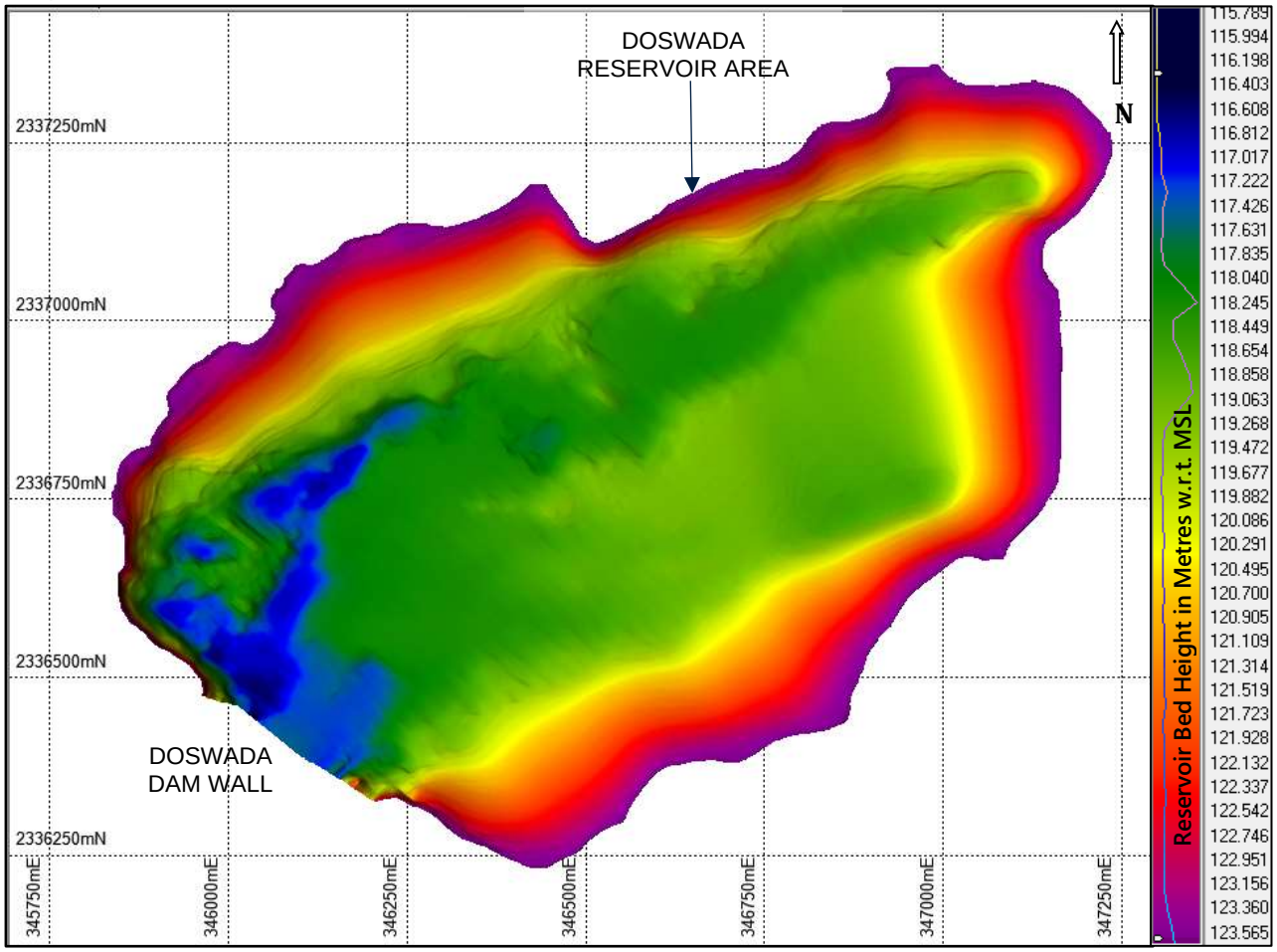

Providing Services for Conducting Bathymetric Survey of Reservoirs of Central Gujarat Under National Hydrology Project

Survey Results of Doswada Reservoir Location | Central Gujarat

JHYD20-174630-Volume 6-Doswada Reservoir/R1 [01] | 12 November 2021

Final Report

Narmada Water Resources, Water Supply and Kalpsar Department / Government of Gujarat

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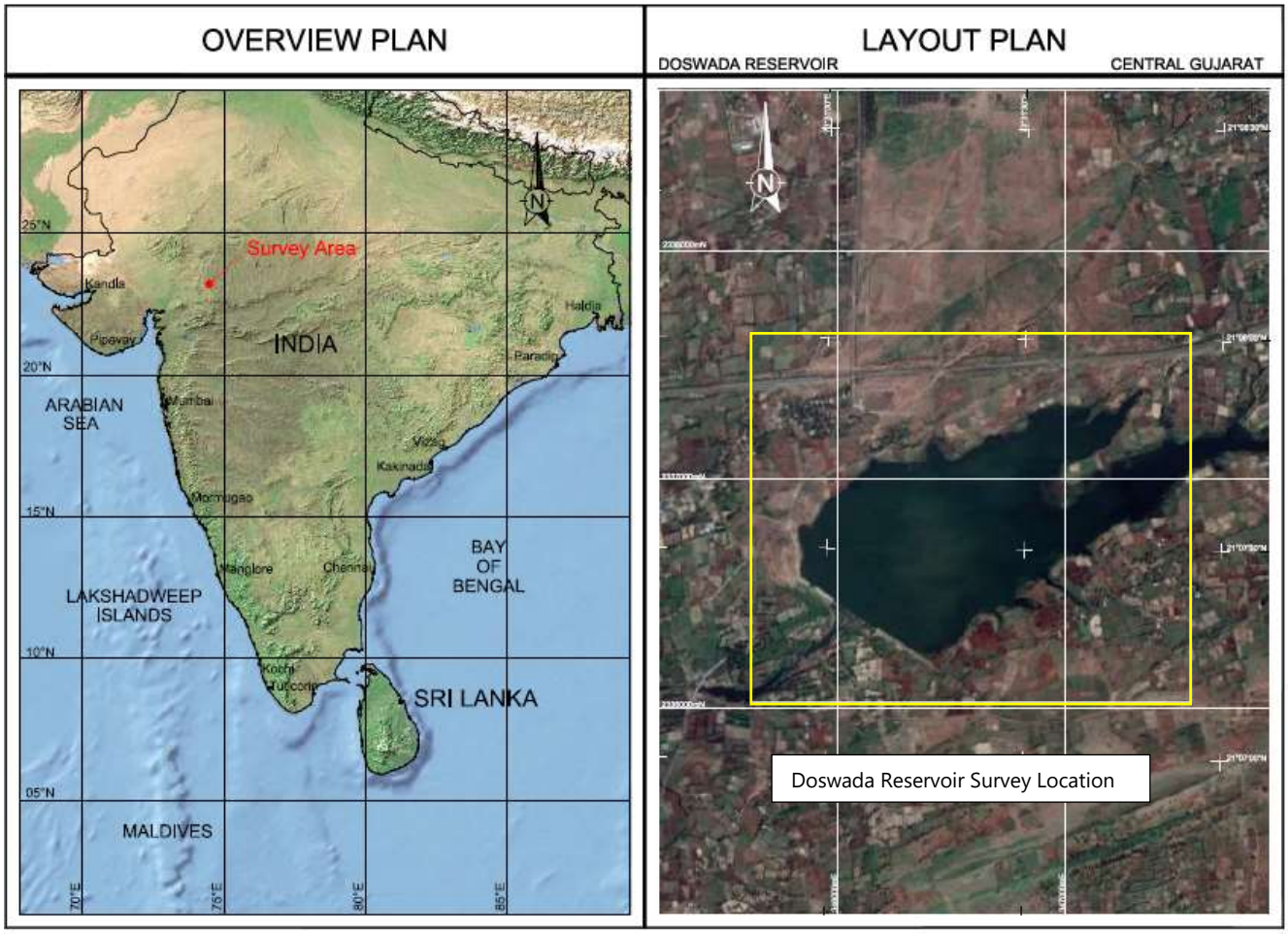
LOCATION MAP



