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# CAPACITY ASSESSMENT OF KUNDALI RESERVOIR DISTRICT PUNE, MAHARASHTRA, BY HYBRID SURVEY (SRS AND BATHYMETRIC SURVEY TECHNIQUE)

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## ABSTRACT

The reservoirs serve the purpose of irrigation, water supply, flood control, power generation, navigation improvement, recreation, etc. All purposes of the reservoir achieved if it is maintained and operated, managed properly. For proper functioning and operation of the reservoir, elevation-area-capacity curve of the reservoir is the most important physical characteristics. Elevation- Area-capacity curve has significant role in determination of the storage capacity which can be used for assessment of revised capacity and water spread area corresponding to each elevation, reservoir operations, reservoir flood routing. But in India, many reservoirs authorities do not have design Elevation-Area-Capacity curve/table along with other necessary hydraulic information due to which concern authorities are facing the problems regarding reservoir planning, operation and management. The Tata Power Company limited ,the owner of kundali reservoir (dist. Pune) do not have the design Elevation-Area –Capacity curve/Table since impounding year 2001 till October 2020. Hence they consulted this issue with Resources Engineering Centre, Maharashtra Engineering Research Institute, Nashik regarding the problem. As core work of Resources Engineering Centre is assessment of reservoir capacity and to update Elevation-Area-Capacity curve/table, survey of Kundali reservoir taken in hand. Due to non- availability of hydraulic data, it is difficult to carry out the survey only by using Remote sensing technique hence MERI has decided to use DGPS based Bathymetric Survey technique coupled with Remote sensing technique. By using these methods the Elevation- Area-Capacity curve/table is generated for Kundali reservoir. This paper elaborates the necessity of Remote Sensing application in hydraulic studies.

***Keywords:*** *Remote Sensing, Sentinel, ERDAS IMAGINE, Bathymetric survey, DGPS, Kundali reservoir*

## INTRODUCTION

Reservoir management involves allocating available water among multiple uses and users. To know the quantum of available water active storage capacity must be needed. Area-capacity curves are important for defining the active storage capacity of the reservoir thereby can be used in reservoir operation, reservoir flood routing, determination of capacity and water spread corresponding to each elevation. The water spread area and capacity corresponding each elevation, detailed survey has been carried out with Resources Engineering Centre, Maharashtra Engineering research Institute, Nashik. Remote sensing technique coupled with DGPS based Bathymetric Survey technique used for this study. Remote sensing technique is fast, economical, have large spatial coverage and a cost-effective, hence can play a significant role in the identification, measuring, and mapping of land resources. DGPS based Bathymetric survey uses advanced technique for positioning Two or more satellite based GPS receivers are used in differential for positioning and Echo sounder is used for depth measurement. GPS reference receiver is located at a known latitude and longitude position and GPS mobile receiver is located on the survey boat. Both the GPS operate in differential mode through a communication link. The cloud free satellite data throughout reservoir operation in single year is not possible; as such data from different years are needed. Due to non-availability cloud free satellite data, the assessment of entire Gross / Live storage cannot be determined; thus SRS survey is carried out from MDDL to FRL. Due to the limitations of depth for roving the boat, the boat cannot cover 100% water spread. The bathymetric survey can be carried out from RBL to the water level on the date of survey; if the elevation on the date of survey is not at FRL then entire Gross storage assessment cannot be done. Due to this limitations capacity assessment of Kundali reservoir is done by Hybrid survey technique, In which Satellite remote sensing survey is done from RL 650.520 m to FRL 652.000 m. while DGPS based Bathymetric survey is done from RL 629.300 m to RL 651.40 m. Eight images of European Space Agency's (ESA) Sentinel 2A satellite are used. Visual interpretation, unsupervised classification of satellite imageries is done using ERDAS IMAGINE software of version 2010 to calculate water spread area. This Paper covers the study of Kundali reservoir, Maharashtra.

