GEOSERVICES
MARITIME PVT. LTD.

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

GMPL REPORT NUMBER: P-SUR-BATHY-009-2020-21-WRD-MUKTESHWAR
SURVEY PERIOD: Hydrographic survey- 05 JAN TO 07 JAN 2021
Topographic survey- 26 JAN TO 30 JAN 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

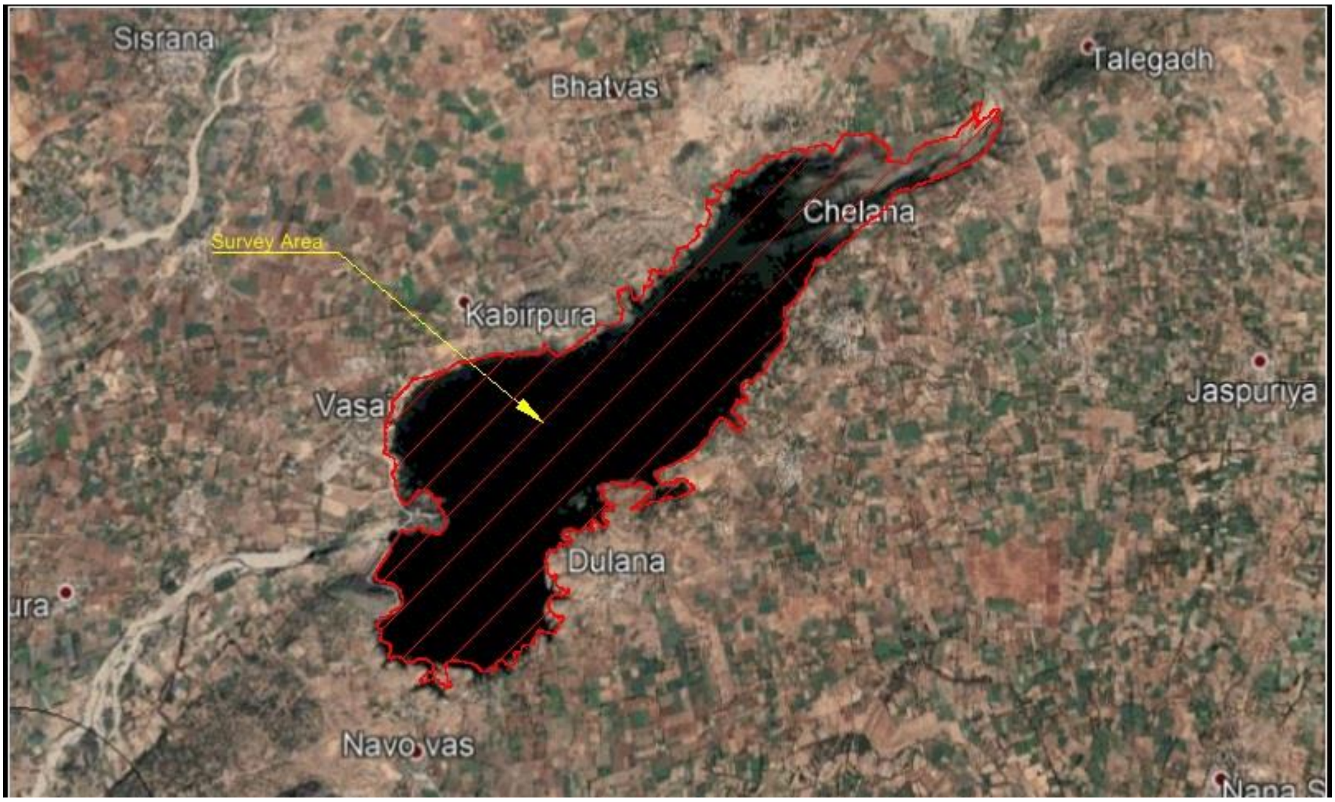

Figure 1.1-1 LOCATION MAP

LOCATION MAP SHOWING SURVEY AREA "MUKTESHWAR 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 Mukteshwar 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 Mukteshwar 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 05 Jan 2021".

1.2 Objective

The main objective of the topographic and bathymetric survey of reservoir is as follow:

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 Mukteshwar Reservoir.

The detailed scope of work was:

i) To measure the water depth of the Mukteshwar Reservoir 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 cm 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 MUKTESHWAR RESERVOIR

MUKTESHWAR RESERVOIR PROJECT		
I	**LOCATION**	
	Coordinates	Latitude 24°02'46" N Longitude 72°38'08" E
	River	Saraswati
	Village	Mukteshwar
	Taluka	Vadgam
	District	Banaskantha
	State	Gujarat
	Nearest Railway Station	Varetha railway station
	Purpose	Irrigation
II	**HYDROLOGY**	
	Catchment Area	306 Sq. Km
	Mean Annual Rainfall	907 mm
III	**DAM**	
	Dam Type	Earthen & Masonary
	Length of the top of the dam	2560 m
IV	**RESERVOIR**	
	MDDL	193.67 m
	FRL	201.65 m
	HFL/MWL	202.12 m
	Gross Storage Capacity	40 MCM
	Gross Storage Capacity at F.R.L.	31.57 MCM
	Dead Storage	5.8 MCM
	Live Storage	25.77 MCM
	Area at FRL	5.8 Sq. km
V	**SPILLWAY**	
	Type	Ogee
	Length of Spillway	104 m
	Maximum Discharge	4698 m^3/s
	Type, Nos. and Size of Gates	Radial, 7, (12.49 m x 8.23 m)
VII	**CANAL**	
	Length of canal	13 (Right), 9.3 (Left) km
	Capacity	1.7 (Right), 3.4 (Left) m3/s
	Gross command area	3726 ha (Right), 7576 ha (left)
	Culturable command area	2100 ha (Right), 4086 ha (left)

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 Mukteshwar Reservoir survey area from 05 JAN TO 07 JAN 2021 & 26 JAN 2021 TO 30 JAN 2021 to acquire bathymetric survey data and Topographic data respectively as per mutually agreed scope and relevant survey specifications.

TRIMBLE DGPS system, Odom Hydrotrac and Sonarmite Echo sounder (215 kHz) were utilised to acquire the bathymetric data within the Mukteshwar 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 Mukteshwar reservoir area.

Four (4) hours of DGPS observation was carried out on OBS-MUKT on dam top (Elevation of dam top was provided by Dam Authority) and one Temporary Bench Marks, TBM 1 was established to cover entire reservoir.

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

- The Minimum elevation within Mukteshwar reservoir is 187.8 m above MSL and
- The Maximum depth within Mukteshwar reservoir is 7.9 m.
- Area covered by bathymetric survey is 2.216 sq km.
- Area covered by topographic survey is 3.445 sq km.

According to recent survey, total area of reservoir at FRL 201.65 m is 5.411 Sq. Km, corresponding storage capacity is 31.184 M Cu. m, and Dead storage at 193.67 m is 4.904 M Cu. m.

The comparison between 1990 and 2021(31 years) data results in a rate of siltation (silt index) of 10.36 Ham/100 Sq. Km/year. Annual percentage loss of gross storage capacity, live storage capacity and dead storage capacity is 0.772%, 0.642% and 1.294 % respectively for FRL 201.65 m.

The comparison of 2007 and 2021 data with respect to 1990 impounding data at FRL 201.65 m results in silt index of 18.36 Ham/100 Sq. Km/year and 10.36 Ham/100 Sq. Km/year 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
Jomon	Surveyor
Abhijith Cherapi	Land Surveyor
Samraj Dwivedi	Survey Engineer
Abhijith KS	Land Surveyor
Shejir	Surveyor
Pruthvi Raj	Surveyor
Ashish Patil	Survey Engineer
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 Mukteshwar reservoir. The equipment setup and configuration diagram has been 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	TRIMBLE DGPS
Single Beam Echo Sounder	Odom Hydrotrac and Sonarmite Echo sounder with Accessories
RTK	Pentax RTK system
Auto Level	Geomax Auto Level & Tripod
Survey Boats	“Aqua Marine 1 & 2” 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 Specifications

Survey Boat 'Aqua Marine 1 & 2' Specifications	
Length overall	3.56m
Breadth moulded	1.88m
Draft	0.50m

Table 4.3-2 SURVEY BOAT SPECIFICATIONS - 'Aqua Marine 1 & 2'

4.3.3 Survey Boat Offset Diagram

The location of the various survey sensors on the survey boat 'Aqua Marine 1 & 2' is given in the vessel-offset diagram on the chart accompanying this report.

