GEOSERVICES MARITIME PVT. LTD.

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

Prepared for:	**Water Resources Investigation Division, Ahmedabad** (Govt. Of Gujarat)	Equity Efficiency Sustainability WRD
Client Reference:	**Executive Engineer Water resources investigation Division Ahmedabad.**	

LOCATION MAP

Figure 1.1-1 LOCATION MAP

LOCATION MAP SHOWING SURVEY AREA "GUHAI RESERVOIR", GUJARAT, INDIA

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

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

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

GUHAI RESERVOIR PROJECT		
I	**LOCATION**	
	Coordinates	Latitude 23°42'21" N Longitude 73°2'29" E
	River	Guhai River
	Village	Khandhol
	Taluka	Himmatnagar
	District	Sabarkantha
	State	Gujarat
	Nearest Railway Station	Himmatnagar Junction
	Purpose	Irrigation and flood control
II	**HYDROLOGY**	
	Catchment Area	422.17 Sq. Km
	Mean Annual Rainfall	931 mm
III	**DAM**	
	Dam Type	Composite
	Length of the top of the dam	4252 m (including Saddles)
	Length of earthen dam	806 m
IV	**RESERVOIR**	
	MDDL	164.75 m
	FRL	173.00 m
	HFL/MWL	174.02 m
	Gross Storage Capacity	68.75 M Cu. m
	Dead Storage Capacity	7.53 M Cu. m
	Live Storage Capacity	61.22 M Cu. m
	Area at FRL	17.2 Sq. Km
V	**SPILLWAY**	
	Type	Ogee
	Length of Spillway	88.72 m
	Crest Level	164.77
	Nos. and Size of Gates	6, (12.50 m x 8.23 m)
VII	**HEAD REGULATOR**	Right Bank
	Location	Ch. 2135 m on right part
	Design Discharge	4.98 cumecs
	Nos. and Size of Gates	1, (1.50 m x 1.80 m)

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.

4 RESOURCES FOR SURVEY WORK

4.1 Personnel

Following staff were involved during the survey work.

Offshore Survey Personnel	
Name	**Function**
Amit Singh	Party Chief
Samraj Dwivedi	Survey Engineer
Ashish Patil	Survey Engineer
Abhijith Cherapi	Surveyor
Rohit Patwal	Land Surveyor
Onshore Project Management and Data QC	
Sudhir Walia	Project Manager
KSN Murthy	Survey Manager
Dhaval Patel	Data Processor

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.

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

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

Survey Boat ‘Aqua Marine’ Specifications	
Length overall	3.56m
Breadth moulded	1.88m
Draft	0.50m

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.

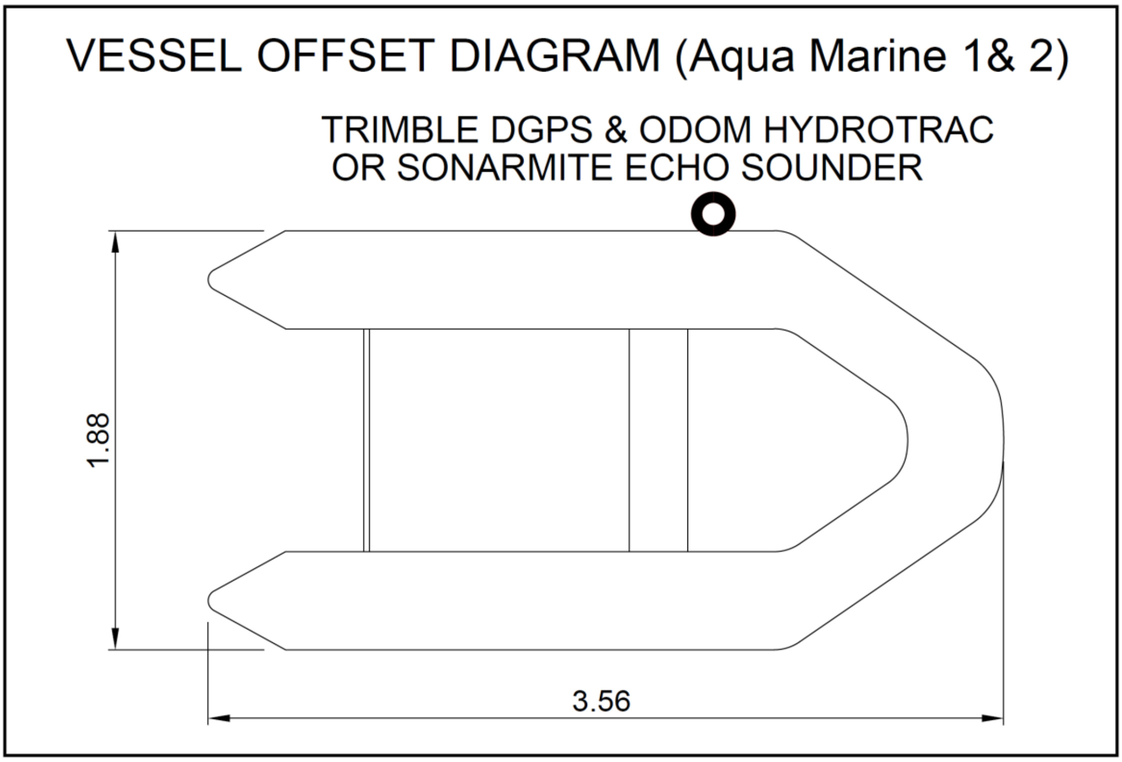

Figure 4.3-1 SURVEY BOAT ‘ AQUA MARINE’ OFFSET DIAGRAM

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.

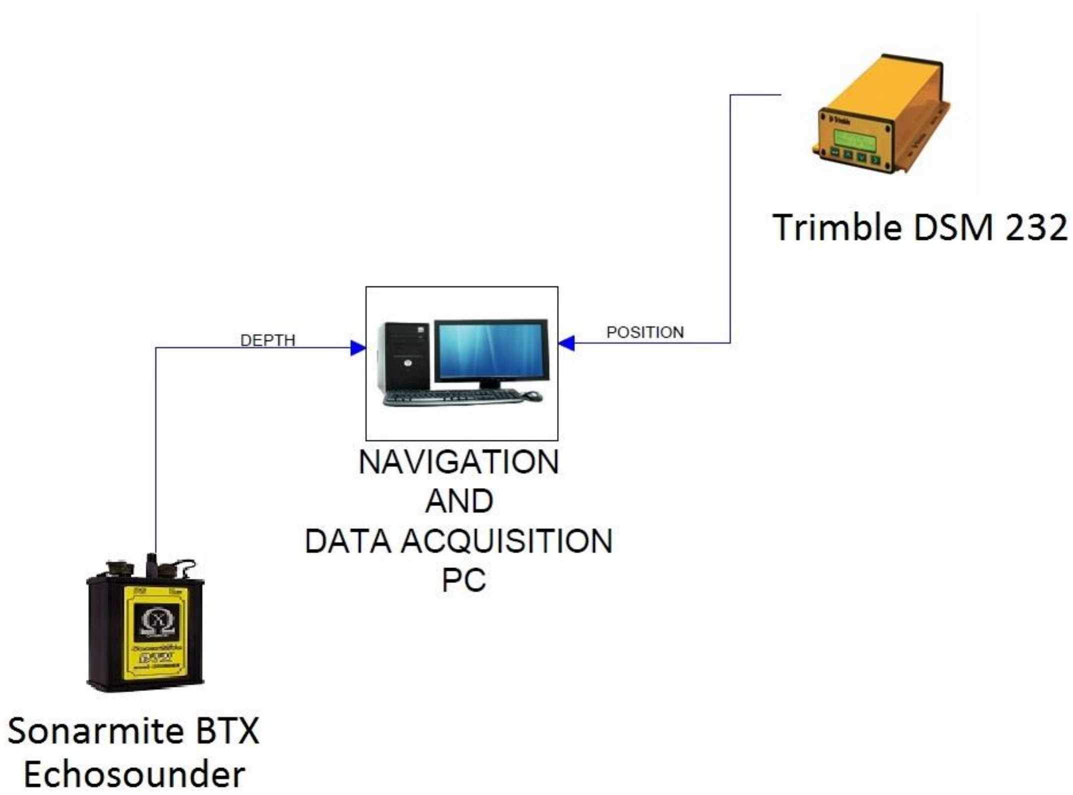

Figure 5.1-1 SBES SURVEY EQUIPMENT CONFIGURATION DIAGRAM ON BOARD

5.2 Geodesy

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

Global Positioning System Geodetic Parameters	
Datum:	World Geodetic System 1984 (WGS84)
Spheroid:	World Geodetic System 1984
Semi major axis:	a = 6 378 137.000 m
Semi minor axis:	b = 6 356 752.314 245 m
Inverse Flattening:	$^1/_f$ = 298.257 223 563
Local Datum Geodetic Parameters	
Datum:	World Geodetic System 1984 (WGS84)
Spheroid:	World Geodetic System 1984
Semi major axis:	a = 6 378 137.000 m
Inverse Flattening:	$^1/_f$ = 298.257 223 563
Local Projection and Grid Parameters	
Map Projection:	Universal Transverse Mercator
Grid System:	UTM Zone 43 N
Central Meridian:	075° 00’ 00” East
Latitude of Origin:	0° 00’ 00” North
False Easting:	500 000 m
False Northing:	0 m