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### *Objectives*

(i) Generating Elevation-Area-Capacity curve for Kundali reservoir,

(ii) Estimating storage capacity from RL (629.300 m)

to FRL (652.000 m),

(iii) To carry out bathymetric Survey to find out the Elevations of water level and Preparation of Elevation - Area - Capacity Table.

## MATERIALS AND METHODS

### *Study area*

Kundali dam is located near Somwadi village in Mawal taluka, Pune district, on the Kundlika River. Dam site is Located at 180 51' 11.48" N to 180 49' 56.17" N latitude and 730 28' 21.41" E to 730 29' 12.97" E longitudes. Location of the dam is shown in Figure 1 as Index Map. Kundali dam serves purpose of Hydro power generation. Catchment area at the dam site is 28.70 sq. km. Dam was completed in the year 2001. FRL of the reservoir is at a level of 652.000 m. Dead storage and live storage capacity of Kundali dam are 0.80 $Mm^3$ and 5.70 $Mm^3$ respectively.

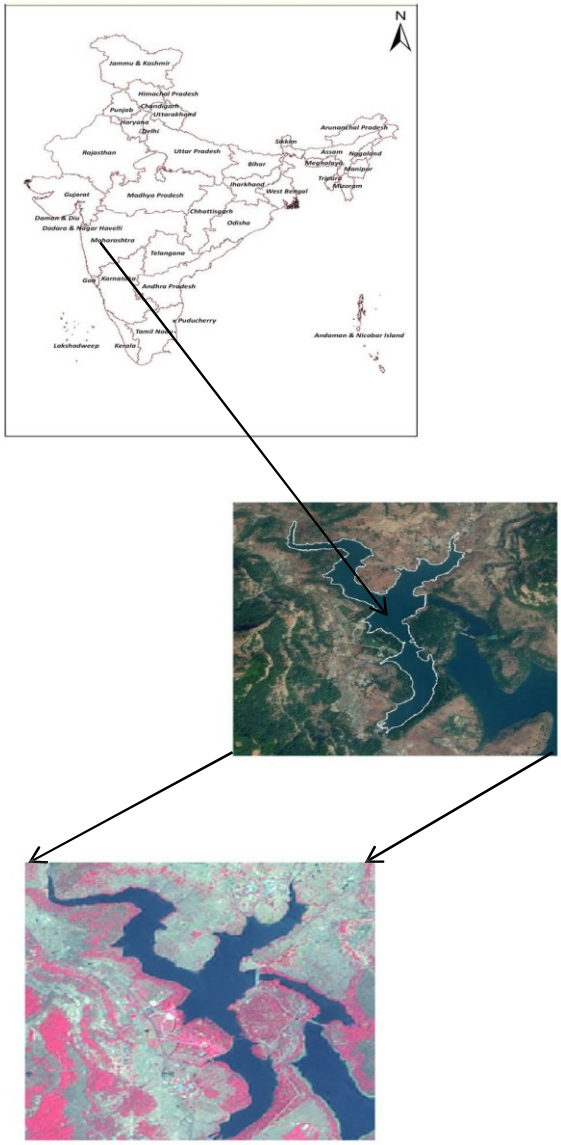



*Fig. 1: Index Map of Kundali reservoir, Maharashtra*

**Field Data**

Index map of reservoir, Latitude and longitude of the reservoir, original area capacity table at 0.1 m interval, salient features of the project and reservoir levels for given dates of satellite pass.

***Satellite data***

Satellite images of Sentinel 2 of European Space Agency (ESA), are used for present study. The details of the satellite data selected for study are shown in Table 1.

