Report on
Topographic and Bathymetric Survey of Reservoirs
for Water Resources Department, Govt. of Gujarat
at Saurashtra and Northern Gujarat Region, Gujarat

Fatehgadh Reservoir

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ABBREVIATIONS

WRD	Water Resources Department
BM	Benchmark
C.M.	Central Meridian
CD	Chart Datum
cm	Centimetre
ddmm.mmm	Degrees minutes. decimal minutes
DGPS	Differential Global Positioning System
DTM	Digital Terrain Model
DSL	Dead Storage Level
FRL	Full reservoir Level
GPS	Global Positioning System
HSE	Health, Safety & Environment
ID	Identification name/number
IHO	International Hydrographic Organization
kHz	Kilohertz
km	Kilometre
KP	Kilometre Post
Lat	Latitude
LBM	Local Benchmark
Long	Longitude
m	Metre
MCum	Million Cubic Metre
MDDL	Minimum Drawdown Level
MSL	Mean Sea Level
MSqm	Million Square Metre
MV	Motor Vessel
NA	Not Applicable
NU	North Up
OSL	Outlet Sill Level
SOW	Scope of Work
SVP	Sound Velocity Profile
UTM	Universal Transverse Mercator projection
w.d.	Water depth
WGS84	World Geodetic System 1984

EXECUTIVE SUMMARY

Ocean Science & Surveying Pvt. Ltd. (OSaS) was contracted by Narmada Water Resources, Water Supply & Kalpsar Department (WRD) to carry out topographic and bathymetric surveys of thirteen reservoirs in the Saurashtra and Northern Gujarat region; namely Bhadar-1, Bhadar-2, Brahmani-1, Und-1, Machhu-1, Machhu-2, Khodiyar, Aji-1, Nara, Tappar, Rudramata, Mitti and Fatehgadh.

This report describes the results of the topographic and bathymetric survey services provided by OSaS to the WRD for topographic and bathymetric mapping of the Fatehgadh reservoir, Kutch (Northern Gujarat) region, Gujarat.

The mobilisation of equipment started on 23rd July 2021. A DGPS consistency check was done on 23rd July by establishing two reference stations (TBMs) using RTK systems. The topographic survey commenced on the 24th July at Fatehgadh reservoir and was completed on 27th July 2021.

The mobilisation of the survey boat SMB Ocean for the bathymetric survey was carried out on 28th July. Initial system preparation and equipment checks were completed on the same day. Bathymetric survey commenced on 28th July and was completed on 30th July 2021.

The survey data was processed on the site on a daily basis and reporting and charting was completed in the OSaS data processing centre in Navi-Mumbai after the survey.

All the co-ordinates in the report and charts are referenced to WGS 84 datum, UTM projection, CM 69° east, zone 42, northern hemisphere.

All bathymetric data has been reduced to MSL using the observed average water level of each day during the survey period. Topographic data has been reduced to MSL using the TBMs established in the field with respect to the known level of FRL

The survey was carried out in daylight hours keeping in mind the safety of personnel and survey equipment.

The construction works for Fatehgadh dam commenced in the year 1979 and were completed in the year 1987. The year of first impounding was 1987 with a gross storage of 07.450 M.cu.m at FRL (22.70m above MSL) over a net catchment area of 103.60 sq.km. The dead storage at OSL (19.50m above MSL) as per impound survey was 0.820 M.cu.m.

In the current survey (2021) the gross storage at FRL (22.70m above M.SL) is 04.042 M.cu.m and the dead storage at OSL (19.50m above MSL) is 0.053 M.cu.m.

Bathymetric and topographic survey was restricted at some places due to the presence of a river with thick vegetation and small streams with unsafe and inaccessible marshy ground.

In the current bathymetric and topographic survey, a minimum elevation of 17.6m was observed in the northeastern portion of the survey area within the bathymetric section. A maximum topographic elevation value of 28.05m was observed in the northwestern portion of the survey area, at the crest of the dam.

The average elevation change within the bathymetric survey area is between 17.6m and 22.0m and average elevation change within the topographic area is between 21.21m and 28.05m.

Most of the outer survey boundaries occur around the 23m elevation contour except at the dam wall areas where elevation contours are mapped between 24m and 28m. Except in the area adjacent to the dam wall, the topography slopes gently from the outer boundaries towards the water-occupied area with a change in elevation between 23m and 21m.

For Fatehgadh dam, two separate water-occupied areas exist in the northeastern and northwestern portions of the survey area. Most of the water-occupied area of the reservoir lies within the 20m elevation contour in the northwestern and northeastern portions of the survey area. The reservoir bed within these areas is slightly irregular, associated with scattered depressions and humps. Within these areas, the elevation contours are mapped between 20m and 18m.

The current survey data (2021) was compared with the original capacity data in 1987.

The comparison between 1987 and 2021 (34 years) data results shows a rate of siltation of 9.68 Ha.m/100sq.km./year. Annual percentage loss of gross storage capacity, live storage capacity and dead storage capacity are 1.35%, 1.17% and 2.75% respectively.

The comparison of current and original capacity data of the 1987 survey shows a decrease in capacity due to sediment deposit at both, the dead storage area and live storage area. The capacity at OSL (19.50m) reduced from 0.824 M.cu.m to 0.053 M.cu.m between the years 1987 and 2021 with a loss in capacity of about 93.57%. The capacity at FRL (22.70m) decreased from 07.450 M.cu.m to 04.042 M.cu.m between the years 1987 and 2021 with a decrease in capacity of about 45.74%.

During the years 1987 to 2021, the increase of sediment deposit from the reservoir bed level to FRL and the corresponding reduction in capacity could be due to the abundant sediment inflow into the reservoir due to floods or erosion of reservoir banks above these levels. The amount of sediment deposited during this period up to OSL (19.50m) is 0.771 M.cu.m. The amount of sediment deposited during this period up to FRL (22.70m) is 3.408 M.cu.m.

1 INTRODUCTION

The Water Resources Department, Govt. of Gujarat is engaged in developing water reservoirs within the state of Gujarat, under a World Bank funding programme towards National Hydrology Projects of Govt. of India. Towards this end, the Water Resources Department, Govt. of Gujarat requires services for conducting bathymetric survey of reservoirs of Saurashtra and northern Gujarat regions under its National Hydrology Project.

Ocean Science & Surveying Pvt. Ltd. (OSaS) was contracted by Narmada Water Resources, Water Supply & Kalpsar Department (WRD) to carry out topographic and bathymetric surveys of thirteen reservoirs in the Saurashtra and northern Gujarat regions; namely Bhadar-1, Bhadar-2, Brahmani-1, Und-1, Machhu-1, Machhu-2, Khodiyar, Aji-1, Nara, Tappar, Rudramata, Mitti and Fatehgadh.

This report describes the results of the topographic and bathymetric survey services provided by OSaS to WRD for topographic and bathymetric mapping of the Fatehgadh reservoir in Kutch (Northern Gujarat) region, Gujarat.

1.1 Background of survey area

The Fatehgadh reservoir is located across Malan river, near the village Fatehgadh in Rapar Taluka of Kutch (northern Gujarat) District, in the western Indian state of Gujarat. The net catchment area for Fatehgadh reservoir is 103.60 sq.km.

The average rainfall in the Fatehgadh basin is 348mm. In winter, the temperature varies between 17^0C and 24^0C in different parts of the region. May is the hottest month, when the temperature varies between 39^0C and 40^0C.

The Fatehgadh dam is located on River Malan. The construction works for Fatehgadh dam commenced in the year 1979 and were completed in the year 1987. It is an earthen type dam. This dam fulfills its operating purpose of irrigation efficiently.

1.2 General Location

The reservoirs of Saurashtra and Northern Gujarat region are shown on the Google Earth image in **Figure 1**.

Figure 1: Survey areas/reservoirs of Saurashtra and Northern Gujarat regions

This report specifically focuses on the results of topographic and bathymetric survey of the Fatehgadh reservoir situated within the Kutch (Northern Gujarat) region, shown in the Google earth image below:

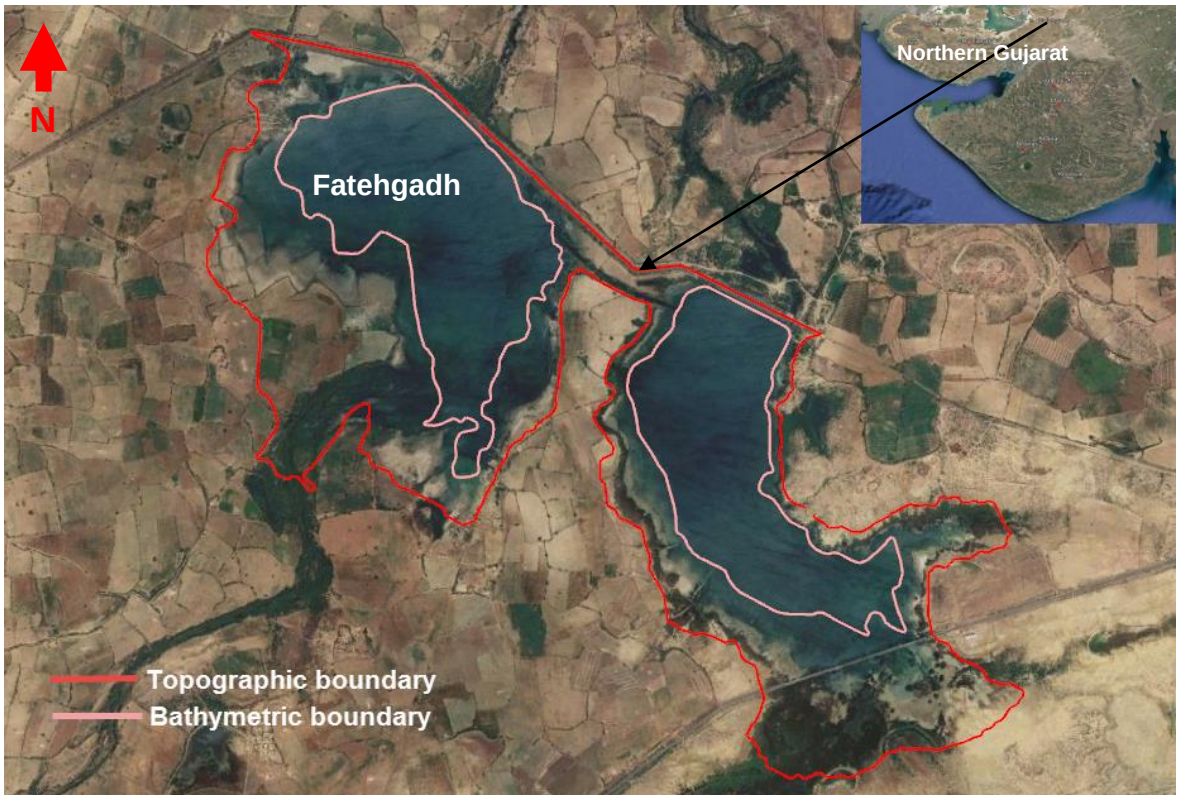


Figure 2: Survey area – Reservoir Fatehgadh

2 SCOPE OF WORK

The scope of work for the survey was:

- To mobilize requisite topographic equipment and personnel at the sites specified by the client.
- To mobilize a suitable vessel along with requisite bathymetric equipment and personnel at the sites specified by the client.
- To carry out topographic and single beam echo sounder bathymetric survey in the specified areas.
- To estimate and study the sedimentation behaviour of the reservoirs in different zones including horizontal zones throughout the reservoirs as well as vertical zones namely (a) dead storage (b) live storage (c) flood storage, if any.
- The integrated bathymetric system will be used to collect data on depth and bottom topography of the reservoirs and rivers. Primary application is reservoir sedimentation surveying; products will be reservoir capacity figures as a function of depth, depth contours and bottom topography change over time.
- To upgrade elevation-area-capacity tables /curves of the reservoirs.
- To prepare contour plan, Longitudinal profile (L-section), Cross section profiles...etc.

2.1 Salient Features of Survey Area

The Fatehgad dam is basically an irrigation scheme located on River Malan in the Kutch (Northern Gujarat) region, in the western Indian state of Gujarat. The construction works for Fatehgadh dam commenced in the year 1979 and were completed in the year 1987. The first impounding of Fatehgadh dam was carried out in 1987.

The following salient features of Fatehgadh reservoir are extracted from the document available in the WRD website regarding the Fatehgadh reservoir.

Website Link: **https://guj-nwrws.gujarat.gov.in/showpage.aspx?contentid=1696&lang=English**

a. Location
   Latitude : 23° 41’ 00” N
   Longitude : 70˚ 47’ 00” E
b. Net Catchment Area : 103.60 sq.km
c. Full Reservoir Level (FRL) : 22.70 m
d. High Flood Level (HFL) : 25.15 m
e. Outlet Sill Level (MDDL/OSL) : 19.50 m
f. Gross Storage : 07.450 M.cu.m
g. Dead Storage : 00.824 M.cu.m
h. Live Storage : 06.626 M.cu.m
i. Area at FRL : 5.29 sq.km

2.2 Survey Design

The topographic and bathymetric survey lines were planned and executed at intervals of 25m throughout the area of survey. Topographic survey was conducted using RTK base and rover system. The limit of topographic survey was up to the FRL of the reservoir, which is 22.70m (74.47ft.) above MSL, as provided by the client. The bathymetric survey was conducted using RTK positioning system and single beam echo sounder. The topographic and bathymetric surveyed areas (in sq.km) for the Fatehgadh reservoir are provided in **Table 1** below.

Name of Reservoir	Bathymetric area surveyed (sq.km.)	Topographic area surveyed (sq.km.)
Fatehgadh	1.41	2.22

Table 1: Surveyed areas for Fatehgadh reservoir

3 SURVEY CONTROL

3.1 Geodesy

The survey operations were conducted in WGS 84 Spheroid, Universal Transverse Mercator projection system, based on the geodetic parameters as presented below. All co-ordinates given within this document are with reference to it.

GEODETIC PARAMETERS	
Satellite Datum	
Datum, Spheroid	WGS-84
Semi-Major Axis	6378137.000 m
Semi Minor Axis	6356752.314 m
Inverse Flattening	298.2572
Projection Parameters	
Grid Projection	Universal Transverse Mercator
Latitude of Origin of Projection	0° (Equator)
Longitude of Origin of Projection	69° E, Zone 42 North
Hemisphere	North
False Easting (metres)	500000 E
False Northing (metres)	0
Scale Factor on CM	0.9996
Units	Metres

Table 2: Geodetic Parameters

3.2 Horizontal and vertical Control

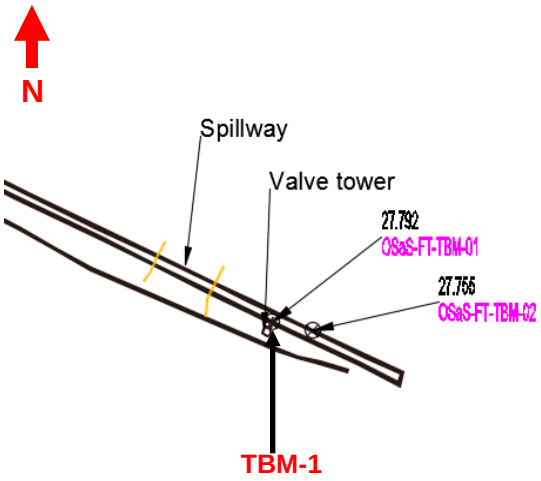
3.2.1 Topographic survey

Two reference stations were established as temporary control points/temporary benchmarks (TBM). The levelling of these TBMs was carried out using an auto level with respect to the known level of FRL which is given as 22.70m (74.47ft.) above MSL, as provided by the client. The base stations of the RTK were set up at these positions and two-hour long continuous observations were conducted using a Hemisphere RTK positioning system to fix the consistency of the position for horizontal control. The system provides real time correction signals, providing centimetre level accuracy. Additional TBMs were established at various parts of the survey area to keep the rover in range with respect to the base station.

The details of the reference stations OSaS-TBM-FT-01 and OSaS-TBM-FT-02 are given in **Figure 3** and **Figure 4**

Station Number:	OSaS-FT-TBM-01	**Latitude:**	23° 41' 22.708" N
Locality:	Fatehgadh, Gujarat	**Longitude:**	70° 48' 08.076" E
Geodetic Datum:	WGS84	**Northing:**	2621027.68 m N
Projection:	Universal Transverse Mercator	**Easting:**	683765.69 m E
Date:	23rd July 2021	**Elevation:**	27.792 m above MSL
Station Description:	A circle with text OS-FT-TBM-1 is drawn with yellow paint on the walkway to the valve tower, at the northeastern part of the dam.		
Access:	Road to the top of the reservoir. The TBM-01 is situated on the walkway to the valve tower, at the northern part of the dam.		

Sketch:



Map:

Photo:

Photo:

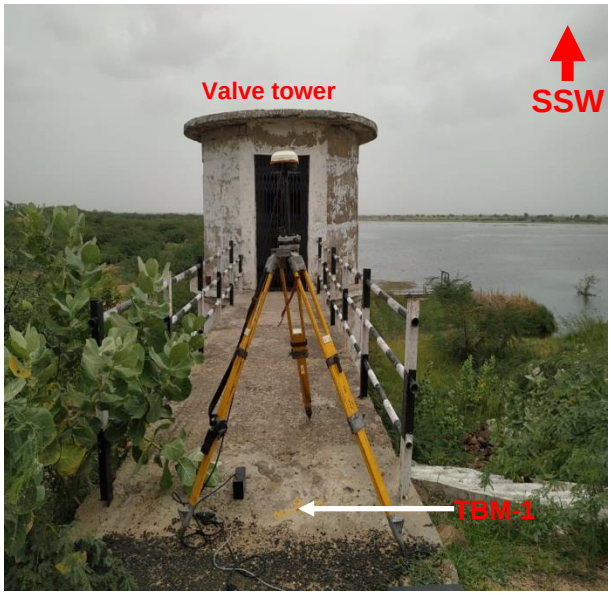
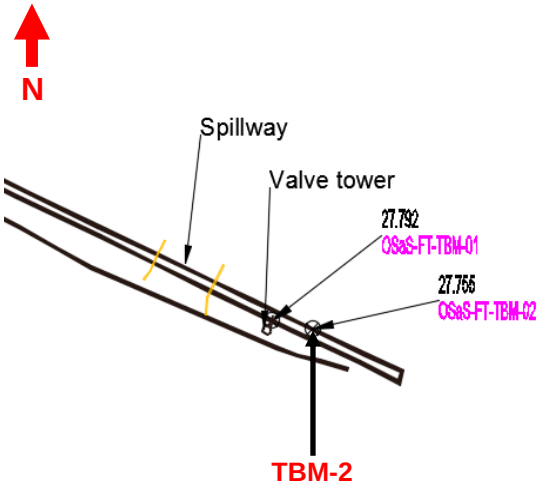


Figure 3: Details of OSaS-FT-TBM-01

Station Number:	OSaS-FT-TBM-02	**Latitude:**	23° 41' 22.544" N
Locality:	Fatehgadh, Gujarat	**Longitude:**	70° 48' 08.901" E
Geodetic Datum:	WGS84	**Northing:**	2621022.92m N
Projection:	Universal Transverse Mercator	**Easting:**	683789.13m E
Date:	23rd July 2021	**Elevation:**	27.755 m above MSL
Station Description:	A circle with text OS-FT-TBM-2 is drawn with yellow paint on the rock adjacent to the road towards the valve tower, at the northeastern part of the dam.		
Access:	Road to the top of the reservoir. The TBM-02 is situated on the rock adjacent to the road towards the valve tower, at the northern part of the dam. TBM-02 is located approximately 25m east of TBM-01.		

