REPORT ON TOPOGRAPHIC & BATHYMETRIC SURVEY
FOR ASSESSMENT OF RESERVOIR CAPACITY & SEDIMENTATION IN GUHAI
RESERVOIR, GUJARAT, INDIA UNDER NATIONAL HYDROLOGY PROJECT

GMPL REPORT NUMBER: P-SUR-BATHY-009-2020-WRD-GUHAI
SURVEY PERIOD: Bathymetry: 23 JAN TO 27 JAN 2021
Topography: 12 FEB TO 16 FEB 2021

<table>
<thead>
<tr>
<th>Prepared for:</th>
<th>Water Resources Investigation Division, Ahmedabad (Govt. Of Gujarat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client Reference:</td>
<td>Executive Engineer Water resources investigation Division Ahmedabad.</td>
</tr>
</tbody>
</table>
LOCATION MAP

Figure 1.1-1 LOCATION MAP

LOCATION MAP SHOWING SURVEY AREA “GUHAI RESERVOIR”, GUJARAT, INDIA
REPORT ON TOPOGRAPHIC & BATHYMETRIC SURVEY FOR ASSESSMENT OF RESERVOIR CAPACITY & SEDIMENTATION IN GUHAI RESERVOIR, GUJARAT, INDIA UNDER NATIONAL HYDROLOGY PROJECT

DOCUMENT ARRANGEMENT

REPORT OF SURVEY WITH CHART / DRAWING

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1 INTRODUCTION, OBJECTIVE & SCOPE OF WORK

1.1 General

Water Resources Investigation Division (WRD) has awarded the contract to Geoservices Maritime Pvt Ltd (GMPL), Navi Mumbai for carrying out Topographic and Bathymetric Survey at Guhai Reservoir, Gujarat. The survey services provided by GMPL comprise of the provision of well-qualified survey personnel and equipment in order to obtain, interpret and report on acquired topographic & bathymetric survey data at the client specified locations.

This report contains the results of survey as against the scope of work and the methodology adopted to achieve the specifications and schedule of the survey work undertaken at Guhai Reservoir.

1.1.1 LIST OF ABBREVIATIONS USED

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>Central Meridian</td>
</tr>
<tr>
<td>DGPS</td>
<td>Differential Global Positioning System</td>
</tr>
<tr>
<td>CSRS</td>
<td>Canadian Spatial Reference System</td>
</tr>
<tr>
<td>FRL</td>
<td>Full Reservoir Level</td>
</tr>
<tr>
<td>GMPL</td>
<td>Geoservices Maritime Private Limited</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>HDOP</td>
<td>Horizontal Dilution of Precision</td>
</tr>
<tr>
<td>KHz</td>
<td>Kilohertz</td>
</tr>
<tr>
<td>HSE</td>
<td>Health Safety Environment</td>
</tr>
<tr>
<td>MSL</td>
<td>Mean Sea Level</td>
</tr>
<tr>
<td>m</td>
<td>metre</td>
</tr>
<tr>
<td>M Cu. m</td>
<td>Million Cubic metre</td>
</tr>
<tr>
<td>Sq. Km</td>
<td>Square Kilometre</td>
</tr>
<tr>
<td>MDDL</td>
<td>Minimum Draw Down Level</td>
</tr>
<tr>
<td>m/s</td>
<td>meter per second</td>
</tr>
<tr>
<td>ms</td>
<td>milliseconds</td>
</tr>
<tr>
<td>MWL</td>
<td>Maximum Water Level</td>
</tr>
<tr>
<td>QA/QC</td>
<td>Quality Assurance / Quality Control</td>
</tr>
<tr>
<td>Rev</td>
<td>Revision</td>
</tr>
<tr>
<td>RTK</td>
<td>Real Time Kinematic</td>
</tr>
<tr>
<td>SBES</td>
<td>Single Beam Echo Sounder</td>
</tr>
<tr>
<td>TBM</td>
<td>Temporary Bench Mark</td>
</tr>
<tr>
<td>UTM</td>
<td>Universal Transverse Mercator</td>
</tr>
<tr>
<td>WGS 84</td>
<td>World Geodetic System 1984</td>
</tr>
<tr>
<td>WRD</td>
<td>Water Resources Investigation Division</td>
</tr>
</tbody>
</table>
1.1.2 Units

- UTM grid coordinates and all linear measurements expressed in metres (m).
- Angular values expressed in degrees (°).
- Time and dates expressed as “09:00 on 24 Jan 2021”.

1.2 Objective

The client’s objectives were:

i) To estimate and study the sedimentation behaviour of reservoir in different zones including horizontal zones throughout the reservoir as well as vertical zones namely dead storage, live storage and flood storage if any.

ii) To upgrade Elevation-Area-Capacity table and curves of the reservoir at regular intervals.

iii) To emphasize on the importance of conducting hydrographic surveys at regular intervals for better operation and water management of the reservoir.

1.3 Scope of Work

The Scope of work for Geoservices Maritime Pvt Ltd was to mobilise, install, interface, operate all survey systems and provide all required survey personnel to undertake Topographic and Bathymetric survey services at Guhai Reservoir.

The detailed scope of work was:

i) To measure the water depth of the Guhai Reservoir at with respect to MSL.

ii) Line spacing shall be 25 m with continues echo sounding.

iii) Reservoir for water level changes during survey shall be tabulated.

iv) Data processing using HYPACK software shall be used.

v) Topographic survey shall be conducted from FRL water level with reasonable overlap with hydrographic survey.

vi) The area not covered under Hydrographic survey up to Maximum Water Level (MWL) shall be surveyed by taking levels at 25 m interval (25 m x 25 m grid).

vii) To carry out the data processing and interpretation of data and preparing of results, charts and drawings.

viii) Estimation of Sedimentation in the Reservoir shall be calculated if previous data is available.

ix) Gross and Live storage capacity of the Reservoir at every 10 m interval shall be provided.

x) Cross Sections showing the bed profile at 100 m interval shall be prepared.

xi) L-Section of the Reservoir may be prepared with lowest bed level at every survey line.
2  SALIENT FEATURES OF GUHAI RESERVOIR

<table>
<thead>
<tr>
<th>I</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coordinates</td>
</tr>
<tr>
<td></td>
<td>River</td>
</tr>
<tr>
<td></td>
<td>Village</td>
</tr>
<tr>
<td></td>
<td>Taluka</td>
</tr>
<tr>
<td></td>
<td>District</td>
</tr>
<tr>
<td></td>
<td>State</td>
</tr>
<tr>
<td></td>
<td>Nearest Railway Station</td>
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<td>Purpose</td>
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<table>
<thead>
<tr>
<th>II</th>
<th>HYDROLOGY</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Catchment Area</td>
</tr>
<tr>
<td></td>
<td>Mean Annual Rainfall</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>III</th>
<th>DAM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dam Type</td>
</tr>
<tr>
<td></td>
<td>Length of the top of the dam</td>
</tr>
<tr>
<td></td>
<td>Length of earthen dam</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IV</th>
<th>RESERVOIR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MDDL</td>
</tr>
<tr>
<td></td>
<td>FRL</td>
</tr>
<tr>
<td></td>
<td>HFL/MWL</td>
</tr>
<tr>
<td></td>
<td>Gross Storage Capacity</td>
</tr>
<tr>
<td></td>
<td>Dead Storage Capacity</td>
</tr>
<tr>
<td></td>
<td>Live Storage Capacity</td>
</tr>
<tr>
<td></td>
<td>Area at FRL</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>SPILLWAY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type</td>
</tr>
<tr>
<td></td>
<td>Length of Spillway</td>
</tr>
<tr>
<td></td>
<td>Crest Level</td>
</tr>
<tr>
<td></td>
<td>Nos. and Size of Gates</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>VII</th>
<th>HEAD REGULATOR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Location</td>
</tr>
<tr>
<td></td>
<td>Design Discharge</td>
</tr>
<tr>
<td></td>
<td>Nos. and Size of Gates</td>
</tr>
</tbody>
</table>

| Table 2-1 SALIENT FEATURES OF RESERVOIR |
3 EXECUTIVE SUMMARY OF RESULTS

GMPL had mobilised their survey team, equipment and Survey Boat “Aqua Marina” which was deployed in the Guhai Reservoir survey area from 23 Jan to 27 Jan 2021 to acquire bathymetric survey data and Topographic data as per mutually agreed scope and relevant survey specifications.