**Table 1 : Dates of pass for satellite data**

| Satellite (m) | Date of pass | Elevation |
|---|---|---|
| Sentinel 2 | 09-May-2021 | 650.52 |
| Sentinel 2 | 19-Apr-2021 | 650.70 |
| Sentinel 2 | 20-Mar-2021 | 651.00 |
| Sentinel 2 | 18-Feb-2021 | 651.30 |
| Sentinel 2 | 08-Feb-2022 | 651.40 |
| Sentinel 2 | 24-Jan-2021 | 651.50 |
| Sentinel 2 | 25-Dec-2021 | 651.81 |
| Sentinel 2 | 05-Nov-2021 | 652.00 |
| Sentinel 2 | 09-May-2021 | 650.52 |

**DGPS based hydrographic survey system**

Echo sounder for depth data collection, Computer system with Helmsman's Display, lap top, VHF Radio, Hydrographic survey software for the survey planning, navigation, Data Collection and post processing of the collected data, Motorized boat as mobile station fitted in with Helmsman's Display, lap Top, VHF Radio and Supporting facilities – UPS, batteries, safety equipment's etc.

## METHODS

The methodology for estimation of live capacity of reservoir using remote sensing consists of following major tasks.

(i) Digital data base creation

(ii) Estimation of water-spread area

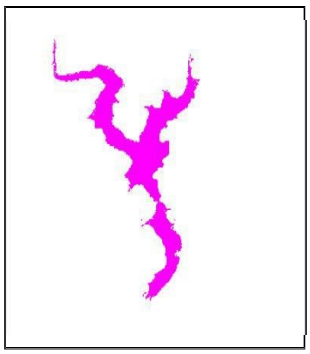
(iii) Calculation of reservoir capacity

**DGPS based hydrographic survey system consisting following methodology**

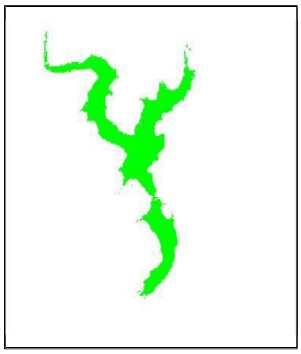
The first step in the DGPS based reservoir survey planning is to select the suitable location for establishing GPS reference station preferably at the known coordinates and from where the GPS antenna will have clear sky view. The survey equipment was mobilized on board "Inflatable Boat". All survey equipment was installed and configured for Single Beam Echo Sounder (SBES) survey. Trimble SPS 855 RTK Rover system receiver system was used during survey.

***Water Spread Area Extraction***

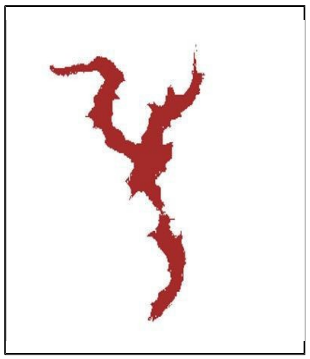
For Kundali reservoir, unsupervised classification outputs were generated for specific scene. The Water Spread Areas (WSA) derived for all the scenes and their corresponding water levels are shown in Figure 3.



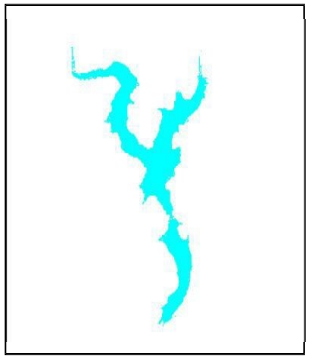
Date: 05-11-2021
(RL 652.000 m)



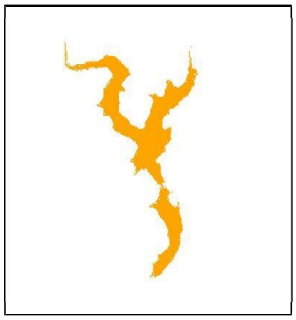
Date: 25-12-2021
(RL 651.810 m)



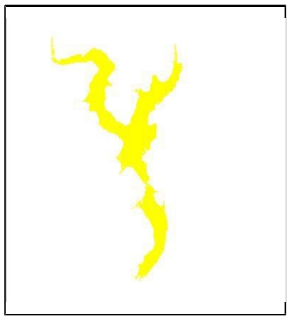
Date: 24-01-2021
(RL 651.500 m)