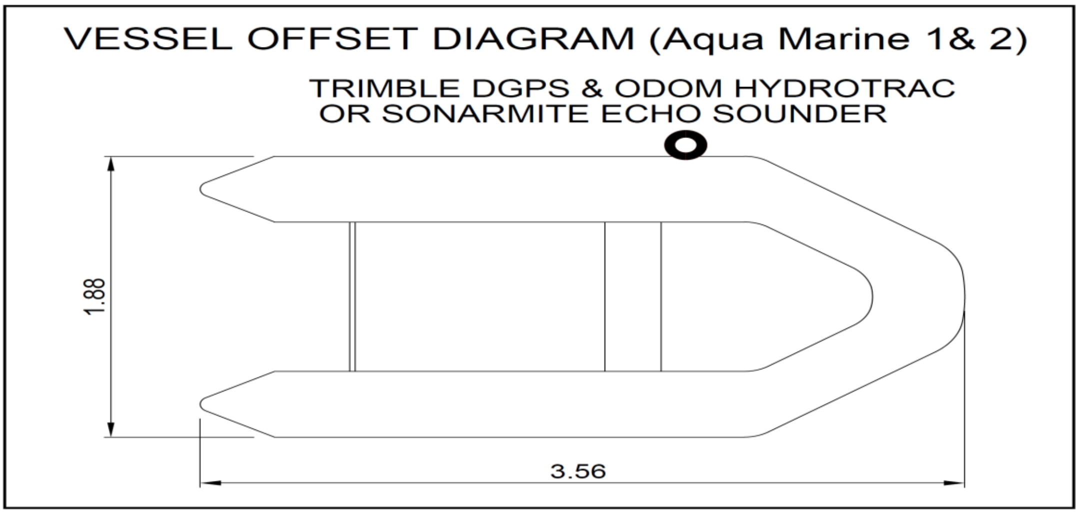

Figure 4.3-1 SURVEY BOAT ' AQUA MARINE 1 & 2 ' OFFSET DIAGRAM

5 DETAILED METHODOLOGY OF SURVEY

5.1 Mobilisation

The bathymetric survey equipment were mobilised on board "Aqua Marine" on 5 JAN 2021. After successful installation, testing and calibrations of survey equipment, the team proceeded for Data acquisition.

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

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

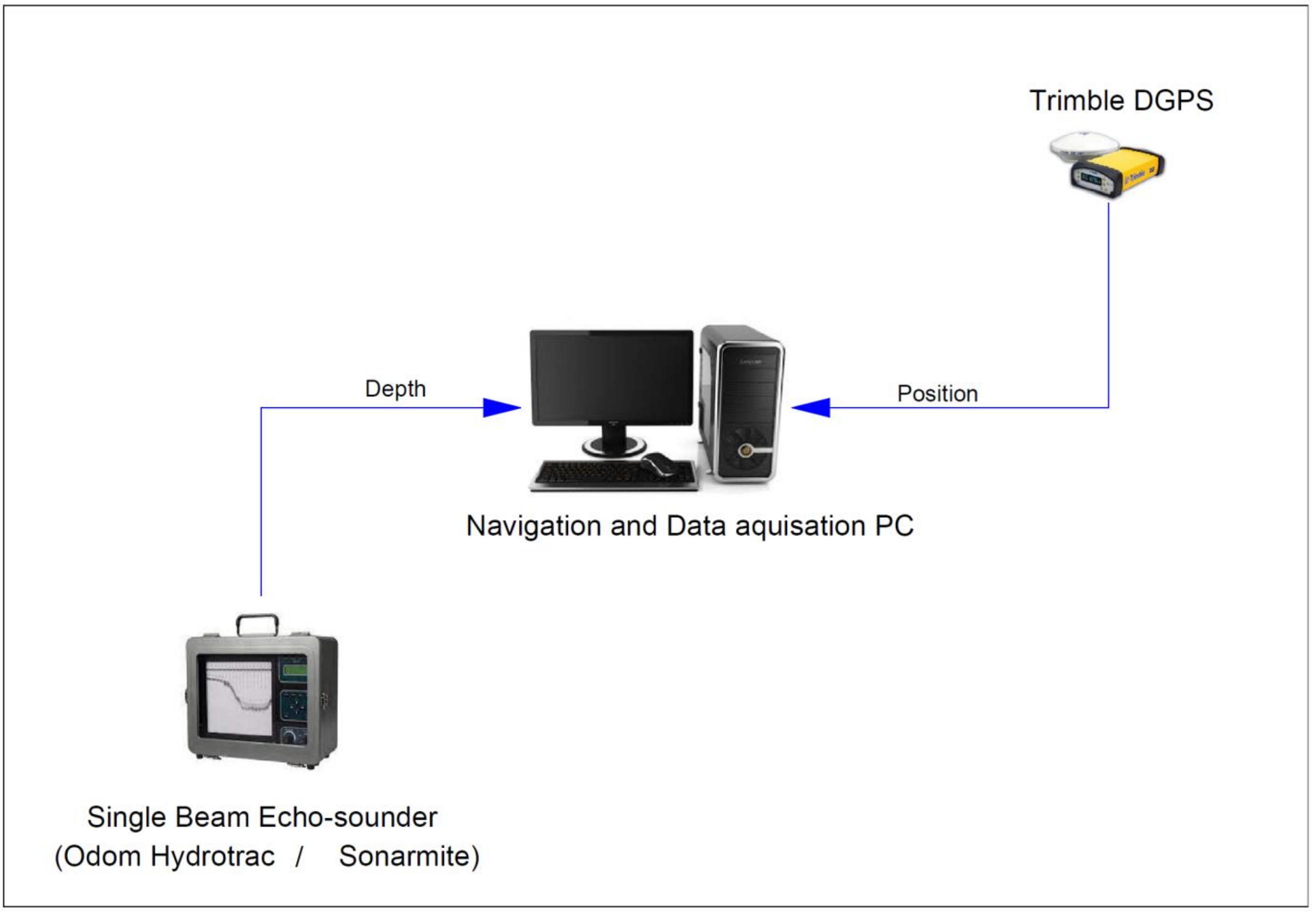

Figure 5.1-1 SBES SURVEY EQUIPMENT CONFIGURATION DIAGRAM ON BOARD

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

Four (4) hours of DGPS observation was carried out on OBS-MUKT on dam top (Elevation of dam top was provided by Dam Authority) and one Temporary Bench Marks, TBM 1 was established to cover entire reservoir.

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

T.B.M. Information – Mukteshwar Reservoir, North Gujarat					
Location	**Latitude (N)**	**Longitude (E)**	**Easting (m)**	**Northing (m)**	**Elevation (m) W.r.t MSL**
OBS-MUKT	24°02'26.2317"	72°37'41.3684"	258786.826	2660758.466	205.948
T.B.M. 1	24°02'26.7391"	72°37'41.6380"	258794.708	2660773.951	213.538

Table 5.3-1 BENCH MARK DETAILS

Figure 5.3-1 BASE SET AT OBS MUKT

5.3.2 Topographic and Bathymetric Survey

For topographic survey, Pentax RTK base was used for DGPS observation on OBS MUKT. Four Hrs. of DGPS observation was carried out. Benchmark Elevation was observed to be 205.948 . RTK DGPS Base station was set up at TBM 1 (Z = 213.538 m) 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 as shown in Figure 5.1-1. 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 PENTAX 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 ‘Odom Hydrotrac / Sonarmite’ with an accuracy of 0.01m was deployed and in principle, higher frequency of 215 kHz was operated. Echo Sounder equipment was 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 Rover Module was used for Topographic Survey.

• Pentax RTK Base station was set up at the OBS-MUKT and configured to transmit the corrections.
• Pentax RTK Rover was used for Topographic survey and one TBM was established to cover whole area.

5.5 Data Acquisition and Quality Control

5.5.1 Online Data Quality Control

The online navigation computer was interfaced to Reson Navisound 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 Reson Navisound 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 bathymetric survey at Mukteshwar Reservoir with due, consent from Client Representative, the survey equipment on board Aqua Marine were demobilised on 07 JAN 2021 while.