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:

BM Observation and T.BM. Information _ GUHAI Reservoir South Gujarat					
Location	**Latitude (N)**	**Longitude (E)**	**Easting (m)**	**Northing (m)**	**Elevation (m) W.r.t MSL**
OBS GUHA	23°42'2.081"	073°03'6.199"	301356.670	2622434.906	178.08
T.B.M.01	23°42'2.584"	073°03'5.831"	301346.481	2622450.526	173.008
T.B.M.02	23°42'4.439"	073°03'9.456"	301449.935	2622506.198	157.459
T.B.M.03	23°41'58.727"	073°03'10.147"	301467.122	2622330.190	155.192
T.B.M.04	23°41'58.547"	073°03'6.893"	301374.867	2622325.921	169.278
T.B.M.05	23°43'27.080"	073°03'23.204"	301874.099	2625043.304	222.040

Table 5.3-1 BENCH MARK DETAILS

Figure 5.3-1 DGPS Observation at Dam top

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 SonarmiteEcho 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 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:-

Date	Time	Water Level (meters)
23/01/2021	0700	167.59
	1900	167.59
24/01/2021	0700	167.58
	19:00	167.58
25/01/2021	0700	167.58
	1900	167.58
26/01/2021	0700	167.57
	1900	167.57
27/01/2021	0700	167.55
	1900	167.55

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:

Sr. No	Drawing Name	Description	Hard Copy format	Soft Copy format
1	P-SUR-009-Guhai-Bathy-01	Bathymetry chart part 1	1:5000	PDF & CAD
2	P-SUR-009- Guhai -Bathy-02	Bathymetry chart part 1	1:5000	PDF & CAD

Sr. No	Drawing Name	Description	Hard Copy format	Soft Copy format
3	P-SUR-009- Guhai -Bathy-03	Bathymetry chart part 1	1:5000	PDF & CAD
4	P-SUR-009- Guhai -Contour-01	Contour chart	1:12500	PDF & CAD
5	P-SUR-009- Guhai -Overview-01	Overview Map of Reservoir	Paper size A3	PDF & CAD
6	Area Capacity Curve Guhai -2021	Area Capacity curve of Reservoir	Paper size A3	PDF & CAD
7	Guhai Cross Sections	38 Cross Section at 100 m interval	Only soft copy	CAD
6	Guhai L- Section	L-Section of Reservoir	Paper size A3	CAD

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=h/3{A1+A2+ Square Root (A1 * A2)}

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

h is difference between two level and

A1 & A2 is area in Sq. Km of successive levels

Level (m)	Dead Storage Capacity (M Cu. M)	Live Storage Capacity (M Cu. M)	Gross Storage Capacity using TIN (M Cu. M)	Gross Storage Capacity using Prismoidal formula (M Cu. M)	Spread Area (Sq. Km)	Remarks
157.00	0.000	0.000	0.000	0.000	0.000	
157.10	0.000	0.000	0.000	0.000	0.000	
157.20	0.000	0.000	0.000	0.000	0.000	
157.30	0.000	0.000	0.000	0.000	0.002	
157.40	0.000	0.000	0.000	0.000	0.003	
157.50	0.001	0.000	0.001	0.001	0.008	
157.60	0.002	0.000	0.002	0.002	0.022	
157.70	0.005	0.000	0.005	0.005	0.029	
157.80	0.008	0.000	0.008	0.008	0.037	
157.90	0.012	0.000	0.012	0.012	0.046	
158.00	0.017	0.000	0.017	0.017	0.052	
158.10	0.023	0.000	0.023	0.023	0.059	

Level (m)	Dead Storage Capacity (M Cu. M)	Live Storage Capacity (M Cu. M)	Gross Storage Capacity using TIN (M Cu. M)	Gross Storage Capacity using Prismoidal formula (M Cu. M)	Spread Area (Sq. Km)	Remarks
158.20	0.029	0.000	0.029	0.029	0.066	
158.30	0.036	0.000	0.036	0.036	0.078	
158.40	0.045	0.000	0.045	0.045	0.091	
158.50	0.054	0.000	0.054	0.054	0.102	
158.60	0.065	0.000	0.065	0.065	0.112	
158.70	0.077	0.000	0.077	0.077	0.122	
158.80	0.089	0.000	0.089	0.089	0.131	
158.90	0.103	0.000	0.103	0.103	0.138	
159.00	0.117	0.000	0.117	0.117	0.144	
159.10	0.132	0.000	0.132	0.132	0.152	
159.20	0.148	0.000	0.148	0.147	0.164	
159.30	0.165	0.000	0.165	0.164	0.175	
159.40	0.183	0.000	0.183	0.183	0.186	
159.50	0.202	0.000	0.202	0.202	0.199	
159.60	0.222	0.000	0.222	0.222	0.214	
159.70	0.245	0.000	0.245	0.244	0.228	
159.80	0.268	0.000	0.268	0.268	0.241	
159.90	0.293	0.000	0.293	0.293	0.255	
160.00	0.319	0.000	0.319	0.319	0.272	
160.10	0.347	0.000	0.347	0.347	0.293	
160.20	0.378	0.000	0.378	0.378	0.328	
160.30	0.412	0.000	0.412	0.412	0.350	
160.40	0.448	0.000	0.448	0.448	0.372	
160.50	0.487	0.000	0.487	0.487	0.395	
160.60	0.527	0.000	0.527	0.527	0.422	
160.70	0.571	0.000	0.571	0.571	0.447	
160.80	0.617	0.000	0.617	0.617	0.470	
160.90	0.665	0.000	0.665	0.665	0.497	
161.00	0.716	0.000	0.716	0.716	0.527	
161.10	0.770	0.000	0.770	0.770	0.556	
161.20	0.827	0.000	0.827	0.827	0.583	
161.30	0.887	0.000	0.887	0.887	0.609	
161.40	0.949	0.000	0.949	0.949	0.637	
161.50	1.014	0.000	1.014	1.014	0.665	
161.60	1.082	0.000	1.082	1.082	0.694	

Level (m)	Dead Storage Capacity (M Cu. M)	Live Storage Capacity (M Cu. M)	Gross Storage Capacity using TIN (M Cu. M)	Gross Storage Capacity using Prismoidal formula (M Cu. M)	Spread Area (Sq. Km)	Remarks
161.70	1.153	0.000	1.153	1.153	0.724	
161.80	1.227	0.000	1.227	1.227	0.755	
161.90	1.304	0.000	1.304	1.304	0.788	
162.00	1.385	0.000	1.385	1.385	0.826	
162.10	1.470	0.000	1.470	1.470	0.865	
162.20	1.558	0.000	1.558	1.558	0.909	
162.30	1.652	0.000	1.652	1.652	0.960	
162.40	1.750	0.000	1.750	1.750	1.008	
162.50	1.853	0.000	1.853	1.853	1.058	
162.60	1.962	0.000	1.962	1.962	1.125	
162.70	2.079	0.000	2.079	2.079	1.199	
162.80	2.201	0.000	2.201	2.201	1.256	
162.90	2.330	0.000	2.330	2.330	1.318	
163.00	2.465	0.000	2.465	2.466	1.392	
163.10	2.608	0.000	2.608	2.608	1.466	
163.20	2.758	0.000	2.758	2.758	1.533	
163.30	2.915	0.000	2.915	2.915	1.602	
163.40	3.079	0.000	3.079	3.079	1.683	
163.50	3.252	0.000	3.252	3.252	1.776	
163.60	3.434	0.000	3.434	3.434	1.850	
163.70	3.622	0.000	3.622	3.622	1.917	
163.80	3.817	0.000	3.817	3.817	1.989	
163.90	4.020	0.000	4.020	4.020	2.063	
164.00	4.230	0.000	4.230	4.230	2.138	
164.10	4.448	0.000	4.448	4.448	2.222	
164.20	4.675	0.000	4.675	4.675	2.330	
164.30	4.914	0.000	4.914	4.914	2.437	
164.40	5.162	0.000	5.162	5.162	2.536	
164.50	5.421	0.000	5.421	5.421	2.634	
164.60	5.689	0.000	5.689	5.689	2.731	
164.70	5.967	0.000	5.967	5.967	2.830	
164.75	**6.110**	0.000	**6.110**	**6.110**	**2.883**	**MDDL**
164.80	6.110	0.145	6.255	6.255	2.934	
164.90	6.110	0.444	6.554	6.554	3.035	
165.00	6.110	0.752	6.862	6.862	3.132	