Sketch:



Map:

Photo:

Photo:

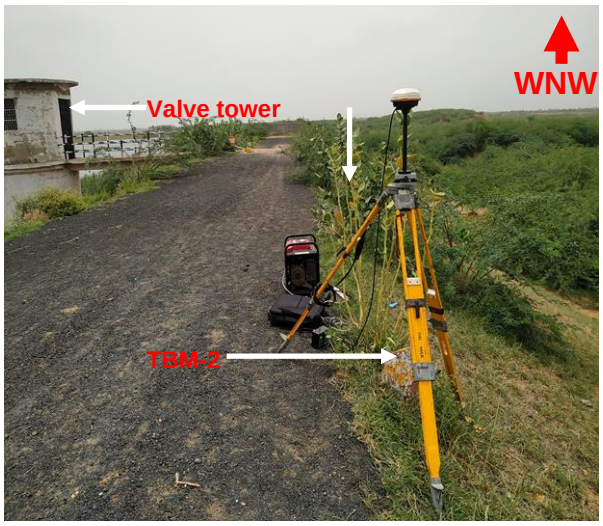


Figure 4: Details of OSaS-FT-TBM-02

3.2.2 *Bathymetric survey*

The same two reference stations, established as temporary control points/temporary benchmarks (TBMs) for the topographic survey were also used as the base stations for RTK positioning during the bathymetric survey. The rover fixed in the survey boat received calculated X Y Z of its position at any point with centimetre level accuracy with respect to the known base positions. The details of these reference stations are given in **Figure 3** and **Figure 4**.

The water level of the reservoir with respect to the known value of FRL (22.70m above MSL) was measured twice a day during the survey. The mean value of these two readings was taken as the datum for the day's work. The depths recorded by the echo sounder were deducted from these levels to obtain the bed levels with respect to MSL. The observed water levels are given in **Table 3.**

Date	Water level				
	Start		End		Average level in metres (MSL, m)
	Time (AM)	Level (MSL, m)	Time (PM)	Level (MSL, m)	
28-07-21	12:00	21.23	04:00	21.22	21.225
29-07-21	11:00	21.29	04:00	21.29	21.290
30-07-21	11:00	21.23	04:00	21.23	21.230

Table 3: Observed Water Levels

3.3 Survey Vessel

A company owned boat, SMB Ocean, was utilised for conducting the survey operations.

Figure 5: Survey vessel – SMB Ocean

4 PERSONNEL

The following survey personnel were involved in the survey at Fatehgadh.

Name	Designation	Duration
Santokh Chand	Project Manager	Project Duration (In Navi-Mumbai office)
Salman Khan	Party Chief / Surveyor	22nd - 30th July 2021
Pankaj Rabary	Survey Engineer	22nd - 30th July 2021
Gaurav Sharma	Survey Engineer	22nd - 30th July 2021
Manoj More	Surveyor	22nd - 30th July 2021
Mr. Mayur Gamit	Client Representative	Project duration

Table 4: Survey Personnel

5 SURVEY EQUIPMENT DETAILS

5.1 General

The equipment used for the survey is described below.

Bathymetry:

- Hemisphere GPS S320 GNSS RTK Base and Rover system with accessories
- Odom MK III dual frequency single beam echo sounder system with accessories
- TSS HS50 heave sensor
- Hypack navigation system
- 2 x computers with associated accessories

Topography:

- Hemisphere GPS S320 GNSS RTK Base and Rover system with accessories
- Geomax Auto Level with accessories.

Adequate spares and back-ups for critical items will be carried on board the survey vessel to ensure that failure of any hardware unit does not adversely affect progress of field work.

5.2 RTK Positioning and Navigation

An RTK system was mobilised at the site to carry out the topographic and bathymetric survey. The system comprises the following:

- Hemisphere GPS R320 GNSS base station
- Hemisphere GPS R320 rover

The base station of the RTK was set up at the temporary benchmark. Real Time Kinematic (RTK) is a technique used to increase the accuracy of GPS signals by using a fixed base station which wirelessly sends out corrections to a moving receiver. By utilising these corrections, the GPS engine can fix the position of the antenna to within 1 - 2cm. GPS Real-Time Kinematic (RTK) operation provides centimetre-level accuracy by eliminating errors that are present in the GPS system. For obtaining corrected positions, a rover receiver and a source of corrections from a base station were used.

Vessel positioning was carried out by the RTK DGPS system and its heading determined by the course made good method (CMG). The positioning system was interfaced to the Hypack navigation software. Vessel track and offset positions were recorded digitally in the navigation software. DGPS positioning accuracy of the moving vessel was better than ±1m.

The vessel's computed position from the DGPS receiver was interfaced to the navigation computer system. Hypack navigation and data acquisition software was used to provide track guidance information for the survey crew and also output the vessel position to assist the helmsman in maintaining the selected track guidance line. The VDU displays the selected survey line, the vessel position in relation to that line and numerical data to assist the helmsman such as the along-line and off-line distances, vessel speed and course made good, gyro heading, distance and bearing to end of line and water depth. The position of each fix, together with other information such as fix numbers, depths, and down line distances were logged to the hard drive.

Sensor offsets on the survey vessel were accurately measured during mobilisation and are included in the mobilisation report.

5.3 Single Beam Echo Sounder System

Bathymetric data was acquired using a dual frequency 33/200 kHz Echotrac DF 3200 MK III single beam echo sounder. The SBES transducer assembly was side-mounted on a pole on the port side of the boat. A hard copy (paper) record was produced in real-time, annotated with line name, fix number, time and date. The digital output was logged by the navigation computer for post-processing.

Calibration

The echo sounder was calibrated at the survey location by conducting a bar-check. The bar-check is carried out by lowering a horizontal steel plate to known, fixed depths below the water surface directly below the echo sounder transducer. Acoustic reflections from the plate at different depths are then recorded and adjustments made to the settings for sound velocity and draft to get accurate results. A bar-check was carried out before commencing the survey and the average speed of sound obtained was entered into the unit.

5.4 Heave Sensor

A MRU-PD heave sensor was fixed on the deck of the boat about 0.5m ahead of the COG. Its output was given to the SBES unit.

5.5 Auto Level Geomax

A Geomax Auto Level was used to establish the local benchmark by transfer and level the TBM with respect to the known level of FRL at 22.70m above MSL, as provided by the client.

5.6 Real Time Kinematic (RTK) For Topographic Survey

A Hemisphere R320 GNSS RTK system with base station and rover was used to conduct the survey. Base stations were established with respect to FRL at the TBM and rover used to fix the positions. This is a positioning system which can measure and calculate the XYZ of any given point with centimetre level accuracy with respect to the known base positions. An AutoCAD drawing can be generated with the help of the XYZ values obtained from this equipment.

5.7 HyPack Software

Navigation data was processed using the Hypack navigation software. Single beam data from the Echotrac DF 3200 MK III echo sounder was also processed using the Hypack software. Hypack provides all of the tools necessary to complete the hydrographic survey requirements. It provides a tool to design a survey, collect data, apply corrections to soundings, remove outliers, plot field sheets, export data to CAD, compute volume quantities, generate contours, create side scan mosaics and create/modify electronic charts.

6 DATA PROCESSING AND INTERPRETATION

This section explains the established terminology and standards for the project and how they were applied to the survey data.

6.1 Navigation Data

Raw DGPS and gyro data were processed and merged to form an edited vessel track file. The final navigation data was reviewed in AutoCAD to confirm the validity of the vessel's position and to aid in the correlation between navigation data and chart location. The survey track plots were then used for data interpretation and generation of the survey charts.

6.2 Bathymetric Data

Single beam data from the Echotrac DF 3200 MK III echo sounder was processed using the Hypack navigation package. The vertical datum for all bathymetric measurements was the known MSL value of FRL. The depth soundings obtained from the single beam echo sounder were reduced to MSL with the help of the observed water level in the reservoir.

Recorded depth data was adjusted for transducer draft and changes in water mass acoustic velocity as per the average velocity of sound in water.

Lakebed Gradient Classification

The following terms were used to describe the lakebed gradients.

CLASSIFICATION	GRADIENT (in terms of Degrees and Slope Interval)	
Very Gentle	<1°	< 1 in 57
Gentle	1° – 4.9°	1 in 57 to 1 in 11.7
Moderate	5° – 9.9°	1 in 11.7 to 1 in 5.7
Steep	10° – 14.9°	1 in 5.7 to 1 in 3.7
Very Steep	>15°	> 1 in 3.7

Table 5: Classification of gradients

Gradients documented in the report should be taken as an indication of general slopes for the area. The localised gradients, particularly near features such as depressions or trenches may occasionally be steeper.

Following the data processing and interpretation phase, the charts were prepared at the OSaS data processing centre, in Navi Mumbai. A team comprising a bathymetry data processor, CAD processor and geophysicist prepared the report and accompanying charts to WRD's specifications.

6.3 Topographic Data

A Hemisphere R320 GNSS RTK system with base station and rover was used to conduct the survey. This is a positioning system which can measure and calculate the XYZ of any given point with centimetre level accuracy with respect to the known base positions. The data is downloaded from the controller system, processed in the OSaS Data Processing Centre in Navi Mumbai and formatted to a compatible ASCII format for plotting in AutoCAD.

6.4 Charting

The results of this survey are presented in six charts. They consist of the following:

- One overview chart displaying a 2-dimensional image of bathymetry and topography
- One contour map displaying elevation contours at 1m intervals
- One chart showing topography and bathymetry of the surveyed area
- One longitudinal profile along the lowest elevation line within the surveyed area
- Two charts showing cross section profiles at 100m intervals within the surveyed area.

Their details are listed after the List of Annexures at the beginning of this report.

7 SURVEY RESULTS

7.1 Overview and Contour Charts

One chart each has been prepared for an overview of the surveyed area as well as elevation contours at 1m intervals, as described in Section 6.4 **Charting**. These charts also show the topographic survey boundary and the boundary between the bathymetric and topographic surveys.

7.2 Bathymetry and Topography

The bathymetric elevations mentioned in this report and associated charts have been reduced to Mean Sea Level (MSL) using the observed average water level of the Fatehgadh reservoir for the corresponding survey day. The topographic elevations are with respect to the known level at FRL (22.70m above MSL). Hence, all the bathymetric and topographic values mentioned in this report are with respect to MSL

The MSL-reduced bathymetric and topographic data are plotted in 1:5000 scale in a 25m x 25m grid. One chart was created for the purpose of plotting bathymetric and topographic data. For more details refer to Section 6.4 **Charting**

The RTK positioning accuracy is metric, resulting in a similar positioning accuracy of single beam echo sounder data since the sensor was side-mounted on the vessel.

The following observations are obtained after the processing and interpretation of all the bathymetric and topographic data acquired during the entire period of survey.

Fatehgadh dam is constructed across Malan River. Malan river exists in the western part of the survey area, bringing a considerable amount of water to Fatehgadh reservoir. In addition, a number of medium and small sized rivers and streams bring water to the dam area.

A minimum elevation of 17.6m was observed in the northeastern portion of the survey area within the bathymetric section. A maximum topographic elevation value of 28.05m is observed in the northwestern portion of the survey area, at the crest of the dam.

Malan river generally flows from south to north. For Fatehgadh dam, two separate water-occupied areas exist, in the northeastern and northwestern portions of the survey area. These two areas are connected through a canal to transfer water between them. The average elevation change within the bathymetric survey area is between 17.6m and 22.0m.

The processed topographic data shows that the land is sloping from all the sides of the survey area towards the dam area. The average elevation change within the topographic area is between 21.21m and 28.05m. Features like bridges, dam wall, roads, canals and nallas are observed within the topographic survey area. The Fatehgadh dam wall is located in the northern portion of the survey area with a spillway at the northeastern end.

Most of the outer survey boundaries occur around the 23m elevation contour except at the dam wall areas where elevation contours are mapped between 24m and 28m. In the northern part of the survey area, along the banks of the dam wall, steep slopes are observed towards the water-occupied area between the elevation contours 28m and 23m. Except in the area adjacent to the dam wall, the topography slopes gently from the outer boundaries towards the water-occupied area with a change in elevation between 23m and 21m.

The survey area is mapped with a major river channel in the western part of the survey area, generally flowing from south to north. Most of the water-occupied area of the reservoir lies within the 20m elevation contour in the northwestern and northeastern portion of the survey area. The reservoir bed within these areas is slightly irregular, associated with scattered depressions and humps. Within these areas, the elevation contours mapped between 20m and 18m.

Bathymetric and topographic survey was restricted at some places due to the presence of the river with thick vegetation and small streams with unsafe and inaccessible marshy ground.

The following **Figure 6** shows a 2-dimensional image of the Fatehgadh reservoir area using the gridded bathymetric and topographic data.

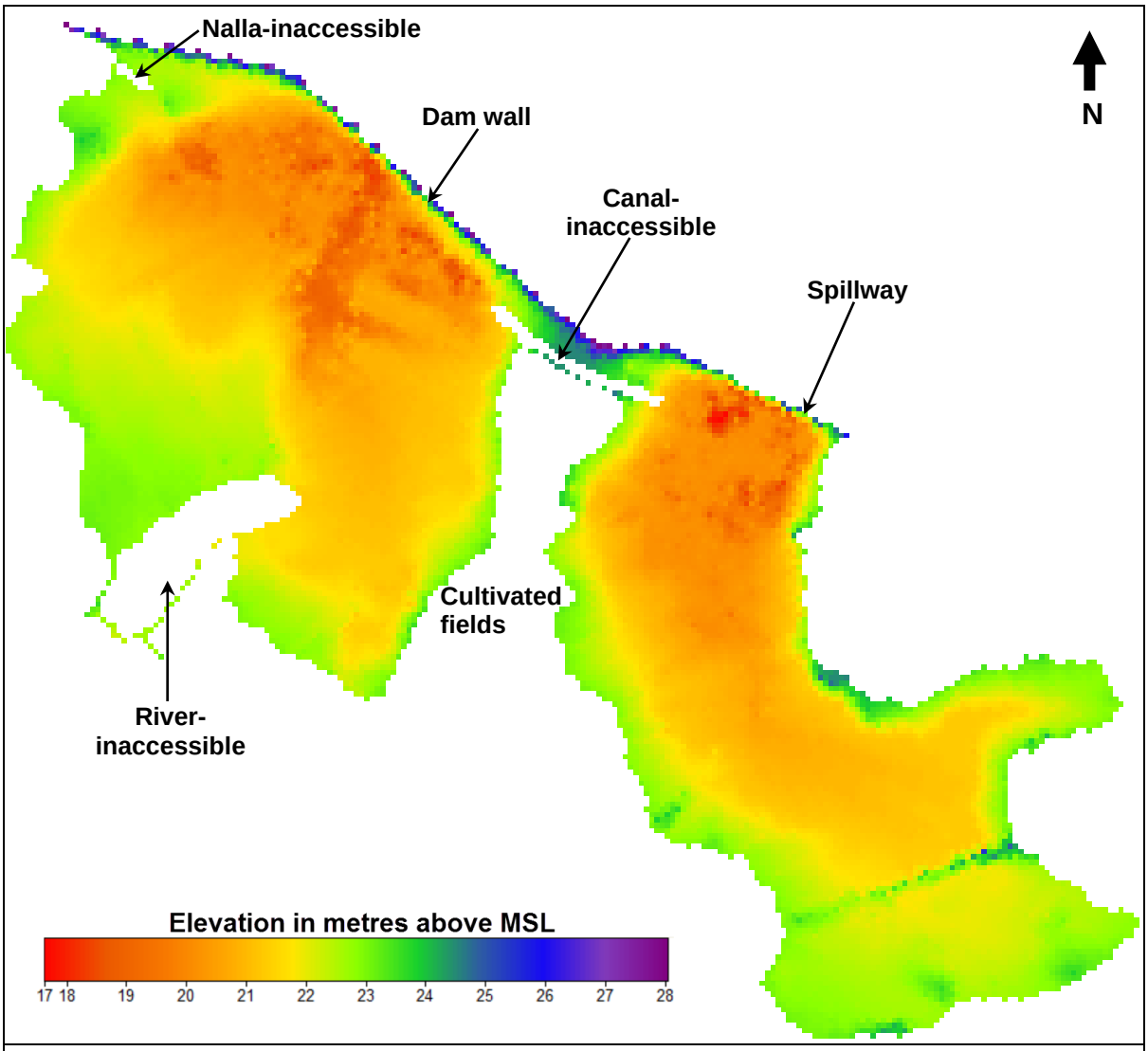


Figure 6: 2D image of the Fatehgadh reservoir area

7.3 Longitudinal Profile

A longitudinal profile of the reservoir was prepared from the line created by connecting the lowest bed level for each survey line. For more details refer to the charts listed in the section on **Charting**.

7.4 Cross Section Profiles

Cross section profiles consist of the bed levels along the survey lines at 100m intervals. The cross-section profiles will also be provided in a Compact Disk/USB drive, as per the instructions mentioned for deliverables. For more details refer to the charts listed in the section on **Charting**.

8 CAPACITY SURVEY RESULTS

8.1 General

It is natural for lakes and reservoirs to trap a major part of the sediment brought into them by the streams in the catchment. Sedimentation of reservoirs is therefore a natural process resulting from the geologic and geo-morphologic processes of water borne erosion.

Sedimentation of reservoirs leads to a gradual loss of their storage capacities available for regulation of supplies. Apart from this, it can cause operational problems created by the entry of large volumes of sediments in the canals or in the turbines, as also due to jamming of hydraulic gates. Reservoir sedimentation can also cause ecological problems due to turbidity, and due to gradual delta formation at the upstream end of the reservoirs. Therefore, sedimentation of reservoirs is a matter of vital concern in all water resources development projects.