EXECUTIVE SUMMARY

Survey Overview– Doswada Reservoir Location	
Preamble:	The Gujarat State Government is implementing World Bank assisted national hydrology project. This project aims to improve the planning, development, and management of water resources, as well as flood forecasting and reservoir operations in real-time. Various activities, including Sediment survey, Water Quality monitoring have been planned under this project. Water Resources department have evolved a comprehensive plan for periodic assessment of reservoir storage capacity and sedimentation of eleven (11) reservoirs. In this regard, **Narmada Water Resources, Water Supply and Kalpsar Department/ Government of Gujarat** contracted **Fugro Survey (India) Pvt. Ltd. (FSINPVT)** to carry out the Bathymetry and Topography survey. Fugro's scope of work consist of Bathymetry and Topography survey at the eleven (11) reservoirs In order to complete the scope, the survey was carried out in two passes at Doswada reservoir location; • Pass 1: Bathymetry / Hydrographic Survey. • Pass 2: Topographical Survey
Data Acquisition:	**FSINPVT** mobilised their bathymetry and topographical survey team and equipment along with survey boat 'Fugro Zodiac' in the month of April 2021 and August 2021 respectively, in order to acquire survey data as per mutually agreed scope and relevant survey specifications.
Survey Location	Doswada Reservoir, Doswada village, Songadh Taluka, Tapi District, Gujarat.
Survey Geodesy:	The survey was conducted in WGS 84 datum, Universal Transverse Mercator (UTM) Projection, Zone 43 N, CM 075°E.
Scope Compliance & Meets Client's objectives:	FSINPVT performed this survey methodically as per the scope of work defined in the contract and the results obtained have met the client's objectives in following areas: ▪ To assess the reservoir storage capacity; ▪ To assess the variations in the reservoir capacity; ▪ To estimate and study sedimentation behaviour in horizontal zones and vertical zones, namely dead storage, live storage and flood storage; ▪ To upgrade Elevation–Area-Capacity tables / curves of reservoir at regular intervals; ▪ To create historical database for further water resources usage planning.
Accuracy and Reliability	The accuracy of the data logged was ensured by calibrating each and every sensor deployed in the current survey. Statistical techniques were applied during the execution of the survey to ensure that the results of survey conform to the agreed levels of accuracy and precision.
Tidal Corrections	All raw water depths were reduced to reservoir water levels. The water level heights or reservoir water levels w.r.t. MSL were observed for the entire survey period and the same was used to calculate the reservoir bed heights w.r.t. MSL.

Survey Findings – Doswada Reservoir Location	
Reservoir Bed Heights	In general, lowest reservoir bed level was found at the upstream face of the dam and it becomes less deeper as we go further upstream from the dam face. Lowest reservoir bed level recorded during bathymetry survey was 115.8 m (346 038 mE, 2 336 446 mN) w.r.t. MSL.
Elevation Area Capacity Survey (2021)	Elevation Area Capacity table and curve of Doswada reservoir was prepared based on bathymetry and topography survey data acquired at 25 m line spacing and 25 m x 25 m grid interval respectively. The processed xyz data was used to prepare DTM. Capacity and areas at various elevations from lowest bed level (115.80 m) to FRL (123.44 m) was calculated using GIS software.
Revised elevation area capacity details	In comparison with 1990 survey data, the present survey results indicate that the gross storage capacity has decreased.
Loss in gross storage capacity	As per 2021 survey results, the loss in Gross storage capacity w.r.t. 1990 or volume of sediment deposited in the Doswada reservoir is 0.165 Mm^3.
Trap efficiency & Sedimentation Index	Trap Efficiency and sedimentation Index calculated for Doswada reservoir as per methodology give in IS 12182-1987 is 87% and 4.835 x 10^9 sec^2/m respectively
Sedimentation rate	The rate of siltation in Doswada reservoir is 0.005 Mm^3/year
Average rate of siltation	The observed rate of siltation in the Doswada reservoir during the 31 year life span (1990 – 2021), works out to 0.858 Ha m/100 sq km/year.
Annual % loss	The annual % loss in gross storage capacity for Doswada reservoir during the 31 year life span is 0.148% and hence, the reservoir is classified as "Significant category" as per IS 12182 (1987).

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APPENDICES

TABLES

FIGURES

LIST OF ABBREVATIONS

BM	Benchmark
Ch	Channel
CM	Central Meridian
CVT	Calibration, Verification & Test
DF	Dual Frequency
DGNSS	Differential Global Navigation Satellite System
DPR	Daily Progress Report
FBF	Fugro Binary Format
FRL	Full Reservoir Level
FSINPVT	Fugro Survey (India) Private Limited
FSL	Full Supply Level
ft	Feet
GLONASS	Global Navigation Satellite System
GPS	Global Positioning System
Ha	Hectare
HSE	Health, Safety and Environment
km	kilometre
m	metre
M ft^3	Millions cubic feet
M m^3	Millions cubic meter
MDDL	Minimum Draw Down Level
m/s	meter per second
ms	milliseconds
MSL	Mean Sea Level
OEM	Original Equipment Manufacturer
QA/QC	Quality Assurance / Quality Control
QMS	Quality Management System
Rel	Release
Rev	Revision
RL	Reference Level
SBES	Single beam Echosounder
Sr	Senior
SoW	Scope of Work
UTM	Universal Transverse Mercator
WGS	World Geodetic System
w.r.t	With respect to

UNITS

UTM grid coordinates and all linear measurements are reported in metres [m].

Angular values are reported in degrees (°).

Time and dates are reported as “18:00 on 12 October 2021

1. Introduction

1.1 General

Reservoirs originated by the construction of dams, is essential for the sustainable health and welfare of civilizations since it supplies water for human consumption, irrigation and energy production. Furthermore, dam reservoirs are used for recreation, navigation and they provide safety in the downstream valleys against extreme flood events and droughts (Bengtsson et al., 2012). All reservoirs are subjected to sedimentation which, without adequate prevention and mitigation counter-measures, threatens their sustainability.

Reservoir sedimentation is the gradual accumulation of the incoming sediment load from a river. This accumulation is a serious problem in many parts of the world and has severe consequences for water management, flood control, and production of energy. Sedimentation affects the safety of dams and reduces energy production, storage, discharge capacity and flood attenuation capabilities. It increases loads on the dam and gates, damages mechanical equipment and creates a wide range of environmental impacts (Schleiss et al., 2016).