Trimble DGPS system, SonarmiteEcho sounder (215 kHz) were utilised to acquire the bathymetric data within the Guhai Reservoir area. A value of 1500 m/s was used as the average velocity of sound in water, which was applied in the setup during acquisition. The data so obtained was then processed and contouring was done using Hypack software. Pentax RTK / Geomax Auto level and Tripod were used for topographic survey in the area.

Topographic and bathymetric data was reduced to Mean Sea Level (MSL). All the data is plotted on scale of 1:5000 for Guhai reservoir area.

The DGPS observation were made for about 4.5 Hours at Dam top near spill way. Five Temporary Bench Marks were established, locations of which are easily accessible via Table 5.1-1.

The values depicted in the charts are the elevation with respect to MSL.

- The Minimum elevation within GUHAI reservoir is 157.15 m above MSL and
- The Maximum depth within GUHAI reservoir is 10.24 m.
- Area covered by bathymetric survey is 6.065 Sq. Km
- Area covered by topographic survey is 9.429 Sq. Km

According to recent survey, total area of reservoir at FRL 173 m is 11.082 Sq. Km, corresponding storage capacity is 67.596 M Cu. m and Dead storage at 164.75 m is 6.11 M Cu. m.

The rate of siltation in the reservoir (up to FRL 173 m) during the last 31 years (1990-2021), was found to be 0.037 M Cu. m / year.

The comparison between 1990 and 2021(31 years) data results in a rate of siltation (silt index) of 0.882 Ham/100 Sq. Km/year. Annual percentage loss of gross storage capacity, live storage capacity and dead storage capacity is 0.054%, -0.014% and 0.604% respectively.
RESOURCES FOR SURVEY WORK

4.1 Personnel

Following staff were involved during the survey work.

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amit Singh</td>
<td>Party Chief</td>
</tr>
<tr>
<td>Samraj Dwivedi</td>
<td>Survey Engineer</td>
</tr>
<tr>
<td>Ashish Patil</td>
<td>Survey Engineer</td>
</tr>
<tr>
<td>Abhijith Cherapi</td>
<td>Surveyor</td>
</tr>
<tr>
<td>Rohit Patwal</td>
<td>Land Surveyor</td>
</tr>
</tbody>
</table>

Onshore Project Management and Data QC

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudhir Walia</td>
<td>Project Manager</td>
</tr>
<tr>
<td>KSN Murthy</td>
<td>Survey Manager</td>
</tr>
<tr>
<td>Dhaval Patel</td>
<td>Data Processor</td>
</tr>
</tbody>
</table>

Table 4.1-1 LIST OF PERSONNEL

4.2 Details of Equipment used

Following equipment and survey sensors were mobilised for the Topographic and Bathymetric survey data acquisition carried out at GUHAI reservoir. The equipment setup and configuration diagram are presented in Figure 4.1.

<table>
<thead>
<tr>
<th>Survey Equipment/Systems Used for the Data Acquisition</th>
<th>Description/Make/Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software / Navigation</td>
<td>HYPACK Navigation and Data Acquisition Software</td>
</tr>
<tr>
<td>Positioning</td>
<td>DGPS Trimble DSM 232</td>
</tr>
<tr>
<td>Single Beam Echo Sounder</td>
<td>Sonarmite BTX Echo sounder with Accessories</td>
</tr>
<tr>
<td>RTK</td>
<td>Pentax RTK system</td>
</tr>
<tr>
<td>Auto Level</td>
<td>Geomax Auto Level &amp; Tripod</td>
</tr>
<tr>
<td>Survey Boat</td>
<td>“Aqua Marine” with OBM</td>
</tr>
<tr>
<td>Laptop</td>
<td>Dell Laptops</td>
</tr>
<tr>
<td>Power Supply</td>
<td>12v Battery &amp; Inverter</td>
</tr>
</tbody>
</table>

Table 4.2-1 LIST OF EQUIPMENT USED FOR SURVEY
4.3 Survey Vessel

Survey Boat ‘Aqua Marine’ was utilised for carrying out the bathymetric survey.

4.3.1 Survey Boat Specifications

<table>
<thead>
<tr>
<th>Survey Boat ‘Aqua Marine’ Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length overall</td>
</tr>
<tr>
<td>Breadth moulded</td>
</tr>
<tr>
<td>Draft</td>
</tr>
</tbody>
</table>

Table 4.3-1 SURVEY BOAT SPECIFICATIONS - ‘AQUA MARINE’

4.3.2 Survey Boat Offset Diagram

The location of the various survey sensors on the survey boat ‘Aqua Marine’ is given in the vessel-offset diagram on the chart accompanying this report.

Figure 4.3-1 SURVEY BOAT ‘ AQUA MARINE’ OFFSET DIAGRAM
5  DETAILED METHODOLOGY OF SURVEY

5.1  Mobilisation

The bathymetric survey equipment were mobilised on board “Aqua Marine” on 23 Jan 2021. After successful installation, testing and calibrations of survey equipment, the team proceeded for Data acquisition.

Pentax RTK, Geomax auto level, Tripod and necessary supporting equipment/tools were mobilised for Topographic survey.

All survey equipment was installed and configured for bathymetric Survey on board “Aqua Marine” as per figure given below.

![Figure 5.1-1 SBES SURVEY EQUIPMENT CONFIGURATION DIAGRAM ON BOARD]()}
5.2 Geodesy

The survey operations were conducted in WGS 84 spheroid, Universal Transverse Mercator projection system based on following Geodetic parameters:-

<table>
<thead>
<tr>
<th>Global Positioning System Geodetic Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datum: World Geodetic System 1984 (WGS84)</td>
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<tr>
<td>Spheroid: World Geodetic System 1984</td>
</tr>
<tr>
<td>Semi major axis: a = 6 378 137.000 m</td>
</tr>
<tr>
<td>Semi minor axis: b = 6 356 752.314 245 m</td>
</tr>
<tr>
<td>Inverse Flattening: $1/f = 298.257 223 563$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Local Datum Geodetic Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datum: World Geodetic System 1984 (WGS84)</td>
</tr>
<tr>
<td>Spheroid: World Geodetic System 1984</td>
</tr>
<tr>
<td>Semi major axis: a = 6 378 137.000 m</td>
</tr>
<tr>
<td>Inverse Flattening: $1/f = 298.257 223 563$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Local Projection and Grid Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map Projection: Universal Transverse Mercator</td>
</tr>
<tr>
<td>Grid System: UTM Zone 43 N</td>
</tr>
<tr>
<td>Central Meridian: 075° 00' 00&quot; East</td>
</tr>
<tr>
<td>Latitude of Origin: 0° 00' 00&quot; North</td>
</tr>
<tr>
<td>False Easting: 500 000 m</td>
</tr>
<tr>
<td>False Northing: 0 m</td>
</tr>
</tbody>
</table>

Table 5.2-1 GEODETIC PARAMETERS

5.3 Survey work at Field

5.3.1 Benchmark and Base station setup

The DGPS observation were made for about 4.5 Hours at Dam top near spill way. Five Temporary Bench Marks were established.