The two dominant factors which influence the rate of silting in any storage reservoir are: (i) the relationship of capacity to inflow and (ii) the content of sediment in the inflow. The other factors that modify the long-term loss of storage capacities are (a) the trap efficiency of the reservoir, (b) the character of the sediment, and (c) the method of reservoir operation. Basically, these three factors mentioned are modifiers and do not usually have a major effect as compared to the capacity-inflow ratio and the sediment content in the inflow.

It is generally recommended to carry out capacity survey of reservoirs periodically so that the quantity of sedimentation taking place can be assessed and timely remedial measures taken. This also serves as a guide for proper sedimentation planning of future reservoirs to ensure that the reservoir sedimentation does not cause unexpected problems in the useful operation of the reservoir.

The capacity surveys in general show that the observed rate of sedimentation is higher than the rate of sedimentation adopted in the original designs. However, it is observed that the rate of sedimentation decreases with the passage of time and the useful life of the reservoir may not get unduly reduced in most cases.

8.2 Effect of Sedimentation in Planning of Reservoirs

It is important to note that storage reservoirs built across rivers and streams lose their capacity on account of deposition of sediment. This deposition, which takes place progressively in time, reduces the active capacity of the reservoir to provide the outputs of water through the passage of time. Accumulation of sediment at or near the dam may interfere with the future functioning of water intakes and hence affects decisions regarding location and height of various outlets. It may also result in greater flow of water into canals / water conveyance systems drawing water from the reservoir. Problems of rise in flood levels in the head reaches and unsightly deposition of sediment from a recreation point of view may also crop up in the course of time.

In this regard, the Bureau of Indian Standards code IS: 12182 - 1987 “Guidelines for determination of effects of sedimentation in planning and performance of reservoir” is an important document which discusses some of the aspects of sedimentation that have to be considered while planning reservoirs. Some of the important points from the code are as follows:

While planning a reservoir, the degree of seriousness and the effect of sedimentation at the proposed location have to be judged from studies, which normally consist of a combination of:

1. Performance Assessment (Simulation) Studies with varying rate of sedimentation.
2. Likely effects of sedimentation at the dam face.

In special cases, where the effects of sedimentation on backwater levels are likely to be significant, backwater studies would be useful to understand the size of river water levels. The steps to be followed for performance assessment studies with varying rates of sedimentation are as follows:

a. Estimation of annual sediment yields into the reservoir or the average annual sediment yield and of trap efficiency expected.
b. Distribution of sediment within the reservoir to obtain a sediment elevation and capacity curve at any appropriate time.

8.3 Earlier Capacity Surveys

8.3.1 Capacity at the time of impounding (1987)

The construction works of Fatehgadh dam commenced in 1979 and were completed in 1987. The first impounding was completed in 1987. The data provided by the client contains the capacity details obtained at the time of impounding from 17.0m above MSL to 26.0m above MSL at intervals of 0.1m.

For ease of further calculations and preparation of elevation-capacity curves, the elevation-capacity data have been extracted from the provided document at intervals of approximately 0.5m, from 17.50m to 22.70m (FRL). **Table 6** shows the elevation-capacity at these intervals.

The details of previous data are given in **Annexure 3**.

8.4 Capacity survey of 2021

The water spread area and its corresponding capacity has been calculated from the acquired bathymetry and topographic data. Hypack software's TIN (Triangulated Irregular Network) MODEL package was used to calculate the Area and Capacity of the Fatehgadh reservoir at intervals of 0.01m with respect to the corresponding elevation above MSL. Within the survey area a few places were not accessible to the survey personnel due to the existing river with thick vegetation and marshy streams areas. However, these areas with elevations below FRL were taken into account while calculating the water spread area by assigning interpolated values with respect to the acquired values around the restricted areas.

The depths recorded by the echo sounder were reduced to obtain the bed levels (bathymetry data) with respect to MSL for the entire surveyed area. The data obtained from the topographic survey was then merged with the bathymetric data to output a single xyz file for the entire surveyed area. Using the Hypack software a TIN (Triangulated irregular network) model was generated from this single xyz file. Further, using the 'TIN to level' option in Hypack software, the required range of levels (minimum and maximum water levels) and the desired interval (in this case 0.01m) at which the capacity/volume and area output is required were input in the software. Finally, a text file was generated by the software which contains all the information on the volume/capacity and area obtained at the specified elevation interval (0.01m) in the reservoir.

The detailed elevation-area-capacity data at 0.01m is available in **Annexure 1**. For ease of further calculations and preparation of elevation-area-capacity curve, the data has been selected at regular intervals of approximately 0.5m from 19.50m (OSL) to 22.70m (FRL).

Table 6 shows the elevation-area-capacity at these intervals.

8.5 Elevation-Area-Capacity Curves

One of the most important physical characteristics of dams and their reservoirs are elevation-area-capacity curves. These curves are important for defining the storage capacity of the reservoir and thereby can be used in reservoir operation, reservoir flood routing, determination of capacity and water spread corresponding to each elevation.

The required elevation-capacity data (1987) are available in the document provided by the client at intervals of 0.1m from 17.0m above MSL to 26.0m above MSL.

The current survey was conducted in 2021 and the data is provided at intervals of 0.01m.

For ease of further calculations and preparation of elevation-area-capacity curve, current survey data in 2021 and the impounding survey data in 1987 have been selected at regular intervals of

approximately 0.5m from 17.5m to 22.70m (FRL).

The following **Table 6** shows the comparative statement of impounding survey data (1987) and current silt survey data (2021).

Elevation (Above MSL, m)	As per 1987 survey		As per 2021 survey		Remarks
	Gross Capacity (M.Cu.m)	Area (M.sq.m or Sq.Km)	Gross Capacity (M.Cu.m)	Area (M.sq.m or Sq.Km)	
17.50	0.076	0.162	0.000	0.000	
18.00	0.151	0.257	0.002	0.001	
18.50	0.319	0.340	0.011	0.003	
19.00	0.487	0.422	0.046	0.016	
19.50	0.824	**0.692**	**0.105**	**0.053**	**MDDL/OSL**
20.00	1.161	0.962	0.220	0.130	
20.50	1.858	1.415	0.587	0.339	
21.00	2.554	1.868	0.989	0.714	
21.50	3.781	3.479	1.666	1.389	
22.00	5.008	5.090	2.081	2.322	
22.50	6.864	5.232	2.619	3.493	
22.70	**7.450**	**5.288**	**2.873**	**4.042**	**FRL**

Table 6: Comparative statement of Fatehgadh reservoir

The above data was used for the preparation of elevation-area-capacity curves. The following **Figure 7** shows the elevation-area-capacity curves of 2021 superimposed on the elevation-area-capacity curves of 1987 impounding survey.

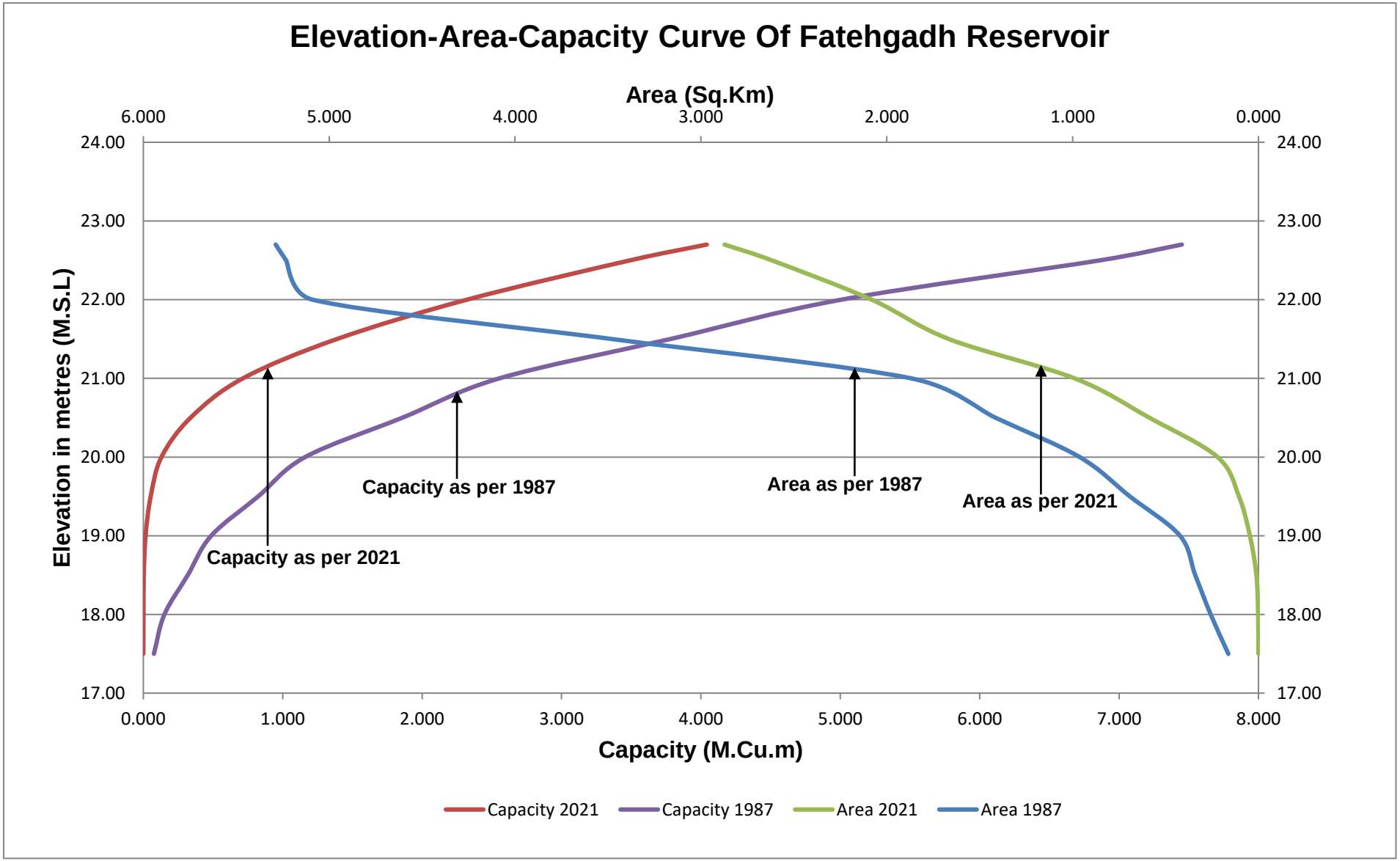


Figure 7: Elevation-Area-Capacity Curves

8.6 Data Comparison between 1987 and 2021

Definitions

Full Reservoir Level: Denoted by FRL this level corresponds to the storage which includes both inactive and active storage and also the flood storage, it is the highest reservoir level that can be maintained without spillway discharge.

Minimum Drawdown Level (MDDL): This is the level below which the water from the reservoir will not be drawn down to maintain a minimum head required in power projects.

Maximum Water Level (MWL*)*: This is the water level that is likely to be attained during the passage of the design flood. This level is also called the highest reservoir level or the highest flood level**.**

Live storage: This is the volume of water actually available at any time between the Dead Storage Level and the Full Reservoir Level.

Outlet Sill Level (OSL) / Dead Storage Level (DSL): This is the level below which there is no outlets to drain the water in the reservoir by gravity.

Dead storage: This is the total storage below the invert level of the lowest discharge outlet from the reservoir. It may be available to contain sedimentation, provided the sediment does not adversely affect the lowest discharge.

8.6.1 Rate of siltation

The decrease of storage and rate of siltation calculations are based on the following basic data.

i) The catchment area of the reservoir is 103.60 sq.km.

ii) The Full Reservoir Level (FRL) of the reservoir is given as 22.70m.

iii) The Outlet Sill Level (OSL) of the reservoir is at 19.50m.

The results obtained after comparing the survey data of the year 1987 with that of 2021 are provided below:

Capacity at FRL (22.70m) as per the 1987 survey	= 07.450 M.cu.m
Capacity at FRL (22.70m) as per 2021 survey	= 04.042 M.cu.m
Siltation in 34 years (1987-2021)	= 07.450 – 04.042
	= 3.408 M.cu.m
Annual siltation	= 3.408/34= 0.100 M.cu.m/yr
Rate of siltation (Siltation index)	= (0.100/103.60) x 1000
	= 0.968 Th.cu.m/sq.km/year
	= **9.68** Ha.m/100sq.km./year

8.6.2 Loss of gross storage capacity at FRL

Capacity at FRL (22.70m) as per the 1987 survey	= 07.450 M.cu.m
Capacity at FRL (22.70m) as per 2021 survey	= 04.042 M.cu.m
Loss of storage capacity in 34 years (1987-2021)	= 07.450 – 04.042
	= 3.408 M.cu.m
Percentage loss of Gross storage capacity up to FRL in 34 years	= (3.408/07.450) x 100
	= 45.74%
Annual percentage loss	= 45.74/34
	= **1.35%**

8.6.3 Loss of dead storage capacity

Capacity at MDDL/OSL (19.50m) as per the 1987 survey	= 0.824 M.cu.m
Capacity at MDDL / OSL as per 2021 survey	= 0.053 M.cu.m
Loss of storage capacity in 34 years (1987-2021)	= 0.824 – 0.053 = 0.771 M.cu.m
Percentage loss of dead storage capacity up to OSL in 34 years	= (0.771/0.824) x 100 = 93.57%
Annual percentage loss	= 93.57/34 = **2.75%**

8.6.4 Loss of live storage capacity

Live storage capacity as per the 1987 survey	= 07.450 – 0.824 = 06.626 M.cu.m
Live storage capacity as per 2021 survey	= 04.042 – 0.053 = 03.989 M.cu.m
Loss of Live storage capacity in 34 years (1987-2021)	= 06.626 - 03.989 = 2.637 M.cu.m
Percentage loss of live storage capacity in 34 years	= (2.637/06.626) x 100 = 39.80%
Annual percentage loss	= 39.80/34 = **1.17%**

8.7 Summary of Capacity Surveys (1987 and 2021)

Reservoir data as per impounding survey:

Year of impounding : 1987
Catchment Area : 103.60 sq.km
Spread area at FRL (22.70m) : 05.92 sq.km
Gross storage at FRL (22.70m) : 07.450 M.cu.m
Dead storage at OSL (19.50m) : 00.824 M.cu.m
Live storage at FRL (22.70m) : 06.626 M.cu.m

Rate of siltation (at FRL 22.70m) with respect to the impounding survey data in the year 1987													
Sr. No	Year of Survey	Capacity in M.cu.m			Siltation in M.cu.m	Period in years	Erosion Rate in M.cu.m/Year	Loss in Capacity in M.cu.m and percentage			Siltation index ham/100 sq.km/Yr	Annual % loss of capacity	Remarks
		Dead	Live	Gross				Dead	Live	Gross			
1	1987	0.824	06.626	07.450	-	-	-	-	-	-	-	-	-
2	2021	0.053	03.989	04.042	3.408	34	0.100	0.771 93.57%	2.637 39.80%	3.408 45.74%	9.68	1.35	Serious category

Table 7: Rate of siltation at FRL (22.70m)

<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 Siltation – Decrease in Gross Capacity/No of Years
Siltation Index – (Erosion rate/Catchment area) x 10000
Annual % loss – Loss in % of Gross Capacity/No. of years

8.8 Loss of Storage due to Sediment Deposit

Reservoirs, created by dams on rivers, lose their storage capacity due to sedimentation. A large proportion of the transported silt eventually gets deposited at different levels of a reservoir and causes reduction not only in dead storage but also in live storage capacities. The consequence of loss in storage due to sediment accumulation may even cause operational problems. Periodic capacity survey of a reservoir is thus essential to ascertain the rate of sedimentation and reduction in storage capacity for efficient and productive management of water resources. Reservoir siltation affects the safety of an old reservoir since the sediment in the reservoirs increases the load on the wall of the dam.

The loss or increase in capacity within the reservoir is directly proportional to the amount of sediment deposited or eroded within the reservoir. This sediment deposition or removal can occur at any level of the reservoir throughout the live and dead storage area. This deposition or erosion of the sediment within the reservoir results in a corresponding loss or increase of capacity.

For Fatehgadh reservoir, the comparison of current capacity data at OSL and FRL to the impounding capacity data of the 1987 survey shows a decrease in capacity due to sediment deposition at both, the dead storage area and the live storage area. The increase of sediment deposit from the lower elevation level to FRL and the corresponding reduction in capacity could be due to the abundant sediment inflow into the reservoir due to floods or erosion of reservoir banks above these levels. The capacity at OSL (19.50m) reduced from 0.824 M.cu.m to 0.053 M.cu.m between the years 1987 and 2021 with a loss in capacity of about 93.57%. The amount of sediment deposited during this period up to OSL is 0.771 M.cu.m. The capacity at FRL (20.70m) decreased from 07.450 M.cu.m to 04.042 M.cu.m between the years 1987 and 2021 with a decrease in capacity of about 45.74%. The amount of sediment deposited during this period up to FRL is 3.408 M.cu.m.

The following **Table 8** shows the amount of deposition of sediment at different levels of reservoir and corresponding percentage loss in storage capacity.

Elevation (Above MSL, m)	Capacity 1987 (M.cu.m)	Area 2021 (M.sq.m or sq.km)	Capacity 2021 (M.cu.m)	Deposition of Sediment (M.cu.m)	% Loss of Capacity	Remarks
17.50	0.076	**0.000**	0.000	0.076	100.00	Sediment deposit, loss of capacity
18.00	0.151	0.002	0.001	0.150	99.34	Sediment deposit, loss of capacity
18.50	0.319	0.011	0.003	0.316	99.06	Sediment deposit, loss of capacity
19.00	0.487	0.046	0.016	0.471	96.71	Sediment deposit, loss of capacity
19.50 (OSL)	0.824	0.105	0.053	0.771	93.57	Sediment deposit, loss of capacity
20.00	1.161	0.220	0.130	1.031	88.80	Sediment deposit, loss of capacity
20.50	1.858	0.587	0.339	1.519	81.75	Sediment deposit, loss of capacity
21.00	2.554	0.989	0.714	1.840	72.04	Sediment deposit, loss of capacity
21.50	3.781	1.666	1.389	2.392	63.26	Sediment deposit,

Elevation (Above MSL, m)	Capacity 1987 (M.cu.m)	Area 2021 (M.sq.m or sq.km)	Capacity 2021 (M.cu.m)	Deposition of Sediment (M.cu.m)	% Loss of Capacity	Remarks
						loss of capacity
22.00	5.008	2.081	2.322	2.686	53.63	Sediment deposit, loss of capacity
22.50	6.864	2.619	3.493	3.371	49.11	Sediment deposit, loss of capacity
22.70 (FRL)	7.450	2.873	4.042	3.408	45.74	Sediment deposit, loss of capacity

Table 8: Loss of storage capacity between 1987 and 2021

The amount of silt present in any reservoir is attributed to the geological nature of the area surrounding the reservoir. If the area is rich in silt, any reservoir located within the area will definitely have a greater proportion of silt in any sediment transported into it. Since erosional sedimentation is a serious problem in different parts of the world today resulting in several reservoirs becoming completely silted over, designers should aim at the following mitigation measures of soil erosion and sediment transport processes:

- Prevention of further land degradation in any catchment to reduce siltation
- Prevention of soil erosion from catchment to reduce siltation of reservoir
- Ensuring adequate irrigation water to the demand area
- Improving land capability moisture regime in the watershed
- Improving land use to match capability
- Maintaining ecological balance in a catchment area
- Educating people in the management of a catchment

8.9 Control Of Sedimentation in Reservoirs

Sedimentation in a reservoir is a natural process which affects the capacity of the reservoir. Excess deposition of sediment directly affects the useful capacity of the reservoir based on the project requirements like irrigation, hydroelectric power, flood control etc. The rate of deposition of sediment largely depends on the annual sediment load carried by the streams and up to what extent the sediment is retained in the reservoir. This, in turn, depends upon a number of factors such as the area and nature of the catchment, level use pattern (cultivation practices, grazing, logging, construction activities and conservation practices), rainfall pattern, storage capacity, period of storage in relation to the sediment load of the stream, particle size distribution in the suspended sediment, channel hydraulics, location and sizes of sluices, outlet works, configuration of the reservoir, and the method and purpose of releases through the dam. An appropriate approach to these factors mentioned above is essential for efficient control of sedimentation and therefore to extend the life of the reservoir.