Reservoir sedimentation is a process of erosion, transportation, deposition and compaction of sediments carried into reservoirs formed and contained by dams. In unregulated, mature rivers with stable catchments, sediment processes are relatively balanced. Construction of a dam decreases flow velocities, initiating or accelerating sedimentation.

Most of the world's reservoirs are in the continuous sediment accumulation stage. Many were designed by estimating sedimentation rates in order to provide a pool with sufficient volume to achieve a specified design life. However, this design life is typically far less than what is actually achievable. Therefore, managing reservoirs to achieve a full sediment balance is essential in order to maximize their lives. As every year sediment gets deposited in dead storage and in live storage of the reservoir, it has long and short range impact on the storage capacity of reservoir (Schellenberg et al., 2017). Correct assessment of the reservoir storage capacity is essential for assessing useful life of the reservoir as well as optimum reservoir operation schedule.

The Gujarat State Government is implementing World Bank assisted national hydrology project. This project aims to improve the planning, development, and management of water resources, as well as flood forecasting and reservoir operations in real-time. Various activities, including Sediment survey, Water Quality monitoring have been planned under this project. Water Resources department have evolved a comprehensive plan for periodic assessment of reservoir storage capacity and sedimentation of eleven (11) reservoirs.

In this regard, **Narmada Water Resources, Water Supply and Kalpsar Department/ Government of Gujarat** contracted **Fugro Survey (India) Pvt. Ltd. (FSINPVT)** to carry out the Bathymetry and Topography survey. Fugro's scope of work consist of Bathymetry and Topography survey at the eleven (11) reservoir as specified by Client.

These survey services comprised of the provision of suitable personnel and equipment in order to obtain, interpret and report on the bathymetry and topography within the survey area. In order to complete the scope, the survey was carried out in two passes at Doswada reservoir;

Pass 1: Bathymetry / Hydrographic Survey;

Pass 2: Topographical Survey.

The bathymetry survey work was performed from the shallow draft boat 'Fugro Zodiac'.

The survey reports are submitted in separate volumes for each reservoir location. This report covers **Bathymetry / Hydrographic and Topographical survey results for Doswada Reservoir location.**

1.2 Study Area

The present study area falls under Mindhola basin spreading across the state of Gujarat. The whole Mindhola basin can be divided into three sections. The first 25 km reach drains the areas of uplands where the elevation is between 400 m to 70 m. In the middle section, the river passes through both steep and moderate slopes. The general elevation of the basin in this section is from 70 m to 5 m. The remaining portion of the basin in the west is subject to inundation in high tides of the sea (National Water Development Agency, NWDA).

The river Mindhola is a small East to West flowing river with length 105 km and catchment lying entirely in Gujarat state. The major tributaries of the river are Khalikhadi, Vijarakhadi, Ghabai Nadi and Chickkhadi rivers. (National Water Development Agency, NWDA)

Mindhola river originates from Jan Khadi of Doswada (Songadh Taluka, Tapi District) near Palsana in Surat city and meets Arabian Sea near Danti after merging with Unn-Sonari creek near Magdalla. Mindhola is a state river flowing within state boundary of Gujarat and considerable part of its catchment area lies in Surat city. The Mindhola river system within Surat city comprises of 7 natural creeks viz. Koyali, Mithi, Kankara, Khajod, Bhedwad, Sonari and Varachha (Varsani & Manoj, 2019).

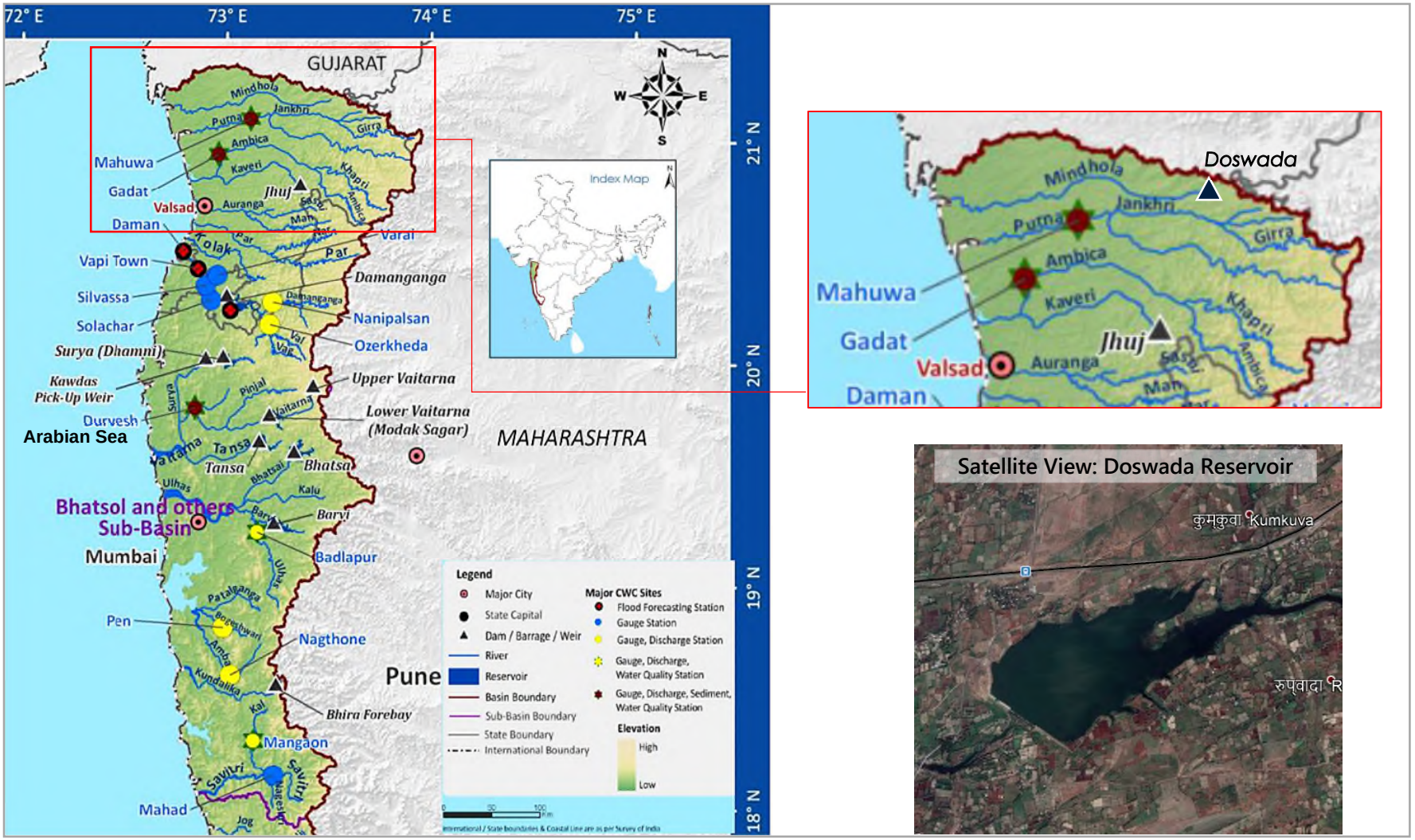


Figure 1.1: Map showing Bhatsol and other Drainage & Sub-basin (Courtesy: India-WRIS, 2014); Satellite Image of Dosawada Reservoir (Google Earth,2018)

1.3 Geology of Study Area

Major geological formations exposed in the Tapi district are Quaternary alluvium, Tertiary limestone and sandstones and Deccan Trap basalt (Sunita Devi, 2013-2014).