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:-

Date	Time	Water Level (meters)
05/01/2021	0800	195.81
05/01/2021	1900	195.81
06/01/2021	0800	195.8
06/01/2021	1900	195.8
07/01/2021	0800	195.78
07/01/2021	1900	195.78

Table 5.8-1 WATER LEVEL

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

One chart has been prepared for Mukteshwar 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-Mukteshwar-Bathy-01	Bathymetry and contour chart	1:5000	PDF & CAD
2	P-SUR-009-Mukteshwar-Overview-01	Overview Map of Reservoir	Paper size A3	PDF & CAD
3	Area Capacity Curve Mukteshwar -2021	Area Capacity curve of Reservoir	Paper size A3	PDF & CAD
4	Mukteshwar Cross Sections	78 Cross Section at 100 m interval	Only soft copy	CAD
5	Mukteshwar L-Section	L-Section of Reservoir	Paper size A3	CAD

Table 5.8-2 LIST OF CHARTS

PDF formatted chart has been attached along the report. Native CAD formatted drawing has been provided as softcopy in CD / Hard Disc.

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 Mukteshwar reservoir.

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

- The Minimum elevation within Mukteshwar reservoir is 187.8 m above MSL and
- The Maximum depth within Mukteshwar reservoir is 7.9 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 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
187.80	0.000	0.000	0.000	0.000	0.000	
187.90	0.000	0.000	0.000	0.000	0.000	
188.00	0.000	0.000	0.000	0.000	0.007	
188.10	0.001	0.000	0.001	0.001	0.017	
188.20	0.004	0.000	0.004	0.004	0.044	
188.30	0.010	0.000	0.010	0.010	0.074	
188.40	0.019	0.000	0.019	0.019	0.105	
188.50	0.031	0.000	0.031	0.030	0.124	
188.60	0.044	0.000	0.044	0.044	0.148	
188.70	0.060	0.000	0.060	0.060	0.172	
188.80	0.079	0.000	0.079	0.078	0.195	
188.90	0.099	0.000	0.099	0.099	0.218	
189.00	0.122	0.000	0.122	0.122	0.250	
189.10	0.150	0.000	0.150	0.150	0.305	

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
189.20	0.184	0.000	0.184	0.184	0.367	
189.30	0.223	0.000	0.223	0.223	0.426	
189.40	0.268	0.000	0.268	0.268	0.475	
189.50	0.318	0.000	0.318	0.318	0.517	
189.60	0.372	0.000	0.372	0.372	0.564	
189.70	0.430	0.000	0.430	0.430	0.600	
189.80	0.492	0.000	0.492	0.491	0.628	
189.90	0.556	0.000	0.556	0.556	0.656	
190.00	0.623	0.000	0.623	0.623	0.688	
190.10	0.694	0.000	0.694	0.693	0.723	
190.20	0.768	0.000	0.768	0.767	0.750	
190.30	0.844	0.000	0.844	0.843	0.773	
190.40	0.922	0.000	0.922	0.922	0.796	
190.50	1.003	0.000	1.003	1.002	0.818	
190.60	1.086	0.000	1.086	1.085	0.835	
190.70	1.170	0.000	1.170	1.169	0.850	
190.80	1.256	0.000	1.256	1.255	0.865	
190.90	1.343	0.000	1.343	1.343	0.884	
191.00	1.432	0.000	1.432	1.432	0.907	
191.10	1.525	0.000	1.525	1.524	0.934	
191.20	1.619	0.000	1.619	1.619	0.962	
191.30	1.717	0.000	1.717	1.716	0.990	
191.40	1.817	0.000	1.817	1.817	1.019	
191.50	1.921	0.000	1.921	1.920	1.047	
191.60	2.027	0.000	2.027	2.027	1.081	
191.70	2.137	0.000	2.137	2.137	1.119	
191.80	2.251	0.000	2.251	2.251	1.160	
191.90	2.369	0.000	2.369	2.369	1.199	
192.00	2.491	0.000	2.491	2.490	1.231	
192.10	2.615	0.000	2.615	2.615	1.258	
192.20	2.742	0.000	2.742	2.742	1.284	
192.30	2.872	0.000	2.872	2.871	1.310	
192.40	3.004	0.000	3.004	3.003	1.333	
192.50	3.138	0.000	3.138	3.138	1.355	
192.60	3.275	0.000	3.275	3.275	1.380	
192.70	3.414	0.000	3.414	3.414	1.406	
192.80	3.556	0.000	3.556	3.556	1.430	
192.90	3.700	0.000	3.700	3.700	1.455	

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
193.00	3.847	0.000	3.847	3.847	1.480	
193.10	3.996	0.000	3.996	3.996	1.504	
193.20	4.148	0.000	4.148	4.148	1.534	
193.30	4.303	0.000	4.303	4.303	1.566	
193.40	4.461	0.000	4.461	4.461	1.598	
193.50	4.623	0.000	4.623	4.622	1.629	
193.60	4.787	0.000	4.787	4.787	1.658	
193.67	**4.904**	**0.000**	**4.904**	**4.904**	**1.678**	**MDDL**
193.70	4.904	0.050	4.954	4.954	1.687	
193.80	4.904	0.220	5.124	5.124	1.711	
193.90	4.904	0.393	5.297	5.296	1.735	
194.00	4.904	0.567	5.471	5.471	1.757	
194.10	4.904	0.744	5.648	5.647	1.775	
194.20	4.904	0.922	5.826	5.826	1.795	
194.30	4.904	1.103	6.007	6.006	1.815	
194.40	4.904	1.285	6.189	6.189	1.835	
194.50	4.904	1.470	6.374	6.373	1.857	
194.60	4.904	1.657	6.561	6.560	1.878	
194.70	4.904	1.846	6.750	6.749	1.907	
194.80	4.904	2.038	6.942	6.941	1.930	
194.90	4.904	2.232	7.136	7.135	1.949	
195.00	4.904	2.427	7.331	7.331	1.966	
195.10	4.904	2.625	7.529	7.528	1.987	
195.20	4.904	2.825	7.729	7.728	2.013	
195.30	4.904	3.028	7.932	7.931	2.047	
195.40	4.904	3.234	8.138	8.138	2.078	
195.50	4.904	3.444	8.348	8.347	2.109	
195.60	4.904	3.656	8.560	8.560	2.141	
195.70	4.904	3.872	8.776	8.776	2.186	
195.80	4.904	4.092	8.996	8.996	2.216	
195.90	4.904	4.315	9.219	9.219	2.241	
196.00	4.904	4.540	9.444	9.444	2.260	
196.10	4.904	4.767	9.671	9.671	2.281	
196.20	4.904	4.997	9.901	9.901	2.325	
196.30	4.904	5.233	10.137	10.137	2.401	
196.40	4.904	5.478	10.382	10.382	2.491	
196.50	4.904	5.732	10.636	10.635	2.580	
196.60	4.904	5.994	10.898	10.898	2.661	

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
196.70	4.904	6.263	11.167	11.167	2.725	
196.80	4.904	6.537	11.441	11.441	2.758	
196.90	4.904	6.815	11.719	11.718	2.787	
197.00	4.904	7.095	11.999	11.998	2.815	
197.10	4.904	7.378	12.282	12.282	2.853	
197.20	4.904	7.666	12.570	12.570	2.911	
197.30	4.904	7.961	12.865	12.865	2.982	
197.40	4.904	8.262	13.166	13.166	3.049	
197.50	4.904	8.570	13.474	13.474	3.102	
197.60	4.904	8.882	13.786	13.786	3.144	
197.70	4.904	9.199	14.103	14.102	3.182	
197.80	4.904	9.519	14.423	14.422	3.219	
197.90	4.904	9.842	14.746	14.746	3.254	
198.00	4.904	10.170	15.074	15.074	3.296	
198.10	4.904	10.502	15.406	15.406	3.354	
198.20	4.904	10.841	15.745	15.745	3.428	
198.30	4.904	11.188	16.092	16.091	3.497	
198.40	4.904	11.540	16.444	16.444	3.558	
198.50	4.904	11.899	16.803	16.803	3.616	
198.60	4.904	12.263	17.167	17.167	3.673	
198.70	4.904	12.634	17.538	17.537	3.729	
198.80	4.904	13.009	17.913	17.913	3.786	
198.90	4.904	13.391	18.295	18.295	3.856	
199.00	4.904	13.781	18.685	18.685	3.932	
199.10	4.904	14.177	19.081	19.081	3.990	
199.20	4.904	14.578	19.482	19.482	4.040	
199.30	4.904	14.985	19.889	19.889	4.090	
199.40	4.904	15.397	20.301	20.300	4.147	
199.50	4.904	15.815	20.719	20.719	4.214	
199.60	4.904	16.239	21.143	21.143	4.280	
199.70	4.904	16.671	21.575	21.574	4.346	
199.80	4.904	17.109	22.013	22.013	4.431	
199.90	4.904	17.557	22.461	22.461	4.529	
200.00	4.904	18.013	22.917	22.917	4.585	
200.10	4.904	18.474	23.378	23.378	4.630	
200.20	4.904	18.939	23.843	23.843	4.676	
200.30	4.904	19.409	24.313	24.313	4.725	
200.40	4.904	19.884	24.788	24.788	4.778	