The details of Bench Marks are presented in the table below:

<table>
<thead>
<tr>
<th>BM Observation and T.BM. Information _ GUHAI Reservoir South Gujarat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>OBS GUHA</td>
</tr>
<tr>
<td>T.B.M.01</td>
</tr>
<tr>
<td>T.B.M.02</td>
</tr>
<tr>
<td>T.B.M.03</td>
</tr>
<tr>
<td>T.B.M.04</td>
</tr>
<tr>
<td>T.B.M.05</td>
</tr>
</tbody>
</table>

Table 5.3-1 BENCH MARK DETAILS
5.3.2 Topographic and Bathymetric Survey

For topographic survey, Pentax RTK base was used for DGPS observation on OBS GUHA. Four Hrs. of DGPS observations were carried out. Dam authority provided benchmark elevation value of 178.08 m. RTK DGPS Base station was set up at OBS GUHA and configured to transmit the correction. Two rovers receiving RTK corrections from the base took spot level from water level to HFL.

For bathymetric survey, Aqua Marine boat was mobilised. Plan line for survey was prepared parallel to dam axis and at 25 m intervals. Survey boat was run on afore mentioned plan line to acquire position as well as depth.

5.4 Survey Systems

5.4.1 Trimble DGPS:

Trimble DGPS system was used during survey.

- Differential correction signals received on board during survey operations continuously from the Satellite based augmentation system.
- The positioning data as well as heading data received with high reliability and integrity.

Trimble DGPS was the primary positioning system currently used for all the surveys. GMPL has provided, install, operate and maintain a Differential Global Positioning System (DGPS) acceptable to the EIC, which fully covered the site of the works and was constantly in operation during the all the surveys. The age of pseudo- range correctors used in position computation was not exceeded 20
seconds; however, any horizontal positioning interpolation was never exceeded the accuracy. Horizontal Dilution of Precision (HDOP) was monitored, and was never exceeded 2 nominally. Satellite geometry alone is not a sufficient statistic for determining horizontal positioning accuracy. Other variables, including satellite pseudo range residual, were used in conjunction with HDOP to estimate horizontal accuracy. A minimum of four satellites were used to compute all positions, Horizontal and Vertical offsets between the GPS antenna and transducer(s) were observed and applied with a precision better than 0.01m. The system was consisting of master receiving reference station (Base) and DGPS Navigator unit (Rover). The navigator’s units (Rover) were installed on Survey launch. The composition was consisting navigational software, track plotters, data storage facilities, echo sounders, sufficient spares to enable uninterrupted operation of the system to the accuracy specified and on-board computers.

5.4.2 Single beam Echo sounder

The single beam echo sounder ‘Sonarmite BTX’ with an accuracy of 0.01m has deployed and in principle, higher frequency of 215 kHz has operated. Echo Sounder equipment has calibrated daily before and after use, by means of a bar-check in the survey area. The calibration results were found satisfactory.

5.4.3 HYPACK Software

HYPACK is a Windows™-based software package used primarily for hydrographic surveying and data processing.

HYPACK performs all of the tasks necessary to complete Single Beam Echo sounder data acquisition/processing from beginning to end. This all-in-one module provides the surveyor with all of the tools needed to design their survey, collect data, process it, reduce it to w.r.t MSL, and generate final products. Whether collecting hydrographic survey data or environmental data, or positioning a vessel in an engineering project, HYPACK provides the tools needed to complete the job.

This software can be interfaced simultaneously to Echo sounders and attitude sensors.

5.4.4 RTK System

Pentax RTK system consists of one Base and two Rover Module. Base is set up on a known point usually Benchmark whose co-ordinates are known and is configured to transmit correction in real time to the two rovers using radio modem.

5.5 Data Acquisition and Quality Control

5.5.1 Online Data Quality Control

The online navigation computer was interfaced to Sonarmite Echo Sounder system. Laptop connected to the Navigation network were time synchronized with the GPS (high precision) time signal allowing all data to be precisely time stamped.
Navigation

The DGPS system performed well at all times and the performance of the system was continuously monitored.

Echo Sounder

The digital output from the Sonarmite Echo Sounder was satisfactory throughout the duration of the survey. The quality of obtained soundings were verified by running suitable cross lines and depths were found to be matching.

5.5.2 Data Processing

The bathymetric survey data was logged using Hypack on Navigation System. The quality of the bathymetric data acquired in the field was monitored continuously onboard the survey boat. Survey data was processed in office and handed over to the client.

5.6 Quality Assurance and HSE Procedures

GMPL has fully documented and self-audited Quality Assurance and Health, Safety and Environmental System procedures in place. The same were followed during all surveying tasks, which was undertaken by the company and its personnel.

Competent field survey staffs were deployed by GMPL to constantly monitor acquired data quality whilst the survey progressing, and was duly documented.

5.7 Demobilisation

Upon successful completion of topographic and bathymetric survey at Guhai Reservoir with due, consent from Client Representative, the survey equipment on board were demobilised on 27 Jan 2021.

5.8 SURVEY DATA PROCESSING AND INTERPRETATION METHODS

5.8.1 General

The survey data was logged and was processed using the HYPACK Software. Position and depth data were processed and checked to ensure good data quality. The same was used for the automated and manual processing of logged data sets.

5.8.2 Navigation and Positioning

The measured offsets for various survey sensors used during the survey were entered into the navigation system and post processed using Hypack processing to enable track charts to be plotted and the ‘corrected’ navigation files to be integrated with other sensor data at a later stage.
5.8.3 Bathymetry Data Processing and Analysis

- The SBES bathymetry survey data was logged using HYPACK and further processed.
- Corrected SBES offset position (computed from vessel antenna) was merged into single beam data for true horizontal positioning.
- Velocity value 1500 m/s was used in the survey area.
- SBES data was further corrected for the transducer draft from water level.
- The depth sounding obtained from SBES were reduced to MSL with the help of observed water level in the reservoir. The data was filtered, cleaned, and combined to create geographically positioned bathymetric data set that has been corrected for tides and sound speed.
- The water level were observed during the entire period of survey. The details are as follows:

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Table 5.8-1 WATER LEVELS

5.8.4 Topographic Data Processing and Analysis

The topographic survey data was cleaned and converted into xyz format. The converted data was merged with the bathymetric data using TIN module of Hypack software and Gridded data (25 x 25 m) was created. This data was used for volume calculations.