Deccan Traps : The Deccan Traps are predominant and oldest rock type in the Tapi district. The traps can be differentiated into two predominant rock types. One is dark gray to bluish black, hard, compact, massive, fine grained basalt. While the other variety is greenish to purplish, soft, medium grained trap which is prone to spheroidal weathering. These flows are characterized by vesicles and amygdaloidal filled with secondary minerals like quartz, amethyst, agate and calcite.

Network of dykes varying in thickness from few centimetres to more than ten meters in width are commonly found intruding the different lava flows and form knife-edge ridges in the "steppe" topography. The usual rock type of these dykes is dolerite or olivine dolerite.

Alluvium: The alluvium occurs in the form of channel fill deposits (124 km^2) and flood plain deposits (298 km^2) in north eastern part of the district.

Tertiary Limestone and sandstones: The limestones in the Tapi district are of Eocene and Palaeocene epoch and consist of nummulitic and sub- nummulitic limestones. While the sandstones belong to the Miocene Epoch and comprise of ferruginous sandstone

The present survey area is located in the Songadh taluka of Tapi district and the major rock type found was Deccan trap basalt.

1.4 Soil Types

The soils of Tapi district are broadly categorized into three types viz. Light coloured soils, Garot soils and black cotton soils (Sunita Devi, 2013-2014).

Light coloured soil: This soil is observed near the banks of the river and consist of clay loam, loam, sandy loam and sand.

Garot soil: This is a sandy alluvial type of soil which contain 40% clay and remaining sand particles.

Black cotton soil: This soil is formed due to decomposition of parent material (Deccan Traps) transported through flow of rivers and are dark brown to very dark greyish brown in colour, containing 40-70% clay.

1.5 Land use pattern

The total area of the Tapi district is 3,139 km^2 and of which 3,005 km^2 is rural area. The rural area comprises of 30.84%, forest land, 19.74% irrigated and 25.15% un-irrigated area (Directorate of Census Operations, Gujarat, 2011)

The Songadh taluka in Tapi district covers an area of 1,35,404 Ha. and consists of 23.57%, forest land, 24.02% non-agriculture land, 3.69% grazing land, 45.95% cultivable land and 2.77% non-cultivable land (GSIDS, 2015).

1.6 Doswada Reservoir Characteristics

The Doswada reservoir is constructed along the Mindhola river (Figure 1.1). Doswada irrigation scheme was executed by Ex. Baroda state in the year 1912 – 1913 and consists of masonry waste weir with earthen dam on either side. The top of dam of the FSL RL was 395 feet.

The dam was subsequently raised by 10 feet in two stages raising the crest of the weir from R.L. 395 feet to 400 feet and from RL 400 feet to 405 feet in the year 1954 - 1955 and 1957 – 1958 respectively.

Table 1.1: Client Supplied Doswada Reservoir Salient Features

Characteristics	Feature
Reservoir name	Doswada Reservoir
Name of Dam	Doswada Dam
Type of Dam	Composite Earthen and Masonry
Purpose	Irrigation and water supply
Name of River	Mindhola
River Basin	Mindhola
Village	Doswada
Taluka	Songadh
District	Tapi from 27 September 2007 (formerly in Surat district)
State	Gujarat
Hydrology	
Total Catchment Area	62.16 km^2
Gujarat State	62.16 km^2
Other State	0
Average rainfall	70" (1788 mm) to 80" (2032 mm)
Maximum observed flood (1971)	31,000 cusecs
Annual Yield in Catchment Area of Doswada Dam	13.25 Mm^3 (2015) 17.47 Mm^3 (2016) 37.54 Mm^3 (2017) 21.27 Mm^3 (2018) 71.96 Mm^3 (2019) 56.05 Mm^3 (2020)
Mean Annual Yield in Catchment Area of Doswada Dam (2015 - 2020)	36.26 Mm^3
Reservoir Details	
Gross storage capacity	5.0 Mm^3 (Original, 1913) 3.80 Mm^3 (1958)

Characteristics	Feature	
Live storage capacity	4.8 Mm^3 (Original, 1913) 3.80 Mm^3 (1958)	
Dead Storage	0.20 Mm^3 (Original, 1913) 0.0 Mm^3 (1958)	
Gross Area under submergence at FRL 405'	113 Ha. i.e., 279 Acres	
Dam Details		
Year of Construction Started	1912-13	
First Raising (395 feet to 400 feet)	1954 - 1955	
Second Raising (400 feet to 405 feet)	1957 - 1958	
Length of the Earthen dam		
R.H.S.	198 m	
L.H.S.	375 m	
Total	573 m	
Top width of dam	12 m	
F.R.L.	120.396 m (1913) 123.44 m (Present)	
Minimum Drawdown Level (MDDL)	118.26 m or i.e., 388 Ft. (Present)	
Slope		
U/S	3 in 1	
D/S	2 in 1	
U/S slope protection	Rubble rip-rap	
D/S slope protection	Grass turfing	
Spillway details		
Type	Broad crested weir	
Location	In river gorge	
Maximum discharge	899.18 m^3/s	
Spillway length	210 m	
Gate type and number	Ungated	
Canals	a) No direct canals from Doswada dam as it is only a storage dam. b) Canal system offtakes from Chikhli Pick-up weir @ 10 km D/S from Doswada dam on river Mindhola near village Nani-Chikhli.	
	Right Bank	Left Bank
Capacity	1.81 Cumecs	-
Type	Unlined	-
Section @ Head	2.45 x 0.90	

1.7 Project Objectives

Primarily the main objective of the survey was to:

- Assess the reservoir storage capacity;
- Assess the variations in the reservoir storage capacity;
- Create historical database for further water resources usage planning.
- However, the main objective of the bathymetry survey was to:
- Estimate and study the sedimentation behaviour of 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
- Upgrade Elevation-Area-Capacity tables / curves of reservoirs at regular intervals.

Table 1.2 provides bathymetry and topography survey area details for Doswada reservoir.

Table 1.2: Doswada Reservoir details for Bathymetry and Topography Survey

Name of Dam / Reservoir	Actual Area (km^2) surveyed	
	Bathymetry Survey	Topography Survey
Doswada	0.35	0.61

1.8 Scope of Work

To achieve the above objective, Fugro carried out survey for eleven (11) reservoir areas in two (02) passes. The scope of work undertaken for Doswada reservoir is as follows:

1.8.1 Pass 1: Bathymetry / Hydrographic Survey

The scope of work for bathymetry survey conforms survey for total area of 0.35 km^2 was covered.

The following scope of work was undertaken in-order to achieve client objectives:

- Bathymetry / Hydrographic survey work was conducted using echosounder for assessment of reservoir capacity and sedimentation at Doswada reservoir of Gujarat.
- Survey lines were run at 25 m segment line spacing and along the survey line continuous data of 25 m x 25 m grid point were captured so that each and every point is included. Additional survey lines were executed as and when required.
- DGNSS positioning system, Dual frequency single beam echosounder system along with associated Navigational system were deployed on all the survey lines.