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
200.50	4.904	20.365	25.269	25.269	4.838	
200.60	4.904	20.852	25.756	25.756	4.898	
200.70	4.904	21.345	26.249	26.249	4.959	
200.80	4.904	21.844	26.748	26.747	5.017	
200.90	4.904	22.348	27.252	27.252	5.070	
201.00	4.904	22.858	27.762	27.761	5.118	
201.10	4.904	23.372	28.276	28.275	5.164	
201.20	4.904	23.890	28.794	28.794	5.208	
201.30	4.904	24.413	29.317	29.317	5.254	
201.40	4.904	24.941	29.845	29.845	5.300	
201.50	4.904	25.473	30.377	30.377	5.345	
201.60	4.904	26.010	30.914	30.914	5.389	
201.65	**4.904**	**26.280**	**31.184**	**31.184**	**5.411**	**FRL**
201.70	4.904	26.551	31.455	31.455	5.435	
201.80	4.904	27.097	32.001	32.001	5.490	
201.90	4.904	27.650	32.554	32.554	5.558	
202.00	4.904	28.208	33.112	33.112	5.608	
202.10	4.904	28.771	33.675	33.675	5.652	
202.12	**4.904**	**28.884**	**33.788**	**33.788**	**5.661**	**HFL**

Table 6.2-1 Capacity and Area

6.3 Comparative Statement of Mukteshwar Reservoir

Elevations in m	Original		Survey by I.B.S. IN FEBRUARY 2007		Survey IN JANUARY 2021		Remarks
	Capacity In (M.cu.m)	Area In (Sq. Km)	Capacity In (M.cu.m)	Area In (Sq. Km)	Capacity In (M.cu.m)	Area In (Sq. Km)	
185.05	0.000	0.000	0.000	0.000	0.000	0.000	
186.00	0.030	0.086	0.000	0.000	0.000	0.000	
186.65	0.130	0.154	0.000	0.000	0.000	0.000	
187.33	0.230	0.226	0.000	0.000	0.000	0.000	
187.50	0.270	0.255	0.000	0.000	0.000	0.000	
187.65	0.330	0.296	0.000	0.000	0.000	0.000	
188.65	0.790	0.612	0.068	0.166	0.052	0.160	
189.00	0.940	0.677	0.148	0.300	0.122	0.250	
189.65	1.570	0.950	0.440	0.480	0.401	0.584	
190.50	2.390	1.277	1.047	0.827	1.003	0.818	
190.65	2.610	1.326	1.174	0.863	1.127	0.843	
191.65	4.130	1.684	2.209	1.194	2.082	1.100	
192.00	4.670	1.772	2.643	1.287	2.491	1.231	
192.65	5.990	2.042	3.538	1.467	3.344	1.393	
193.50	7.730	2.334	4.874	1.753	4.623	1.629	
193.65	8.130	2.400	5.130	1.765	4.870	1.673	
193.67	**8.132**	**2.409**	**5.164**	**1.771**	**4.904**	**1.678**	**M.D.D.L**
194.65	10.780	2.821	7.010	2.145	6.655	1.891	
195.00	11.720	2.996	7.748	2.279	7.331	1.966	
195.65	13.850	3.242	9.271	2.485	8.667	2.160	
196.50	16.650	3.593	11.540	2.877	10.636	2.580	
196.65	17.240	3.663	11.976	2.938	11.032	2.693	
197.65	21.180	4.092	15.108	3.344	13.944	3.164	
198.00	22.560	4.295	16.304	3.484	15.074	3.296	
198.65	25.540	4.518	18.668	3.711	17.352	3.701	
199.50	29.444	4.891	22.030	4.051	20.719	4.214	
199.65	30.220	4.946	22.638	4.101	21.358	4.312	
200.65	35.380	5.316	26.539	4.374	26.002	4.929	
201.00	37.190	5.447	28.455	4.450	27.762	5.118	
201.65	**41.000**	**5.805**	**31.459**	**4.680**	**31.184**	**5.411**	**FRL**

Table 6.3-1 COMPARATIVE STATEMENT OF MUKTESHWAR RESERVOIR

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

RL (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.65	0.67	0.7	0.8	0.9
187											0.000	0.000
188	0.000	0.001	0.004	0.010	0.019	0.031	0.044	0.052	0.055	0.060	0.079	0.099
189	0.122	0.150	0.184	0.223	0.268	0.318	0.372	0.401	0.413	0.430	0.492	0.556
190	0.623	0.694	0.768	0.844	0.922	1.003	1.086	1.127	1.144	1.170	1.256	1.343
191	1.432	1.525	1.619	1.717	1.817	1.921	2.027	2.082	2.104	2.137	2.251	2.369
192	2.491	2.615	2.742	2.872	3.004	3.138	3.275	3.344	3.372	3.414	3.556	3.700
193	3.847	3.996	4.148	4.303	4.461	4.623	4.787	4.870	**4.904**	4.954	5.124	5.297
194	5.471	5.648	5.826	6.007	6.189	6.374	6.561	6.655	6.693	6.750	6.942	7.136
195	7.331	7.529	7.729	7.932	8.138	8.348	8.560	8.667	8.711	8.776	8.996	9.219
196	9.444	9.671	9.901	10.137	10.382	10.636	10.898	11.032	11.086	11.167	11.441	11.719
197	11.999	12.282	12.570	12.865	13.166	13.474	13.786	13.944	14.007	14.103	14.423	14.746
198	15.074	15.406	15.745	16.092	16.444	16.803	17.167	17.352	17.426	17.538	17.913	18.295
199	18.685	19.081	19.482	19.889	20.301	20.719	21.143	21.358	21.444	21.575	22.013	22.461
200	22.917	23.378	23.843	24.313	24.788	25.269	25.756	26.002	26.100	26.249	26.748	27.252
201	27.762	28.276	28.794	29.317	29.845	30.377	30.914	**31.184**	31.292	31.455	32.001	32.554
202	33.112	33.675										
202.12	**33.788**											

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

Note: Gross storage capacity for FRL at 201.65 m is 31.184 M Cu. m, dead storage at 193.67 00 m is 4.904 M Cu. m and HFL at 202.12 m 33.788 M Cu. m.

6.5 Live Storage Capacity in M Cu. m of the Reservoir - Year 2021:

RL (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.65	0.67	0.7	0.8	0.9
193									0.000	0.050	0.220	0.393
194	0.567	0.744	0.922	1.103	1.285	1.470	1.657	1.751	1.789	1.846	2.038	2.232
195	2.427	2.625	2.825	3.028	3.234	3.444	3.656	3.763	3.807	3.872	4.092	4.315
196	4.540	4.767	4.997	5.233	5.478	5.732	5.994	6.128	6.182	6.263	6.537	6.815
197	7.095	7.378	7.666	7.961	8.262	8.570	8.882	9.040	9.103	9.199	9.519	9.842
198	10.170	10.502	10.841	11.188	11.540	11.899	12.263	12.448	12.522	12.634	13.009	13.391
199	13.781	14.177	14.578	14.985	15.397	15.815	16.239	16.454	16.540	16.671	17.109	17.557
200	18.013	18.474	18.939	19.409	19.884	20.365	20.852	21.098	21.196	21.345	21.844	22.348
201	22.858	23.372	23.890	24.413	24.941	25.473	26.010	**26.280**	26.388	26.551	27.097	27.650
202	28.208	28.771										
202.12	**28.884**											

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

Note: Live storage capacity for FRL at 201.65 m 26.28 M Cu. m and HFL at 202.12 m is 28.884 M Cu. m.