5.8.5 Preparation of Drawings

After the data processing phase, five drawings has been prepared for Guhai Reservoir, the details of which are presented in the table below:

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# REPORT ON TOPOGRAPHIC & BATHYMETRIC SURVEY FOR ASSESSMENT OF RESERVOIR CAPACITY & SEDIMENTATION IN GUHAI RESERVOIR, GUJARAT, INDIA UNDER NATIONAL HYDROLOGY PROJECT

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**Table 5.8-2 LIST OF CHARTS**
6 DETAILED TOPOGRAPHIC AND BATHYMETRIC SURVEY RESULTS

6.1 General

Kindly refer to drawings in conjunction with the following:

Topographic and bathymetric data was reduced to the water level w.r.t MSL. All the data is plotted on scale of 1:5000 for Guhai reservoir.

The values depicted in the charts are the depths with respect to MSL.

- The Minimum elevation within GUHAI DAM is 309.54 m above MSL and
- The Maximum depth within GUHAI DAM is 11.58 m

6.2 Capacity and Area Calculation:

Hypack software’s TIN (Triangulated Irregular Network) MODEL was used to calculate capacity and area of the reservoir at intervals of 10 cm. In addition, volume was also calculated using prismoidal formula as given below:

\[ V = \frac{h}{3} \left( A_1 + A_2 + \sqrt{A_1 \times A_2} \right) \]

where \( V \) is volume in M Cu. m between two levels,

\( h \) is difference between two level and

\( A_1 \) & \( A_2 \) is area in Sq. Km of successive levels

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## REPORT ON TOPOGRAPHIC & BATHYMETRIC SURVEY FOR ASSESSMENT OF RESERVOIR CAPACITY & SEDIMENTATION IN GUHAI RESERVOIR, GUJARAT, INDIA UNDER NATIONAL HYDROLOGY PROJECT

### GMPL Report No. P-SUR-BATHY-009-2020-21-WRD-GUHAI

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Table 6.2-1 Capacity and Area
### 6.3 Comparative Statement of Guhai Reservoir

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Original</th>
<th>AS per 2021</th>
<th>Remark</th>
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</thead>
<tbody>
<tr>
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<td>Area (Sq. Km)</td>
<td>Gross Storage Capacity (M Cu. m)</td>
<td>Area (Sq. Km)</td>
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Table 6.3-1 COMPARATIVE STATEMENT OF GUHAI RESERVOIR
6.4 Gross Capacity in M Cu. m of the Reservoir - Year 2021:

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<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.75</th>
<th>0.8</th>
<th>0.9</th>
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</thead>
<tbody>
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<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.001</td>
<td>0.002</td>
<td>0.005</td>
<td>0.007</td>
<td>0.008</td>
<td>0.008</td>
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<td>0.045</td>
<td>0.054</td>
<td>0.065</td>
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<td>0.089</td>
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<td>0.165</td>
<td>0.183</td>
<td>0.202</td>
<td>0.222</td>
<td>0.245</td>
<td>0.256</td>
<td>0.268</td>
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<td>0.487</td>
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<td>0.571</td>
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<td>1.082</td>
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<td>1.652</td>
<td>1.750</td>
<td>1.853</td>
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</table>

Table 6.4-1 GROSS STORAGE CAPACITY IN M cu. m YEAR -2021

Note: Gross storage capacity for FRL at 173 m is 67.597 M Cu. m, Dead storage at 164.75 m is 6.110 M Cu. m and HFL at 174.02 m is 81.323 M Cu. m.
### 6.5 Live Storage Capacity in M Cu. m of the Reservoir - Year 2021:

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<th>0.3</th>
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<th>0.6</th>
<th>0.7</th>
<th>0.75</th>
<th>0.8</th>
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<td>0.000</td>
<td>0.000</td>
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<td>0.000</td>
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<td>66.306</td>
<td>67.642</td>
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<td>70.438</td>
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</table>

Table 6.5-1 LIVE STORAGE CAPACITY IN M cu. m YEAR -2021

Note: Live storage capacity for FRL at 173 m is 61.488 M Cu. m and HFL at 174.02 m is 75.214 M Cu. m.
6.6 Spread Area in Sq. Km of the Reservoir - Year 2021:

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<th>0.6</th>
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<th>0.8</th>
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<td>0.000</td>
<td>0.000</td>
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</tr>
</tbody>
</table>

Table 6.6-1 SPREAD AREA IN SQ. KM YEAR -2021

Note: Spread Area for FRL at 173 m is 11.082 Sq. Km and HFL at 174.02 m is 15.494 Sq. Km.
6.7 Sediment Analysis:

6.7.1 Observed Rate of Sedimentation

The reservoir was impounded during the year 1990. As per survey total area of reservoir at FRL 173 m was 17.12 Sq. Km, corresponding storage capacity was 82.12 M Cu. m, and Dead storage at 164.75 m was 7.53 M Cu. m.

The reservoir was recently surveyed by means of integrated bathymetric and topographic survey in year 2021. As per recent survey, total area of reservoir at FRL 173 m is 11.082 Sq. Km, corresponding storage capacity is 67.596 M Cu. m and Dead storage at 164.75 m is 6.11 M Cu. m.

The rate of siltation in the reservoir (up to FRL 173 m) during the last 31 years (1990-2021), was found to be 0.037 M Cu. m / year.
Original Reservoir data:
Year of Impounding : 1990
Catchment Area : 422.17 Sq. Km
Surface area at 173 m : 17.12 Sq. Km
Live storage at 173 m : 61.22 M Cu. m
Dead storage at 164.75 m : 7.53M Cu. m
Gross storage at 173 m : 68.75 M Cu. m

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Year of Survey</th>
<th>Capacity in M Cu. m</th>
<th>Period in years</th>
<th>Silt Deposited in M Cu. m</th>
<th>Silt Rate in M Cu. m/year</th>
<th>Loss in Capacity in M Cu. m and percentage</th>
<th>Silt Index ham/100 Sq. Km/Yr.</th>
<th>Annual % loss</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>1990</td>
<td>Dead : 7.53, Live : 61.22, Gross : 68.75</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Dead : - , Live : - , Gross : -</td>
<td>-</td>
<td>-</td>
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<tr>
<td>2</td>
<td>2021 (Hydrographic survey)</td>
<td>Dead : 6.11, Live : 61.486, Gross : 67.596</td>
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<td>1.42 , -0.266 , 1.154</td>
<td>0.882</td>
<td>0.05%</td>
<td>Insignificant Category</td>
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</table>

Table 6.7-1 RATE OF SEDIMENTATION

According to IS -12182 (1987)
Annual % loss - Class of Reservoir
Rate of Silt = Loss in Gross Capacity in M Cu. m/No of Years
Silt Index = (Silt Rate/Catchment area) x 10000
Annual % Loss = Loss in % of Gross Capacity/No of years
6.8 Conclusion
- By above table we can conclude that the capacity of reservoir is decreased due to deposition of sediments in the reservoir especially at dead storage.
- The annual percentage loss from survey of the year 2021 is 0.05%.
- Reservoir is classified as “Insignificant category” as per IS 12182-1987 and requires actions to control deposition of sediments in the reservoir.

6.9 Methods for controlling the sedimentation
According to IS-6518:2017 there are several factors involved in controlling sedimentation in reservoirs and they relate to aspects on,

a) Design of reservoir.
b) Control of sediment inflow.
c) Control of sediment deposition.
d) Removal of sediments.

All these aspects are to be simultaneously taken note of and appropriate measures be adopted.