There are numerous techniques developed to control the sedimentation in reservoirs, broadly classified as:

I. Suitable design of reservoir
II. Restrict the sediment inflow
III. Limit the sediment deposition
IV. Regular removal of deposited sediment

8.9.1 Suitable design of reservoir

The volume of discharge directly affects the rate of sedimentation. The rate of sedimentation increases with the volume of discharge. The higher deposition of sediment within a reservoir increases the surface

area of the water, thereby resulting in greater loss of water by evaporation. This will ultimately result in 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. Periodic reservoir sediment surveys provide information about the rate of sediment deposited, and hence can enable us to make necessary steps to limit the same. The sedimentation may take place not only in the dead storage area of a reservoir; reservoir studies have revealed significant deposition of sediment in the live storage area of a reservoir as well.

The capacity of reservoirs largely depends on various factors. Hence the following points need to be considered for their optimum design.

- Topographical, geological and geomorphological factors which directly affect the sediment yield
- Sediment delivery characteristics of the channel system
- The efficiency of the reservoir as a sediment trap
- The ratio of capacity of the reservoir to the inflow
- Configuration of the reservoir
- Method of operation of the reservoir
- Provisions for silt exclusion

8.9.2 Restrict the sediment inflow

The sediment inflow to the reservoirs can be controlled by proper watershed management and soil conservation measures to check production and transport of sediment to the catchment area. Also adopt adequate ppreventive measures to check the inflow of sediment into the reservoir. Soil conservation involves the prevention of loss of the topmost layer of the soil from erosion or prevention of reduced fertility caused by over usage, acidification, salinization or other chemical soil contamination. The soil conservation measures are further sub-divided as:

- Engineering
- Agronomy
- Forestry

Engineering methods

Check dams

One of the methods of soil conservation is the use of check dams. A check dam is a small dam which can be either temporary or permanent, built across a minor channel, swale, or drainage ditch. They are used to slow the velocity of concentrated water flows, a practice that helps reduce erosion.

Contour trenching and bunding

In the contour trenching method, the surrounding area of the reservoir is ploughed, like contour lines. These contour lines create a water break which reduces the formation of rills and gullies during times of heavy precipitation, allowing more time for the water to settle into the soil. Also, trenches can be artificially dug along the contour lines. Water flowing down the hill is retained by the trenches, and infiltrates the soil below. Manually dug trenches are smaller, machine dug trenches can be deeper. The dimensions and the format of the trenches should correspond to the local climate and soil conditions.

A similar practice is contour bunding where stones are placed around the contours of slopes. Contour bunding or contour bundling, and contour farming involves the placement of lines of stones along the natural rises of a landscape. These techniques help to capture and hold rainfall before it can become runoff. Contour bunds also help to control soil erosion.

Gully Plugging

A gully plug is a small, temporary or permanent dam constructed across a drainage ditch, swale, or channel to lower the speed of concentrated flows. These dams can be constructed using locally available materials. These small dams reduce the speed of water flow and minimise the erosive power of runoff. They also promote the deposition of eroded materials to further stabilise the gullies.

Agronomy methods

Agronomic conservation measures function by reducing the impact of raindrops through interception and thus reducing soil erosion and increasing infiltration rates, and also reducing surface runoff and soil erosion. The major agronomic soil and water conservation practices are strip cropping, mixed cropping, intercropping, fallowing, mulching, contour ploughing, crop rotation, conservation tillage, and agroforestry.

Forestry methods

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

8.9.3 Limit sediment deposition

The amount of suspended sediment is comparatively large during and just after flood flow. The settlement of sediment in the reservoir can be controlled by adequate operation of outlets in such a manner as to permit selective withdrawals of water having a higher-than-average sediment content. Thus, more water wasted at peak time of inflow will result a low level of sediment to deposit in the reservoir. There are two methods:

Density Current

Water at various levels of a reservoir often contains radically different concentrations of suspended sediment, particularly during and after flood flows and if all waste-water could be withdrawn at those levels where the concentration is highest, a significant amount of sediment might be removed from the reservoir. The density differences between the sediment-laden inflow and the clear water in the reservoir leads to a turbidity current which plunges beneath the clear water and moves towards the dam as a submerged current. The proper allocation of gates or sluices can remove a significant amount of sediment-saturated water and therefore can reduce the amount of sedimentation.

Waste-Water Release

This method is applicable only when a reservoir is of such a size that a small part of large flood flows will fill it. A series of outlets at various elevations can eject sediment-saturated water. This method, which can remove considerable amount of sediment from the reservoir through proper gate control, will differ greatly with different locations. The drawback of this method is that waste-water release is only possible when water can be or should be wasted.

8.9.4 Regular removal of deposited sediment

Removal of accumulated sediment is considered as the last resort as the operations are very expensive unless the excavated sediment is economically usable. The removal of sediment deposits may be accomplished by a variety of mechanical and hydraulic methods, such as excavation, dredging, draining & flushing, sluicing aided by measures like hydraulic or mechanical agitation or blasting of the sediment.

Excavation

Excavation is the removal of the sediment by hand or power operated shovel, dragline scraper or other mechanical means after draining most of the water. 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.

Dredging

In this method, the deposit is removed from the bottom of the reservoir irrespective of the level of storage using mechanical or hydraulic equipment. The various types of dredging are mechanical dredging by bucket, suction dredging with floating pipeline and a pump on a barge and siphon dredging with a floating pipe extending over the dam or connected to an opening in the dam and with a pump on a barge.

Draining and flushing

This method, also called flood sluicing, involves a relatively slow release of all stored water in a reservoir through gates or valves located near the 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 is directed against the sediment deposits.

Sluicing with Controlled Water

In this method the controlled water supply permits choosing the time of sluicing more advantageously and 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. 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.

Sluicing with Hydraulics and Mechanical Agitation

In this method, stirring up, breaking up or moving deposits of a sediment into a stream current moving through a drained reservoir basin or into 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.

9 CONCLUSIONS

- The construction works for Fatehgadh dam commenced in the year 1979 and were completed in 1987. The year of first impounding was 1987 with a gross storage of 07.450 M.cu.m at FRL (22.70m above MSL) over a net catchment area of 103.60 sq.km. The dead storage at OSL (19.50m above MSL) as per the impound survey was 0.824 M.cu.m.
- In the current survey (2021) the gross storage at FRL (22.70m above M.SL) is 04.042 M.cu.m and the dead storage at OSL (19.50m above MSL) is 0.053 M.cu.m.
- Bathymetric and topographic survey was restricted at some places due to the presence of the river with thick vegetation and small streams with unsafe and inaccessible marshy ground.
- In the current bathymetric and topographic survey, a minimum elevation of 17.6m was observed in the northeastern portion of the survey area within the bathymetric section. A maximum topographic elevation value of 28.05m is observed in the northwestern portion of the survey area, on the crest of the dam.
- The average elevation change within the bathymetric survey area is between 17.6m and 22.0m and average elevation change within the topographic area is between 21.21m and 28.05m.
- Most of the outer survey boundaries occur around the 23m elevation contour except at the dam wall areas where elevation contours are mapped between 24m and 28m. Except in the area adjacent to the dam wall, the topography slopes gently from the outer boundaries towards the water-occupied area with a change in elevation between 23m and 21m.
- Two separate water-occupied areas exist for Fatehgadh dam; in the northeastern and northwestern portions of the survey area. Most of the water-occupied area of the reservoir lies within the 20m elevation contour in the northwestern and northeastern portions of the survey area. The reservoir bed within these areas is slightly irregular, associated with scattered depressions and humps. Within these areas, the elevation contours are mapped between 20m and 18m.
- The current survey data (2021) was compared with the original capacity data of 1987.
- The comparison between 1987 and 2021 (34 years) data results shows a rate of siltation of 9.68 Ha.m/100sq.km./year. Annual percentage loss of gross storage capacity, live storage capacity and dead storage capacity are 1.35%, 1.17% and 2.75% respectively.
- The comparison of current and original capacity data of the 1987 survey shows a decrease in capacity due to sediment deposit at both, the dead storage area and live storage area. The capacity at OSL (19.50m) reduced from 0.824 M.cu.m to 0.053 M.cu.m between the years 1987 and 2021 with a loss in capacity of about 93.57%. The capacity at FRL (22.70m) decreased from 07.450 M.cu.m to 04.042 M.cu.m between the years 1987 and 2021, a decrease in capacity of about 45.74%.
- During the years 1987 to 2021, the increase of sediment deposit from the reservoir bed level to FRL and the corresponding reduction in capacity could be due to the abundant sediment inflow into the reservoir due to floods or erosion of reservoir banks above these levels. The amount of sediment deposited during this period up to OSL (19.50m) is 0.771 M.cu.m. The amount of sediment deposited during this period up to FRL (22.70m) is 3.408 M.cu.m.

10 REFERENCES

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Annexure - 1

Elevation-Area-Capacity (2021)

Fatehgadh Reservoir

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
58.99	17.98	0.000	0.000	0.022	0.002	0.000	0.000	0.000	0.000
59.02	17.99	0.000	0.000	0.022	0.002	0.000	0.000	0.035	0.001
59.06	18.00	0.000	0.000	0.022	0.002	0.000	0.000	0.035	0.001
59.09	18.01	0.000	0.000	0.022	0.002	0.000	0.000	0.035	0.001
59.12	18.02	0.000	0.000	0.022	0.002	0.000	0.000	0.035	0.001
59.15	18.03	0.000	0.000	0.022	0.002	0.000	0.000	0.035	0.001
59.19	18.04	0.000	0.000	0.022	0.002	0.000	0.000	0.035	0.001
59.22	18.05	0.000	0.000	0.022	0.002	0.000	0.000	0.035	0.001
59.25	18.06	0.000	0.000	0.022	0.002	0.000	0.000	0.035	0.001
59.28	18.07	0.000	0.000	0.022	0.002	0.000	0.000	0.035	0.001
59.32	18.08	0.000	0.000	0.022	0.002	0.000	0.000	0.035	0.001
59.35	18.09	0.000	0.000	0.022	0.002	0.000	0.000	0.035	0.001
59.38	18.10	0.000	0.000	0.022	0.002	0.000	0.000	0.035	0.001
59.42	18.11	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001
59.45	18.12	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001
59.48	18.13	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001
59.51	18.14	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001
59.55	18.15	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001
59.58	18.16	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001
59.61	18.17	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001
59.65	18.18	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001
59.68	18.19	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001
59.71	18.20	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001
59.74	18.21	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
59.78	18.22	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001
59.81	18.23	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001
59.84	18.24	0.000	0.000	0.032	0.003	0.000	0.000	0.035	0.001
59.88	18.25	0.000	0.000	0.043	0.004	0.000	0.000	0.035	0.001
59.91	18.26	0.000	0.000	0.043	0.004	0.000	0.000	0.035	0.001
59.94	18.27	0.000	0.000	0.043	0.004	0.000	0.000	0.035	0.001
59.97	18.28	0.000	0.000	0.043	0.004	0.000	0.000	0.035	0.001
60.01	18.29	0.000	0.000	0.043	0.004	0.000	0.000	0.035	0.001
60.04	18.30	0.000	0.000	0.043	0.004	0.000	0.000	0.035	0.001
60.07	18.31	0.000	0.000	0.043	0.004	0.000	0.000	0.035	0.001
60.10	18.32	0.000	0.000	0.054	0.005	0.000	0.000	0.035	0.001
60.14	18.33	0.000	0.000	0.054	0.005	0.000	0.000	0.071	0.002
60.17	18.34	0.000	0.000	0.054	0.005	0.000	0.000	0.071	0.002
60.20	18.35	0.000	0.000	0.054	0.005	0.000	0.000	0.071	0.002
60.24	18.36	0.000	0.000	0.054	0.005	0.000	0.000	0.071	0.002
60.27	18.37	0.000	0.000	0.065	0.006	0.000	0.000	0.071	0.002
60.30	18.38	0.000	0.000	0.065	0.006	0.000	0.000	0.071	0.002
60.33	18.39	0.000	0.000	0.065	0.006	0.000	0.000	0.071	0.002
60.37	18.40	0.000	0.000	0.075	0.007	0.000	0.000	0.071	0.002
60.40	18.41	0.000	0.000	0.075	0.007	0.000	0.000	0.071	0.002
60.43	18.42	0.000	0.000	0.086	0.008	0.000	0.000	0.071	0.002
60.47	18.43	0.000	0.000	0.086	0.008	0.000	0.000	0.071	0.002
60.50	18.44	0.000	0.000	0.086	0.008	0.000	0.000	0.071	0.002
60.53	18.45	0.000	0.000	0.097	0.009	0.000	0.000	0.071	0.002

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
60.56	18.46	0.000	0.000	0.097	0.009	0.000	0.000	0.071	0.002
60.60	18.47	0.000	0.000	0.108	0.010	0.000	0.000	0.071	0.002
60.63	18.48	0.000	0.000	0.108	0.010	0.000	0.000	0.106	0.003
60.66	18.49	0.000	0.000	0.118	0.011	0.000	0.000	0.106	0.003
60.70	18.50	0.000	0.000	0.118	0.011	0.000	0.000	0.106	0.003
60.73	18.51	0.000	0.000	0.118	0.011	0.000	0.000	0.106	0.003
60.76	18.52	0.000	0.000	0.129	0.012	0.000	0.000	0.106	0.003
60.79	18.53	0.000	0.000	0.129	0.012	0.000	0.000	0.106	0.003
60.83	18.54	0.000	0.000	0.129	0.012	0.000	0.000	0.106	0.003
60.86	18.55	0.000	0.000	0.140	0.013	0.000	0.000	0.106	0.003
60.89	18.56	0.000	0.000	0.140	0.013	0.000	0.000	0.106	0.003
60.93	18.57	0.000	0.000	0.140	0.013	0.000	0.000	0.141	0.004
60.96	18.58	0.000	0.000	0.151	0.014	0.000	0.000	0.141	0.004
60.99	18.59	0.000	0.000	0.151	0.014	0.000	0.000	0.141	0.004
61.02	18.60	0.000	0.000	0.161	0.015	0.000	0.000	0.141	0.004
61.06	18.61	0.000	0.000	0.161	0.015	0.000	0.000	0.141	0.004
61.09	18.62	0.000	0.000	0.172	0.016	0.000	0.000	0.141	0.004
61.12	18.63	0.000	0.000	0.172	0.016	0.000	0.000	0.177	0.005
61.15	18.64	0.000	0.000	0.183	0.017	0.000	0.000	0.177	0.005
61.19	18.65	0.000	0.000	0.183	0.017	0.000	0.000	0.177	0.005
61.22	18.66	0.000	0.000	0.194	0.018	0.000	0.000	0.177	0.005
61.25	18.67	0.000	0.000	0.205	0.019	0.000	0.000	0.177	0.005
61.29	18.68	0.000	0.000	0.215	0.020	0.000	0.000	0.177	0.005
61.32	18.69	0.000	0.000	0.226	0.021	0.000	0.000	0.212	0.006

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
61.35	18.70	0.000	0.000	0.237	0.022	0.000	0.000	0.212	0.006
61.38	18.71	0.000	0.000	0.248	0.023	0.000	0.000	0.212	0.006
61.42	18.72	0.000	0.000	0.248	0.023	0.000	0.000	0.212	0.006
61.45	18.73	0.000	0.000	0.258	0.024	0.000	0.000	0.247	0.007
61.48	18.74	0.000	0.000	0.269	0.025	0.000	0.000	0.247	0.007
61.52	18.75	0.000	0.000	0.269	0.025	0.000	0.000	0.247	0.007
61.55	18.76	0.000	0.000	0.280	0.026	0.000	0.000	0.247	0.007
61.58	18.77	0.000	0.000	0.291	0.027	0.000	0.000	0.283	0.008
61.61	18.78	0.000	0.000	0.291	0.027	0.000	0.000	0.283	0.008
61.65	18.79	0.000	0.000	0.301	0.028	0.000	0.000	0.283	0.008
61.68	18.80	0.000	0.000	0.312	0.029	0.000	0.000	0.283	0.008
61.71	18.81	0.000	0.000	0.323	0.030	0.000	0.000	0.318	0.009
61.75	18.82	0.000	0.000	0.323	0.030	0.000	0.000	0.318	0.009
61.78	18.83	0.000	0.000	0.334	0.031	0.000	0.000	0.318	0.009
61.81	18.84	0.000	0.000	0.344	0.032	0.000	0.000	0.353	0.010
61.84	18.85	0.000	0.000	0.344	0.032	0.000	0.000	0.353	0.010
61.88	18.86	0.000	0.000	0.355	0.033	0.000	0.000	0.353	0.010
61.91	18.87	0.000	0.000	0.366	0.034	0.000	0.000	0.388	0.011
61.94	18.88	0.000	0.000	0.377	0.035	0.000	0.000	0.388	0.011
61.98	18.89	0.000	0.000	0.388	0.036	0.000	0.000	0.388	0.011
62.01	18.90	0.000	0.000	0.388	0.036	0.000	0.000	0.424	0.012
62.04	18.91	0.000	0.000	0.398	0.037	0.000	0.000	0.424	0.012
62.07	18.92	0.000	0.000	0.409	0.038	0.000	0.000	0.424	0.012
62.11	18.93	0.000	0.000	0.420	0.039	0.000	0.000	0.459	0.013