Level (m)	Dead Storage Capacity (M Cu. M)	Live Storage Capacity (M Cu. M)	Gross Storage Capacity using TIN (M Cu. M)	Gross Storage Capacity using Prismoidal formula (M Cu. M)	Spread Area (Sq. Km)	Remarks
165.10	6.110	1.071	7.180	7.180	3.234	
165.20	6.110	1.399	7.509	7.509	3.342	
165.30	6.110	1.738	7.848	7.848	3.440	
165.40	6.110	2.087	8.197	8.197	3.534	
165.50	6.110	2.446	8.555	8.555	3.636	
165.60	6.110	2.814	8.924	8.924	3.743	
165.70	6.110	3.194	9.304	9.304	3.849	
165.80	6.110	3.584	9.694	9.694	3.959	
165.90	6.110	3.986	10.096	10.096	4.072	
166.00	6.110	4.399	10.508	10.509	4.187	
166.10	6.110	4.823	10.933	10.933	4.294	
166.20	6.110	5.258	11.367	11.367	4.403	
166.30	6.110	5.704	11.814	11.814	4.523	
166.40	6.110	6.162	12.272	12.272	4.638	
166.50	6.110	6.632	12.741	12.741	4.748	
166.60	6.110	7.112	13.221	13.222	4.859	
166.70	6.110	7.604	13.713	13.713	4.978	
166.80	6.110	8.108	14.217	14.217	5.102	
166.90	6.110	8.624	14.734	14.734	5.230	
167.00	6.110	9.154	15.263	15.263	5.356	
167.10	6.110	9.695	15.805	15.805	5.472	
167.20	6.110	10.248	16.358	16.358	5.587	
167.30	6.110	10.813	16.922	16.922	5.701	
167.40	6.110	11.388	17.498	17.498	5.817	
167.50	6.110	11.976	18.086	18.086	5.940	
167.60	6.110	12.577	18.686	18.686	6.065	
167.70	6.110	13.189	19.299	19.299	6.192	
167.80	6.110	13.815	19.925	19.924	6.320	
167.90	6.110	14.453	20.563	20.563	6.446	
168.00	6.110	15.104	21.214	21.213	6.572	
168.10	6.110	15.768	21.877	21.877	6.700	
168.20	6.110	16.444	22.554	22.553	6.828	
168.30	6.110	17.133	23.243	23.243	6.959	
168.40	6.110	17.836	23.946	23.945	7.096	
168.50	6.110	18.552	24.662	24.662	7.232	

Level (m)	Dead Storage Capacity (M Cu. M)	Live Storage Capacity (M Cu. M)	Gross Storage Capacity using TIN (M Cu. M)	Gross Storage Capacity using Prismoidal formula (M Cu. M)	Spread Area (Sq. Km)	Remarks
168.60	6.110	19.282	25.392	25.392	7.363	
168.70	6.110	20.025	26.135	26.135	7.496	
168.80	6.110	20.782	26.891	26.891	7.629	
168.90	6.110	21.551	27.661	27.660	7.760	
169.00	6.110	22.334	28.443	28.443	7.893	
169.10	6.110	23.130	29.239	29.239	8.029	
169.20	6.110	23.940	30.049	30.049	8.169	
169.30	6.110	24.764	30.874	30.873	8.322	
169.40	6.110	25.603	31.713	31.713	8.463	
169.50	6.110	26.456	32.566	32.566	8.596	
169.60	6.110	27.322	33.432	33.431	8.723	
169.70	6.110	28.201	34.310	34.310	8.844	
169.80	6.110	29.091	35.201	35.200	8.961	
169.90	6.110	29.993	36.103	36.102	9.075	
170.00	6.110	30.906	37.016	37.015	9.186	
170.10	6.110	31.830	37.940	37.939	9.293	
170.20	6.110	32.764	38.874	38.873	9.389	
170.30	6.110	33.708	39.817	39.816	9.475	
170.40	6.110	34.659	40.769	40.768	9.557	
170.50	6.110	35.619	41.728	41.727	9.636	
170.60	6.110	36.586	42.696	42.695	9.708	
170.70	6.110	37.560	43.670	43.669	9.772	
170.80	6.110	38.540	44.650	44.649	9.834	
170.90	6.110	39.527	45.636	45.635	9.893	
171.00	6.110	40.519	46.628	46.627	9.950	
171.10	6.110	41.517	47.626	47.625	10.006	
171.20	6.110	42.520	48.630	48.629	10.062	
171.30	6.110	43.529	49.639	49.637	10.116	
171.40	6.110	44.543	50.653	50.652	10.169	
171.50	6.110	45.563	51.672	51.671	10.219	
171.60	6.110	46.587	52.697	52.695	10.268	
171.70	6.110	47.616	53.726	53.725	10.317	
171.80	6.110	48.650	54.760	54.759	10.365	
171.90	6.110	49.689	55.799	55.798	10.413	
172.00	6.110	50.733	56.843	56.841	10.463	

Level (m)	Dead Storage Capacity (M Cu. M)	Live Storage Capacity (M Cu. M)	Gross Storage Capacity using TIN (M Cu. M)	Gross Storage Capacity using Prismoidal formula (M Cu. M)	Spread Area (Sq. Km)	Remarks
172.10	6.110	51.782	57.891	57.890	10.513	
172.20	6.110	52.836	58.945	58.944	10.567	
172.30	6.110	53.895	60.005	60.004	10.625	
172.40	6.110	54.961	61.071	61.069	10.685	
172.50	6.110	56.033	62.142	62.141	10.747	
172.60	6.110	57.110	63.220	63.219	10.812	
172.70	6.110	58.195	64.305	64.303	10.877	
172.80	6.110	59.286	65.396	65.394	10.942	
172.90	6.110	60.383	66.493	66.492	11.009	
173.00	**6.110**	**61.488**	**67.597**	**67.596**	**11.082**	**FRL**
173.10	6.110	62.602	68.712	68.712	11.246	
173.20	6.110	63.770	69.880	69.883	12.168	
173.30	6.110	65.015	71.125	71.125	12.686	
173.40	6.110	66.306	72.416	72.416	13.137	
173.50	6.110	67.642	73.752	73.752	13.573	
173.60	6.110	69.020	75.130	75.130	13.986	
173.70	6.110	70.438	76.548	76.548	14.375	
173.80	6.110	71.894	78.003	78.003	14.726	
173.90	6.110	73.383	79.492	79.492	15.052	
174.00	6.110	74.905	81.014	81.015	15.411	
174.02	**6.110**	**75.214**	**81.323**	**81.324**	**15.494**	**HFL**

Table 6.2-1 Capacity and Area

6.3 Comparative Statement of Guhai Reservoir

Elevation (m)	Original		AS per 2021		Remark
	Area (Sq. Km)	Gross Storage Capacity (M Cu. m)	Area (Sq. Km)	Gross Storage Capacity (M Cu. m)	
154.93	0.000	0.000	0.000	0.000	
155.00	0.002	0.001	0.000	0.000	
156.00	0.028	0.008	0.000	0.000	
157.00	0.123	0.114	0.000	0.000	
158.00	0.218	0.221	0.052	0.017	
159.00	0.383	0.591	0.144	0.117	
160.00	0.547	0.961	0.272	0.319	
161.00	0.768	1.718	0.527	0.716	
162.00	0.989	2.475	0.826	1.385	
163.00	1.539	3.980	1.392	2.465	
164.00	2.089	5.484	2.138	4.230	
164.75	**2.696**	**7.530**	**2.883**	**6.110**	**MDDL**
165.00	2.898	8.261	3.132	7.180	
166.00	3.708	11.185	4.187	10.509	
167.00	4.942	14.600	5.356	15.264	
168.00	6.175	20.957	6.572	21.214	
169.00	7.452	28.377	7.893	28.443	
170.00	8.728	35.797	9.186	37.016	
171.00	10.413	46.187	9.950	46.629	
172.00	12.097	56.577	10.463	56.843	
173.00	**14.100**	**68.750**	**11.082**	**67.597**	**FRL**