6.6 Spread Area in Sq.Km of the Reservoir - Year 2021:

RL (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.65	0.67	0.7	0.8	0.9
187											0.000	0.000
188	0.007	0.017	0.044	0.074	0.105	0.124	0.148	0.160	0.165	0.172	0.195	0.218
189	0.250	0.305	0.367	0.426	0.475	0.517	0.564	0.584	0.591	0.600	0.628	0.656
190	0.688	0.723	0.750	0.773	0.796	0.818	0.835	0.843	0.846	0.850	0.865	0.884
191	0.907	0.934	0.962	0.990	1.019	1.047	1.081	1.100	1.108	1.119	1.160	1.199
192	1.231	1.258	1.284	1.310	1.333	1.355	1.380	1.393	1.398	1.406	1.430	1.455
193	1.480	1.504	1.534	1.566	1.598	1.629	1.658	1.673	1.678	1.687	1.711	1.735
194	1.757	1.775	1.795	1.815	1.835	1.857	1.878	1.891	1.897	1.907	1.930	1.949
195	1.966	1.987	2.013	2.047	2.078	2.109	2.141	2.160	2.169	2.186	2.216	2.241
196	2.260	2.281	2.325	2.401	2.491	2.580	2.661	2.693	2.704	2.725	2.758	2.787
197	2.815	2.853	2.911	2.982	3.049	3.102	3.144	3.164	3.171	3.182	3.219	3.254
198	3.296	3.354	3.428	3.497	3.558	3.616	3.673	3.701	3.712	3.729	3.786	3.856
199	3.932	3.990	4.040	4.090	4.147	4.214	4.280	4.312	4.325	4.346	4.431	4.529
200	4.585	4.630	4.676	4.725	4.778	4.838	4.898	4.929	4.941	4.959	5.017	5.070
201	5.118	5.164	5.208	5.254	5.300	5.345	5.389	**5.411**	5.420	5.435	5.490	5.558
202	5.608	5.652										
202.12	**5.661**											

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

Note: Spread Area for FRL at 201.65 m is 5.411 Sq. Km and HFL at 202.12m is 5.661 Sq. Km.

6.7 Sediment Analysis:

6.7.1 Observed Rate of Sedimentation

The reservoir was impounded during the year 1990. As per original project report, FRL is 201.65 m. As per original project report, total area of reservoir at FRL 201.65 m is 5.81 Sq. Km, corresponding storage capacity is 32.81 M Cu. m, and Dead storage at 193.67 m is 8.19 M Cu. m.

The reservoir was surveyed by Remote Sensing Technique in the year 2007. As per survey of the year 2007, total area of reservoir at FRL 201.65m was 4.68 Sq. Km, corresponding storage capacity was 31.459 M Cu. m, and Dead storage at 193.67 m was 5.164 M Cu. m.

The reservoir was surveyed by means of integrated bathymetric and topographic survey in year 2021. As per recent survey, total area of reservoir at FRL 201.65 m is 5.411 Sq. Km, corresponding storage capacity is 31.184 M Cu. m, and Dead storage at 193.67 m is 4.904 M Cu. m.

The rate of siltation in the reservoir (up to FRL 201.65m) during the last 31 years (1990-2021) according to survey of the year 2021 was found to be 0.316452 M Cu. m / year.

Original Reservoir data:

Year of Impounding	: 1990
Catchment Area	: 305.62 Sq. Km
Surface area at 201.65m	: 5.81 Sq. Km
Live storage at 201.65m	: 32.81 M Cu. m
Dead storage at 193.67m	: 8.19 M Cu. m
Gross storage at 201.65m	: 41.00 M Cu. m

Rate of Sedimentation (at FRL 201.65m) with respect to impounding year 1990

Sr. No	Year of Survey	Capacity in M Cu. m			Periods in year	Silt Deposited in M Cu. M	Silt Rate in M Cu. m/year	Loss in Capacity in M Cu. m and percentage			Siltation Rate ham/100 Sq. Km/Yr.	Annual % loss	Remarks
		Dead	Live	Gross				Dead	Live	Gross			
1	**1990**	8.19	32.81	41	-	-	-	-	-	-	3.57	-	
2	**1998 by Conventional Method**	5.8	25.77	31.57	8	9.43	1.179	2.39 29.182%	7.04 21.457%	9.43 23.000%	38.57	2.875%	**Serious Category**
3	**Jan-2007 by I.B.S.**	5.164	26.295	31.459	17	9.541	0.561	3.026 36.947%	6.515 19.857%	9.541 23.271%	18.36	1.369%	**Serious Category**
4	**2021 Bathymetric and topographic survey**	4.904	26.28	31.184	31	9.816	0.317	3.286 40.122%	6.530 19.902%	9.816 23.941%	10.36	0.772%	**Serious Category**

Table 6.7-1 RATE OF SEDIMENTATION

According to IS -12182 (1987)

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/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 significantly due to deposition of sediments in the reservoir. The annual percentage loss from survey of the year 1998, 2007 and 2021 is observed to be 2.875%, 1.369 and 0.772% respectively.
- The decrease in annual percentage loss from 1.367%(2006 survey) to 0.772%(2021 survey) is because at initial stage after dam construction sedimentation takes place at higher rate compare to later on.