6.9.1 Design of Reservoirs
The capacity of reservoirs is governed by a number of factors which are covered in IS 5477 (Parts 1 to 4). From the point of view of sediment deposition, the following points may be given due consideration:

a) The sediment yield which depends on the topographical, geological and geomorphological set up, meteorological factors, land use/land cover, intercepting tanks, etc.;
b) Sediment delivery characteristics of the channel system;
c) The efficiency of the reservoir as sediment trap;
d) The ratio of capacity of reservoir to the inflow;
e) Configuration of reservoir;
f) Method of operation of reservoir; and
g) Provisions for silt exclusion.

- The rate of sediment delivery increases with the quantum of discharge.
- The percentage of sediment trapped by a reservoir with a given drainage area increases with the increased capacity. In some cases an increased capacity will however, result in greater loss of water due to evaporation. However, with the progress of sedimentation, there is decrease of storage capacity which in turn lowers the trap efficiency of the reservoir.
- The capacity of the reservoir and the size and characteristics of the reservoir and its drainage area are the most important factors governing the annual rate of accumulation of sediment. Periodical reservoir sedimentation surveys provide guidance on the rate of sedimentation. In the absence of observed data for the reservoir concerned, data from other reservoirs of similar capacity and catchment characteristics may be adopted.
Sedimentation takes place not only in the dead storage but also in the live storage space in the reservoir. The practice for design of reservoir is to use the observed suspended sediment data available from key hydrological networks and also the data available from hydrographic surveys of other reservoirs in the same region.

This data may be used to simulate sedimentation status over a period of reservoir life as mentioned in IS 12182.

- Raising the Dam at Periodic Intervals:

Engineering economic analysis of some reservoir projects probably would show that it is cheaper to build a substantially lower dam initially, and to raise it at intervals until its ultimate height for the given original capacity so that long useful life may result. Stage-wise construction also provides lower trapping efficiency and less evaporation in the initial stages.

However, this method may not be feasible in all the existing dams. Wherever this method is contemplated, proper consideration should be given on the strength.

### 6.9.2 Control of Sediment Inflow

There are many methods for controlling sediment inflows and they can be divided as follows:

1. Watershed management/soil conservation measures to check production and transport of sediment in the catchment area

1.1. The engineering methods

1.1.1. Check Dams

   a) They help to arrest degradation of stream bed thereby arresting the slope failure; and

   b) They reduce the velocity of stream flow, thereby causing the deposition of the sediment load.

Check dams become necessary, where the channel gradients are steep and there is a heavy inflow of sediment from the watershed. They are constructed of local material like earth, rock, timber, etc. These are suitable for small catchment varying in size from 40 to 400 hectares. It is necessary to provide small check dams on the subsidiary streams flowing into the main streams besides the check dams in the main stream. Proper consideration should be given to the number and location of check dams required. It is preferable to minimize the height of the check dams. If the stream has, a very-steep slope, it is desirable to start with a smaller height for the check dams than may ultimately be necessary.

Check dams may generally cost more per unit of storage than the reservoirs they protect. Therefore, it may not always be possible to adopt them as a primary method of sediment control in new reservoirs. However, feasibility of providing check dams at later date should not be overlooked while planning the construction of a new reservoir

1.1.2. Contour Bunding and Trenching

These are important methods of controlling soil erosion on the hills and sloping lands, where gradients of cultivated fields or terraces are flatter, say up to 10 percent. By these methods the
hill side is split up into small compartments on which the rain is retained and surface run-off is modified with prevention of soil erosion. In addition to contour bunding, side trenching is also provided as per requirement.

1.1.3. **Gully Plugging**

This is done by small rock fill dams. These dams will be effective in filling up the gullies with sediment coming from the upstream of the catchment and also prevent further widening of the gully.

1.1.4. **Bank Protection**

This is achieved by terracing, revetment, retaining walls, gabions and spurs.

1.2. **Agronomy**

The agronomic measures include establishment of vegetative screen, contour farming, strip cropping and crop rotation.

1.3. **Forestry**

Forestry measures include forest conservancy, control on grazing, lumbering, operations and forest fires along with management and protection of forest plantations.

2. **Preventive measures to check inflow of sediment into the reservoir**

2.1. Restricting the waste/sediment entering into the reservoirs due to agricultural and infrastructural activities surrounding the submergence.

2.2. **Construction of by-pass channels or conduits.**

The various methods in this category require the construction of some type of diversion dam or weir at the head of the reservoir basin, and a canal, tunnel or conduit leading around the reservoir to a point below the dam where the flow may re-enter the main channels. In such cases the flood flows of sediment laden water are by-passed to the downstream of the dam. In some cases where topography permits construction of new off channel reservoirs can be considered. These reservoirs will invariably have a forebay and check dam on the upstream for trapping the sediment. The stored water in the fore bay is led to the reservoir and the sediment trapped is flushed through by by-pass channel/ conduit/tunnel to the main channel downstream of the dam.

6.9.3 **Control of Sediment Deposition**

The deposition of sediment in a reservoir may be controlled to a certain extent by designing and operating gates or other outlets in the dam in such a manner as to permit selective withdrawals of water having a higher than average sediment content. The suspended sediment content of the water in reservoirs is higher during and just after flood flow. Thus, more the water wasted at such times, the smaller will be the percentage of the total sediment load to settle into permanent deposits. There are generally three methods:
• **Density current**

Water at various levels of a reservoir often contains radically different concentrations of suspended sediment particularly during and after flood flows. If all wastewater could be withdrawn at those levels where the concentration is highest, a significant amount of sediment might be removed from the reservoir. Because a submerged outlet draws water towards it from all directions, the vertical dimension of the opening should be small with respect to the thickness of the layer and the rate of withdrawal also should be low.

• **Waste-water release**

Controlling the sedimentation by controlling waste-water release is obviously possible only when water can be or should be wasted. This method is applicable only when a reservoir is of such size that a small part of large flood flows will fill it.

In the design of the dam, sediment may be passed through or over it as an effective method of silt control by placing a series of outlets at various elevations. The percentage of total sediment load that might be ejected from the reservoir through proper gate control will differ greatly with different locations. It is probable that as much as 20 percent of the sediment inflow could be passed through many reservoirs by venting through outlets designed and controlled.

• **Scouring Sluicing**

This method is somewhat similar to both the control of waste-water release and the draining and flushing methods.

The distinctions amongst them are the following:

a) The waste-water release method ejects sediment laden flood flows through deep spillway gates or large under-sluices at the rate of discharge that prevents sedimentation.

b) Drainage and flushing method involves the slow release of stored water from the reservoir through small gates or valves making use of normal or low flow to entrain and carry the sediment, and

c) Scouring sluicing depends for its efficiency on either the scouring action exerted by the sudden rush of impounded water under a high head through under-sluices or on the scouring action of high flood discharge coming into the reservoir.

Scouring sluicing method can be used in the following:

i. Small power dams that depend to a great extent on pondage but not on storage;

ii. Small irrigation reservoirs, where only a small fraction of the total annual flow can be stored;

iii. Any reservoir in narrow channels, gorges, etc, where water wastage can be afforded; and

iv. When the particular reservoir under treatment is a unit in an interconnected system so that the other reservoirs can supply the water needed.
6.9.4 Removal of Sediment Deposit

The most practical means of maintaining the storage capacity are those designed to prevent accumulation of permanent deposits as the removal operations are extremely expensive, unless the material removed is usable. Therefore, the redemption of lost storage by removal should be adopted as a last resort. The removal of sediment deposit implies in general, that the deposits are sufficiently compacted or consolidated to act as a solid and, therefore, are unable to flow along with the water. The removal of sediment deposits may be accomplished by a variety of mechanical and hydraulic or methods, such as excavation, dredging, siphoning, draining, flushing, flood sluicing, and sluicing aided by such measures as hydraulic or mechanical agitation or blasting of the sediment. The excavated sediments may be suitably disposed off so that, these do not find the way again in the reservoir.