1.8.2 Pass 2: Topographical Survey

Topographical survey was carried out using Total station and equivalent levelling instruments. The total area of 0.61 km^2 was covered in the topographical survey. Following scope of work was undertaken in order to achieve client objectives:

- Topographical survey was conducted to facilitate hydrographic survey so as to fill up the gaps between MWL area and reservoir submergence area till current water level for assessment of reservoir capacity and sedimentation at the reservoir locations.
- Topographical survey was carried out from FSL to present water level of reservoir, with sufficient overlap with hydrographic survey for preparing overall contour map of reservoir.
- The area not covered through hydrographic survey upto maximum water level (MWL), was surveyed by taking levels at 25 m interval along range lines laid at 25 m interval (25 m x 25 m grid).

1.9 Survey Execution

The survey boat 'Fugro Zodiac' was mobilized at Doswada reservoir location to carry out the survey. Survey operations were executed as per the mutually agreed survey execution schedule.

1.10 Reference Documents

Table 1.3: Reference Documentation

Sl/No.	Document Name	Document identity
1	FSINPVT Quote / Contract	NOA No. WRIDn/SK/NOA/1588/2020 Dated 09 November 2020
2	FSINPVT Survey Procedure	JHYD20-174630/SP/P0/Rev.0 dated 01 December 2020

1.11 Deliverables

Final report and Charts / Drawings to be delivered as per the contract, as listed in Appendix F to this Report, have been duly submitted. Details of the Charts accompanying this report are also placed at Appendix F.

2. Survey Specifications and Resources

The bathymetry / hydrographic survey and topography survey conformed to the following mutually agreed scope of work and were conducted as per the methodology described in the standard work instruction by FSINPVT.

2.1 Survey Geodesy

The survey was conducted in WGS84 Datum and grid coordinates in terms of Universal Transverse Mercator (UTM) projection (Zone 43 N, CM 075° E) as per client's instruction. The details of the Geodetic parameters are as follows:

Table 2.1: Geodetic Datum, Projection Parameters

Global Positioning System Geodetic Parameters	
Datum:	World Geodetic System 1984
Spheroid:	World Geodetic System 1984
Semi major axis:	a = 6 378 137.000 m
Inverse Flattening:	1/f = 298.257 223 563
Map Projection:	Universal Transverse Mercator
Grid System:	UTM Zone 43 N;
Central Meridian:	075° 00′ 00″ East
Latitude of Origin:	0° 00′ 00″ North
False Easting:	500 000 m
False Northing:	0 m
Scale factor on Central Meridian:	0.9996
Units:	Metre
Notes: • The Client has specified the above Datum and Transformation parameters to be used for this survey. • Fugro's Starfix software suite always uses WGS84 as the primary datum for all geodetic calculations.	

2.2 Horizontal Control

Spatial Dual was used for positioning the survey vessel during this survey. Spatial Dual is a rugged GPS aided inertial navigation system that provides accurate position, velocity, acceleration and orientation under the most demanding conditions. It combines temperature calibrated accelerometers, gyroscopes, magnetometers and a pressure sensor with a dual antenna RTK GNSS receiver. They are coupled in a sophisticated fusion algorithm to deliver accurate and reliable navigation and orientation.

The computer running Starfix NG was used for navigation, data logging and online quality control of the survey data.

2.3 Vertical Control / Water Level Corrections

All vertical levels were reduced to respective water level references. The water level heights or reservoir water levels w.r.t. MSL were observed for the entire survey period and the same was used to calculate the reservoir bed height. Observed reservoir water level heights is tabulated below:

Table 2.2: Observed Reservoir Water Level Heights at Doswada Reservoir

Date	Observed Reservoir Water Level Heights w.r.t. MSL at Doswada Reservoir [m]
21-04-2021	120.02
22-04-2021	120.02
23-04-2021	120.02

2.4 Accuracy and Precision of Results

The accuracy of the data logged was ensured by calibrating each and every survey sensor deployed for the current survey, for eliminating systematic errors or bias. Internationally accepted survey work practices were adopted for carrying out such calibrations, sensor alignments and field verifications.

The quality of the data logged was monitored on-line using Fugro's on-line QC tools and ensured it met the agreed accuracy and precision levels. At the data processing, charting and reporting stages, the results of survey were further analysed and checked to ensure that they conformed to the agreed levels of accuracy and precision. The precision (or the repeatability) of the results of survey were controlled by adopting 'Statistical' techniques.

2.5 Survey Personnel Deployed

Following FSINPVT staffs were associated to bathymetry survey for this project.

Table 2.3: List of Survey Personnel – Bathymetry Survey 'Fugro Zodiac'

Bathymetry Survey Personnel	
Personnel Name	Function
Pritam Seth	Party Chief / Surveyor
Atul Bhoyte	Engineer
MD Salman Khan	Fugro Zodiac Operator

Following FSINPVT staffs were associated to topography survey for this project.

Table 2.4: List of Survey Personnel – Topography Survey

Topography Survey Personnel	
Personnel Name	Function
Rambabu Sah+ Survey Assistants	Topography Survey Team

Following onshore FSINPVT staffs were associated to this project.

Table 2.5: List of Personnel – Onshore Project Management and Data QC

Onshore Project Management and Data QC	
Rahul Patkar	Service Line Manager
Vikas Walanj/Anantha Krishnan	Project Manager
R.B. Jayaraman	Client Deliverable Manager
Avijit Nag	Survey Manager
G.N. Hariharan	Chief Geophysicist
Avinash Vasudevan	Reporting Manager
Prashant Mishra	Reporting Project Supervisor
K. Srinivas	Data Centre Manager

2.6 Equipment Deployed

Following equipment and systems were deployed for the survey work. The equipment setup and configuration diagram on the survey boat Fugro Zodiac is placed at Appendix C to this document.

Table 2.6: Survey Equipment / Systems Deployed for Bathymetry Survey in Fugro Zodiac

Equipment / System	Description / Make / Model/Resolution /Accuracies
Software / Navigation	Starfix.NG PC based data acquisition and survey vessel navigation package.
Positioning	Trimble BX-992 & Spatial Dual Receivers
Heading Sensor	Spatial Dual
Motion Sensor	Spatial Dual
Sound Velocity	Odom DigiBar Pro
Single beam Echosounder	Echotrac CV100 Dual Frequency Single Beam Echosounder

Table 2.7: Survey Equipment / Systems Deployed for Topographical Survey

Equipment / System	Description / Make / Model/Resolution /Accuracies
Land Survey	GNSS RTK CHC I 80 System along with accessories and consumables.

2.7 Survey Vessel

Shallow draft boat 'Fugro Zodiac' was used to carry out the bathymetry / hydrographic survey.

Figure 2.1: Survey boat Fugro Zodiac

2.8 Survey Database Used

Details of all existing engineering structures within the survey area, as supplied by the Client and interface boundaries drawn between land and water body, shallow patches taken from Google Earth images, were used as a background file in the navigation system during the entire tenure of survey.

- Client supplied FRL – 123.44 m w.r.t. MSL
- Full Reservoir Level (FRL) – 123.44 m w.r.t. MSL
- Water line – 120.02 m approximately.