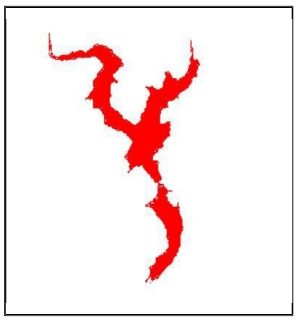
Date: 08-02-2022
(RL 651.400 m)



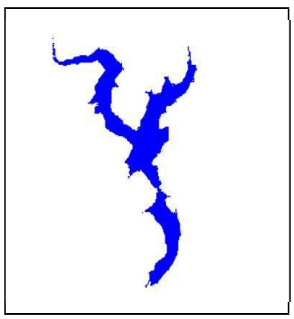
Date: 18-02-2021
(RL 651.300 m)



Date: 20-03-2021
(RL 651.000 m)



Date: 19-04-2021
(RL 650.700 m)



Date: 09-05-2021
(RL 650.520 m)

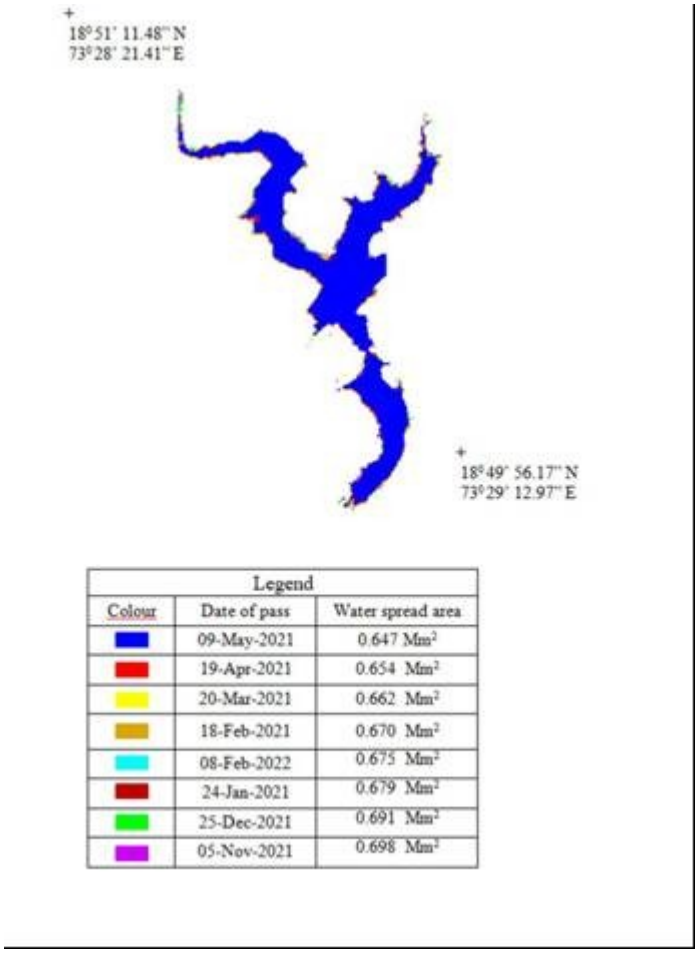



**Fig 3: Water spread areas on different dates of satellite pass**

**Topographic Data Generation**

As the data from SRS & DGPS based Bathymetric survey is available, necessary to merged them for further topographic data generation. This study considered as Hybrid survey. The Hybrid survey utilizes the area extracted from water level 629.300 m to 650.000 m by DGPS based Bathymetric survey technique and for water level 650.520 m to 652.00 m area extracted by SRS technique. These values are as shown in Table 2