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
62.14	18.94	0.000	0.000	0.431	0.040	0.000	0.000	0.459	0.013
62.17	18.95	0.000	0.000	0.441	0.041	0.000	0.000	0.494	0.014
62.20	18.96	0.000	0.000	0.452	0.042	0.000	0.000	0.494	0.014
62.24	18.97	0.000	0.000	0.463	0.043	0.000	0.000	0.494	0.014
62.27	18.98	0.000	0.000	0.474	0.044	0.000	0.000	0.530	0.015
62.30	18.99	0.000	0.000	0.484	0.045	0.000	0.000	0.530	0.015
62.34	19.00	0.000	0.000	0.495	0.046	0.000	0.000	0.565	0.016
62.37	19.01	0.000	0.000	0.506	0.047	0.000	0.000	0.565	0.016
62.40	19.02	0.000	0.000	0.527	0.049	0.000	0.000	0.600	0.017
62.43	19.03	0.000	0.000	0.538	0.050	0.000	0.000	0.600	0.017
62.47	19.04	0.000	0.000	0.549	0.051	0.000	0.000	0.636	0.018
62.50	19.05	0.000	0.000	0.560	0.052	0.000	0.000	0.636	0.018
62.53	19.06	0.000	0.000	0.570	0.053	0.000	0.000	0.671	0.019
62.57	19.07	0.000	0.000	0.592	0.055	0.000	0.000	0.671	0.019
62.60	19.08	0.000	0.000	0.603	0.056	0.000	0.000	0.706	0.020
62.63	19.09	0.000	0.000	0.614	0.057	0.000	0.000	0.706	0.020
62.66	19.10	0.000	0.000	0.635	0.059	0.000	0.000	0.742	0.021
62.70	19.11	0.000	0.000	0.646	0.060	0.000	0.000	0.777	0.022
62.73	19.12	0.000	0.000	0.657	0.061	0.000	0.000	0.777	0.022
62.76	19.13	0.000	0.000	0.667	0.062	0.000	0.000	0.812	0.023
62.80	19.14	0.000	0.000	0.678	0.063	0.000	0.000	0.812	0.023
62.83	19.15	0.000	0.000	0.700	0.065	0.000	0.000	0.848	0.024
62.86	19.16	0.000	0.000	0.710	0.066	0.000	0.000	0.883	0.025
62.89	19.17	0.000	0.000	0.721	0.067	0.000	0.000	0.883	0.025

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
62.93	19.18	0.000	0.000	0.732	0.068	0.000	0.000	0.918	0.026
62.96	19.19	0.000	0.000	0.743	0.069	0.000	0.000	0.953	0.027
62.99	19.20	0.000	0.000	0.753	0.070	0.000	0.000	0.953	0.027
63.02	19.21	0.000	0.000	0.764	0.071	0.000	0.000	0.989	0.028
63.06	19.22	0.000	0.000	0.775	0.072	0.000	0.000	1.024	0.029
63.09	19.23	0.000	0.000	0.786	0.073	0.000	0.000	1.059	0.030
63.12	19.24	0.000	0.000	0.797	0.074	0.000	0.000	1.059	0.030
63.16	19.25	0.000	0.000	0.807	0.075	0.000	0.000	1.095	0.031
63.19	19.26	0.000	0.000	0.818	0.076	0.000	0.000	1.130	0.032
63.22	19.27	0.000	0.000	0.829	0.077	0.000	0.000	1.165	0.033
63.25	19.28	0.000	0.000	0.840	0.078	0.000	0.000	1.165	0.033
63.29	19.29	0.000	0.000	0.850	0.079	0.000	0.000	1.201	0.034
63.32	19.30	0.000	0.000	0.861	0.080	0.000	0.000	1.236	0.035
63.35	19.31	0.000	0.000	0.872	0.081	0.000	0.000	1.271	0.036
63.39	19.32	0.000	0.000	0.883	0.082	0.000	0.000	1.307	0.037
63.42	19.33	0.000	0.000	0.904	0.084	0.000	0.000	1.307	0.037
63.45	19.34	0.000	0.000	0.915	0.085	0.000	0.000	1.342	0.038
63.48	19.35	0.000	0.000	0.926	0.086	0.000	0.000	1.377	0.039
63.52	19.36	0.000	0.000	0.936	0.087	0.000	0.000	1.413	0.040
63.55	19.37	0.000	0.000	0.947	0.088	0.000	0.000	1.448	0.041
63.58	19.38	0.000	0.000	0.958	0.089	0.000	0.000	1.483	0.042
63.62	19.39	0.000	0.000	0.969	0.090	0.000	0.000	1.519	0.043
63.65	19.40	0.000	0.000	0.990	0.092	0.000	0.000	1.554	0.044
63.68	19.41	0.000	0.000	1.001	0.093	0.000	0.000	1.554	0.044

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)		
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)	
63.71	19.42	0.000	0.000	1.012	0.094	0.000	0.000	1.589	0.045	
63.75	19.43	0.000	0.000	1.023	0.095	0.000	0.000	1.624	0.046	
63.78	19.44	0.000	0.000	1.044	0.097	0.000	0.000	1.660	0.047	
63.81	19.45	0.000	0.000	1.055	0.098	0.000	0.000	1.695	0.048	
63.85	19.46	0.000	0.000	1.066	0.099	0.000	0.000	1.730	0.049	
63.88	19.47	0.000	0.000	1.087	0.101	0.000	0.000	1.766	0.050	
63.91	19.48	0.000	0.000	1.098	0.102	0.000	0.000	1.801	0.051	
63.94	19.49	0.000	0.000	1.109	0.103	0.000	0.000	1.836	0.052	
63.98	**19.50**	**0.00**	**0.00**	**1.130**	**0.105**	**0.000**	**0.000**	**1.872**	**0.053**	**OSL**
64.01	19.51	0.03	0.01	1.141	0.106	0.035	0.001	1.907	0.054	
64.04	19.52	0.07	0.02	1.163	0.108	0.071	0.002	1.942	0.055	
64.07	19.53	0.10	0.03	1.173	0.109	0.141	0.004	2.013	0.057	
64.11	19.54	0.13	0.04	1.195	0.111	0.177	0.005	2.048	0.058	
64.14	19.55	0.16	0.05	1.206	0.112	0.212	0.006	2.084	0.059	
64.17	19.56	0.20	0.06	1.227	0.114	0.247	0.007	2.119	0.060	
64.21	19.57	0.23	0.07	1.249	0.116	0.283	0.008	2.154	0.061	
64.24	19.58	0.26	0.08	1.259	0.117	0.318	0.009	2.190	0.062	
64.27	19.59	0.30	0.09	1.281	0.119	0.353	0.010	2.225	0.063	
64.30	19.60	0.33	0.10	1.302	0.121	0.424	0.012	2.295	0.065	
64.34	19.61	0.36	0.11	1.324	0.123	0.459	0.013	2.331	0.066	
64.37	19.62	0.39	0.12	1.345	0.125	0.494	0.014	2.366	0.067	
64.40	19.63	0.43	0.13	1.356	0.126	0.530	0.015	2.401	0.068	
64.44	19.64	0.46	0.14	1.378	0.128	0.600	0.017	2.472	0.070	
64.47	19.65	0.49	0.15	1.399	0.130	0.636	0.018	2.507	0.071	

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
64.50	19.66	0.52	0.16	1.421	0.132	0.671	0.019	2.543	0.072
64.53	19.67	0.56	0.17	1.442	0.134	0.706	0.020	2.578	0.073
64.57	19.68	0.59	0.18	1.464	0.136	0.777	0.022	2.649	0.075
64.60	19.69	0.62	0.19	1.475	0.137	0.812	0.023	2.684	0.076
64.63	19.70	0.66	0.20	1.496	0.139	0.883	0.025	2.755	0.078
64.67	19.71	0.69	0.21	1.518	0.141	0.918	0.026	2.790	0.079
64.70	19.72	0.72	0.22	1.539	0.143	0.953	0.027	2.825	0.080
64.73	19.73	0.75	0.23	1.561	0.145	1.024	0.029	2.896	0.082
64.76	19.74	0.79	0.24	1.582	0.147	1.059	0.030	2.931	0.083
64.80	19.75	0.82	0.25	1.604	0.149	1.130	0.032	3.002	0.085
64.83	19.76	0.85	0.26	1.636	0.152	1.165	0.033	3.037	0.086
64.86	19.77	0.89	0.27	1.658	0.154	1.236	0.035	3.108	0.088
64.90	19.78	0.92	0.28	1.679	0.156	1.271	0.036	3.143	0.089
64.93	19.79	0.95	0.29	1.701	0.158	1.342	0.038	3.214	0.091
64.96	19.80	0.98	0.30	1.722	0.160	1.413	0.040	3.284	0.093
64.99	19.81	1.02	0.31	1.744	0.162	1.448	0.041	3.320	0.094
65.03	19.82	1.05	0.32	1.776	0.165	1.519	0.043	3.390	0.096
65.06	19.83	1.08	0.33	1.798	0.167	1.554	0.044	3.426	0.097
65.09	19.84	1.12	0.34	1.819	0.169	1.624	0.046	3.496	0.099
65.12	19.85	1.15	0.35	1.851	0.172	1.695	0.048	3.567	0.101
65.16	19.86	1.18	0.36	1.873	0.174	1.766	0.050	3.637	0.103
65.19	19.87	1.21	0.37	1.905	0.177	1.801	0.051	3.673	0.104
65.22	19.88	1.25	0.38	1.938	0.180	1.872	0.053	3.743	0.106
65.26	19.89	1.28	0.39	1.959	0.182	1.942	0.055	3.814	0.108

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
65.29	19.90	1.31	0.40	1.991	0.185	2.013	0.057	3.885	0.110
65.32	19.91	1.35	0.41	2.024	0.188	2.084	0.059	3.955	0.112
65.35	19.92	1.38	0.42	2.056	0.191	2.119	0.060	3.991	0.113
65.39	19.93	1.41	0.43	2.088	0.194	2.190	0.062	4.061	0.115
65.42	19.94	1.44	0.44	2.120	0.197	2.260	0.064	4.132	0.117
65.45	19.95	1.48	0.45	2.153	0.200	2.331	0.066	4.202	0.119
65.49	19.96	1.51	0.46	2.196	0.204	2.401	0.068	4.273	0.121
65.52	19.97	1.54	0.47	2.228	0.207	2.472	0.070	4.344	0.123
65.55	19.98	1.57	0.48	2.271	0.211	2.578	0.073	4.450	0.126
65.58	19.99	1.61	0.49	2.314	0.215	2.649	0.075	4.520	0.128
65.62	20.00	1.64	0.50	2.368	0.220	2.719	0.077	4.591	0.130
65.65	20.01	1.67	0.51	2.422	0.225	2.790	0.079	4.662	0.132
65.68	20.02	1.71	0.52	2.476	0.230	2.860	0.081	4.732	0.134
65.72	20.03	1.74	0.53	2.530	0.235	2.966	0.084	4.838	0.137
65.75	20.04	1.77	0.54	2.583	0.240	3.037	0.086	4.909	0.139
65.78	20.05	1.80	0.55	2.648	0.246	3.108	0.088	4.979	0.141
65.81	20.06	1.84	0.56	2.723	0.253	3.214	0.091	5.085	0.144
65.85	20.07	1.87	0.57	2.788	0.259	3.284	0.093	5.156	0.146
65.88	20.08	1.90	0.58	2.863	0.266	3.390	0.096	5.262	0.149
65.91	20.09	1.94	0.59	2.949	0.274	3.496	0.099	5.368	0.152
65.94	20.10	1.97	0.60	3.035	0.282	3.602	0.102	5.474	0.155
65.98	20.11	2.00	0.61	3.122	0.290	3.673	0.104	5.544	0.157
66.01	20.12	2.03	0.62	3.208	0.298	3.779	0.107	5.650	0.160
66.04	20.13	2.07	0.63	3.305	0.307	3.885	0.110	5.756	0.163

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
66.08	20.14	2.10	0.64	3.412	0.317	4.026	0.114	5.898	0.167
66.11	20.15	2.13	0.65	3.509	0.326	4.132	0.117	6.003	0.170
66.14	20.16	2.17	0.66	3.617	0.336	4.238	0.120	6.109	0.173
66.17	20.17	2.20	0.67	3.724	0.346	4.344	0.123	6.215	0.176
66.21	20.18	2.23	0.68	3.843	0.357	4.485	0.127	6.357	0.180
66.24	20.19	2.26	0.69	3.961	0.368	4.626	0.131	6.498	0.184
66.27	20.20	2.30	0.70	4.080	0.379	4.732	0.134	6.604	0.187
66.31	20.21	2.33	0.71	4.198	0.390	4.873	0.138	6.745	0.191
66.34	20.22	2.36	0.72	4.316	0.401	5.015	0.142	6.886	0.195
66.37	20.23	2.40	0.73	4.435	0.412	5.156	0.146	7.028	0.199
66.40	20.24	2.43	0.74	4.564	0.424	5.297	0.150	7.169	0.203
66.44	20.25	2.46	0.75	4.672	0.434	5.474	0.155	7.345	0.208
66.47	20.26	2.49	0.76	4.790	0.445	5.615	0.159	7.487	0.212
66.50	20.27	2.53	0.77	4.887	0.454	5.792	0.164	7.663	0.217
66.54	20.28	2.56	0.78	4.994	0.464	5.933	0.168	7.805	0.221
66.57	20.29	2.59	0.79	5.091	0.473	6.109	0.173	7.981	0.226
66.60	20.30	2.62	0.80	5.188	0.482	6.286	0.178	8.158	0.231
66.63	20.31	2.66	0.81	5.274	0.490	6.427	0.182	8.299	0.235
66.67	20.32	2.69	0.82	5.350	0.497	6.604	0.187	8.476	0.240
66.70	20.33	2.72	0.83	5.425	0.504	6.780	0.192	8.652	0.245
66.73	20.34	2.76	0.84	5.500	0.511	6.992	0.198	8.864	0.251
66.77	20.35	2.79	0.85	5.565	0.517	7.169	0.203	9.041	0.256
66.80	20.36	2.82	0.86	5.630	0.523	7.345	0.208	9.217	0.261
66.83	20.37	2.85	0.87	5.683	0.528	7.522	0.213	9.394	0.266

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
66.86	20.38	2.89	0.88	5.748	0.534	7.699	0.218	9.570	0.271
66.90	20.39	2.92	0.89	5.802	0.539	7.910	0.224	9.782	0.277
66.93	20.40	2.95	0.90	5.856	0.544	8.087	0.229	9.959	0.282
66.96	20.41	2.99	0.91	5.909	0.549	8.299	0.235	10.171	0.288
66.99	20.42	3.02	0.92	5.952	0.553	8.476	0.240	10.347	0.293
67.03	20.43	3.05	0.93	6.006	0.558	8.687	0.246	10.559	0.299
67.06	20.44	3.08	0.94	6.049	0.562	8.864	0.251	10.736	0.304
67.09	20.45	3.12	0.95	6.092	0.566	9.076	0.257	10.948	0.310
67.13	20.46	3.15	0.96	6.135	0.570	9.288	0.263	11.159	0.316
67.16	20.47	3.18	0.97	6.189	0.575	9.464	0.268	11.336	0.321
67.19	20.48	3.22	0.98	6.232	0.579	9.676	0.274	11.548	0.327
67.22	20.49	3.25	0.99	6.275	0.583	9.888	0.280	11.760	0.333
67.26	20.50	3.28	1.00	6.318	0.587	10.100	0.286	11.972	0.339
67.29	20.51	3.31	1.01	6.361	0.591	10.312	0.292	12.184	0.345
67.32	20.52	3.35	1.02	6.415	0.596	10.524	0.298	12.395	0.351
67.36	20.53	3.38	1.03	6.458	0.600	10.736	0.304	12.607	0.357
67.39	20.54	3.41	1.04	6.512	0.605	10.948	0.310	12.819	0.363
67.42	20.55	3.44	1.05	6.555	0.609	11.159	0.316	13.031	0.369
67.45	20.56	3.48	1.06	6.609	0.614	11.371	0.322	13.243	0.375
67.49	20.57	3.51	1.07	6.652	0.618	11.583	0.328	13.455	0.381
67.52	20.58	3.54	1.08	6.706	0.623	11.795	0.334	13.667	0.387
67.55	20.59	3.58	1.09	6.760	0.628	12.007	0.340	13.879	0.393
67.59	20.60	3.61	1.10	6.814	0.633	12.254	0.347	14.126	0.400
67.62	20.61	3.64	1.11	6.867	0.638	12.466	0.353	14.338	0.406

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
67.65	20.62	3.67	1.12	6.921	0.643	12.678	0.359	14.550	0.412
67.68	20.63	3.71	1.13	6.975	0.648	12.925	0.366	14.797	0.419
67.72	20.64	3.74	1.14	7.040	0.654	13.137	0.372	15.009	0.425
67.75	20.65	3.77	1.15	7.093	0.659	13.384	0.379	15.256	0.432
67.78	20.66	3.81	1.16	7.158	0.665	13.631	0.386	15.503	0.439
67.81	20.67	3.84	1.17	7.223	0.671	13.843	0.392	15.715	0.445
67.85	20.68	3.87	1.18	7.287	0.677	14.091	0.399	15.962	0.452
67.88	20.69	3.90	1.19	7.352	0.683	14.338	0.406	16.209	0.459
67.91	20.70	3.94	1.20	7.427	0.690	14.585	0.413	16.457	0.466
67.95	20.71	3.97	1.21	7.502	0.697	14.832	0.420	16.704	0.473
67.98	20.72	4.00	1.22	7.578	0.704	15.079	0.427	16.951	0.480
68.01	20.73	4.04	1.23	7.653	0.711	15.327	0.434	17.198	0.487
68.04	20.74	4.07	1.24	7.728	0.718	15.574	0.441	17.445	0.494
68.08	20.75	4.10	1.25	7.815	0.726	15.821	0.448	17.693	0.501
68.11	20.76	4.13	1.26	7.901	0.734	16.068	0.455	17.940	0.508
68.14	20.77	4.17	1.27	7.998	0.743	16.351	0.463	18.222	0.516
68.18	20.78	4.20	1.28	8.084	0.751	16.598	0.470	18.470	0.523
68.21	20.79	4.23	1.29	8.181	0.760	16.880	0.478	18.752	0.531
68.24	20.80	4.27	1.30	8.277	0.769	17.128	0.485	18.999	0.538
68.27	20.81	4.30	1.31	8.385	0.779	17.410	0.493	19.282	0.546
68.31	20.82	4.33	1.32	8.482	0.788	17.693	0.501	19.564	0.554
68.34	20.83	4.36	1.33	8.600	0.799	17.975	0.509	19.847	0.562
68.37	20.84	4.40	1.34	8.719	0.810	18.258	0.517	20.129	0.570
68.41	20.85	4.43	1.35	8.837	0.821	18.540	0.525	20.412	0.578

