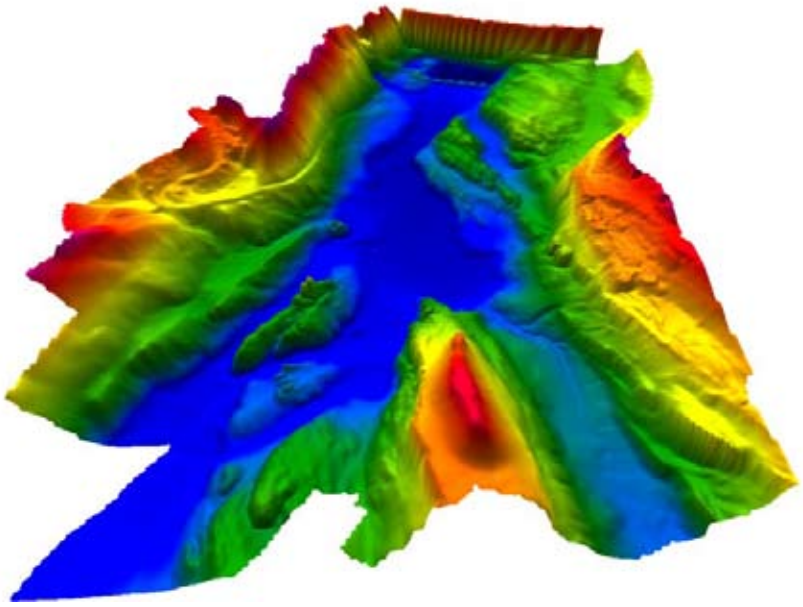

Figure 6 : Three-dimensional view of river bathymetry developed by multibeam bathymetric survey

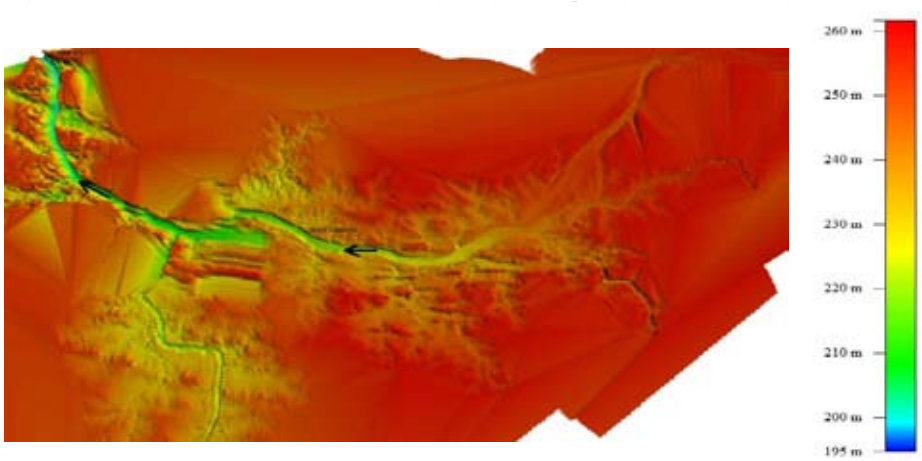

Figure 7 : Digital Elevation Model developed using single beam bathymetric survey

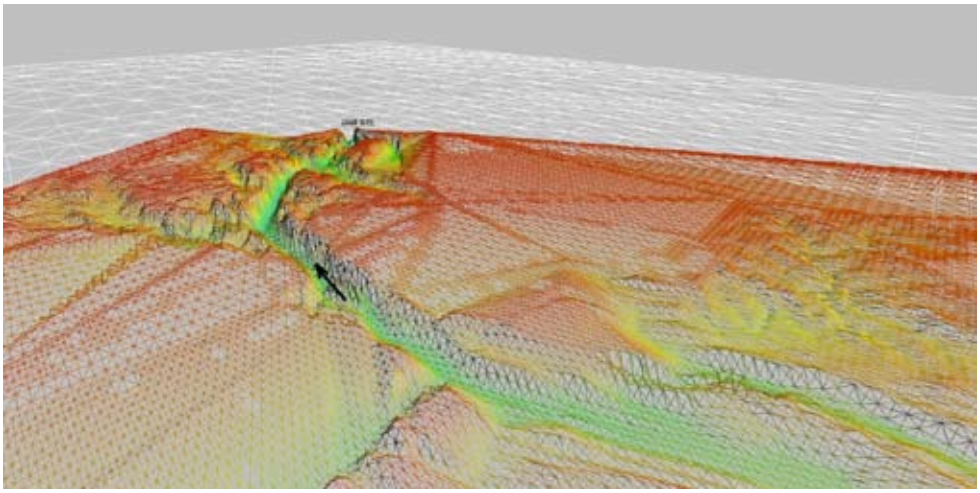

Figure 8 : Three-dimensional view depicting the bathymetry of river Narmada near the dam area

6. CONCLUSION

The combination of single seam and multi beam bathymetric survey was very much suitable for assessing the sediment deposition pattern in storage reservoirs and revising the Elevation- Capacity curve. Multi beam survey of the critical area can provide detailed map of reservoir bed, which can be utilized for optimizing reservoir operation.

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