Table 6.3-1 COMPARATIVE STATEMENT OF GUHAI RESERVOIR

6.4 Gross Capacity in M Cu. m of the Reservoir - Year 2021:

RL (m)	0	0.02	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.75	0.8	0.9
157	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.005	0.007	0.008	0.012
158	0.017	0.018	0.023	0.029	0.036	0.045	0.054	0.065	0.077	0.083	0.089	0.103
159	0.117	0.120	0.132	0.148	0.165	0.183	0.202	0.222	0.245	0.256	0.268	0.293
160	0.319	0.325	0.347	0.378	0.412	0.448	0.487	0.527	0.571	0.594	0.617	0.665
161	0.716	0.727	0.770	0.827	0.887	0.949	1.014	1.082	1.153	1.190	1.227	1.304
162	1.385	1.402	1.470	1.558	1.652	1.750	1.853	1.962	2.079	2.139	2.201	2.330
163	2.465	2.493	2.608	2.758	2.915	3.079	3.252	3.434	3.622	3.719	3.817	4.020
164	4.230	4.273	4.448	4.675	4.914	5.162	5.421	5.689	5.967	**6.110**	6.255	6.554
165	6.862	6.925	7.180	7.509	7.848	8.197	8.555	8.924	9.304	9.497	9.694	10.096
166	10.508	10.592	10.933	11.367	11.814	12.272	12.741	13.221	13.713	13.964	14.217	14.734
167	15.263	15.371	15.805	16.358	16.922	17.498	18.086	18.686	19.299	19.610	19.925	20.563
168	21.214	21.345	21.877	22.554	23.243	23.946	24.662	25.392	26.135	26.511	26.891	27.661
169	28.443	28.601	29.239	30.049	30.874	31.713	32.566	33.432	34.310	34.754	35.201	36.103
170	37.016	37.200	37.940	38.874	39.817	40.769	41.728	42.696	43.670	44.159	44.650	45.636
171	46.628	46.828	47.626	48.630	49.639	50.653	51.672	52.697	53.726	54.242	54.760	55.799
172	56.843	57.052	57.891	58.945	60.005	61.071	62.142	63.220	64.305	64.849	65.396	66.493
173	**67.597**	67.819	68.712	69.880	71.125	72.416	73.752	75.130	76.548	77.271	78.003	79.492
174	81.014	**81.323**										

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:

RL (m)	0	0.02	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.75	0.8	0.9
164	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.145	0.444
165	0.752	0.815	1.071	1.399	1.738	2.087	2.446	2.814	3.194	3.388	3.584	3.986
166	4.399	4.483	4.823	5.258	5.704	6.162	6.632	7.112	7.604	7.854	8.108	8.624
167	9.154	9.261	9.695	10.248	10.813	11.388	11.976	12.577	13.189	13.501	13.815	14.453
168	15.104	15.236	15.768	16.444	17.133	17.836	18.552	19.282	20.025	20.402	20.782	21.551
169	22.334	22.492	23.130	23.940	24.764	25.603	26.456	27.322	28.201	28.644	29.091	29.993
170	30.906	31.090	31.830	32.764	33.708	34.659	35.619	36.586	37.560	38.049	38.540	39.527
171	40.519	40.718	41.517	42.520	43.529	44.543	45.563	46.587	47.616	48.133	48.650	49.689
172	50.733	50.942	51.782	52.836	53.895	54.961	56.033	57.110	58.195	58.740	59.286	60.383
173	**61.488**	61.710	62.602	63.770	65.015	66.306	67.642	69.020	70.438	71.162	71.894	73.383
174	74.905	**75.214**										

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:

RL (m)	0	0.02	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.75	0.8	0.9
157	0.000	0.000	0.000	0.000	0.002	0.003	0.008	0.022	0.029	0.033	0.037	0.046
158	0.052	0.054	0.059	0.066	0.078	0.091	0.102	0.112	0.122	0.127	0.131	0.138
159	0.144	0.145	0.152	0.164	0.175	0.186	0.199	0.214	0.228	0.235	0.241	0.255
160	0.272	0.276	0.293	0.328	0.350	0.372	0.395	0.422	0.447	0.458	0.470	0.497
161	0.527	0.532	0.556	0.583	0.609	0.637	0.665	0.694	0.724	0.740	0.755	0.788
162	0.826	0.833	0.865	0.909	0.960	1.008	1.058	1.125	1.199	1.228	1.256	1.318
163	1.392	1.407	1.466	1.533	1.602	1.683	1.776	1.850	1.917	1.952	1.989	2.063
164	2.138	2.153	2.222	2.330	2.437	2.536	2.634	2.731	2.830	2.883	2.934	3.035
165	3.132	3.152	3.234	3.342	3.440	3.534	3.636	3.743	3.849	3.903	3.959	4.072
166	4.187	4.209	4.294	4.403	4.523	4.638	4.748	4.859	4.978	5.041	5.102	5.230
167	5.356	5.379	5.472	5.587	5.701	5.817	5.940	6.065	6.192	6.256	6.320	6.446
168	6.572	6.597	6.700	6.828	6.959	7.096	7.232	7.363	7.496	7.562	7.629	7.760
169	7.893	7.920	8.029	8.169	8.322	8.463	8.596	8.723	8.844	8.903	8.961	9.075
170	9.186	9.207	9.293	9.389	9.475	9.557	9.636	9.708	9.772	9.803	9.834	9.893
171	9.950	9.961	10.006	10.062	10.116	10.169	10.219	10.268	10.317	10.341	10.365	10.413
172	10.463	10.473	10.513	10.567	10.625	10.685	10.747	10.812	10.877	10.910	10.942	11.009
173	**11.082**	11.099	11.246	12.168	12.686	13.137	13.573	13.986	14.375	14.553	14.726	15.052
174	15.411	**15.494**										

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

Rate of Sedimentation (at FRL 173 m) with respect to impounding year 1990													
Sr. No	**Year of Survey**	**Capacity in M Cu. m**			**Period in years**	**Silt Deposited in M Cu. m**	**Silt Rate in M Cu. m/year**	**Loss in Capacity in M Cu. m and percentage**			**Silt Index ham/100 Sq. Km/Yr.**	**Annual % loss**	**Remarks**
		Dead	**Live**	**Gross**				**Dead**	**Live**	**Gross**			
1	1990	7.53	61.22	68.75	-	-	-	-	-	-	-	-	
2	2021 (Hydrographic survey)	6.11	61.486	67.596	31	1.154	0.037	1.42 18.86%	-0.266 -0.43%	1.154 1.68%	0.882	0.05%	**Insignificant Category**

Table 6.7-1 RATE OF SEDIMENTATION

<u>**According to IS -12182 (1987)**</u>

Annual % loss	**-**	**Class of Reservoir**
Up to 0.1	-	Insignificant
0.1 to 0.5	-	Significant
Above 0.5	-	Serious

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 hydrologica1 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 unti1 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:

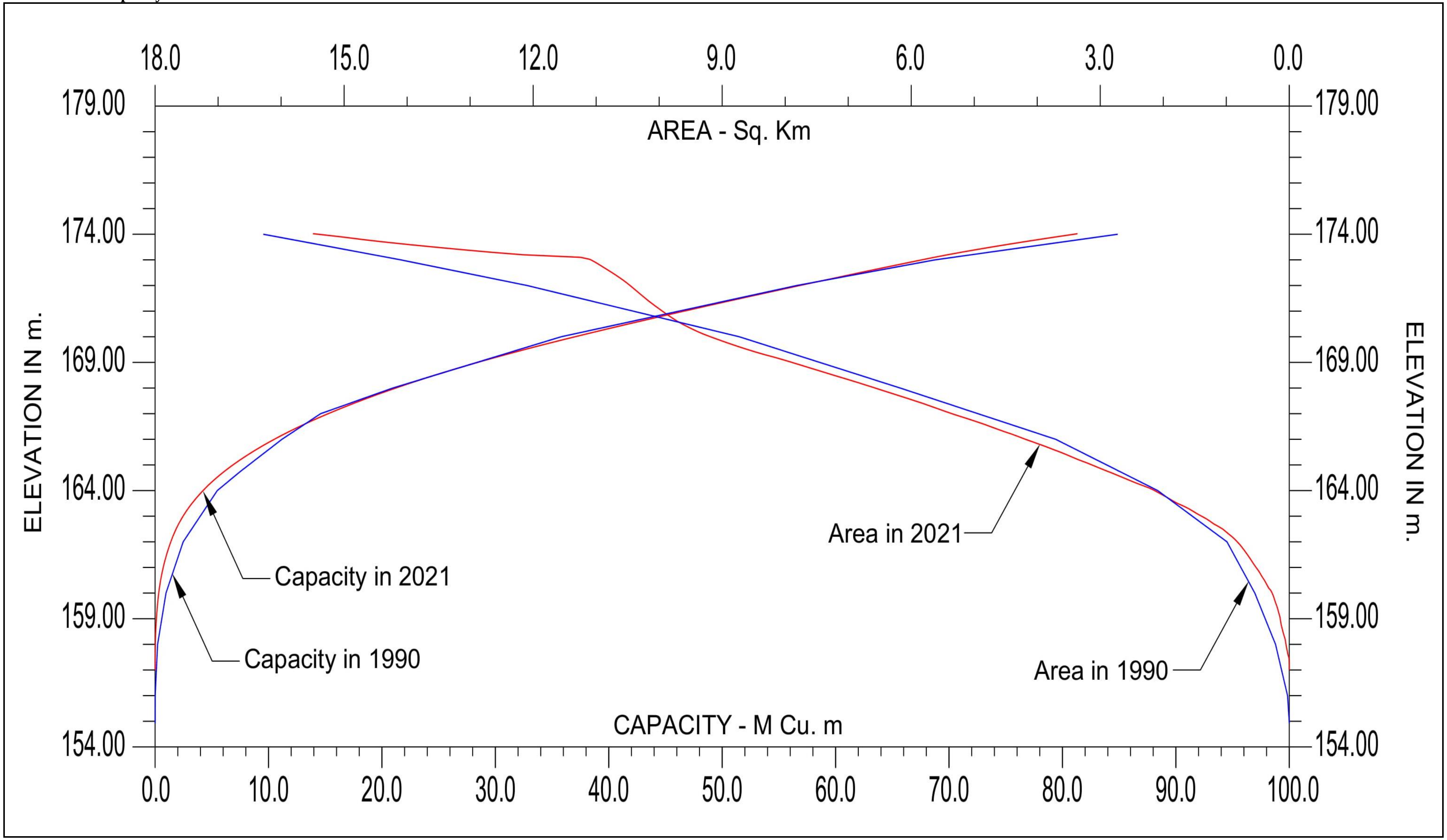

Figure 6.10-1 AREA – CAPACITY - CURVE

6.11 Segment, Contour, Wire Frame Map and L section:

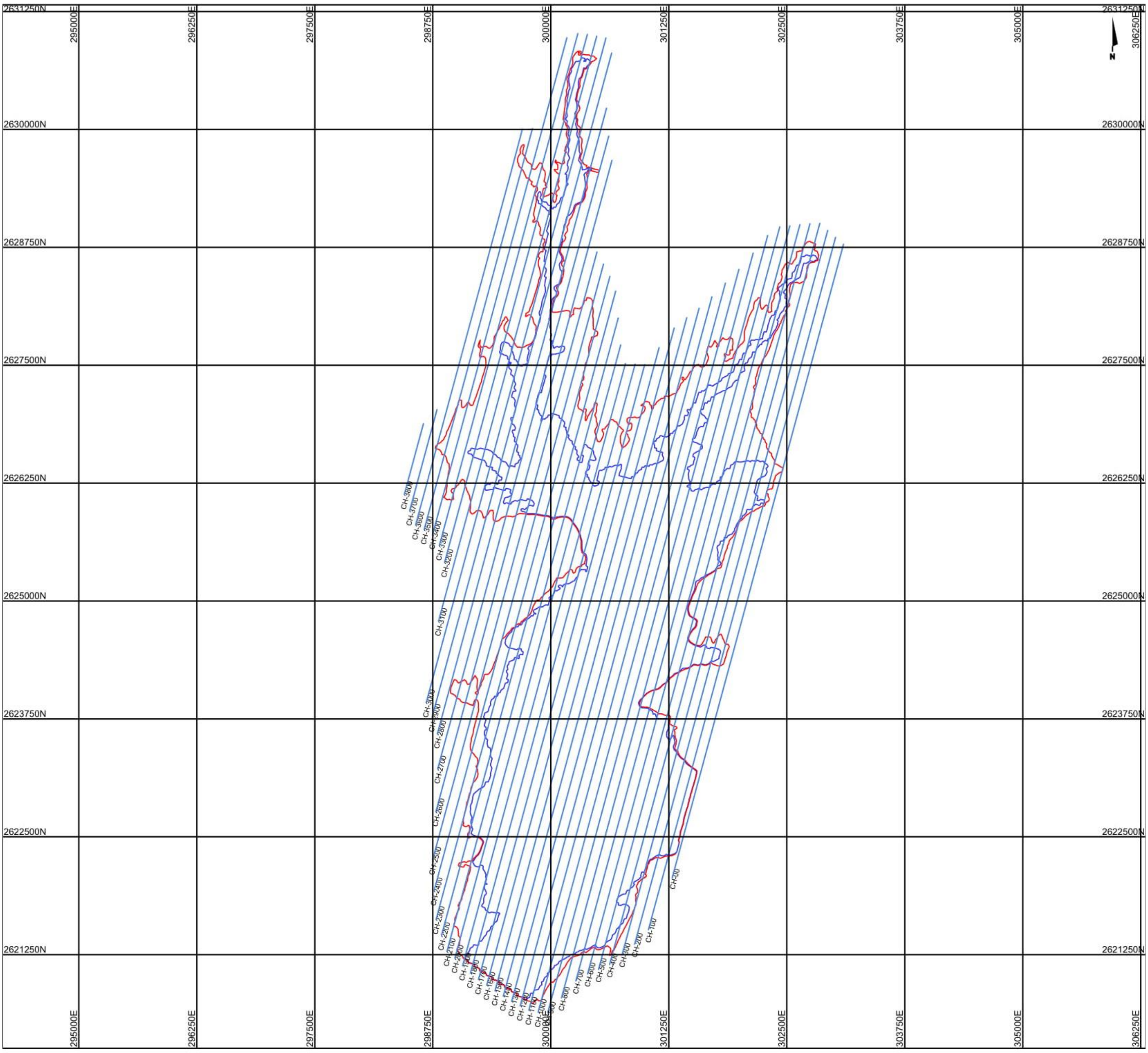

Figure 6.11-1 SEGMENT MAP FOR CROSS SECTION

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.