**Table 2: Details of elevation & water spread area extracted from SRS & DGPS based Bathymetric survey technique.**

| Survey Technique | Water elevation m | Water spread area $Mm^2$ |
|---|---|---|
| **Bathymetry** | **RL 629.300** | 0.0000 |
| | 630.000 | 0.0023 |
| | 631.000 | 0.0124 |
| | 632.000 | 0.0246 |
| | 633.000 | 0.0390 |
| | 634.000 | 0.0557 |
| | 635.000 | 0.0745 |

| | | |
|---|---|---|
| | 636.000 | 0.0956 |
| | 637.000 | 0.1188 |
| | 638.000 | 0.1442 |
| | 639.000 | 0.1719 |
| | 640.000 | 0.2017 |
| | 641.000 | 0.2338 |
| | 642.000 | 0.2680 |
| | 643.000 | 0.3044 |
| | 644.000 | 0.3431 |
| | 645.000 | 0.3839 |
| | 646.000 | 0.4270 |
| | 647.000 | 0.4722 |
| | 648.000 | 0.5196 |
| | 649.000 | 0.5693 |
| | 650.000 | 0.6211 |
| **SRS** | 650.520 | 0.6489 |
| | 650.700 | 0.6587 |
| | 651.000 | 0.6752 |
| | 651.300 | 0.6918 |
| | 651.400 | 0.6974 |
| | 651.500 | 0.7030 |
| | 651.810 | 0.7205 |
| | FRL 652.000 | 0.7314 |

***Generation of Second Order Polynomial Equation***

As per the Table 1, the water spread area is plotted against the elevation which will give a polynomial equation of second order with a constant (R square) which is as fallows $y = 0.0011x2 + 0.0074x - 0.0034$ $R^2 = 0.9986$ (R = Coefficient of co-relation) Where x = Elevation difference in meters y = Water spread area in $Mm^2$

***Water Spread Area at Regular Interval***

Water levels on the dates of pass for selected satellite data are not available at regular interval. However to get WSA values at regular interval of elevation, area-elevation curve is plotted for the reservoir and a second order polynomial has been fitted. The areas at an elevation interval of 1 m are computed from this best fit equation. These values are given in Table 3

***Calculation of reservoir capacity***

Computation of reservoir capacities at different elevations have been derived using following formula

Where V is reservoir capacity between two successive elevation of h1 and h2

H is the elevation difference, H = (h1 – h2)

A1 and A2 are areas of reservoir water spread at elevation h1 and h2 respectively.

The cumulative live capacities derived at different elevation have been shown in Table 3.

Elevation area curve is shown in Figure 4 and tabulated in Table 3. Elevation capacity curves is shown in Figure 5 and tabulated in Table 3. In Figure 6 elevation-area capacity curve is drawn and tabulated in Table 3.

**Table 3: Areal extent and cumulative gross storage capacity of reservoir at regular interval at 1 m defined from graph form RL 629.300 m to FRL652.000 m**

| Water elevation m | Water spread area $Mm^2$ Year 2021-22 | Cumulative capacity $Mm^3$ Year 2021-22 |
|---|---|---|
| **RL 629.300** | 0.0000 | 0.000 |
| 630.000 | 0.0023 | 0.000 |
| 631.000 | 0.0124 | 0.007 |
| 632.000 | 0.0246 | 0.025 |
| 633.000 | 0.0390 | 0.056 |
| 634.000 | 0.0557 | 0.103 |
| 635.000 | 0.0745 | 0.168 |
| 636.000 | 0.0956 | 0.253 |
| 637.000 | 0.1188 | 0.360 |
| 638.000 | 0.1442 | 0.491 |
| 639.000 | 0.1719 | 0.649 |
| 640.000 | 0.2017 | 0.836 |
| 641.000 | 0.2338 | 1.053 |
| 642.000 | 0.2680 | 1.304 |
| 643.000 | 0.3044 | 1.590 |
| 644.000 | 0.3431 | 1.914 |
| 645.000 | 0.3839 | 2.277 |
| 646.000 | 0.4270 | 2.682 |
| 647.000 | 0.4722 | 3.132 |
| 648.000 | 0.5196 | 3.627 |
| 649.000 | 0.5693 | 4.172 |
| 650.000 | 0.6211 | 4.767 |
| 650.520 | 0.6489 | 5.097 |
| 650.700 | 0.6587 | 5.215 |
| 651.000 | 0.6752 | 5.415 |
| 651.300 | 0.6918 | 5.620 |
| 651.400 | 0.6974 | 5.689 |
| 651.500 | 0.7030 | 5.759 |
| 651.810 | 0.7205 | 5.980 |
| **FRL 652.000** | 0.7314 | 6.118 |