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 Mukteshwar Reservoir

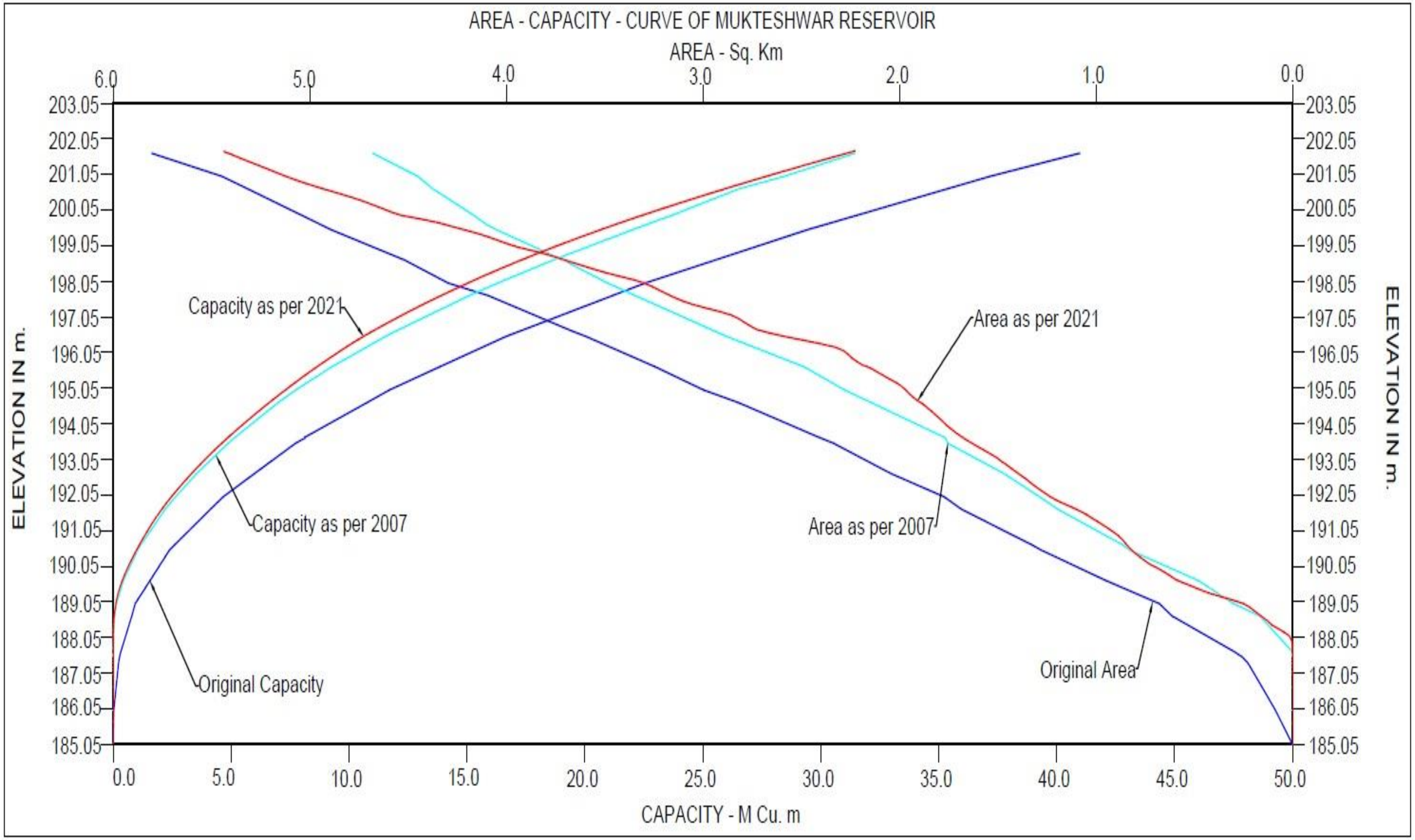

Figure 6.10-1 AREA – CAPACITY - CURVE

6.11 Segment, Contour map, 3D image and L-Section:

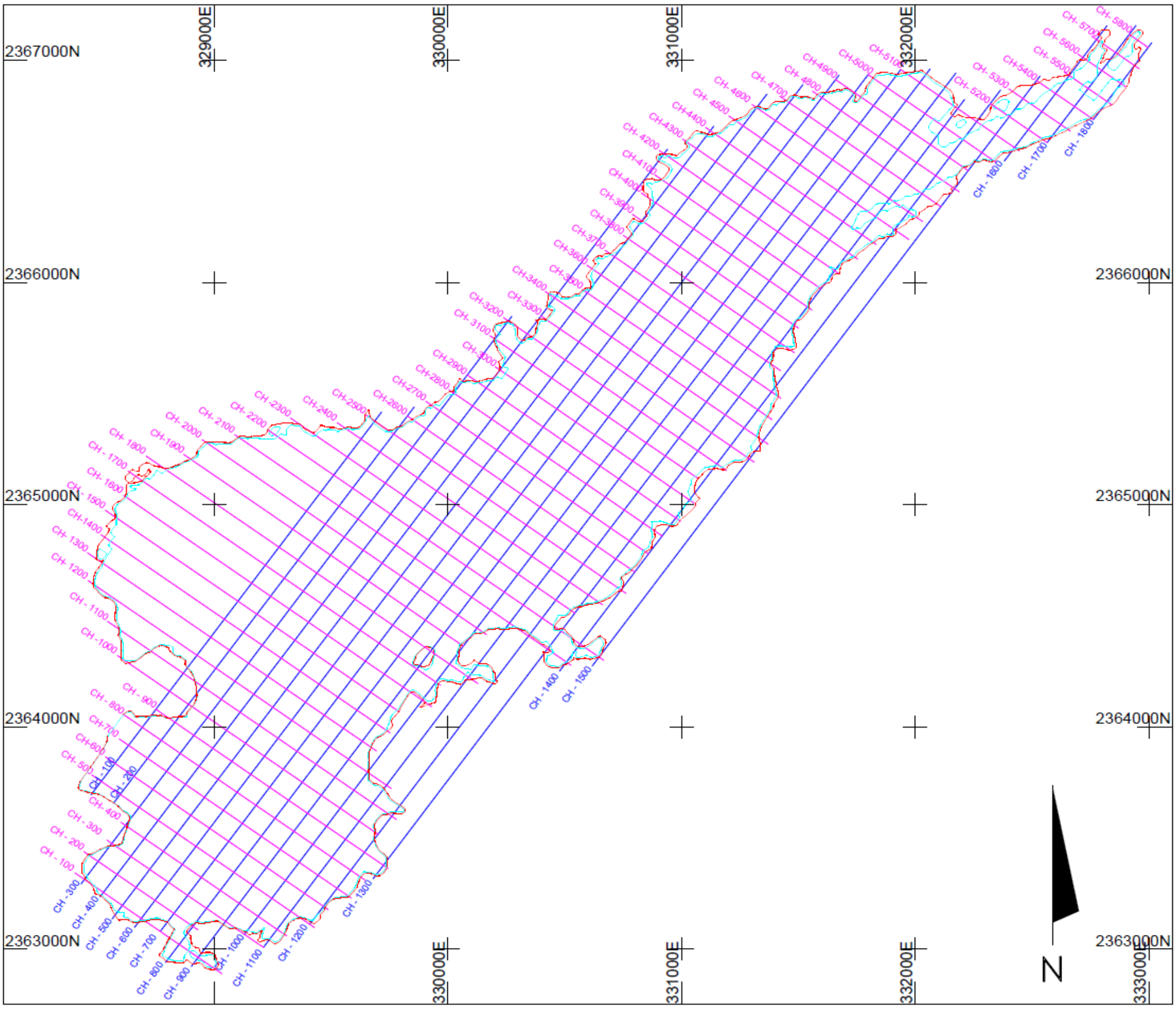

Figure 6.11-1 SEGMENT MAP

River Bed profile at 100m interval were prepared and are provided as soft copy in CD/Hard Disc. Total 78 profiles were prepared.