3. Survey Data Acquisition

3.1 Survey planning, Preparation & Transportation to Site

The bathymetry survey equipment and personnel with survey boat 'Fugro Zodiac' arrived at Doswada reservoir location on 19 April 2021 and equipment was mobilised on-board the survey boat on 20 - 21 April 2021.

After field testing / verification / calibration of all survey equipment bathymetry survey was carried out and completed on 23 April 2021. Refer Appendix A to this document for diary of events.

The topography survey equipment and personnel arrived at Doswada reservoir location and commenced and completed survey on 9 August 2021.

3.2 Equipment Setup Configuration and Calibration

All survey equipment was installed and configured on-board the survey boat as per the 'Equipment Layout Diagram' placed at Appendix C to this document.

The location of the various survey sensors on the survey boat is given in the 'Vessel Offset Diagram' placed at Appendix B to this document.

3.3 Field Calibration and Verifications

All equipment used for the survey work were calibrated and bench tested prior to their mobilisation for this task. In addition, after installation on the survey vessels, extensive calibration, verification and tests were carried out in the field before deploying them for actual data acquisition. Standard survey methods were used for carrying out these calibrations / verifications and data acquisition, as described in the following paragraphs.

Refer to Appendix D of this document for the 'Results of the Calibrations / Verifications of Survey Sensors'.

3.3.1 Heading Sensor Alignment

Vessel heading was obtained onboard 'Fugro Zodiac' from Spatial Dual. Spatial dual features dual antenna moving baseline RTK. This enables it to provide extremely accurate heading both at rest and at movement. It's a great option for situations where magnetic heading isn't possible due to interference or where extra precision is required. The system was tested at FSINPVT workshop prior to mobilization for the survey. The performance of the system was found to be satisfactory during the period of survey.

3.3.2 Navigation System – DGNSS

The Positioning System on board 'Fugro Zodiac' was Spatial Dual. Position observations were done at Doswada reservoir benchmark locations, using Trimble BX-992 and Spatial Dual receiver. Refer Appendix E for Benchmark description and Appendix D for details on position system verification results. The performance of the system was found to be satisfactory. Summary of the results of the position system verification is tabulated below:

Table 3.1: Results of Positioning System Verification at TBM1

Positioning System Verification Results With BX-992 and Spatial Dual Receiver (TBM1)						
World Geodetic System 84, UTM Projection, CM 075° East, Zone 43 North						
Sensor	Serial No.	Easting [mE]	Northing [mN]	Latitude	Longitude	Ellipsoidal Height [m]
Trimble BX-992	025-00009601	345 941.429	2 336 497.587	21°07'23.39446"N	073°30'59.60168"E	62.57
Spatial Dual	025-00006405	345 941.494	2 336 497.560	21°07'23.39359"N	073°30'59.60393"E	62.731
Difference		**-0.065**	**0.027**	--	--	**-0.161**

Table 3.2: Results of Positioning System Verification at TBM2

Positioning System Verification Results With BX-992 and Spatial Dual Receiver (TBM2)						
World Geodetic System 84, UTM Projection, CM 075° East, Zone 43 North						
Sensor	Serial No.	Easting [mE]	Northing [mN]	Latitude	Longitude	Ellipsoidal Height [m]
Trimble BX-992	025-00009601	345 874.27	2 336 548.161	21°07'25.01856"N	073°30'57.25770"E	62.698
Spatial Dual	025-00006405	345 874.421	2 336 548.161	21°07'25.01862"N	073°30'57.26308"E	62.846
Difference		**-0.155**	**0**	--	--	**-0.148**

3.3.3 Sound Velocity Measurements

Sound Velocity in the water column was measured in the survey area at regular intervals using sound velocity probe. Sound velocity profiles (cast) thus generated were used during post processing of SBES data.

3.3.4 Heave Compensator

Spatial dual is a high precision source for heave information. The system was tested at FSINPVT workshop prior to mobilization for the survey. The performance of the system was found to be satisfactory during the period of survey.

3.3.5 Single Beam Echosounder

Echotrac CV100 dual frequency single beam echosounder was used for measuring water depths within the survey corridor. The echo sounder system was bench tested at FSINPVT workshop prior to mobilization for the survey. The echo sounder transducer was vertically side mounted on the survey boat and its draft below the waterline was measured and recorded. Heave compensator was connected to the echo sounder receiver. The echo sounder system was interfaced with the Starfix NG navigation and survey system for logging the depth vs position data. Sound velocity within water column was measured on a regular basis using sound velocity profiler and average sound velocity was entered in the top side unit of the echo sounder.

Table 3.3: Summary of Single Beam Echosounder Calibration Results by 'Bar Check' Method

Summary of SBES Calibration Results on-board 'Fugro Zodiac'			
Date	SBES Sensor Type	Average (m)	Standard Deviation
21 April 2021	Echotrac CV100 SBES	-0.01	0.0082

3.4 Data Acquisition and Online Quality Control

On successful completion of mobilization and Calibration, Verification & Testing of all equipment as per the standard work practices, the survey data acquisition commenced as per the project plan to achieve the objectives of survey.

Navigation System, Heading and Bathymetry

The navigation data and vessel heading from the spatial dual, was logged continuously and monitored using the Starfix NG navigation suite. The survey data was logged in Fugro Binary Format (.FBF).

Event Markings

The on-line computer system was interfaced for closure to the analogue traces on the survey vessel. Event marks corresponding to position fixes were generated automatically from the on-line Navigation Computer interface at regular intervals of 25 m across the ground.

Survey Run-Line Logs

Survey lines were planned as per scope of work and digital pre-plots for the area was prepared prior to commencement of survey. These lines were run on the navigational computer while doing the survey and this enabled the Navigator to guide the boat along the planned survey line all the time. A survey line log was maintained which consists the particulars about the surveyed line, Date, Time, Session Number, Event Number, KP, Sensors Deployed and all the significant events occurred during the survey.

3.4.1 On-line QC of Data Logged

FSINPVT follows standard procedures and has standard formats for documenting the Quality Control of acquired data for each sensor deployed during the survey. Experienced operators were constantly monitoring the real time data quality as the survey progressed. A log of profiles was maintained, and quality of data was noted. Re-shoots of survey lines were carried out as and when required.

All computers connected to the Navigation network were synchronized with the GPS (high precision) 1PPS time signal by means of the Starfix Timing Module, allowing all data to be time stamped.

The quality of data being recorded was constantly monitored in real time and fine-tuned to obtain the best quality. The data / record obtained from each survey sensor such as Navigation, Heading, SBES and Spatial dual were quality checked and an extract of the same were made available for verification and confirmation to proceed further.

3.5 Topography Survey Control of Work

3.5.1 RTK Verification

The RTK system verification was carried out by 'Static Observations' for 30 minutes at Doswada Dam Temporary Benchmark 1 (TBM1) and Temporary Benchmark 2 (TBM2).

3.5.2 RTK Position Comparison

The RTK observed position at Temporary Benchmark (TBM2) at Doswada Dam was compared with its Trimble BX-992 Receiver position. Results of the comparison is tabulated below:

Table 3.4: Results of RTK Position Comparison

Sensor	Model No.	Easting (mE)	Northing (mN)
TBM2 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	345 874.266	2 336 548.161
RTK Rover 1	CHC I 80	345 874.266	2 336 548.161
Difference		0.000	0.000
TBM2 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	345 874.266	2 336 548.161
RTK Rover 2	CHC I 80	345 874.373	2 336 548.176
Difference		-0.107	-0.015
TBM2 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009601	345 874.266	2 336 548.161
RTK Rover 3	CHC I 80	345 874.374	2 336 548.187
Difference		-0.108	-0.026

Refer Appendix D for RTK comparison details.