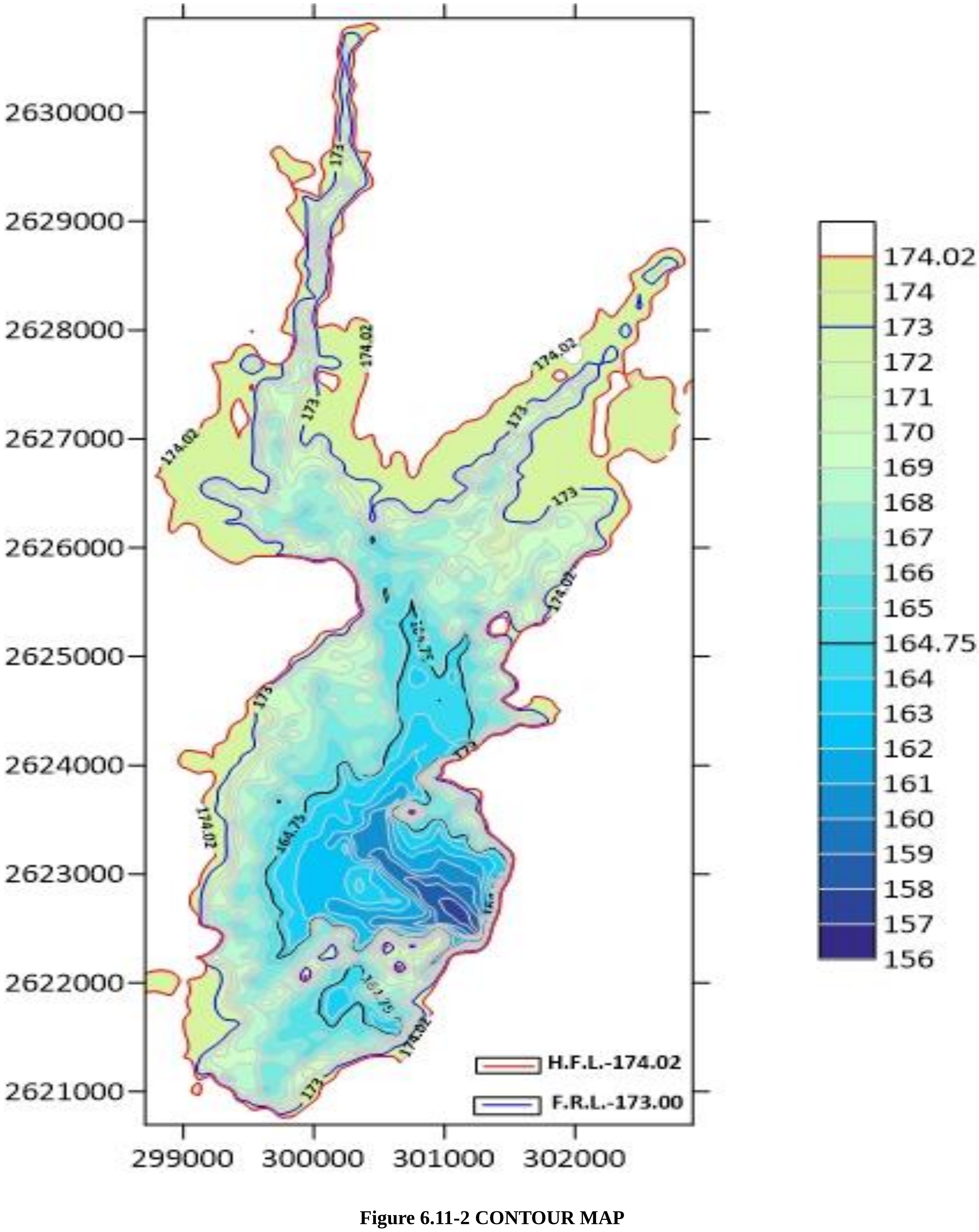

Figure 6.11-2 CONTOUR MAP

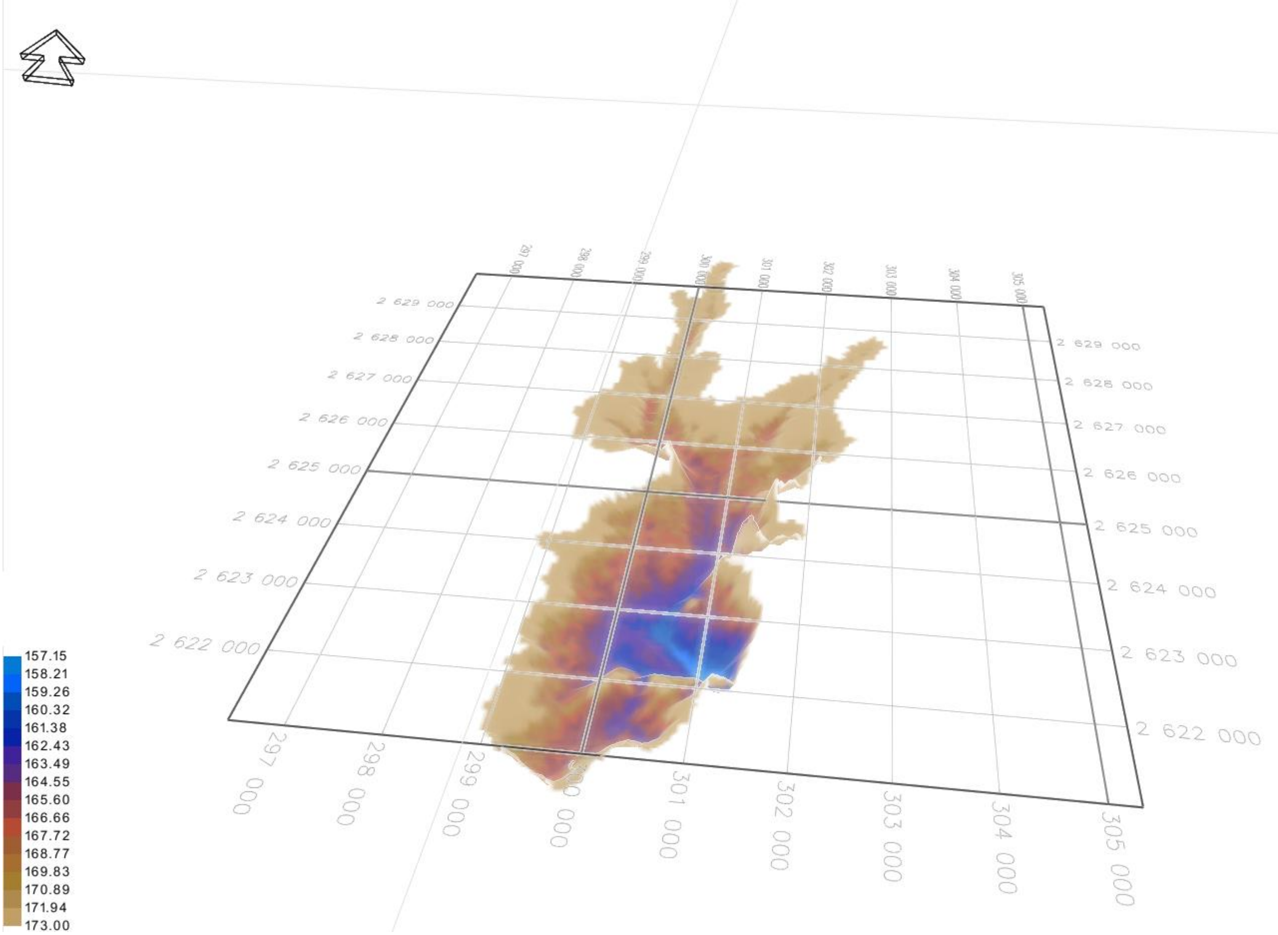

Figure 6.11-3 WIRE FRAME MAP

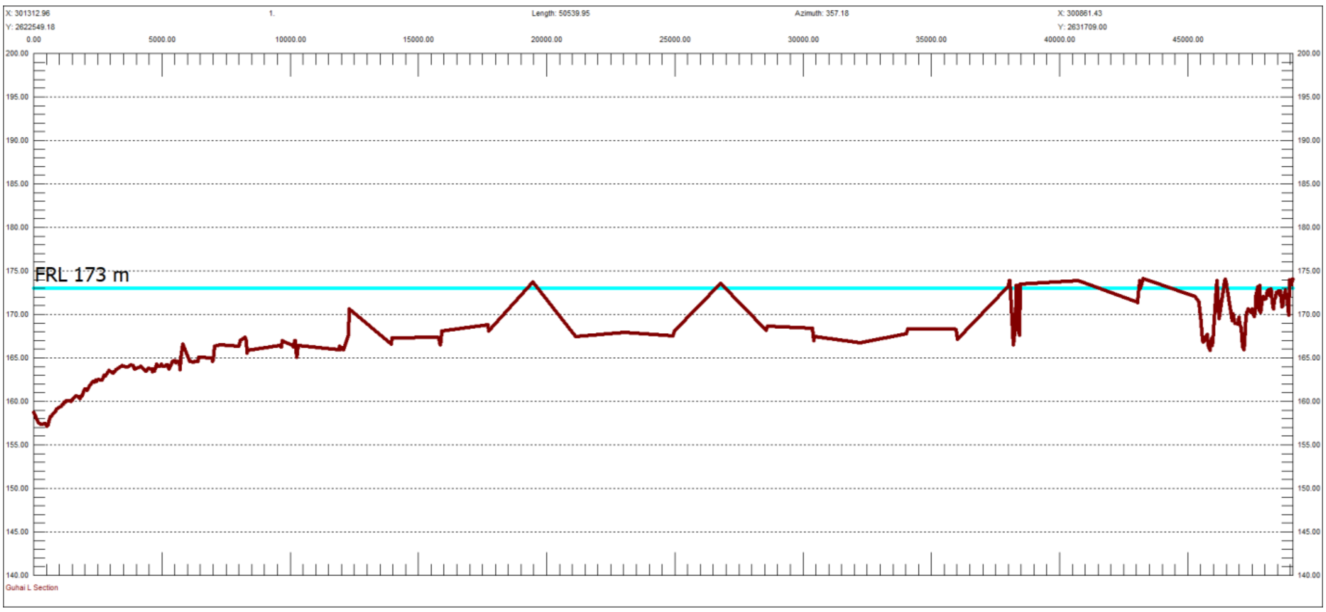

Figure 6.11-4 L SECTION

7 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.