1. Excavation

The method involves draining most of or all the water in the basin and removing the sediment by hand or power operated shovel, dragline scraper or other mechanical means.

The excavation of silt and clay, which constitute most of the material in larger reservoirs, is more difficult than the excavation of sand and gravel. Fine-textured sediment cannot be excavated easily from larger reservoirs unless it is relatively fluid or relatively compact.

2. Dredging

This involves the removal of deposits from the bottom of a reservoir and their conveyance to some other point by mechanical or hydraulic means, while water storage is being maintained.

Dredging practices are grouped as:

a) Mechanical dredging by bucket, ladder, etc;

b) Suction dredging with floating pipeline and a pump usually mounted on a barge; and

c) Siphon dredging with a floating pipe extending over the dam or connected to an opening in the dam and usually with a pump on a barge.

NOTES

1) Practicality of the two methods, namely, excavation and dredging, requires to be carefully considered in any particular case.

2) Suitable measures to prevent deposition of the dredged silt in the natural channel where it is discharged need to be adopted.

3. Draining and Flushing

The method involves relatively slow release of all stored water in a reservoir through gates or valves located near bottom of the dam and the maintenance thereafter of open outlets for a shorter or longer period during which normal stream flow cuts into or directed against the sediment deposits. Therefore, this method may be adopted in flood control reservoirs.

4. Sluicing with Controlled Water

This method differs from the flood sluicing in that the controlled water supply permits choosing the time of sluicing more advantageously and that the water may be directed more
effectively against the sediment deposits. While the flood sluicing depends either on the occurrence of flood or on being able to release rapidly all of a full or nearly full supply of water in the main reservoir is empty. The advantage of this method is that generally more sediment can be removed per unit of water used than in flood scouring or draining and flushing.

5. Sluicing with Hydraulic and Mechanical Agitation

Methods that stir up break up or move deposits of sediment into a stream current flowing through a drained reservoir basin or into a lake current moving through and out of a full reservoir will tend to make the removal of sediment from the reservoir more complete. Wherever draining, flushing or sluicing appear to be warranted, the additional use of hydraulic means for stirring up the sediment deposits, or sloughing them off, into a stream flowing through the reservoir basin should be considered. It has, however, limited application.
6.10 Area – Capacity – Curve of GUHAI Reservoir:

Figure 6.10-1 AREA – CAPACITY - CURVE
6.11 Segment, Contour, Wire Frame Map and L section:

![Segment, Contour, Wire Frame Map and L section](image)

Figure 6.11-1 SEGMENT MAP FOR CROSS SECTION

Cross sections showing bed profile at 100m interval were prepared and are provided as soft copy in CD/Hard Disc. Total 36 cross section profiles were prepared.
Figure 6.11-2 CONTOUR MAP
Figure 6.11-3 WIRE FRAME MAP

Figure 6.11-4 L SECTION
DGPS OBSERVATION REPORT

AUSPOS GPS Processing Report
February 13, 2021

This document is a report of the GPS data processing undertaken by the AUSPOS Online GPS Processing Service (version: AUSPOS 2.4). The AUSPOS Online GPS Processing Service uses International GNSS Service (IGS) products (final, rapid, ultra-rapid depending on availability) to compute precise coordinates in International Terrestrial Reference Frame (ITRF) anywhere on Earth and Geocentric Datum of Australia (GDA) within Australia. The Service is designed to process only dual frequency GPS phase data.

An overview of the GPS processing strategy is included in this report.

Please direct any correspondence to geodesy@ga.gov.au

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Geoscience Australia
Home Page: http://www.ga.gov.au
1 User Data

All antenna heights refer to the vertical distance from the Ground Mark to the Antenna Reference Point (ARP).

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<td>2007/03/12 11:43:00</td>
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</table>

2 Processing Summary

MGNPOS 2.4 Job Number: 7366
User: sam_hdfwedi@gmail.com
© Commonwealth of Australia (Geoscience Australia) 2021
3 Computed Coordinates, ITRF2014

All coordinates are based on the IGS realisation of the ITRF2014 reference frame. All
the given ITRF2014 coordinates refer to a mean epoch of the site observation data. All
coordinates refer to the Ground Mark.

3.1 Cartesian, ITRF2014

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3.2 Geodetic, GRS80 Ellipsoid, ITRF2014

Geoid-ellipsoidal separations, in this section, are computed using a spherical harmonic
synthesis of the global EGM2008 geoid. More information on the EGM2008 geoid can be
found at http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/.

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<th>Derived Above Geoid Height (m)</th>
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3.3 UTM Grid, GRS80 Ellipsoid, ITRF2014

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</table>

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3.4 Positional Uncertainty (95% C.L.) - Geodetic, ITRF2014

<table>
<thead>
<tr>
<th>Station</th>
<th>Longitude (East) (m)</th>
<th>Latitude (North) (m)</th>
<th>Ellipsoidal Height (Up) (m)</th>
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4 Ambiguity Resolution - Per Baseline

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<tr>
<th>Baseline</th>
<th>Ambiguities Resolved</th>
<th>Baseline Length (km)</th>
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</thead>
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<tr>
<td>K113 - TASH</td>
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<tr>
<td>CHUM - POL2</td>
<td>70.6</td>
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<tr>
<td>IT3C - SEYG</td>
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<tr>
<td>069C - TASH</td>
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<td>POL2 - U3UM</td>
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<td>CHUM - TASH</td>
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<td>AVERAGE</td>
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</table>

Please note for a regional solution, such as used by AUSPOS, ambiguity resolution success rate of 50% or better for a baseline formed by a user site indicates a reliable solution.
5 Computation Standards

5.1 Computation System

<table>
<thead>
<tr>
<th>Software</th>
<th>Bernese GNSS Software Version 5.2</th>
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<tbody>
<tr>
<td>GNSS system(s)</td>
<td>GPS only.</td>
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</tbody>
</table>

5.2 Data Preprocessing and Measurement Modelling

<table>
<thead>
<tr>
<th>Data preprocessing</th>
<th>Phase preprocessing is undertaken in a baseline by baseline mode using triple-differences. In most cases, cycle slips are fixed by the simultaneous analysis of different linear combinations of L1 and L2. If a cycle slip cannot be fixed reliably, bad data points are removed or new ambiguities are set up. A data screening step on the basis of weighted postfit residuals is also performed, and outliers are removed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic observable</td>
<td>Carrier phase with an elevation angle cutoff of 7° and a sampling rate of 3 minutes. However, data cleaning is performed at a sampling rate of 30 seconds. Elevation dependent weighting is applied according to 1/sin(θ)^2 where θ is the satellite elevation.</td>
</tr>
<tr>
<td>Modeled observable</td>
<td>Double differences of the ionosphere-free linear combination.</td>
</tr>
<tr>
<td>Ground antenna phase centre calibrations</td>
<td>IGS14 absolute phase-centre variation model is applied.</td>
</tr>
<tr>
<td>Topospheric Model</td>
<td>A priori model is the GMF mapped with the DRY-GMF.</td>
</tr>
<tr>
<td>Topospheric Estimation</td>
<td>Zenith delay corrections are estimated relying on the WET-GMF mapping function in intervals of 2 hour. N-S and E-W horizontal delay parameters are solved for every 24 hours.</td>
</tr>
<tr>
<td>Topospheric Mapping Function</td>
<td>GMF</td>
</tr>
<tr>
<td>Ionosphere</td>
<td>First-order effect eliminated by forming the ionosphere-free linear combination of L1 and L2. Second and third order applied.</td>
</tr>
<tr>
<td>Tidal displacements</td>
<td>Solid earth tidal displacements are derived from the complete model from the IERS Conventions 2010, but ocean tide loading is not applied.</td>
</tr>
<tr>
<td>Atmospheric loading</td>
<td>Applied</td>
</tr>
<tr>
<td>Satellite centre of mass correction</td>
<td>IGS14 phase-centre variation model applied</td>
</tr>
<tr>
<td>Satellite phase centre calibration</td>
<td>IGS14 phase-centre variation model applied</td>
</tr>
<tr>
<td>Satellite trajectories</td>
<td>Best available IGS products.</td>
</tr>
<tr>
<td>Earth Orientation</td>
<td>Best available IGS products.</td>
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5.3 Estimation Process