3.5.3 Topographical Survey Methodology

The area not covered under hydrographic survey i.e., between the existing water level at the time of survey up to Full Reservoir Level (FRL)- 123.44 m has been carried out by topography survey method.

The topography survey was carried out using GNSS RTK CHC I 80 system. The RTK system consist of two units i.e., Base receiver and Rover receiver. Corrected GPS signals are transmitted in real time from a base receiver at a known location to one or more rover receivers. Following steps were carried out while commencing and executing the topography survey operations:

- Components of Base and Rover receivers were setup at benchmark locations.
- Tripod was setup at base station i.e., at the temporary benchmark location (TBM1) established by Fugro by levelling method and thereafter the tripod was levelled and the RTK base station was configured.
- The rover receiver along with RTK pole was installed at TBM2 location. Static observation was carried out subsequently as part of verification.
- The Base receiver is installed at TBM1 and configured the system with known coordinates and elevation (levelling carried out by Fugro). The rover receiver position and elevation are verified by setting up the system at TBM2.
- The level or height transfer for temporary Benchmark established by Fugro were carried out w.r.t. client supplied reference level. The levelling report is placed in Appendix E.
- Thereafter survey commenced by placing the rover receiver at 25 m grid interval and logging the position (easting, northing) and the elevation in relation to the base.
- Whenever the radio RTK coverage between rover receiver and base receiver is reduced, new check points were created and the base receiver was shifted to this newly created check point.
- Above procedure was followed and survey completed from the existing water line till achieving the HFL mark.

Figure 3.1: Doswada Temporary Benchmark 1 (TBM1)

Figure 3.2: Doswada Temporary Benchmark (TBM-02)

3.6 Survey Coverage and Scope Completion

FSINPVT carried out the bathymetry and topography survey operation methodically to meet the client's objectives from this survey.

- The survey work was carried out on par with the mutually agreed scope and objectives mentioned in the Section 1.6 of this document.
- Survey scope from existing water level up to the Full Reservoir Level (FRL)- 123.44 m, was achieved by undertaking topography survey.

All the bathymetric survey lines were run at appropriate spacing i.e., 25 m, so as to obtain data of 25 m x 25 m grid points.

4. Data Processing and Interpretation

4.1 Navigation and Positioning

- The survey data was logged in Fugro Binary format (FBF), and processed using the Starfix.Proc software. Heading, motion and position data were processed and checked to ensure good data quality. The position data for the various survey sensors were processed and plotted to allow commencement of the interpretation of the bathymetry data.
- The measured offsets for all survey sensors were entered into the navigation system and processed using Starfix.Proc to enable track charts to be plotted and 'corrected' navigation files to be integrated with other sensor data at a later stage. These included:
    - GPS position absolute of the primary & secondary positioning systems.
    - Common Reference Point

4.2 Bathymetry Data Processing

- SBES bathymetry data was reduced to MSL, applying observed Reservoir Water Level / Height heights recorded at Dam. (Refer Figure 4.1)
- The data was filtered, cleaned, and combined to create geographically positioned bathymetric data set that has been corrected for MSL and sound speed.
- Starfix.Workbench & Mproc was used to quality check the data.

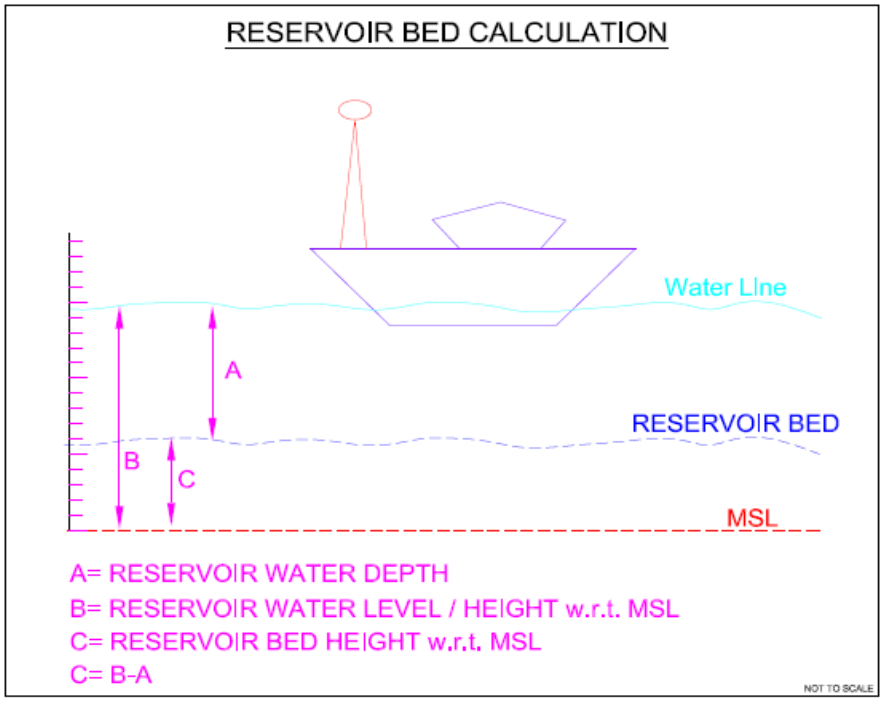


Figure 4.1: Reservoir Bed Height Calculation w.r.t. MSL

4.3 Creating Digital Terrain Model (DTM)

The bathymetric data and topographic data were then combined to create a vector point shapefile in GIS software. The boundary of the reservoir was then digitized around the point shapefile. Two types of boundaries were constructed. First boundary is outside the reservoir and second type of boundary consisted of the boundary around islands in the reservoir. This point shapefile was then utilized for creation of DTM. The DTM for the reservoir can be created by use of various algorithms such as Kriging, Radial Basis function, Inverse Distance Weighting (IDW) method and local polynomial function. Among these various methods, IDW can give the best interpolation accuracy for reservoirs (Shiferaw and Abebe, 2020). IDW method is a weighted average interpolation method. For every grid node, the resulting value Z will be calculated using the formula as given in (1).

$$Z = \frac{\sum_{i=1}^{n} \frac{Z_i}{r_i^p}}{\sum_{i=1}^{n} \frac{1}{r_i^p}} \quad (1)$$

Where:

- Z_i is the known value at point i,
- r_i is the distance from grid node to point i,
- p is the weighting power,
- n is the number of points in Search Ellipse.

Therefore, in this study IDW method has been used for the interpolation for the creation of DTM. The DTM thus created was saved in Tiff format. The created DTM was smoothed by use of various filtering operations. Thereafter, the DTM was clipped through extract by mask operations using the mask of boundary shapefiles created before. The final DTM thus obtained after clipping the DTM was then used for further analysis.

Contour maps at 1 m interval was also prepared using the DTM in Starfix.Workbench software.