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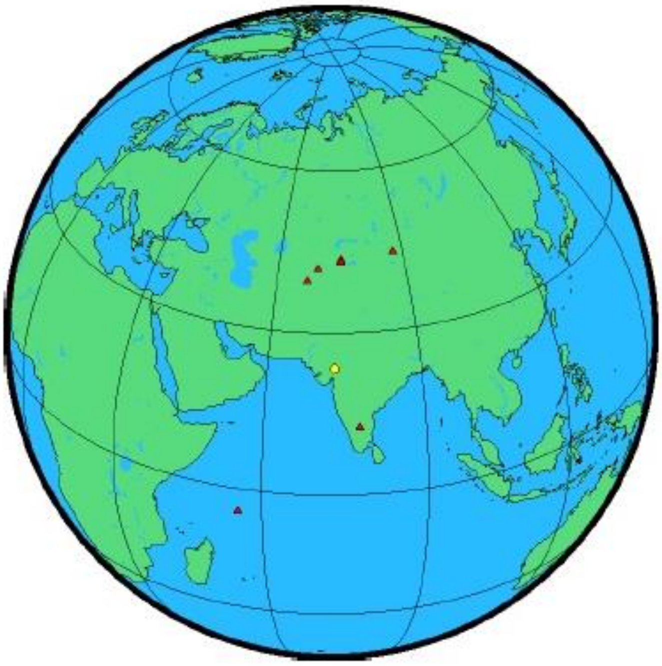
1 User Data

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

Station (s)	Submitted File	Antenna Type	Antenna Height (m)	Start Time	End Time
OBSG	OBSG_12022021_164021.210	TIAPENG6 NONE	1.800	2021/02/12 08:41:00	2021/02/12 11:43:00

2 Processing Summary



Date	User Stations	Reference Stations	Orbit Type
2021/02/12 08:41:00	OBSG	CHUM IISC KIT3 POL2 SEYG TASH URUM	IGS ultra rapid

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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

Station	X (m)	Y (m)	Z (m)	ITRF2014 @
OBSG	1703420.393	5589679.182	2548002.876	12/02/2021
CHUM	1228950.353	4508080.005	4327868.539	12/02/2021
IISC	1337935.755	6070317.124	1427877.335	12/02/2021
KIT3	1944944.700	4556652.352	4004326.059	12/02/2021
POL2	1239970.928	4530790.158	4302578.870	12/02/2021
SEYG	3597835.860	5240884.120	-516780.938	12/02/2021
TASH	1695944.773	4487138.668	4190140.755	12/02/2021
URUM	193030.130	4606851.270	4393311.494	12/02/2021

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/.

Station	Latitude (DMS)	Longitude (DMS)	Ellipsoidal Height(m)	Derived Above Geoid Height(m)
OBSG	23 42 02.08119	73 03 06.19902	125.079	178.389
CHUM	42 59 54.60557	74 45 03.97454	716.338	759.328
IISC	13 01 16.21562	77 34 13.37602	843.690	929.611
KIT3	39 08 05.16366	66 53 07.62173	622.475	659.572
POL2	42 40 47.17460	74 41 39.37355	1714.203	1754.269
SEYG	-4 40 43.43094	55 31 50.27735	-37.624	3.378
TASH	41 19 40.97919	69 17 44.05696	439.696	483.266
URUM	43 48 28.61935	87 36 02.42008	858.830	922.209

3.3 UTM Grid, GRS80 Ellipsoid, ITRF2014

Station	East (m)	North (m)	Zone	Ellipsoidal Height (m)	Derived Above Geoid Height(m)
OBSG	301356.670	2622434.906	43	125.079	178.389
CHUM	479712.403	4760678.447	43	716.338	759.328
IISC	778796.703	1440886.655	43	843.690	929.611
KIT3	317236.775	4333861.160	42	622.475	659.572
POL2	474951.458	4725300.182	43	1714.203	1754.269
SEYG	337019.659	9482677.646	40	-37.624	3.378
TASH	524734.362	4575216.870	42	439.696	483.266
URUM	548313.471	4850717.926	45	858.830	922.209

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User: samrajdwivedi@gmail.com

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

Station	Longitude(East) (m)	Latitude(North) (m)	Ellipsoidal Height(Up) (m)
OBSC	0.013	0.013	0.060
CHUM	0.008	0.006	0.014
IISC	0.012	0.008	0.016
KIT3	0.008	0.006	0.015
POL2	0.008	0.006	0.014
SEYG	0.012	0.008	0.016
TASH	0.008	0.006	0.014
URUM	0.012	0.010	0.030

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4 Ambiguity Resolution - Per Baseline

Baseline	Ambiguities Resolved	Baseline Length (km)
KIT3 - TASH	75.0 %	318.371
CHUM - POL2	70.6 %	35.732
IISC - SEYG	83.3 %	3094.641
OBSG - TASH	76.9 %	1977.945
POL2 - URUM	63.1 %	1053.614
CHUM - TASH	73.4 %	487.331
AVERAGE	73.7%	1161.272

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.

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5 Computation Standards

5.1 Computation System

Software	Bernese GNSS Software Version 5.2.
GNSS system(s)	GPS only.

5.2 Data Preprocessing and Measurement Modelling

Data preprocessing	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.
Basic observable	Carrier phase with an elevation angle cutoff of 7° and a sampling rate of 3 minutes. However, data cleaning is performed a sampling rate of 30 seconds. Elevation dependent weighting is applied according to $1/\sin(e)^2$ where e is the satellite elevation.
Modelled observable	Double differences of the ionosphere-free linear combination.
Ground antenna phase centre calibrations	IGS14 absolute phase-centre variation model is applied.
Tropospheric Model	A priori model is the GMF mapped with the DRY-GMF.
Tropospheric Estimation	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.
Tropospheric Mapping Function	GMF
Ionosphere	First-order effect eliminated by forming the ionosphere-free linear combination of L1 and L2. Second and third effect applied.
Tidal displacements	Solid earth tidal displacements are derived from the complete model from the IERS Conventions 2010, but ocean tide loading is not applied.
Atmospheric loading	Applied
Satellite centre of mass correction	IGS14 phase-centre variation model applied
Satellite phase centre calibration	IGS14 phase-centre variation model applied
Satellite trajectories	Best available IGS products.
Earth Orientation	Best available IGS products.

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5.3 Estimation Process

Adjustment	Weighted least-squares algorithm.
Station coordinates	Coordinate constraints are applied at the Reference sites with standard deviation of 1mm and 2mm for horizontal and vertical components respectively.
Troposphere	Zenith delay parameters and pairs of horizontal delay gradient parameters are estimated for each station in intervals of 2 hours and 24 hours.
Ionospheric correction	An ionospheric map derived from the contributing reference stations is used to aid ambiguity resolution.
Ambiguity	Ambiguities are resolved in a baseline-by-baseline mode using the Code-Based strategy for 180-6000km baselines, the Phase-Based L5/L3 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.

5.4 Reference Frame and Coordinate Uncertainty

Terrestrial reference frame	IGS14 station coordinates and velocities mapped to the mean epoch of observation.
Australian datums	GDA2020 and GDA94.
Derived AHD	For stations within Australia, AUSGeoid2020 (V20180201) is used to compute AHD. AUSGeoid2020 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.
Above-geoid heights	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 2159, and contains additional coefficients extending to degree 2190 and order 2159.
Coordinate uncertainty	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.