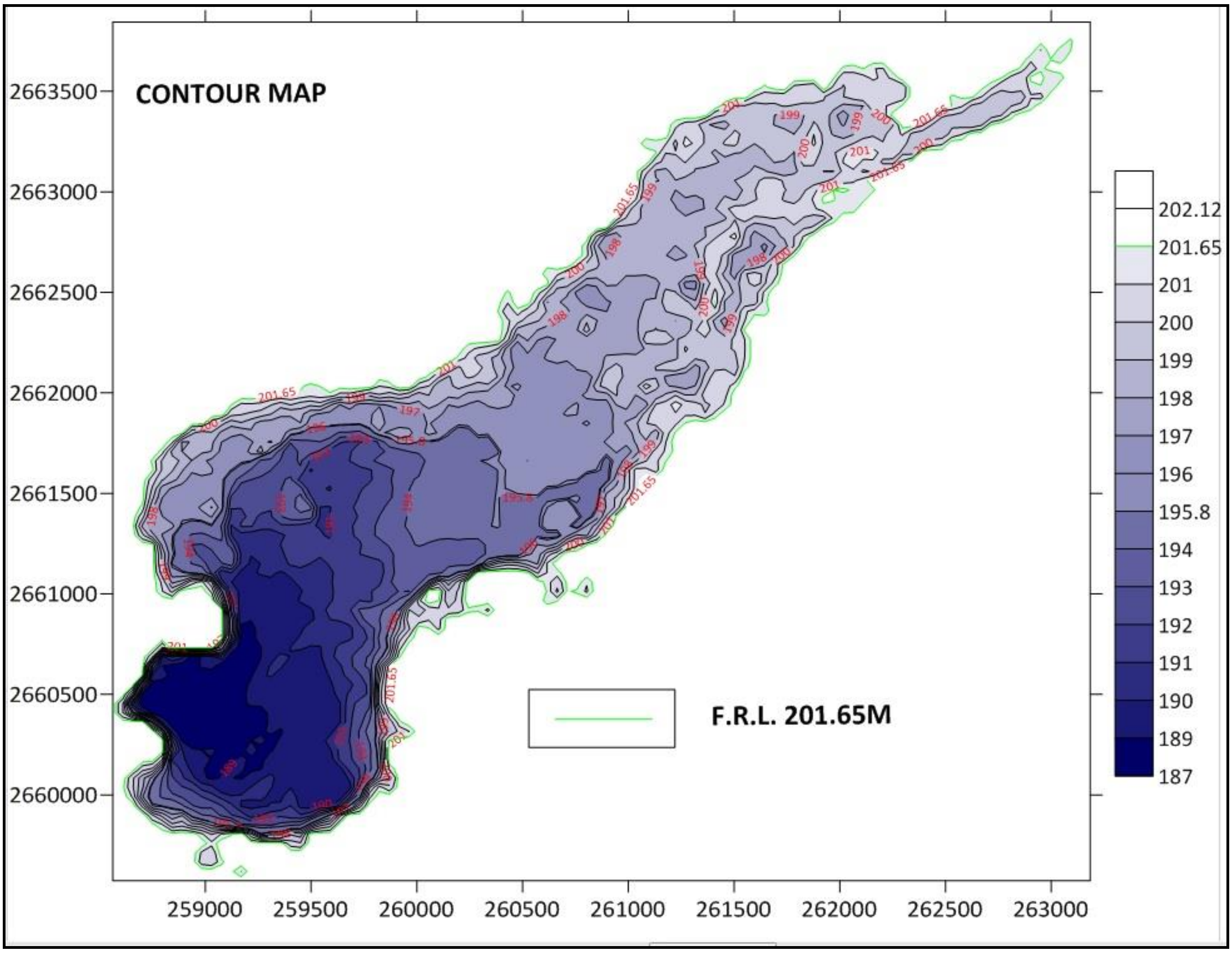

Figure 6.11-2 CONTOUR MAP

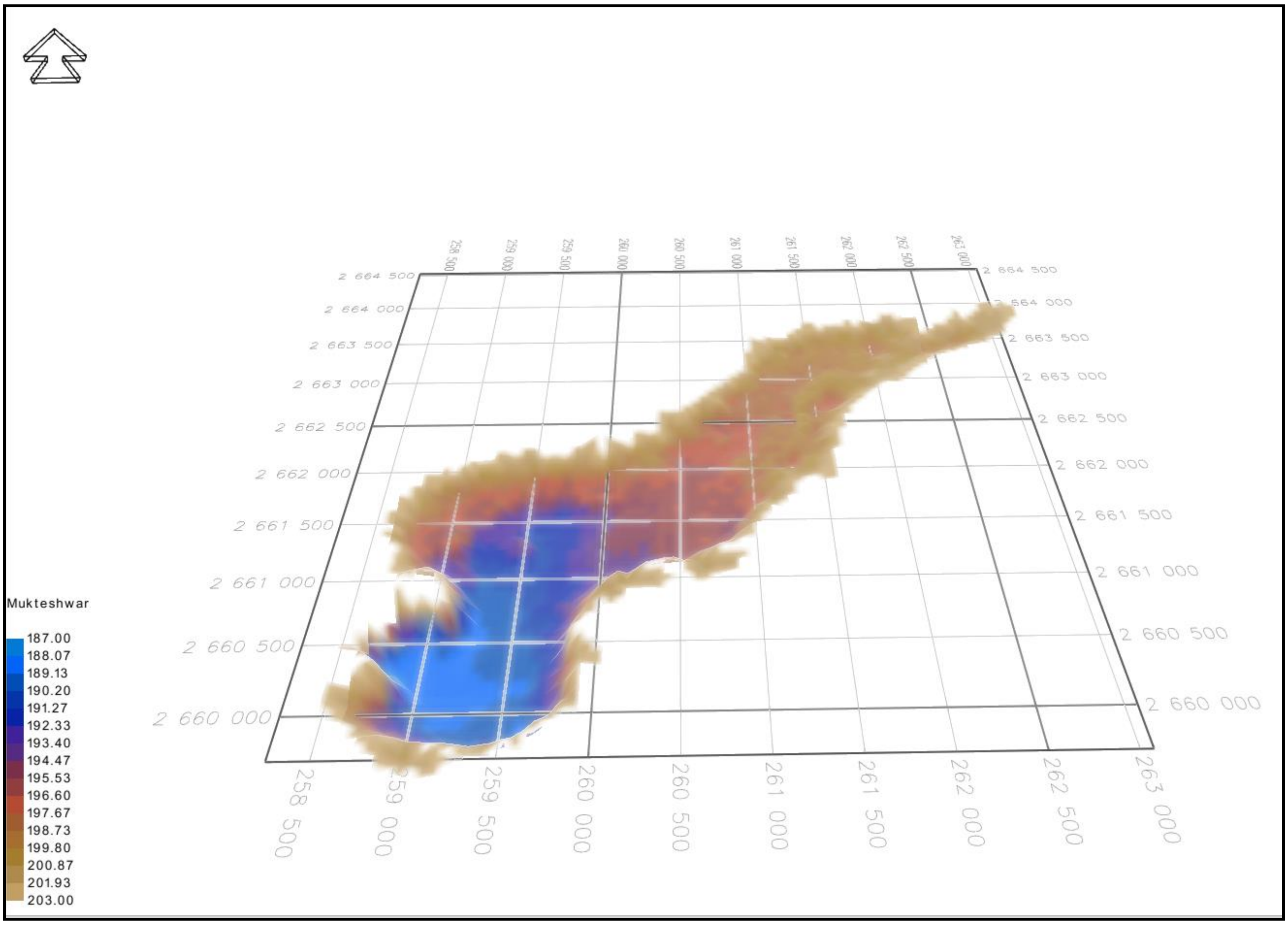

Figure 6.11-3 3D Image

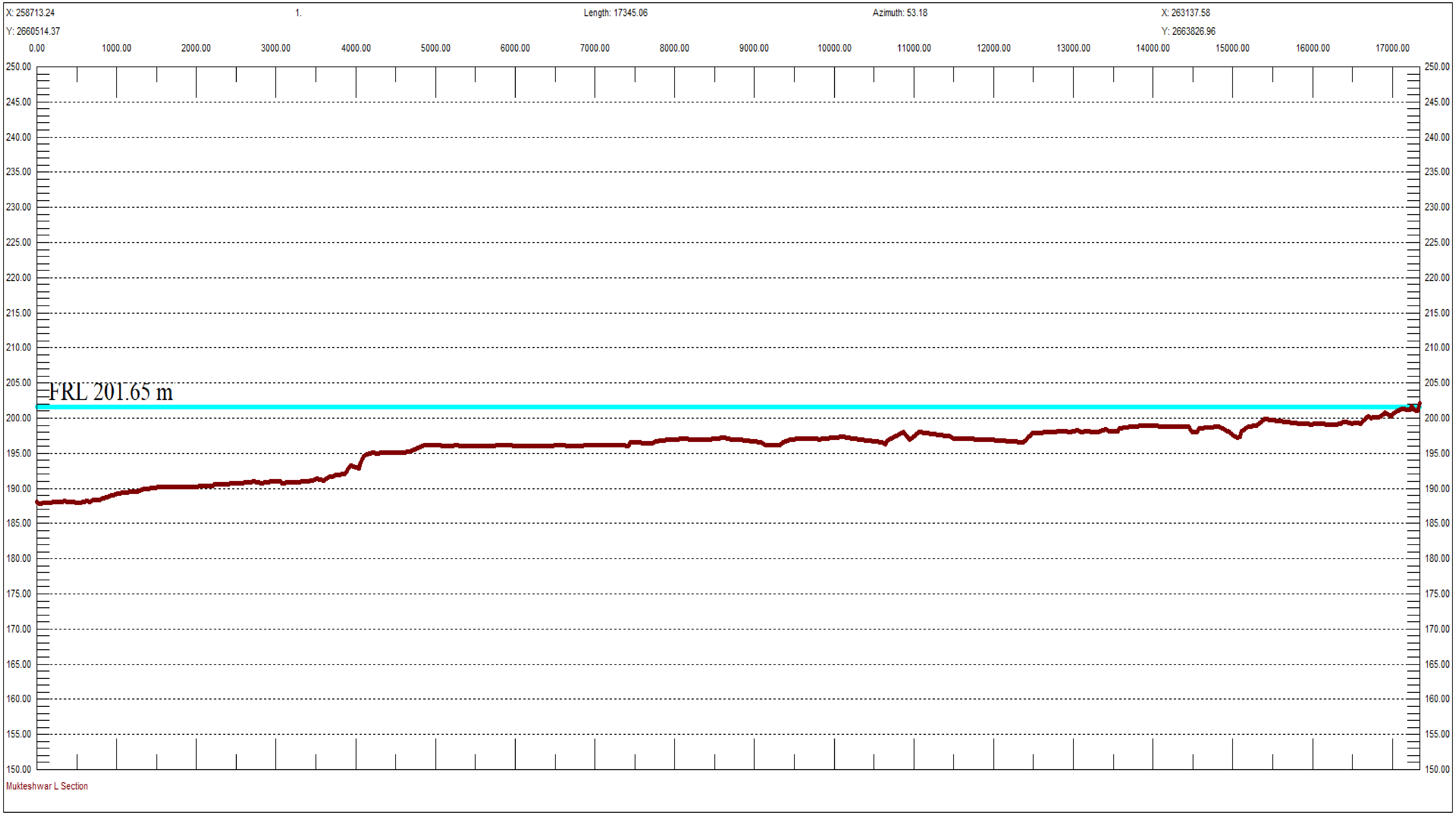

Figure 6.11-4 L-Section

7 DGPS OBSERVATION REPORT

Australian Government
Geoscience Australia

AUSPOS GPS Processing Report

January 27, 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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User: samrajdwivedi@gmail.com

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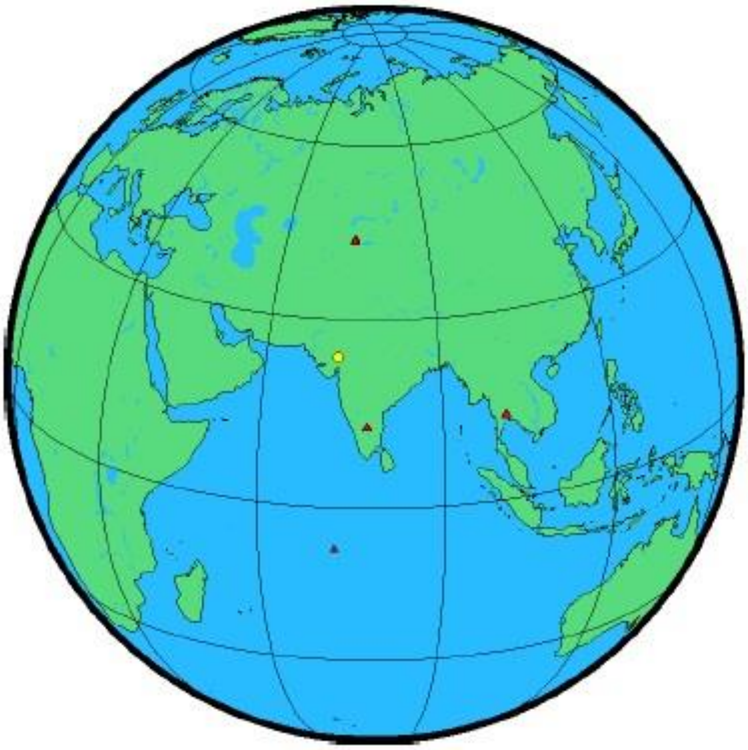
Australian Government
Geoscience Australia