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
68.44	20.86	4.46	1.36	8.956	0.832	18.823	0.533	20.694	0.586
68.47	20.87	4.49	1.37	9.074	0.843	19.141	0.542	21.012	0.595
68.50	20.88	4.53	1.38	9.203	0.855	19.423	0.550	21.295	0.603
68.54	20.89	4.56	1.39	9.322	0.866	19.741	0.559	21.613	0.612
68.57	20.90	4.59	1.40	9.440	0.877	20.059	0.568	21.930	0.621
68.60	20.91	4.63	1.41	9.558	0.888	20.341	0.576	22.213	0.629
68.64	20.92	4.66	1.42	9.666	0.898	20.659	0.585	22.531	0.638
68.67	20.93	4.69	1.43	9.784	0.909	20.977	0.594	22.849	0.647
68.70	20.94	4.72	1.44	9.903	0.920	21.330	0.604	23.202	0.657
68.73	20.95	4.76	1.45	10.021	0.931	21.648	0.613	23.520	0.666
68.77	20.96	4.79	1.46	10.150	0.943	21.966	0.622	23.837	0.675
68.80	20.97	4.82	1.47	10.269	0.954	22.319	0.632	24.191	0.685
68.83	20.98	4.86	1.48	10.398	0.966	22.637	0.641	24.508	0.694
68.86	20.99	4.89	1.49	10.527	0.978	22.990	0.651	24.862	0.704
68.90	21.00	4.92	1.50	10.645	0.989	23.343	0.661	25.215	0.714
68.93	21.01	4.95	1.51	10.785	1.002	23.696	0.671	25.568	0.724
68.96	21.02	4.99	1.52	10.915	1.014	24.049	0.681	25.921	0.734
69.00	21.03	5.02	1.53	11.044	1.026	24.402	0.691	26.274	0.744
69.03	21.04	5.05	1.54	11.184	1.039	24.756	0.701	26.627	0.754
69.06	21.05	5.09	1.55	11.324	1.052	25.144	0.712	27.016	0.765
69.09	21.06	5.12	1.56	11.453	1.064	25.497	0.722	27.369	0.775
69.13	21.07	5.15	1.57	11.603	1.078	25.886	0.733	27.757	0.786
69.16	21.08	5.18	1.58	11.743	1.091	26.274	0.744	28.146	0.797
69.19	21.09	5.22	1.59	11.883	1.104	26.663	0.755	28.534	0.808

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
69.23	21.10	5.25	1.60	12.034	1.118	27.051	0.766	28.923	0.819
69.26	21.11	5.28	1.61	12.185	1.132	27.440	0.777	29.311	0.830
69.29	21.12	5.31	1.62	12.335	1.146	27.863	0.789	29.735	0.842
69.32	21.13	5.35	1.63	12.486	1.160	28.252	0.800	30.123	0.853
69.36	21.14	5.38	1.64	12.648	1.175	28.676	0.812	30.547	0.865
69.39	21.15	5.41	1.65	12.809	1.190	29.099	0.824	30.971	0.877
69.42	21.16	5.45	1.66	12.970	1.205	29.523	0.836	31.395	0.889
69.46	21.17	5.48	1.67	13.132	1.220	29.947	0.848	31.819	0.901
69.49	21.18	5.51	1.68	13.304	1.236	30.371	0.860	32.242	0.913
69.52	21.19	5.54	1.69	13.466	1.251	30.830	0.873	32.701	0.926
69.55	21.20	5.58	1.70	13.649	1.268	31.254	0.885	33.125	0.938
69.59	21.21	5.61	1.71	13.821	1.284	31.713	0.898	33.584	0.951
69.62	21.22	5.64	1.72	14.004	1.301	32.172	0.911	34.043	0.964
69.65	21.23	5.68	1.73	14.198	1.319	32.631	0.924	34.502	0.977
69.69	21.24	5.71	1.74	14.413	1.339	33.090	0.937	34.962	0.990
69.72	21.25	5.74	1.75	14.650	1.361	33.584	0.951	35.456	1.004
69.75	21.26	5.77	1.76	14.876	1.382	34.043	0.964	35.915	1.017
69.78	21.27	5.81	1.77	15.091	1.402	34.538	0.978	36.409	1.031
69.82	21.28	5.84	1.78	15.306	1.422	35.032	0.992	36.904	1.045
69.85	21.29	5.87	1.79	15.511	1.441	35.562	1.007	37.434	1.060
69.88	21.30	5.91	1.80	15.705	1.459	36.056	1.021	37.928	1.074
69.91	21.31	5.94	1.81	15.898	1.477	36.586	1.036	38.458	1.089
69.95	21.32	5.97	1.82	16.071	1.493	37.116	1.051	38.987	1.104
69.98	21.33	6.00	1.83	16.232	1.508	37.645	1.066	39.517	1.119

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
70.01	21.34	6.04	1.84	16.361	1.520	38.175	1.081	40.047	1.134
70.05	21.35	6.07	1.85	16.480	1.531	38.705	1.096	40.577	1.149
70.08	21.36	6.10	1.86	16.587	1.541	39.270	1.112	41.142	1.165
70.11	21.37	6.14	1.87	16.695	1.551	39.800	1.127	41.671	1.180
70.14	21.38	6.17	1.88	16.802	1.561	40.365	1.143	42.236	1.196
70.18	21.39	6.20	1.89	16.899	1.570	40.894	1.158	42.766	1.211
70.21	21.40	6.23	1.90	17.007	1.580	41.459	1.174	43.331	1.227
70.24	21.41	6.27	1.91	17.093	1.588	42.024	1.190	43.896	1.243
70.28	21.42	6.30	1.92	17.190	1.597	42.590	1.206	44.461	1.259
70.31	21.43	6.33	1.93	17.319	1.609	43.155	1.222	45.026	1.275
70.34	21.44	6.36	1.94	17.416	1.618	43.720	1.238	45.591	1.291
70.37	21.45	6.40	1.95	17.513	1.627	44.285	1.254	46.156	1.307
70.41	21.46	6.43	1.96	17.599	1.635	44.850	1.270	46.721	1.323
70.44	21.47	6.46	1.97	17.685	1.643	45.450	1.287	47.322	1.340
70.47	21.48	6.50	1.98	17.771	1.651	46.015	1.303	47.887	1.356
70.51	21.49	6.53	1.99	17.847	1.658	46.615	1.320	48.487	1.373
70.54	21.50	6.56	2.00	17.933	1.666	47.180	1.336	49.052	1.389
70.57	21.51	6.59	2.01	18.019	1.674	47.781	1.353	49.652	1.406
70.60	21.52	6.63	2.02	18.116	1.683	48.381	1.370	50.253	1.423
70.64	21.53	6.66	2.03	18.202	1.691	48.981	1.387	50.853	1.440
70.67	21.54	6.69	2.04	18.288	1.699	49.582	1.404	51.454	1.457
70.70	21.55	6.73	2.05	18.374	1.707	50.182	1.421	52.054	1.474
70.73	21.56	6.76	2.06	18.471	1.716	50.783	1.438	52.654	1.491
70.77	21.57	6.79	2.07	18.557	1.724	51.383	1.455	53.255	1.508

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
70.80	21.58	6.82	2.08	18.643	1.732	51.983	1.472	53.855	1.525
70.83	21.59	6.86	2.09	18.729	1.740	52.619	1.490	54.491	1.543
70.87	21.60	6.89	2.10	18.815	1.748	53.219	1.507	55.091	1.560
70.90	21.61	6.92	2.11	18.901	1.756	53.855	1.525	55.727	1.578
70.93	21.62	6.96	2.12	18.977	1.763	54.455	1.542	56.327	1.595
70.96	21.63	6.99	2.13	19.063	1.771	55.091	1.560	56.963	1.613
71.00	21.64	7.02	2.14	19.149	1.779	55.727	1.578	57.598	1.631
71.03	21.65	7.05	2.15	19.235	1.787	56.362	1.596	58.234	1.649
71.06	21.66	7.09	2.16	19.321	1.795	56.963	1.613	58.834	1.666
71.10	21.67	7.12	2.17	19.407	1.803	57.598	1.631	59.470	1.684
71.13	21.68	7.15	2.18	19.493	1.811	58.269	1.650	60.141	1.703
71.16	21.69	7.19	2.19	19.580	1.819	58.905	1.668	60.777	1.721
71.19	21.70	7.22	2.20	19.666	1.827	59.541	1.686	61.412	1.739
71.23	21.71	7.25	2.21	19.741	1.834	60.176	1.704	62.048	1.757
71.26	21.72	7.28	2.22	19.816	1.841	60.847	1.723	62.719	1.776
71.29	21.73	7.32	2.23	19.902	1.849	61.483	1.741	63.355	1.794
71.33	21.74	7.35	2.24	19.978	1.856	62.154	1.760	64.026	1.813
71.36	21.75	7.38	2.25	20.053	1.863	62.790	1.778	64.661	1.831
71.39	21.76	7.41	2.26	20.128	1.870	63.461	1.797	65.332	1.850
71.42	21.77	7.45	2.27	20.215	1.878	64.131	1.816	66.003	1.869
71.46	21.78	7.48	2.28	20.290	1.885	64.767	1.834	66.639	1.887
71.49	21.79	7.51	2.29	20.365	1.892	65.438	1.853	67.310	1.906
71.52	21.80	7.55	2.30	20.451	1.900	66.109	1.872	67.981	1.925
71.56	21.81	7.58	2.31	20.527	1.907	66.780	1.891	68.652	1.944

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
71.59	21.82	7.61	2.32	20.613	1.915	67.451	1.910	69.323	1.963
71.62	21.83	7.64	2.33	20.688	1.922	68.157	1.930	70.029	1.983
71.65	21.84	7.68	2.34	20.774	1.930	68.828	1.949	70.700	2.002
71.69	21.85	7.71	2.35	20.860	1.938	69.499	1.968	71.371	2.021
71.72	21.86	7.74	2.36	20.936	1.945	70.206	1.988	72.077	2.041
71.75	21.87	7.78	2.37	21.022	1.953	70.877	2.007	72.748	2.060
71.78	21.88	7.81	2.38	21.108	1.961	71.583	2.027	73.455	2.080
71.82	21.89	7.84	2.39	21.194	1.969	72.254	2.046	74.126	2.099
71.85	21.90	7.87	2.40	21.280	1.977	72.960	2.066	74.832	2.119
71.88	21.91	7.91	2.41	21.388	1.987	73.666	2.086	75.538	2.139
71.92	21.92	7.94	2.42	21.496	1.997	74.373	2.106	76.244	2.159
71.95	21.93	7.97	2.43	21.603	2.007	75.079	2.126	76.951	2.179
71.98	21.94	8.01	2.44	21.711	2.017	75.785	2.146	77.657	2.199
72.01	21.95	8.04	2.45	21.818	2.027	76.492	2.166	78.363	2.219
72.05	21.96	8.07	2.46	21.937	2.038	77.198	2.186	79.070	2.239
72.08	21.97	8.10	2.47	22.044	2.048	77.940	2.207	79.811	2.260
72.11	21.98	8.14	2.48	22.152	2.058	78.646	2.227	80.518	2.280
72.15	21.99	8.17	2.49	22.281	2.070	79.387	2.248	81.259	2.301
72.18	22.00	8.20	2.50	22.400	2.081	80.129	2.269	82.001	2.322
72.21	22.01	8.23	2.51	22.507	2.091	80.871	2.290	82.742	2.343
72.24	22.02	8.27	2.52	22.626	2.102	81.612	2.311	83.484	2.364
72.28	22.03	8.30	2.53	22.733	2.112	82.354	2.332	84.226	2.385
72.31	22.04	8.33	2.54	22.841	2.122	83.095	2.353	84.967	2.406
72.34	22.05	8.37	2.55	22.949	2.132	83.837	2.374	85.709	2.427

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
72.38	22.06	8.40	2.56	23.056	2.142	84.614	2.396	86.486	2.449
72.41	22.07	8.43	2.57	23.164	2.152	85.356	2.417	87.227	2.470
72.44	22.08	8.46	2.58	23.272	2.162	86.133	2.439	88.004	2.492
72.47	22.09	8.50	2.59	23.379	2.172	86.874	2.460	88.746	2.513
72.51	22.10	8.53	2.60	23.487	2.182	87.651	2.482	89.523	2.535
72.54	22.11	8.56	2.61	23.594	2.192	88.428	2.504	90.300	2.557
72.57	22.12	8.60	2.62	23.713	2.203	89.205	2.526	91.077	2.579
72.60	22.13	8.63	2.63	23.831	2.214	89.982	2.548	91.854	2.601
72.64	22.14	8.66	2.64	23.950	2.225	90.759	2.570	92.630	2.623
72.67	22.15	8.69	2.65	24.057	2.235	91.536	2.592	93.407	2.645
72.70	22.16	8.73	2.66	24.176	2.246	92.348	2.615	94.220	2.668
72.74	22.17	8.76	2.67	24.283	2.256	93.125	2.637	94.997	2.690
72.77	22.18	8.79	2.68	24.402	2.267	93.937	2.660	95.809	2.713
72.80	22.19	8.83	2.69	24.509	2.277	94.749	2.683	96.621	2.736
72.83	22.20	8.86	2.70	24.628	2.288	95.562	2.706	97.433	2.759
72.87	22.21	8.89	2.71	24.746	2.299	96.339	2.728	98.210	2.781
72.90	22.22	8.92	2.72	24.854	2.309	97.186	2.752	99.058	2.805
72.93	22.23	8.96	2.73	24.961	2.319	97.998	2.775	99.870	2.828
72.97	22.24	8.99	2.74	25.069	2.329	98.811	2.798	100.682	2.851
73.00	22.25	9.02	2.75	25.177	2.339	99.623	2.821	101.494	2.874
73.03	22.26	9.06	2.76	25.284	2.349	100.470	2.845	102.342	2.898
73.06	22.27	9.09	2.77	25.392	2.359	101.283	2.868	103.154	2.921
73.10	22.28	9.12	2.78	25.510	2.370	102.130	2.892	104.002	2.945
73.13	22.29	9.15	2.79	25.618	2.380	102.978	2.916	104.849	2.969

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
73.16	22.30	9.19	2.80	25.726	2.390	103.790	2.939	105.662	2.992
73.20	22.31	9.22	2.81	25.844	2.401	104.637	2.963	106.509	3.016
73.23	22.32	9.25	2.82	25.952	2.411	105.485	2.987	107.357	3.040
73.26	22.33	9.28	2.83	26.059	2.421	106.368	3.012	108.240	3.065
73.29	22.34	9.32	2.84	26.178	2.432	107.215	3.036	109.087	3.089
73.33	22.35	9.35	2.85	26.285	2.442	108.063	3.060	109.935	3.113
73.36	22.36	9.38	2.86	26.404	2.453	108.946	3.085	110.818	3.138
73.39	22.37	9.42	2.87	26.522	2.464	109.793	3.109	111.665	3.162
73.43	22.38	9.45	2.88	26.641	2.475	110.676	3.134	112.548	3.187
73.46	22.39	9.48	2.89	26.770	2.487	111.559	3.159	113.431	3.212
73.49	22.40	9.51	2.90	26.899	2.499	112.442	3.184	114.314	3.237
73.52	22.41	9.55	2.91	27.039	2.512	113.325	3.209	115.197	3.262
73.56	22.42	9.58	2.92	27.168	2.524	114.208	3.234	116.079	3.287
73.59	22.43	9.61	2.93	27.308	2.537	115.091	3.259	116.962	3.312
73.62	22.44	9.65	2.94	27.437	2.549	116.009	3.285	117.880	3.338
73.65	22.45	9.68	2.95	27.566	2.561	116.892	3.310	118.763	3.363
73.69	22.46	9.71	2.96	27.685	2.572	117.810	3.336	119.682	3.389
73.72	22.47	9.74	2.97	27.803	2.583	118.728	3.362	120.600	3.415
73.75	22.48	9.78	2.98	27.932	2.595	119.646	3.388	121.518	3.441
73.79	22.49	9.81	2.99	28.061	2.607	120.564	3.414	122.436	3.467
73.82	22.50	9.84	3.00	28.191	2.619	121.483	3.440	123.354	3.493
73.85	22.51	9.88	3.01	28.320	2.631	122.401	3.466	124.272	3.519
73.88	22.52	9.91	3.02	28.438	2.642	123.319	3.492	125.191	3.545
73.92	22.53	9.94	3.03	28.567	2.654	124.272	3.519	126.144	3.572

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)		
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)	
73.95	22.54	9.97	3.04	28.697	2.666	125.191	3.545	127.062	3.598	
73.98	22.55	10.01	3.05	28.836	2.679	126.144	3.572	128.016	3.625	
74.02	22.56	10.04	3.06	28.976	2.692	127.098	3.599	128.969	3.652	
74.05	22.57	10.07	3.07	29.116	2.705	128.051	3.626	129.923	3.679	
74.08	22.58	10.10	3.08	29.267	2.719	129.005	3.653	130.876	3.706	
74.11	22.59	10.14	3.09	29.407	2.732	129.958	3.680	131.830	3.733	
74.15	22.60	10.17	3.10	29.547	2.745	130.947	3.708	132.819	3.761	
74.18	22.61	10.20	3.11	29.687	2.758	131.900	3.735	133.772	3.788	
74.21	22.62	10.24	3.12	29.827	2.771	132.889	3.763	134.761	3.816	
74.25	22.63	10.27	3.13	29.956	2.783	133.878	3.791	135.750	3.844	
74.28	22.64	10.30	3.14	30.085	2.795	134.867	3.819	136.739	3.872	
74.31	22.65	10.33	3.15	30.214	2.807	135.856	3.847	137.727	3.900	
74.34	22.66	10.37	3.16	30.354	2.820	136.844	3.875	138.716	3.928	
74.38	22.67	10.40	3.17	30.494	2.833	137.833	3.903	139.705	3.956	
74.41	22.68	10.43	3.18	30.634	2.846	138.822	3.931	140.694	3.984	
74.44	22.69	10.47	3.19	30.774	2.859	139.846	3.960	141.718	4.013	
74.48	**22.70**	**10.50**	**3.20**	**30.925**	**2.873**	**140.870**	**3.989**	**142.742**	**4.042**	**FRL**
74.51	22.71	10.53	3.21	31.065	2.886	141.859	4.017	143.731	4.070	
74.54	22.72	10.56	3.22	31.215	2.900	142.883	4.046	144.755	4.099	
74.57	22.73	10.60	3.23	31.366	2.914	143.907	4.075	145.779	4.128	
74.61	22.74	10.63	3.24	31.506	2.927	144.967	4.105	146.839	4.158	
74.64	22.75	10.66	3.25	31.657	2.941	145.991	4.134	147.863	4.187	
74.67	22.76	10.70	3.26	31.797	2.954	147.015	4.163	148.887	4.216	
74.70	22.77	10.73	3.27	31.936	2.967	148.075	4.193	149.946	4.246	

Elevation (MSL, ft)	Elevation (MSL, m)	Depth of water from DWL/OSL		Area (M.sq.ft)	Area (M.sq.m)	Live Capacity		Gross Capacity Total (Live + Dead)	
		ft	m			Volume (M.cu.ft)	Volume (M.cu.m)	Volume (M.cu.ft)	Volume (M.cu.m)
74.74	22.78	10.76	3.28	32.087	2.981	149.134	4.223	151.006	4.276
74.77	22.79	10.79	3.29	32.238	2.995	150.193	4.253	152.065	4.306
74.80	22.80	10.83	3.30	32.378	3.008	151.253	4.283	153.125	4.336

Annexure - 2

Mobilisation and Calibration Report

1 MOBILISATION

1.1 Introduction

Ocean Science & Surveying Pvt. Ltd. (OSaS) was contracted by Narmada Water Resources, Water Supply & Kalpsar Department (WRD) to carry out topographic and bathymetric survey of thirteen reservoirs in the Saurashtra & northern Gujarat region; namely Bhadar-1, Bhadar-2, Brahmani-1, Und-1, Machhu-1, Machhu-2, Khodiyar, Aji-1, Nara, Tappar, Rudramata, Mitti and Fatehgadh.