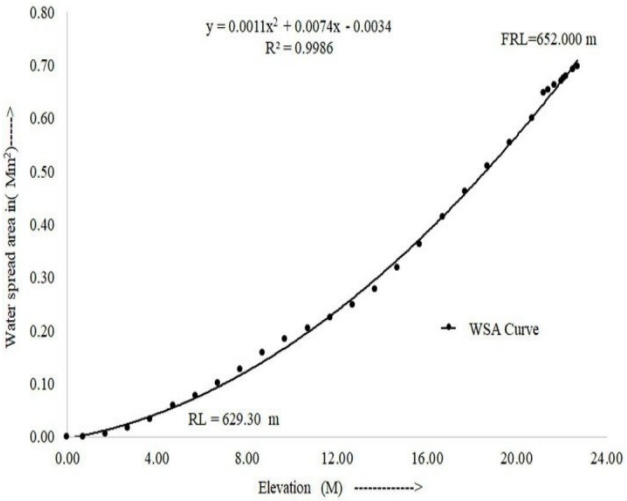



**Fig 4: Elevation-Area curve for Kundali reservoir, Maharashtra**

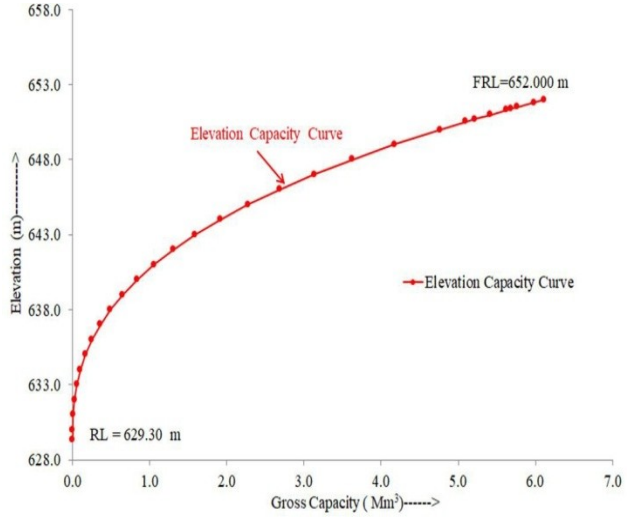



**Fig. 5: Elevation-Capacity curve for Kundali reservoir, Maharashtra**

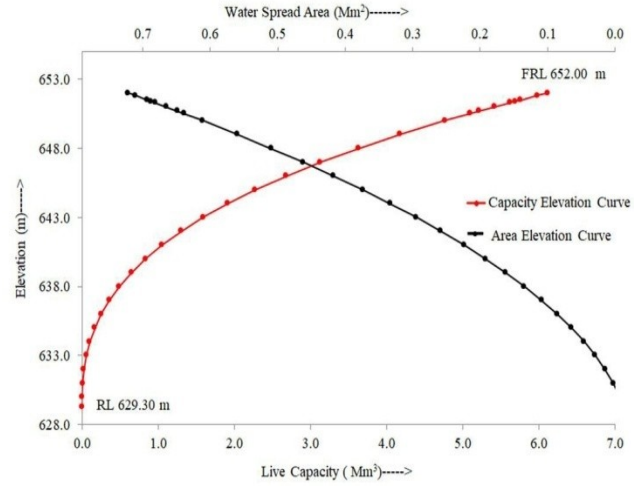
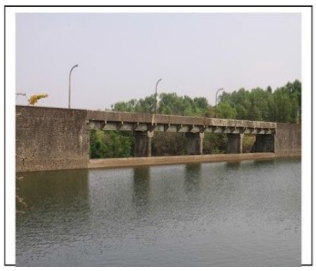