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8 SINGLE BEAM ECHOSOUNDER BAR CHECK RESULTS

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title: **Bathymetric Survey**	Vessel: **Inflatable Boat**	Place: **Guhai Dam**
Date: **23-Jan-21**	Time: **13:15**		
Observed By: **Amit Singh**		Echosounder Model and SL. No. **Sonarmite**	Area Depth **9**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity Average	Sound Velocity Upto Depth
0.4				1500	8

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

Observations while lowering			Observations while hoisting		
Bar Depth (m)	ES Reading (m)	Difference (m)	Bar Depth (m)	ES Reading (m)	Difference (m)
2	2.01	-0.01	8	8.02	-0.02
4	3.99	0.01	6	6.01	-0.01
6	6.01	-0.01	4	3.99	0.01
8	7.98	0.02	2	2	0
	Average	0.0025		Average	-0.0050
	Std. Dev	0.0150		Std. Deviation	0.0129
				Cumulative Average	0.00
				Cumulative Std. Deviation	0.0015

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Approved By: Survey Manager

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title: **Bathymetric Survey**	Vessel: **Inflatable Boat**	Place: **Guhai Dam**
Date: **24-Jan-21**	Time: **10:35**		
Observed By: **Amit Singh**		Echosounder Model and SL. No. **Sonarmite**	Area Depth **8**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	Upto Depth
0.4				1500	6
Barcheck Frequency selected		Survey Frequency:		Manufacturer's Accuracy	
210		210		0.20 % of Depth	0.02 m

Observations while lowering			Observations while hoisting		
Bar Depth (m)	ES Reading (m)	Difference (m)	Bar Depth (m)	ES Reading (m)	Difference (m)
2	2.02	-0.02	6	6.02	-0.02
4	3.99	0.01	4	4.01	-0.01
6	5.98	0.02	2	2	0
	Average	0.0033		Average	-0.0100
	Std. Dev	0.0208		Std. Deviation	0.0100
				Cumulative Average	0.00
				Cumulative Std. Deviation	0.0076

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Approved By: Survey Manager

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title: **Bathymetric Survey**	Vessel: **Inflatable Boat**	Place: **Guhai Dam**
Date: **25-Jan-21**	Time: **9:00**		
Observed By: **Amit Singh**		Echosounder Model and SL. No. **Sonarmite**	Area Depth **7**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	Upto Depth
0.4				1500	5
Barcheck Frequency selected		Survey Frequency:		Manufacturer's Accuracy	
210		210		0.20 % of Depth	0.01 m

Observations while lowering			Observations while hoisting		
Bar Depth (m)	ES Reading (m)	Difference (m)	Bar Depth (m)	ES Reading (m)	Difference (m)
2	2.01	-0.01	5	5.01	-0.01
3	2.98	0.02	4	4.02	-0.02
4	3.99	0.01	3	3.02	-0.02
5	4.99	0.01	2	2	0
	Average	0.0075		Average	-0.0125
	Std. Dev	0.0126		Std. Deviation	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

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title:		Vessel:		Place:
	Bathymetric Survey		**Inflatable Boat**		**Guhai Dam**
Date: **26-Jan-21**	Time: **9:20**				
Observed By: **Amit Singh**			Echosounder Model and SL. No. **Sonarmite**		Area Depth **6**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	**Upto Depth**
0.4				**1500**	**4**
Barcheck Frequency selected		**Survey Frequency:**		Manufacturer's Accuracy	
210		**210**		0.20 % of Depth	0.01 m

Observations while lowering			Observations while hoisting		
Bar Depth (m)	ES Reading (m)	Difference (m)	Bar Depth (m)	ES Reading (m)	Difference (m)
2	2.02	-0.02	4	4.01	-0.01
3	3	0	3	2.99	0.01
4	3.98	0.02	2	2.01	-0.01
	Average	0.0000		Average	-0.0033
	Std. Dev	0.0200		Std. Deviation	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

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title:	Vessel:	Place:
	Bathymetric Survey	**Inflatable Boat**	**Guhai Dam**
Date: **27-Jan-21**	Time: **9:10**		
Observed By: **Amit Singh**		Echosounder Model and SL. No. **Sonarmite**	Area Depth **5**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	Upto Depth
0.4				1500	4
Barcheck Frequency selected		Survey Frequency:		Manufacturer's Accuracy	
210		210		0.20 % of Depth	0.01 m

Observations while lowering			Observations while hoisting		
Bar Depth (m)	ES Reading (m)	Difference (m)	Bar Depth (m)	ES Reading (m)	Difference (m)
2	2.01	-0.01	4	4.01	-0.01
3	2.99	0.01	3	3.01	-0.01
4	3.98	0.02	2	2	0
	Average	0.0067		Average	-0.0067
	Std. Dev	0.0153		Std. Deviation	0.0058
				Cumulative Average	0.00
				Cumulative Std. Deviation	0.0067

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

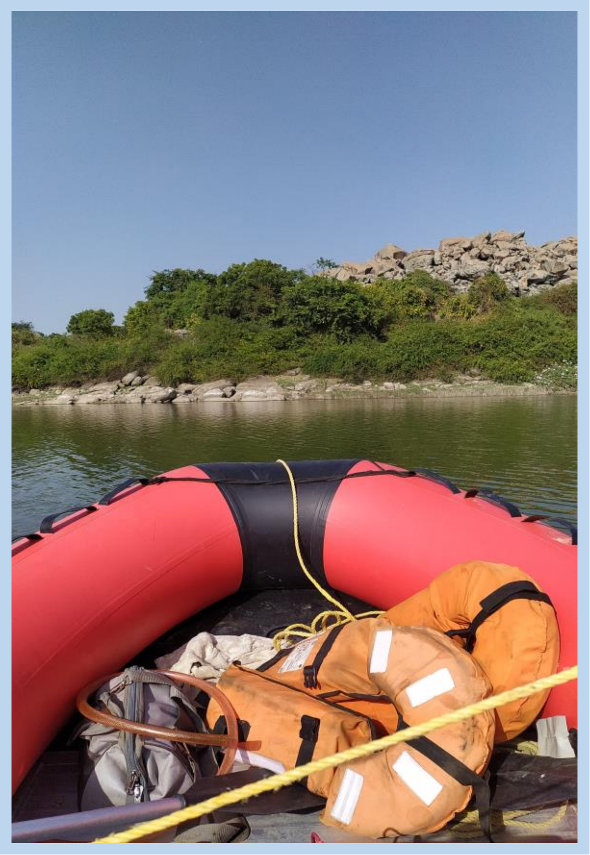
Approved By: Survey Manager

9 PHOTOGRAPHS

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

Water level scale

Survey carried out near Dam walls



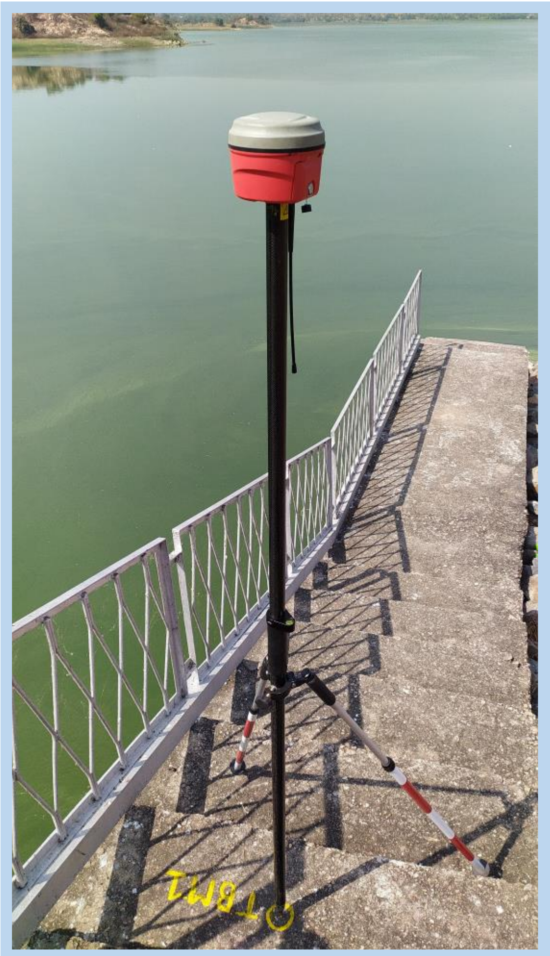
Survey in process

Dam boundary

Survey Area

Base Observation

Dam Shutter Area



Survey Observation

Survey in process

END OF REPORT