This report documents the mobilisation and calibrations carried out by OSaS for the topographic survey and on board SMB Ocean for the bathymetric survey of **Fatehgadh** reservoir at Saurashtra region, Gujarat.

The survey team arrived at the survey site on 22nd July 2021. After necessary meetings with the client representative on 23rd July, two TBMs, spaced 25m apart, were established by marking TBM-01 on the walkway to the valve tower of the dam and TBM-02 on the rock adjacent to the road towards the valve tower. DGPS observations were carried out at each of these points for about 2 hours. The levelling of these TBMs was carried out with respect to the known level of FRL (22.70m above MSL) provided by the client. The topographic survey commenced on the 24th July at Fatehgadh reservoir and completed on 27th July 2021.

The mobilisation of the survey boat SMB Ocean was carried out on 28th July 2021 while the boat was near the valve tower of Fatehgadh reservoir. Initial system preparation and equipment checks were completed on the same day. The bar check couldn't be carried out due to very shallow depth observed within the reservoir. Bathymetric survey commenced on 28th July and completed on 30th July 2021.

1.2 HSE Checks

A safety induction was given by the Party Chief prior to survey, detailing personnel responsibilities in the event of emergency, life jacket locations, safety gear locations and procedures and signals for emergencies.

Back deck procedures were explained and enforced with no single man operations and all non-essential personnel keeping clear of operations. PPE included safety boots, hardhats and cover-all's for all personnel involved in back deck operations.

1.3 Survey Equipment list on SMB Ocean

1.3.1 *Navigation and Positioning*

Item	Quantity
Hemisphere DGPS system with cables	1
Navigation computer with Hypack software	1
Moxa 8-port cable	4
Hemisphere Atlas Link RTK system with all accessories	3

1.3.2 *Single beam Echo sounder*

Item	Quantity
Odom MK III single beam echo sounder	2
Dual frequency transducer and mounting pole	2
Bar check	1
MRU-PD	2

1.3.3 *Levelling equipment*

Item	Quantity
Geomax auto level complete with all accessories	1 set

1.3.4 *Power Systems*

Item	Quantity
2KVA Stabilizer	2
1KVA generator	2
24V power supply	4
Exide battery 100Ah	1
Invertor	1
12V External battery	3
12V External battery charger	3

1.3.5 *Miscellaneous*

Item	Quantity
LCD monitors	8
Laptop	2
Helmets / life jackets	8
Tool box	1
Tripod and tribatch	4 & 3
Ranging Rod	3
Antenna T-section	2 Sets
RF Antenna	3
10m RF antenna cable	3
Echo rolls	52 nos
HP printer	1 nos
UPS	2 Sets
Switch board	8 Sets
Drill machine	1 Set

1.4 Vessel Offset Diagram

The equipment offsets in the survey motor boat (SMB) Ocean are shown in the figure below:

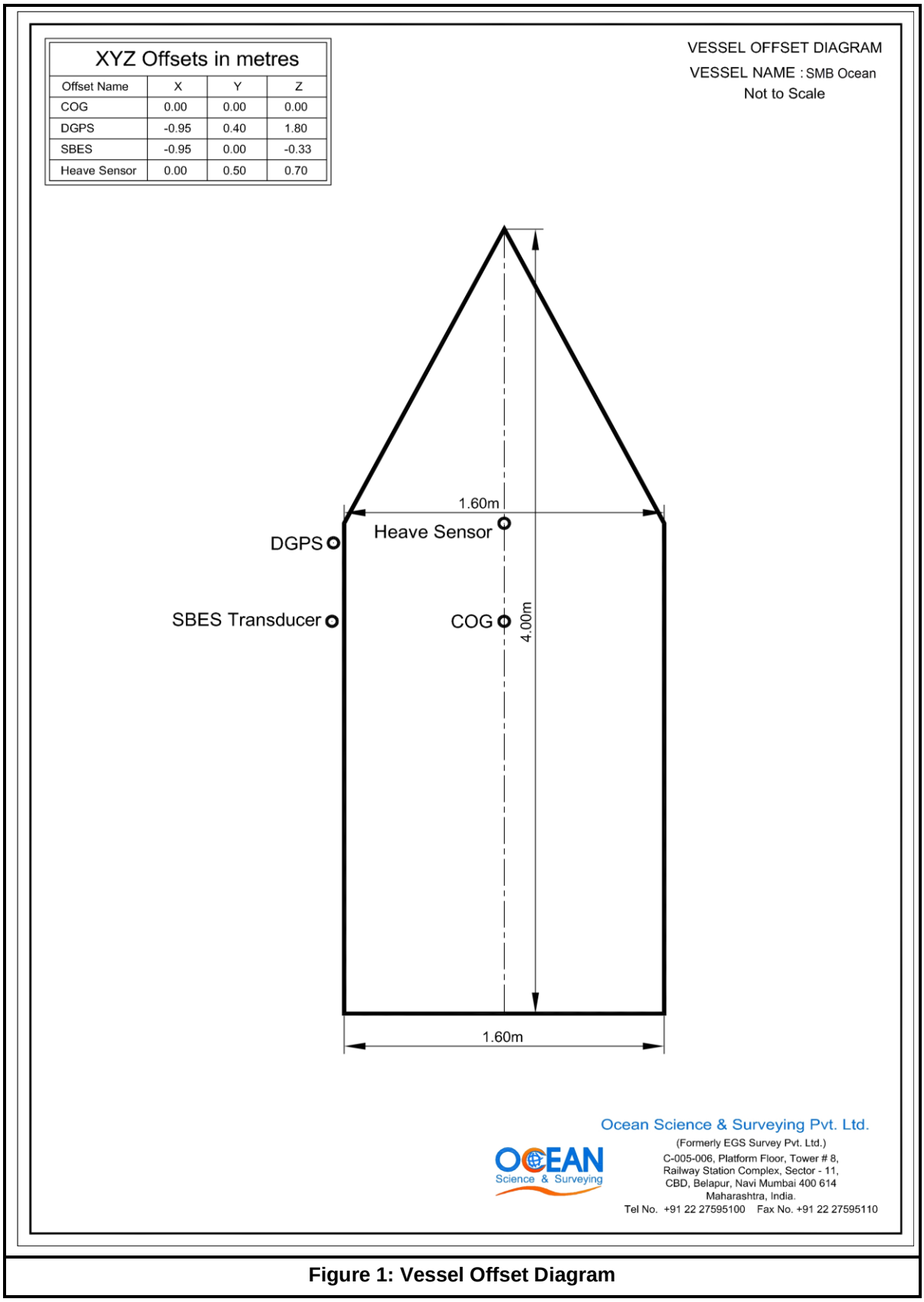


Figure 1: Vessel Offset Diagram

2 EQUIPMENT CALIBRATIONS

2.1 RTK system Calibrations

The details of the RTK system consistency checks are as follows:

In order to determine the integrity and reliability of the positioning system, the system was checked for its consistency during mobilisation.

Two points were manually marked; TBM-01 on the walkway to the valve tower of the dam and TBM-02 on the rock adjacent to the road towards the valve tower, both approximately 25m apart. About 2 hours of DGPS observations were carried out at each of the two points. After observations, the two points were established as temporary control points/ temporary benchmark (TBM). The levelling of these TBMs were completed using Geomax auto level with respect to the known level of the FRL, which is given as 22.70m above MSL, provided by the client. The base stations of the Hemisphere Atlas Link RTK were set up at these positions and two-hour continuous observations were conducted using Hemisphere RTK positioning system to fix the consistency of the position for horizontal control. The system provides real time correction signals, providing centimetre level accuracy.

The details of reference stations OSaS-FT-TBM -01 and OSaS-FT-TBM-02 are provided in **Table 1** and **Table 2**.

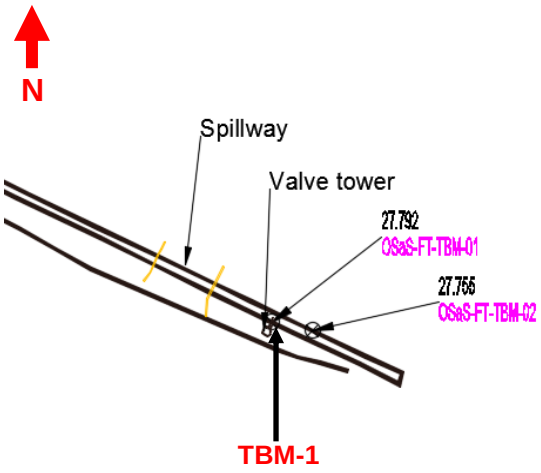
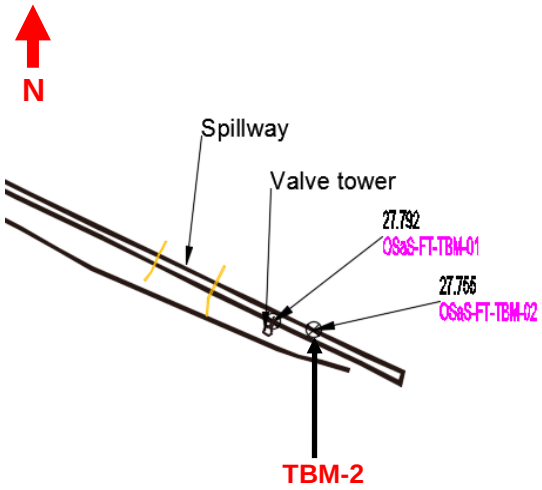
<table>
<tr><td>Station Number:</td><td>OSaS-FT-TBM-01</td><td>Latitude:</td><td>23° 41' 22.708" N</td></tr>
<tr><td>Locality:</td><td>Fatehgadh, Gujarat</td><td>Longitude:</td><td>70° 48' 08.076" E</td></tr>
<tr><td>Geodetic Datum:</td><td>WGS84</td><td>Northing:</td><td>2621027.68 m N</td></tr>
<tr><td>Projection:</td><td>Universal Transverse Mercator</td><td>Easting:</td><td>683765.69 m E</td></tr>
<tr><td>Date:</td><td>23rd July 2021</td><td>Elevation:</td><td>27.792 m above MSL</td></tr>
<tr><td>Station Description:</td><td colspan="3">A circle with text OS-FT-TBM-1 is drawn with yellow paint on the walkway to the valve tower, at the northeastern part of the dam.</td></tr>
<tr><td>Access:</td><td colspan="3">Road to the top of the reservoir. The TBM-01 is situated on the walkway to the valve tower, at the northern part of the dam.</td></tr>
<tr><td colspan="2">Sketch:</td><td colspan="2">Map:</td></tr>
<tr><td colspan="2"> 
</td><td colspan="2"> 
</td></tr>
<tr><td colspan="2">Photo:</td><td colspan="2">Photo:</td></tr>
<tr><td colspan="2"> 
</td><td colspan="2"> 
</td></tr>
</table>

Table 1: Details of OSaS-FT-TBM-01

Station Number:	OSaS-FT-TBM-02	**Latitude:**	23° 41' 22.544" N
Locality:	Fatehgadh, Gujarat	**Longitude:**	70° 48' 08.901" E
Geodetic Datum:	WGS84	**Northing:**	2621022.92m N
Projection:	Universal Transverse Mercator	**Easting:**	683789.13m E
Date:	23rd July 2021	**Elevation:**	27.755 m above MSL
Station Description:	A circle with text OS-FT-TBM-2 is drawn with yellow paint on the rock adjacent to the road towards the valve tower, at the northeastern part of the dam.		
Access:	Road to the top of the reservoir. The TBM-02 is situated on the rock adjacent to the road towards the valve tower, at the northern part of the dam. TBM-02 is located approximately 25m east of TBM-01.		

Sketch:



Map:

Photo:

Photo:

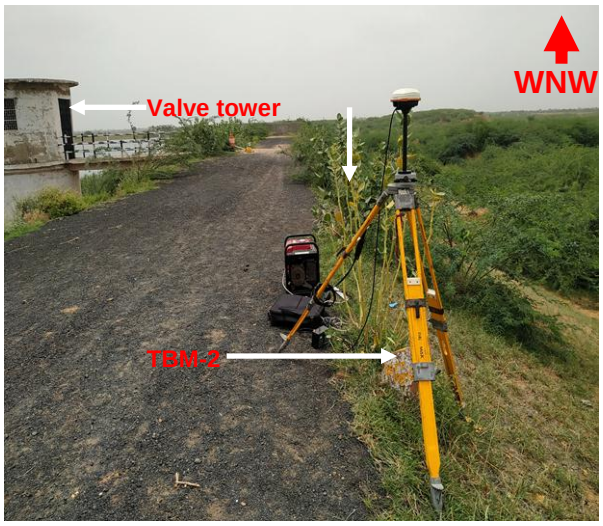


Table 2: Details of OSaS-FT-TBM-02

2.2 Single Beam Echo Sounder

The bar check couldn't be carried out due to very shallow depth encountered within the reservoir. The average speed of sound through the water column was input to the single beam echo sounder before the start of survey operations.

3 CONCLUSIONS

Mobilisation for this project, including calibration and verification were carried out on board SMB Ocean in a safe and acceptable manner. All systems performed to the specifications throughout the length of the survey.

Annexure - 3

Previous Data – 1987

Fatehgadh Reservoir

The following document provided by the client has been used to extract the salient features of Fatehgadh reservoir. The provided document contains the impounding survey details from 17.0m above MSL to 26.0m above MSL. The elevation-area-capacity data extracted from this document have been used for the calculations of rate of siltation and preparation of elevation-area-capacity curves.

FATEHGADH IRRIGATION SCHEME

TAL.RAPAR, DIST.KACHCHH

SALIENT FETURE

.0	Name of Project	:-	Fatehgadh Irrigation Scheme

.0	Location		
	a. Across river	:-	Malan
	b. Nearest Village	:-	Fatehgadh
	c. Taluka	:-	RAPAR
	d. District	:-	Kachchh
	e. State	:-	Gujarat
	f. Location of Dam	:-	Lat. 23°-41' N Long. 70°-47' E
	g. Nearest Railway Station	:-	Adesar of the Kachchh District, Broad Guage Railway Line of the W.R. is 30 Km. away from the Dam site.
	h. Road Communication		25 Km. from Rapar city from Fatehgadhvillage.
	i. Dam Construction Start Year	:-	1979
	j. Dam Constructed Year	:-	1987
	k. Estimate cost	:-	Rs.129.67 Lakh

3.0	HYDROLOGY		
A	Catchment Area		
	i. Total catchment area at Dam site	:-	103.60
	ii. Catchment area in Gujarat Territory	:-	103.60
	iii. Catchment area consider for availabilitv of water at FATEHGADH Dam site	:-	103.60
	iv. Net free catchment area available at FATEHGADH for water planning.	:-	103.60
B	Average Rain Fall	:-	348 M.M.
C	Floods	:-	
	i. Maximum flood Observed	:-	714.00 Cumecs
	ii. Maximum probable flood (M.P.F.)	:-	1196.00 Cumecs
	iii Standard probable flood (S.P.F.)	:-	544.00 Cumecs
	iv. Riverbed level in meter	:-	17.50
	v. Sill R.L. of Canal H.R. in meter	:-	19.50
	F.R.L. in meter	:-	22.70
	M.W.L. in meter	:-	27.70

4.0	Reservoir Capacity Data		MM3	MCFT
	i. Design. Gross capacity @ F.R.L.	:-	7.45	263.09
	Revised Gross capacity @ F.R.L.	:-		
	ii. Design Dead storage @ RL	:-	0.82	28.95
	Revised Dead storage @ RL	:-		
	iii. Design Live storage	:-	6.63	234.13
	Revised Live storage	:-		

	Area at Full Reservoir Level	:-	5.28 km^2
	Effective Storage Capacity	:-	6.63 MM^3
	Area under Submergence (Only culturable)	:-	110 hac.

5.0	Spillway	
	Type	Chute
	Length	35 m
	Energy Dissipater	Stilling basin
	Maximum discharge	1246 m^3/s
	Type nos. and size of gates	Ungated

6.0	Details of Dam		Meter	Foot
i.	River gorge portion	:-		
	a. Earthen dam	:-	4130.00	13546.40
	b. Spillway	:-	35.00	114.80
	c. Bed Rock	:-	Clays Shale/ Clay & friable sandstone	
ii.	Total Length of Dam			
	Maximum height from the deepest foundation to the top of road way earthen dam in gorge portion	:-	17.10	56.08
iii.	Width of Road way of earthen dam	:-	6.00	19.68
	Free Board in Meter	:-	2.50	
	Top of Dam	:-	27.70	
	Submergence area in hectare	:-	852 hac.	
	Height above G.L. of Earthen dam (In m)	:-	11.28	
	Length of the Left Earthen Dam (In m)	:-	2130.00	
	Length of the Right Earthen Dam (In m)	:-	2000.00	
	Total Length (In m)	:-	4130.00	
	Maximum height above the lowest point of foundation	:-	11.20 m	

KACHCHH IRRIGATION DIVISION, BHUJ.
FATEHGADH IRRIGATION SCHEME.
Area Capacity Table.

O.S.L.: 19.50 M.
F.R.L.: 22.70 M.