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
REAL	REAL_26012021_154345.210	TIAPENG6 NONE	1.744	2021/01/26 07:44:00	2021/01/26 11:40:00

2 Processing Summary



Date	User Stations	Reference Stations	Orbit Type
2021/01/26 07:44:00	REAL	CHUM CUSV DGAR IISC POL2	IGS ultra rapid

AUSPOS 2.4 Job Number: # 5793
User: samrajdwivedi@gmail.com

2

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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 @
REAL	1740153.006	5562413.231	2582455.521	26/01/2021
CHUM	1228950.356	4508080.007	4327868.541	26/01/2021
CUSV	-1132915.008	6092528.532	1504633.160	26/01/2021
DGAR	1916268.718	6029977.741	-801719.378	26/01/2021
IISC	1337935.755	6070317.122	1427877.337	26/01/2021
POL2	1239970.929	4530790.161	4302578.880	26/01/2021

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)
REAL	24 02 26.23171	72 37 41.36838	153.922	204.667
CHUM	42 59 54.60555	74 45 03.97442	716.342	759.332
CUSV	13 44 09.28914	100 32 02.12536	74.253	105.602
DGAR	-7 16 10.84986	72 22 12.88461	-64.940	8.941
IISC	13 01 16.21569	77 34 13.37601	843.688	929.609
POL2	42 40 47.17478	74 41 39.37354	1714.212	1754.278

3.3 UTM Grid, GRS80 Ellipsoid, ITRF2014

Station	East (m)	North (m)	Zone	Ellipsoidal Height (m)	Derived Above Geoid Height(m)
REAL	258786.826	2660758.466	43	153.922	204.667
CHUM	479712.400	4760678.447	43	716.342	759.332
CUSV	665854.726	1519047.239	47	74.253	105.602
DGAR	209611.519	9195594.995	43	-64.940	8.941
IISC	778796.702	1440886.657	43	843.688	929.609
POL2	474951.458	4725300.187	43	1714.212	1754.278

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

Station	Longitude(East) (m)	Latitude(North) (m)	Ellipsoidal Height(Up) (m)
REAL	31.858	22.771	21.517
CHUM	0.008	0.006	0.013
CUSV	0.010	0.006	0.013
DGAR	0.009	0.006	0.013
IISC	0.009	0.006	0.013
POL2	0.008	0.006	0.013

4 Ambiguity Resolution - Per Baseline

Baseline	Ambiguities Resolved	Baseline Length (km)
CHUM - REAL	0.0 %	2102.240
CHUM - POL2	68.4 %	35.732
DGAR - IISC	78.9 %	2303.736
CUSV - DGAR	21.7 %	3823.702
IISC - REAL	0.0 %	1323.932
AVERAGE	33.8%	1917.868

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.

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.

8 SINGLE BEAM ECHOSOUNDER BAR CHECK RESULTS

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title:		Vessel:		Place:
	Bathymetric Survey		**Inflatable Boat**		**Mukteshwar Dam**
Date:	Time:		Client:		
05-Jan-21	**16:35**		**Water Resources Investigation division**		
Observed By:			Echosounder Model and SL. No.		Area Depth
Amit Singh			**Sonarmite**		**7**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	**Upto Depth**
0				**1500**	**6**
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	2.03	-0.03	5	5.01	-0.01
3	3.01	-0.01	4	4.02	-0.02
4	4.02	-0.02	3	3.02	-0.02
5	5	0	2	2	0
	Average	-0.0150		Average	-0.0125
	Std. Dev	0.0129		Std. Deviation	0.0096
				Cumulative Average	-0.01
				Cumulative Std. Deviation	0.0024

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Client's Representative

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title:	Vessel:	Place:
	Bathymetric Survey	**Inflatable Boat**	**Mukteshwar Dam**
Date:	Time:	Client:	
06-Jan-21	**09:15**	**Water Resources Investigation division**	
Observed By:		Echosounder Model and SL. No.	Area Depth
Amit Singh		**Sonarmite**	**7**

Echosounder Settings

Draft HI	Index "k" HI	Draft LO	Index "k" LO	Sound Velocity	
				Average	Upto Depth
0				1500	6
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	1.98	0.02	5	5.01	-0.01
3	2.97	0.03	4	4.02	-0.02
4	4.01	-0.01	3	2.99	0.01
5	4.99	0.01	2	2.01	-0.01

	Average	0.0125	Average	-0.0075
	Std. Dev	0.0171	Std. Deviation	0.0126
			Cumulative Average	0.00
			Cumulative Std. Deviation	0.0032

The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Client's Representative

GEOSERVICES MARITIME PVT. LTD.

QUALITY MANUAL AND PROCEDURE

Singlebeam Echosounder Barcheck Correction Table

Project No.	Project Title:	Vessel:	Place:
	Bathymetric Survey	**Inflatable Boat**	**Mukteshwar Dam**
Date: **07-Jan-21**	Time: **09:06**	Client: **Water Resources Investigation division**	
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				1500	6
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	5	4.99	0.01
3	3.01	-0.01	4	3.98	0.02
4	4	0	3	3.02	-0.02
5	5.01	-0.01	2	1.98	0.02
	Average	-0.0100		Average	0.0075
	Std. Dev	0.0082		Std. Deviation	0.0189
				Cumulative Average	0.00
				Cumulative Std. Deviation	0.0076

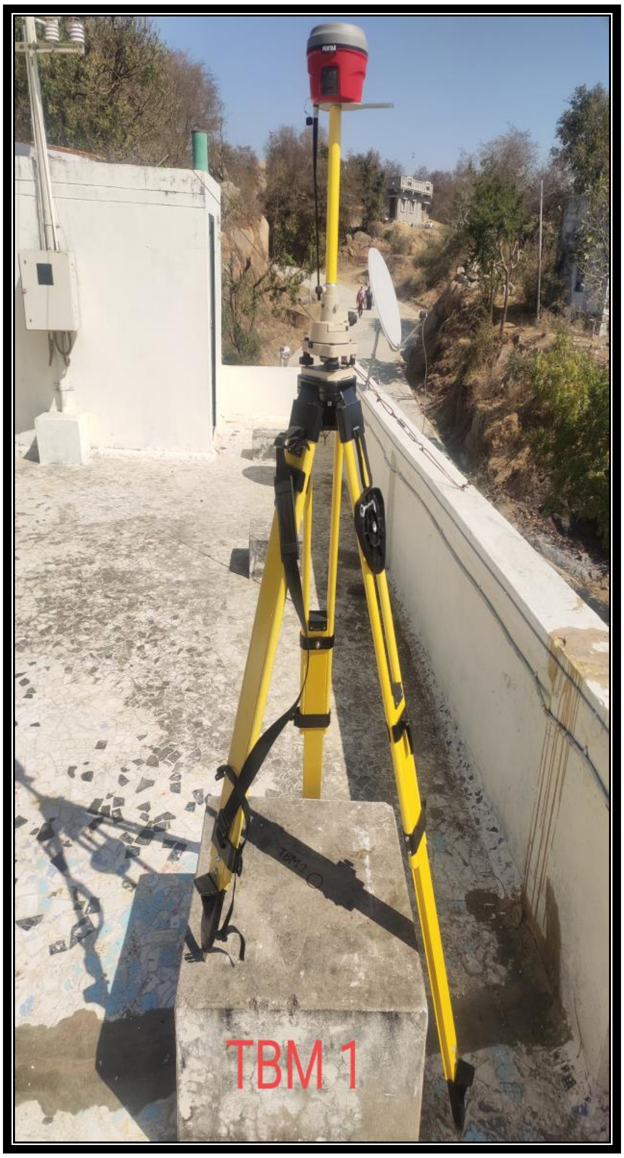
The Echosounder Barcheck Values are Negligible for Application

GMPL Party Chief

Client's Representative

9 PHOTOGRAPHS

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



TBM1

RTK Base Set up At Dam

Bathy survey near Spillway

Bathy Survey

END OF REPORT