**Fig. 6: Elevation - Area - Capacity curve for Kundali reservoir, Maharashtra**

**Ground Truth Data Collection**

For Kundali reservoir, first field visit has been carried out on 27th November 2020, reservoir level on the day of visit was observed 652.000 m (FRL). Second field visit of the reservoir has been carried out on 24th January 2021, 651.50 m water level observed on that day. Third field visit of the reservoir has been carried out on 19th March 2021; reservoir level on the day of visit observed 651.000 m and Fourth field visit of the reservoir has been carried out on 12th January 2022; reservoir level on the day of visit observed 651.700 m respectively. Ground truth scenario shown by following photographs.

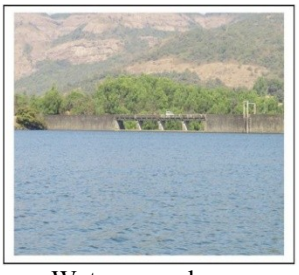


Dam view

Water spread area

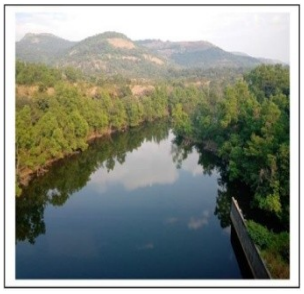
GPS Reading in Submergence

GPS Reading in Submergence



Water spread area

Gauge level



Dense Forest Surrounding Dam

Vegetation nearby Submergence

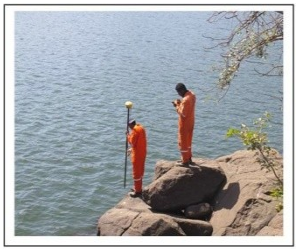
**Bathymetric Survey Supervision**

Bathymetric survey supervision of the Kundali reservoir has been carried out on 09th February 2022. The reservoir level on the day of survey was observed 651.400 m. Photographs of Bathymetric surveys are shown in following pictures.

Dam top

Base Station Setup on Dam Top

Installation of Rover with Inflatable aquamarine boat



Reading taken at Water Level 1

Reading taken at Water Level 2

Reading taken at Water Level 3

Reading taken at Water Level 4

Ground truthing team

***Accuracy assessment of Hybrid survey***

As Bathymetric survey carried out below RL 651.40 m and SRS survey RL 650.52 m to FRL 652.00 m in hybrid survey. Overall accuracy of this study is **98.55%.** The details of water spread area extracted by both techniques at particular levels are shown in Table 4.

**Table 4: Accuracy assessment of Hybrid survey**

| Sr. no. | Water Level (m) | Bathymetry Area Ha | SRS Area Ha | Difference | Percentage Accuracy (%) |
|---|---|---|---|---|---|
| 1 | 650.70 | 63.306 | 65.350 | 2.044 | 96.87 |
| 2 | 651.00 | 64.813 | 66.200 | 1.387 | 97.90 |
| 3 | 651.30 | 66.575 | 66.950 | 0.375 | 99.44 |
| 4 | 651.40 | 67.968 | 67.450 | 0.518 | 100.00 |
| **OVERALL ACCURACY** | | | | | **98.55** |

## RESULTS AND DISCUSSION

I. Present Gross storage capacity of Kundali reservoir from RL 629.300 m to FRL 652.000 m is assessed as 6.118 $Mm^3$.

II. It is recommended that Kundali reservoir should be surveyed once in every 10 year for better management of water planning.

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