Dead Storage 0.82 Mcum.
Live Storage 6.63 Mcum.
Gross Storage 7.45 Mcum.
:

Elevation R.L. in M.	Area of Contour in Msqm.	Cummulative capacity in Mcum.	Live storage capacity in	Remarks. Storage in %
1	2	3	4	5
17.00	0.06588	0.00000	-	0.000
17.10	0.08502	0.01511	-	0.203
17.20	0.10416	0.03022	-	0.406
17.30	0.12330	0.04533	-	0.609
17.40	0.14243	0.06044	-	0.811
17.50	0.16157	0.07556	-	1.014
17.60	0.18071	0.09067	-	1.217
17.70	0.19985	0.10578	-	1.420
17.80	0.21899	0.12089	-	1.623
17.90	0.23813	0.13600	-	1.826
18.00	0.25727	0.15111	-	2.028
18.10	0.27372	0.18473	-	2.480
18.20	0.29017	0.21834	-	2.931
18.30	0.30663	0.25196	-	3.382
18.40	0.32308	0.28558	-	3.833
18.50	0.33953	0.31919	-	4.284
18.60	0.35599	0.35281	-	4.736
18.70	0.37244	0.38642	-	5.187
18.80	0.38889	0.42004	-	5.638
18.90	0.40534	0.45366	-	6.089
19.00	0.42180	0.48727	-	6.541
19.10	0.47583	0.55464	-	7.445
19.20	0.52987	0.62201	-	8.349
19.30	0.58391	0.68937	-	9.253
19.40	0.63794	0.75674	-	10.158
19.50	0.69198	0.82411	-	11.062
19.60	0.74601	0.89147	0.06737	11.966
19.70	0.80005	0.95884	0.13473	12.870
19.80	0.85409	1.02621	0.20210	13.775
19.90	0.90812	1.09357	0.26947	14.679
20.00	0.96216	1.16094	0.33683	15.583
20.10	1.05276	1.30028	0.47617	17.453
20.20	1.14336	1.43961	0.61551	19.324
20.30	1.23396	1.57895	0.75484	21.194
20.40	1.32456	1.71828	0.89418	23.064
20.50	1.41516	1.85762	1.03351	24.934
20.60	1.50576	1.99695	1.17285	26.805
20.70	1.59636	2.13629	1.31218	28.675
20.80	1.68696	2.27562	1.45152	30.545
20.90	1.77756	2.41496	1.59085	32.416

Elevation R.L. in M.	Area of Contour in Msqm.	Cummulative capacity in Mcum.	Live storage capacity in	Remarks. Storage in %
1	2	3	4	5
21.00	1.86816	2.55429	1.73019	34.286
21.10	2.19030	2.79964	1.97553	37.579
21.20	2.51245	3.04498	2.22087	40.872
21.30	2.83460	3.29032	2.46622	44.165
21.40	3.15675	3.53566	2.71156	47.459
21.50	3.47890	3.78101	2.95690	50.752
21.60	3.80105	4.02635	3.20224	54.045
21.70	4.12319	4.27169	3.44759	57.338
21.80	4.44534	4.51703	3.69293	60.631
21.90	4.76749	4.76238	3.93827	63.925
22.00	5.08964	5.00772	4.18361	67.218
22.10	5.11803	5.37903	4.55492	72.202
22.20	5.14642	5.75034	4.92623	77.186
22.30	5.17481	6.12165	5.29754	82.170
22.40	5.20320	6.49296	5.66885	87.154
22.50	5.23159	6.86427	6.04016	92.138
22.60	5.25998	7.23557	6.41147	97.122
22.70	5.28837	7.45000	6.62589	100.000
22.80	5.31676	7.97819	7.15409	107.090
22.90	5.34515	8.34950	7.52540	112.074
23.00	5.37354	8.72081	7.89670	117.058
23.10	5.47059	9.25365	8.42954	124.210
23.20	5.56764	9.78649	8.96238	131.362
23.30	5.66469	10.31933	9.49522	138.514
23.40	5.76174	10.85217	10.02806	145.667
23.50	5.85879	11.38501	10.56090	152.819
23.60	5.95584	11.91784	11.09374	159.971
23.70	6.05289	12.45068	11.62658	167.123
23.80	6.14994	12.98352	12.15942	174.275
23.90	6.24699	13.51636	12.69226	181.428
24.00	6.34404	14.04920	13.22509	188.580
24.10	6.52750	14.77340	13.94929	198.301
24.20	6.71097	15.49760	14.67349	208.021
24.30	6.89444	16.22179	15.39769	217.742
24.40	7.07791	16.94599	16.12189	227.463
24.50	7.26137	17.67019	16.84609	237.184
24.60	7.44484	18.39439	17.57028	246.905
24.70	7.62831	19.11859	18.29448	256.625
24.80	7.81178	19.84279	19.01868	266.346
24.90	7.99525	20.56698	19.74288	276.067
25.00	8.17871	21.29118	20.46708	285.788
25.10	8.35105	22.19385	21.36975	297.904
25.20	8.52339	23.09652	22.27241	310.020
25.30	8.69573	23.99919	23.17508	322.137
25.40	8.86807	24.90186	24.07775	334.253
25.50	9.04041	25.80453	24.98042	346.369
25.60	9.21275	26.70720	25.88309	358.486

Elevation R.L. in M.	Area of Contour in Msqm.	Cummulative capacity in Mcum.	Live storage capacity in	Remarks. Storage in %
1	2	3	4	5
25.70	9.38509	27.60987	26.78576	370.602
25.80	9.55743	28.51253	27.68843	382.719
25.90	9.72977	29.41520	28.59110	394.835
26.00	9.90211	30.31787	29.49377	406.951

Executive Engineer
Kachchh Irrigation Division
BHUJ.

Annexure - 4
Daily Progress Reports

OCEAN Science & Surveying	DAILY PROGRESS REPORT	Form No.:	Sy01R
		Revision:	01
		Date:	11/07/2014
		Approved By	PKT

Location Fatehgadh Dam DPR No. 001

Client:	Narmada Water Resources, Water Supply & Kalpsar Department	Project No:	P34320
Vessel:	OSaS SMB	Date:	22-07-2021
Location:	Fatehgadh Dam	Sheet No:	1 of 1
Party Chief: Salman		Client Rep.	

Survey Personnel:

1.Pankaj Rabary	2. Gaurav Sharma	3. Manoj More
4.	5.	6.
7.	8.	9.
10.		

Equipment				
	RTK system	SBES system	Auto level	Heave sensor
	Hypacknav system	Bar check	Generator	
	Computer			

Time (hrs)		**Activities**
0800	1130	Boat and equipment loaded in truck and left for Fatehgadh Dam
1530	2000	Team reached Fatehgadh, boat landed to dam and equipment secured safely.
2000	2230	Team checked in hotel at Rapar.

		Today's coverage		Cumulative coverage	
		Bathymetry:**- sq.km**	Line km:	Bathymetry:**-sq.km**	Line km:
		Topo:**-sq.km**	Line km:	Topo:**-sq.km**	Line km:
		Weather downtime today:		Cumulative weather downtime: **0 hour**	

Plan for next 24 hours: Benchmark establishment, observation and levelling.

Remarks:

Salman **Party Chief**	**Client Representative**

OCEAN Science & Surveying	**DAILY PROGRESS REPORT**	*Form No.:*	Sy01R
		Revision:	01
		Date:	11/07/2014
		Approved By	PKT

Location Fatehgadh Dam DPR No. 002

Client:	Narmada Water Resources, Water Supply & Kalpsar Department	Project No:	P34320
Vessel:	OSaS SMB	Date:	23-07-2021
Location:	Fatehgadh Dam	Sheet No:	1 of 1
Party Chief: Salman		Client Rep.	

Survey Personnel:

1. Pankaj Rabary	2. Gaurav Sharma	3.Manoj More
4.	5.	6.
7.	8.	9.
10.		

Equipment	RTK system	SBES system	Auto level	Heave sensor
	Hypack nav system	Bar check	Generator	
	Computer			

Time (hrs)		**Activities**
0630	0830	Team checked out from hotel and reached dam site.
0830	1700	Vertical datum established, TBM observation carried out.
1700	2030	Arranged accommodation for team at Fatehgadh.

		Today's coverage		Cumulative coverage	
		Bathymetry:**- sq.km**	Line km:	Bathymetry:**- sq.km**	Line km:
		Topo:**- sq.km**	Line km:	Topo:**- sq.km**	Line km:
		Weather downtime today:		Cumulative weather downtime: **0 hour**	

Plan for next 24 hours: Start of topo survey.

Remarks:

Party Chief	**Client Representative**

OCEAN Science & Surveying	DAILY PROGRESS REPORT	Form No.:	Sy01R
		Revision:	01
		Date:	11/07/2014
		Approved By	PKT

Location Fatehgadh Dam **DPR No. 003**

Client:	Narmada Water Resources, Water Supply & Kalpsar Department	Project No:	P34320
Vessel:	OSaS SMB	Date:	24-07-2021
Location:	**Fatehgadh Dam**	Sheet No:	1 of 1
Party Chief: Salman		Client Rep.	

Survey Personnel:

1. Pankaj Rabary	2. Gaurav Sharma	3.Manoj More
4.	5.	6.
7.	8.	9.
10.		

Equipment				
	RTK system	SBES system	Auto level	Heave sensor
	Hypack nav system	Bar check	Generator	
	Computer			

Time (hrs)		**Activities**
0715	0745	Team reached dam site.
0745	0815	Set up RTK base station.
0815	1830	Survey carried out.
1830	1915	Secured base and team returned to guest house.

	Today's coverage		Cumulative coverage	
	Bathymetry:**- sq.km**	Line km:	Bathymetry:**- sq.km**	Line km:
	Topo:**- 0.63sq.km**	Line km:**25.2**	Topo:**- 0.63sq.km**	Line km: **25.2**
	Weather downtime today:		Cumulative weather downtime: **0 hour**	

Plan for next 24 hours: Continue topo survey.

Remarks:

Salman **Party Chief**	**Client Representative**

OCEAN Science & Surveying	DAILY PROGRESS REPORT	Form No.:	Sy01R
		Revision:	01
		Date:	11/07/2014
		Approved By	PKT

Location Fatehgadh Dam **DPR No. 004**

Client:	Narmada Water Resources, Water Supply & Kalpsar Department	Project No:	P34320
Vessel:	OSaS SMB	Date:	25-07-2021
Location:	**Fatehgadh Dam**	Sheet No:	1 of 1
Party Chief: Salman		Client Rep.	

Survey Personnel:

1. Pankaj Rabary	2. Gaurav Sharma	3.Manoj More
4.	5.	6.
7.	8.	9.
10.		

Equipment				
	RTK system	SBES system	Auto level	Heave sensor
	Hypack nav system	Bar check	Generator	
	Computer			

Time (hrs)		**Activities**
0730	0755	Team reached dam site.
0755	0830	Set up RTK base station.
0830	1845	Survey carried out.
1845	1920	Secured base and team returned to guest house.

	Today's coverage		Cumulative coverage	
	Bathymetry:**- sq.km**	Line km:	Bathymetry:**- sq.km**	Line km:
	Topo:**- 0.49sq.km**	Line km:**19.6**	Topo:**- 1.12sq.km**	Line km: **44.8**
	Weather downtime today:		Cumulative weather downtime: **0 hour**	

Plan for next 24 hours: Continue topo survey.

Remarks:

Salman **Party Chief**	**Client Representative**

OCEAN Science & Surveying	DAILY PROGRESS REPORT	Form No.:	Sy01R
		Revision:	01
		Date:	11/07/2014
		Approved By	PKT

Location Fatehgadh Dam DPR No. 005

Client:	Narmada Water Resources, Water Supply & Kalpsar Department	Project No:	P34320
Vessel:	OSaS SMB	Date:	26-07-2021
Location:	Fatehgadh Dam	Sheet No:	1 of 1
Party Chief: Salman		Client Rep.	

Survey Personnel:

1. Pankaj Rabary	2. Gaurav Sharma	3.Manoj More
4.	5.	6.
7.	8.	9.
10.		

Equipment	RTK system	SBES system	Auto level	Heave sensor
	Hypack nav system	Bar check	Generator	
	Computer			

Time (hrs)		Activities
0730	0755	Team reached dam site.
0755	1400	Survey was not started due to rain, Waiting on weather.
1400	1430	Set up RTK base station.
1430	1815	Survey carried out.
1815	1850	Secured base and team returned to guest house.

		Today's coverage		Cumulative coverage	
		Bathymetry: **- sq.km**	Line km:	Bathymetry: **- sq.km**	Line km:
		Topo:**- 0.23sq.km**	Line km:**9.2**	Topo:- **1.35sq.km**	Line km: **54**
		Weather downtime today: **5 hours**		Cumulative weather downtime: **5 hours**	

Plan for next 24 hours: Continue topo survey.

Remarks:

Salman **Party Chief**	**Client Representative**

OCEAN Science & Surveying	DAILY PROGRESS REPORT	Form No.:	Sy01R
		Revision:	01
		Date:	11/07/2014
		Approved By	PKT

Location Fatehgadh Dam DPR No. 006

Client:	Narmada Water Resources, Water Supply & Kalpsar Department	Project No:	P34320
Vessel:	OSaS SMB	Date:	27-07-2021
Location:	**Fatehgadh Dam**	Sheet No:	1 of 1
Party Chief: Salman		Client Rep.	

Survey Personnel:

1. Pankaj Rabary	2. Gaurav Sharma	3.Manoj More
4.	5.	6.
7.	8.	9.
10.		

Equipment				
	RTK system	SBES system	Auto level	Heave sensor
	Hypack nav system	Bar check	Generator	
	Computer			

Time (hrs)		**Activities**
0715	0740	Team reached dam site.
0740	0810	Set up RTK base station.
0810	1845	Survey carried out.
1845	1930	Secured base and team returned to guest house.
Note: -		**Topo survey completed.**

		Today's coverage		Cumulative coverage	
		Bathymetry: **- sq.km**	Line km:	Bathymetry: **- sq.km**	Line km:
		Topo:**- 0.87sq.km**	Line km:**34.8**	Topo:**- 2.22sq.km**	Line km: **88.8**
		Weather downtime today: 0 hours		Cumulative weather downtime: 0 hours	

Plan for next 24 hours: Boat mobilisation and start bathy survey.

Remarks:

Salman **Party Chief**	**Client Representative**

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		Date:	11/07/2014
		Approved By	PKT

Location Fatehgadh Dam DPR No. 007

Client:	Narmada Water Resources, Water Supply & Kalpsar Department	Project No:	P34320
Vessel:	OSaS SMB	Date:	28-07-2021
Location:	**Fatehgadh Dam**	Sheet No:	1 of 1
Party Chief: Salman		Client Rep.	

Survey Personnel:

1. Pankaj Rabary	2. Gaurav Sharma	3.Manoj More
4.	5.	6.
7.	8.	9.
10.		

Equipment	RTK system	SBES system	Auto level	Heave sensor
	Hypack nav system	Bar check	Generator	
	Computer			

Time (hrs)		Activities
0730	0800	Team reached dam site.
0800	1100	Boat mobilised and set up RTK base station.
1100	1630	Survey carried out.
1630	1800	Demobilised the boat to shift it to the other part of the dam.
1800	1900	Secured base and team returned to guest house.
Note:		Fatehgadh Dam has two parts separated by a small channel which is not accessible by boat. One part has been completed today.

	Today's coverage		Cumulative coverage	
Bathymetry:	**0.275 sq.km**	Line km: **11**	Bathymetry: **0.275 sq.km**	Line km: **11**
Topo:	**- 0.000sq.km**	Line km: **0.00**	Topo: **- 2.220sq.km**	Line km: **88.80**
Weather downtime today: 0 hours			Cumulative weather downtime: 05 hours	

Plan for next 24 hours: Boat drop in second part of the dam, remobilisation boat and continue bathy survey.

Remarks:

Salman	
Party Chief	**Client Representative**

OCEAN Science & Surveying	DAILY PROGRESS REPORT	Form No.:	Sy01R
		Revision:	01
		Date:	11/07/2014
		Approved By	PKT

Location Fatehgadh Dam DPR No. 008

Client:	Narmada Water Resources, Water Supply & Kalpsar Department	Project No:	P34320
Vessel:	OSaS SMB	Date:	29-07-2021
Location:	Fatehgadh Dam	Sheet No:	1 of 1
Party Chief: Salman		Client Rep.	

Survey Personnel:

1. Pankaj Rabary	2. Gaurav Sharma	3.Manoj More
4.	5.	6.
7.	8.	9.
10.		

Equipment				
	RTK system	SBES system	Auto level	Heave sensor
	Hypack nav system	Bar check	Generator	
	Computer			

Time (hrs)		**Activities**
0720	0810	Team reached dam site.
0810	1000	Boat landed in the second part of the dam.
1000	1200	Boat mobilised and set up RTK base station.
1200	1830	Survey carried out.
1830	1930	Secured base and team returned to guest house.

		Today's coverage		Cumulative coverage	
		Bathymetry:**0.80 - sq.km**	Line km: **32**	Bathymetry: **- 1.07sq.km**	Line km: **43**
		Topo:**- 0.00sq.km**	Line km:**0.00**	Topo:- **2.22sq.km**	Line km: **88.8**
		Weather downtime today: 0 hours		Cumulative weather downtime: 05 hours	

Plan for next 24 hours:

Remarks:

Salman **Party Chief**	**Client Representative**

OCEAN Science & Surveying	**DAILY PROGRESS REPORT**	*Form No.:*	Sy01R
		Revision:	01
		Date:	11/07/2014
		Approved By	PKT

Location Fatehgadh Dam **DPR No. 009**

Client:	Narmada Water Resources, Water Supply & Kalpsar Department	Project No:	P34320
Vessel:	OSaS SMB	Date:	30-07-2021
Location:	**Fatehgadh Dam**	Sheet No:	1 of 1
Party Chief: Salman		Client Rep.	

Survey Personnel:

1. Pankaj Rabary	2. Gaurav Sharma	3.Manoj More
4.	5.	6.
7.	8.	9.
10.		

Equipment	RTK system	SBES system	Auto level	Heave sensor
	Hypack nav system	Bar check	Generator	
	Computer			

Time (hrs)		**Activities**
0740	0820	Team reached Dam site.
0820	0850	set up RTK base station.
0850	1740	Survey carried out.
1740	1800	Secured base and team returned to guest house.
Note:		**Site completed.**

	Today's coverage		Cumulative coverage	
	Bathymetry:**0.34 - sq.km**	Line km: **13.6**	Bathymetry: **- 1.41sq.km**	Line km: **56.6**
	Topo:**- 0.00sq.km**	Line km:**0.00**	Topo:**- 2.22sq.km**	Line km: **88.8**
	Weather downtime today: 0 hours		Cumulative weather downtime: 05 hours	

Plan for next 24 hours: Team will demobilise and shift to Khodiyar Dam.

Remarks:

Party Chief	**Client Representative**