<table>
<thead>
<tr>
<th>Adjustment</th>
<th>Weighted least-squares algorithm.</th>
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<tbody>
<tr>
<td>Station coordinates</td>
<td>Coordinate constraints are applied at the Reference sites with standard deviation of 1mm and 2mm for horizontal and vertical components respectively.</td>
</tr>
<tr>
<td>Troposphere</td>
<td>Zenith delay parameters and pairs of horizontal delay gradient parameters are estimated for each station in intervals of 2 hours and 24 hours.</td>
</tr>
<tr>
<td>Ionospheric correction</td>
<td>An ionospheric map derived from the contributing reference stations is used to aid ambiguity resolution.</td>
</tr>
<tr>
<td>Ambiguity</td>
<td>Ambiguities are resolved in a baseline-by-baseline mode using the CODE-Based strategy for 180-6000km baselines, the Phase-Based L1/L2 strategy for 18-200km baselines, the Quasi-Ionosphere-Free (QIF) strategy for 18-2000km baselines and the Direct L1/L2 strategy for 0-20km baselines.</td>
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5.4 Reference Frame and Coordinate Uncertainty

<table>
<thead>
<tr>
<th>Terrestrial reference frame</th>
<th>IGS14 station coordinates and velocities mapped to the mean epoch of observation.</th>
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<tbody>
<tr>
<td>Australian datums</td>
<td>GDA2020 and GDA94.</td>
</tr>
<tr>
<td>Derived AHD</td>
<td>For stations within Australia, AUSGeod2020 [V20180261] is used to compute AHD. AUSGeod2020 is the Australia-wide gravimetric quasigeoid model that has been a posteriori fitted to the AHD. For reference, derived AHD is always determined from the GDA2020 coordinates. In the GDA94 section of the report, AHD values are assumed to be identical to those derived from GDA2020.</td>
</tr>
<tr>
<td>Above-geoid heights</td>
<td>Earth Gravitational Model EGM2008 released by the National Geospatial-Intelligence Agency (NGA) EGM Development Team is used to compute above-geoid heights. This gravitational model is complete to spherical harmonic degree and order 2156, and contains additional coefficients extending to degree 2190 and order 2156.</td>
</tr>
<tr>
<td>Coordinate uncertainty</td>
<td>Coordinate uncertainty is expressed in terms of the 95% confidence level for GDA94, GDA2020 and ITRF2014. Uncertainties are scaled using an empirically derived model which is a function of data span, quality and geographical location.</td>
</tr>
</tbody>
</table>
SINGLE BEAM ECHOSOUNDER BAR CHECK RESULTS

### Singlebeam Echosounder Barcheck Correction Table

<table>
<thead>
<tr>
<th>Project No.</th>
<th>Project Title: Bathymetric Survey</th>
<th>Vessel: Inflatable Boat</th>
<th>Place: Guhai Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date: 23-Jan-21</td>
<td>Time: 13:15</td>
<td>Observed By: Amit Singh</td>
<td>Echosounder Model and SL. No. Sonarmite</td>
</tr>
</tbody>
</table>

#### Echosounder Settings

<table>
<thead>
<tr>
<th>Draft HI</th>
<th>Index &quot;k&quot; HI</th>
<th>Draft LO</th>
<th>Index &quot;k&quot; LO</th>
<th>Sound Velocity Average</th>
<th>Upto Depth 1500 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>210</td>
<td>210</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Barcheck Frequency selected Survey Frequency: Manufacturer's Accuracy 210 210 0.20 % of Depth 0.02 m

#### Observations while lowering

<table>
<thead>
<tr>
<th>Bar Depth (m)</th>
<th>ES Reading (m)</th>
<th>Difference (m)</th>
<th>Bar Depth (m)</th>
<th>ES Reading (m)</th>
<th>Difference (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.01</td>
<td>-0.01</td>
<td>8</td>
<td>8.62</td>
<td>-0.02</td>
</tr>
<tr>
<td>4</td>
<td>3.99</td>
<td>0.01</td>
<td>6</td>
<td>6.01</td>
<td>-0.01</td>
</tr>
<tr>
<td>6</td>
<td>6.01</td>
<td>-0.01</td>
<td>4</td>
<td>3.99</td>
<td>0.01</td>
</tr>
<tr>
<td>8</td>
<td>7.98</td>
<td>0.02</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

#### Observations while hoisting

<table>
<thead>
<tr>
<th>Bar Depth (m)</th>
<th>ES Reading (m)</th>
<th>Difference (m)</th>
<th>Bar Depth (m)</th>
<th>ES Reading (m)</th>
<th>Difference (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average Std. Dev</th>
<th>0.0025 0.0150</th>
<th>Average Std. Deviation</th>
<th>-0.0050 0.0129</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative Average</td>
<td>0.00</td>
<td>Cumulative Std. Deviation</td>
<td>0.0015</td>
</tr>
</tbody>
</table>

The Echosounder Barcheck Values are Negligible for Application

Approved By: Survey Manager

GMPL Report No. P-SUR-BATHY-009-2020-21-WRD-GUHAI
## Singlebeam Echosounder Barcheck Correction Table

<table>
<thead>
<tr>
<th>Project No.</th>
<th>Project Title: Bathymetric Survey</th>
<th>Vessel: Inflatable Boat</th>
<th>Place: Guhaid Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>Time:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-Jan-21</td>
<td>10:35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed By</td>
<td>Amit Singh</td>
<td>Echosounder Model and SL. No.</td>
<td>Area Depth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sonarmite</td>
<td>8</td>
</tr>
</tbody>
</table>

### Echosounder Settings

- **Draft HI**
- **Index "k" HI**
- **Draft LO**
- **Index "k" LO**
- **Sound Velocity**
  - **Average**
  - **Upto Depth**

<table>
<thead>
<tr>
<th>Barcheck Frequency selected</th>
<th>Survey Frequency:</th>
</tr>
</thead>
<tbody>
<tr>
<td>210</td>
<td>Manufacturer's Accuracy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Observed while lowering</th>
<th>Observations while hoisting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar Depth (m)</td>
<td>ES Reading (m)</td>
</tr>
<tr>
<td>2</td>
<td>2.02</td>
</tr>
<tr>
<td>4</td>
<td>3.99</td>
</tr>
<tr>
<td>6</td>
<td>5.98</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0033</td>
<td>0.0208</td>
</tr>
<tr>
<td></td>
<td>0.0100</td>
</tr>
</tbody>
</table>

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Approved By: Survey Manager
### Singlebeam Echosounder Barcheck Correction Table

<table>
<thead>
<tr>
<th>Project No.</th>
<th>Project Title: Bathymetric Survey</th>
<th>Vessel: Inflatable Boat</th>
<th>Place: Guhai Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>25-Jan-21</td>
<td>Time: 9:00</td>
<td></td>
</tr>
<tr>
<td>Observed By:</td>
<td>Amit Singh</td>
<td>Echosounder Model and SL. No.</td>
<td>Area Depth</td>
</tr>
<tr>
<td></td>
<td>Sonarmite</td>
<td></td>
<td>7</td>
</tr>
</tbody>
</table>

#### Echosounder Settings

<table>
<thead>
<tr>
<th>Draft HI</th>
<th>Index &quot;k&quot; HI</th>
<th>Draft LO</th>
<th>Index &quot;k&quot; LO</th>
<th>Sound Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Upto Depth</td>
</tr>
<tr>
<td>1500</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Barcheck Frequency selected**: 210

**Survey Frequency**: 210

**Manufacturer's Accuracy**: 0.20 % of Depth

**Depth**: 0.01 m

### Observations while lowering

<table>
<thead>
<tr>
<th>Bar Depth (m)</th>
<th>ES Reading (m)</th>
<th>Difference (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.01</td>
<td>-0.01</td>
</tr>
<tr>
<td>3</td>
<td>2.98</td>
<td>0.02</td>
</tr>
<tr>
<td>4</td>
<td>3.99</td>
<td>0.01</td>
</tr>
<tr>
<td>5</td>
<td>4.99</td>
<td>0.01</td>
</tr>
</tbody>
</table>

### Observations while hoisting

<table>
<thead>
<tr>
<th>Bar Depth (m)</th>
<th>ES Reading (m)</th>
<th>Difference (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
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<tr>
<td>4</td>
<td>4.02</td>
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<tr>
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<td>-0.02</td>
</tr>
<tr>
<td>2</td>
<td>2.00</td>
<td>0.01</td>
</tr>
</tbody>
</table>

#### Statistics

- **Average**: 0.0075
- **Std. Dev**: 0.0126
- **Average**: -0.0125
- **Std. Dev**: 0.0096
- **Cumulative Average**: 0.00
- **Cumulative Std. Deviation**: 0.0021

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Approved By: Survey Manager
### Singlebeam Echosounder Barcheck Correction Table

<table>
<thead>
<tr>
<th>Project No.</th>
<th>Project Title: Bathymetric Survey</th>
<th>Vessel: Inflatable Boat</th>
<th>Place: Guhai Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>26-Jan-21</td>
<td>9:20</td>
<td></td>
</tr>
<tr>
<td>Observed By:</td>
<td>Amit Singh</td>
<td>Echosounder Model and SL. No.</td>
<td>Area Depth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sonarmite</td>
<td>6</td>
</tr>
</tbody>
</table>

#### Echosounder Settings

<table>
<thead>
<tr>
<th>Draft HI</th>
<th>Index &quot;k&quot; HI</th>
<th>Draft LO</th>
<th>Index &quot;k&quot; LO</th>
<th>Sound Velocity</th>
</tr>
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<tbody>
<tr>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
<td>Average 1500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Upto Depth 4</td>
</tr>
<tr>
<td>Barcheck Frequency selected</td>
<td>Survey Frequency: Manufacturer's Accuracy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>210</td>
<td>210</td>
<td>210</td>
<td>0.20 % of Depth</td>
<td>0.01 m</td>
</tr>
</tbody>
</table>

#### Observations while lowering

<table>
<thead>
<tr>
<th>Bar Depth (m)</th>
<th>ES Reading (m)</th>
<th>Difference (m)</th>
<th>Bar Depth (m)</th>
<th>ES Reading (m)</th>
<th>Difference (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.02</td>
<td>-0.02</td>
<td>4</td>
<td>4.01</td>
<td>-0.01</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>2.99</td>
<td>0.01</td>
</tr>
<tr>
<td>4</td>
<td>3.98</td>
<td>0.02</td>
<td>2</td>
<td>2.01</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

#### Observations while hoisting

<table>
<thead>
<tr>
<th>Bar Depth (m)</th>
<th>ES Reading (m)</th>
<th>Difference (m)</th>
<th>Bar Depth (m)</th>
<th>ES Reading (m)</th>
<th>Difference (m)</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Average | 0.00000 | Average | -0.0033 |
| Std. Dev | 0.0200 | Std. Dev | 0.0115 |
| Cumulative Average | 0.00 | Cumulative Std. Deviation | 0.0060 |

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Approved By: Survey Manager
## Singlebeam Echosounder Barcheck Correction Table

<table>
<thead>
<tr>
<th>Project No.</th>
<th>Project Title: Bathymetric Survey</th>
<th>Vessel: Inflatable Boat</th>
<th>Place: Guhai Dam</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Time: 9:10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed By: Amit Singh</td>
<td>Echosounder Model and SL. No.</td>
<td>Area Depth</td>
<td>Sonarmite 5</td>
</tr>
</tbody>
</table>

### Echosounder Settings

<table>
<thead>
<tr>
<th>Draft HI</th>
<th>Index &quot;k&quot; HI</th>
<th>Draft LO</th>
<th>Index &quot;k&quot; LO</th>
<th>Sound Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
<td>Average 1500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Upto Depth 4</td>
</tr>
</tbody>
</table>

Barcheck Frequency selected 210 210

Survey Frequency: Manufacturer's Accuracy

<table>
<thead>
<tr>
<th>Barcheck Frequency</th>
<th>0.20 % of Depth</th>
<th>0.01 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>210</td>
<td>210</td>
<td>210</td>
</tr>
</tbody>
</table>

### Observations while lowering

<table>
<thead>
<tr>
<th>Bar Depth (m)</th>
<th>ES Reading (m)</th>
<th>Difference (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.01</td>
<td>-0.01</td>
</tr>
<tr>
<td>3</td>
<td>2.99</td>
<td>0.01</td>
</tr>
<tr>
<td>4</td>
<td>3.98</td>
<td>0.02</td>
</tr>
</tbody>
</table>

### Observations while hoisting

<table>
<thead>
<tr>
<th>Bar Depth (m)</th>
<th>ES Reading (m)</th>
<th>Difference (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>4.01</td>
<td>-0.01</td>
</tr>
<tr>
<td>3</td>
<td>3.01</td>
<td>-0.01</td>
</tr>
<tr>
<td>2</td>
<td>2.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

### Average and Std. Dev.

<table>
<thead>
<tr>
<th>Barcheck Frequency</th>
<th>Average</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0067</td>
<td>0.0153</td>
<td></td>
</tr>
<tr>
<td>0.0067</td>
<td>0.0086</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Cumulative Average</th>
<th>Cumulative Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.0067</td>
</tr>
</tbody>
</table>

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Approved By: Survey Manager
9 PHOTOGRAPHS

The following Photographs showing the Survey activities and features available at site

Water level scale

Survey carried out near Dam walls
Survey in process

Dam boundary
Survey Area

Base Observation
Dam Shutter Area

Survey Observation
Survey in process
END OF REPORT