4.4 Development of Area Capacity Curves

Area Capacity curves are useful tools for operational and planning purposes such as water management and sediment monitoring. By comparing the area capacity curves at different times, the rate of sedimentation in the reservoirs can be determined. These curves show the capacity and surface area of the reservoir at an indicated elevation above the reference elevation level. The elevation area capacity curves are prepared using the DTM for the reservoir site. For, this study the reference elevation level used for the preparation of Area capacity curve is 115.80 m which is the lowest bed level for the reservoir and the maximum level considered is 123.44 m which is Full Reservoir Level (FRL) of the reservoir. The incremental value for elevation used for developing these curves is kept at 0.1 m. The surface area at the successive intervals was obtained in GIS software by intersecting the DTM with horizontal planes at an interval of 0.1 m starting from the zero-bed elevation till the MWL. The incremental volume (ΔV_i) between two contours was then calculated and integrated from bottom to specified

elevation to obtain the required capacity at specified elevation. The method and formula used for volume calculation is the cone formula given by the equation 2.

$$\Delta V = \frac{h}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right) \quad (2)$$

Where, ΔV is the incremental volume between two successive elevations; h is the incremental height between two successive elevations; A1 and A2 are the areas of two successive elevations.

4.5 Sedimentation in Different Zones of Reservoir

The sediment entering into the reservoir carried by the flowing river from the upstream catchments get deposited in the reservoir with the passage of time and reduces the live as well as dead storage capacity of the reservoir. This causes the bed level near the dam to rise. Live storage is from the level MDDL to FRL. Dead storage is from Bed Level to MDDL. Gross storage is from Bed Level to FRL. The sedimentation in different zones of reservoir is shown in Figure 4.2.

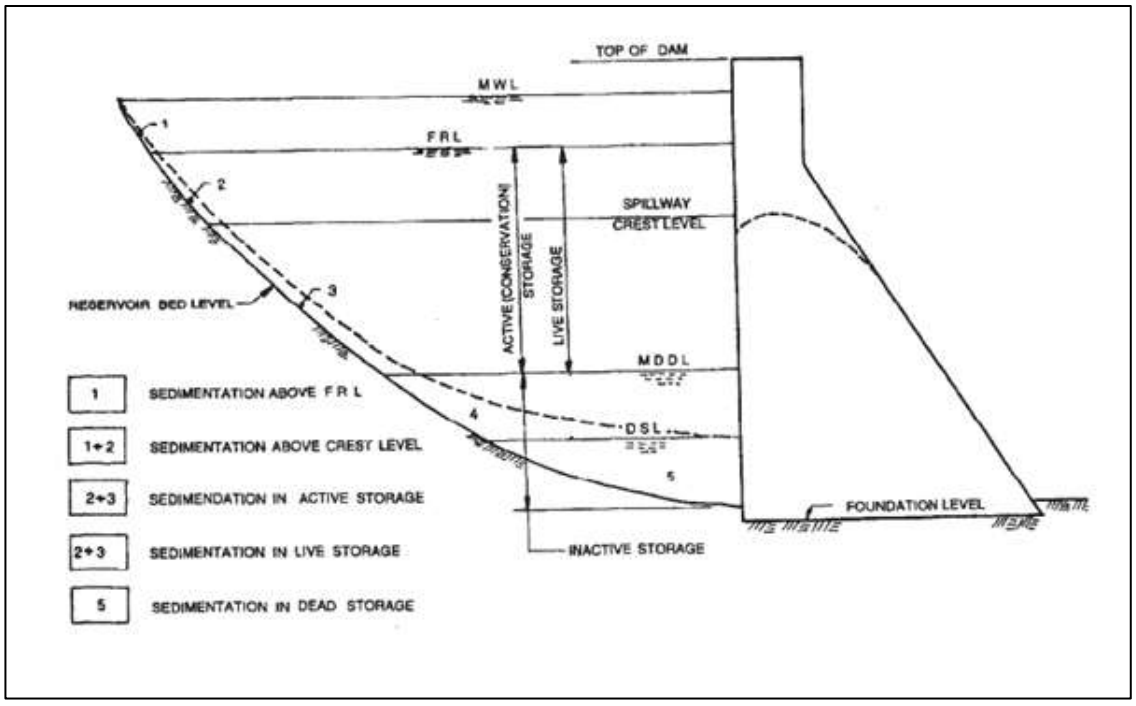


Figure 4.2: Sedimentation in different zones of reservoir (Ref: IS 5477-Part 1,1999)

The trap efficiency and the silt index has been calculated based on the methodology given in IS 12182, 1987. The gross capacity of reservoir as per present survey at FSL is 3.430 Mm^3 and client supplied Mean Annual inflow is 36.26 Mm^3. The values of trap efficiency were calculated using Brune's curve for the capacity inflow ratio for the reservoir. The silt index is calculated as the ratio of period of retention and flow velocity in the reservoir. The details of the calculations of period of retention and flow velocity are given in standard codes such as IS 12182, 1987. The values for Doswada reservoir are shown in Table 5.4.

At last, sedimentation volumes are compared with sedimentation volumes from previous year surveys (if available) and rate of sedimentation, loss of capacity as well as annual loss percentage is computed and compared with the values of previous years (if available) to arrive at meaningful conclusions. The sedimentation quantities as well as loss of storage capacities, rate of siltation as well as trap efficiency and sedimentation index are shown in Section 5.3.

The Sedimentation rate and Annual % loss is calculated using the equations (3) and (4)

$$\textit{Sedimentation rate (Ha m/ 100 Sq km/year)} = \frac{100 * \text{loss of gross capacity (Ha m)}}{\text{Catchment Area (Sq km)} * \text{Number of years between the surveys}} \quad (3)$$

$$Annual\ \%\ loss = \frac{\text{Annual Sedimentation rate (M cu m)}}{\text{Original Gross capacity of reservoir (M cu m)}}\ x\ 100 \quad (4)$$

4.6 Charting the Results of Bathymetry and Topography Data

- Chart showing reservoir bed heights are provided for the current survey at 1:2000 scale.
- Chart showing contour map at 1 m interval for Doswada reservoir is also provided at 1:2000 scale.
- Chart showing reservoir bed relief image prepared from bathymetry and topography survey data is provided at 1:2000 scale.
- L-section of the reservoir and C-section at 100 m interval are provided as soft copy.

The results of the survey were submitted as per the documents in the 'List of Deliverables' placed at Appendix F.

5. Survey Results – Doswada Reservoir

Survey results are detailed in the following sections. The following text should be read in conjunction with the Charts as listed in Appendix F to this document.

Data acquisition for Doswada reservoir was carried out from lowest bed level to Full Reservoir Level (FRL) of 123.44 m.

5.1 Reservoir Bed Heights

The lowest reservoir bed level was found at the upstream face of the dam & it becomes less deeper as we go further upstream from the dam face.

The reservoir bed topography was found uneven with lowest bed level of 115.80 m w.r.t. MSL.

The reservoir bed tends to get shallower as we go further towards north-east, south-east & north-west directions away from the reservoir dam wall within the survey area. Reservoir area is spreading towards north, west & east directions.

Lowest reservoir bed level recorded was 115.8 m (346 038 mE, 2 336 446 mN) w.r.t. MSL, within the survey area.

The following figures show the gridded bathymetry and topography data for the Doswada reservoir.

Figure 5.1: Image showing gridded SBES Bathymetry and topography data (superimposed with satellite imagery) of reservoir bed heights in metres from lowest bed level to FRL

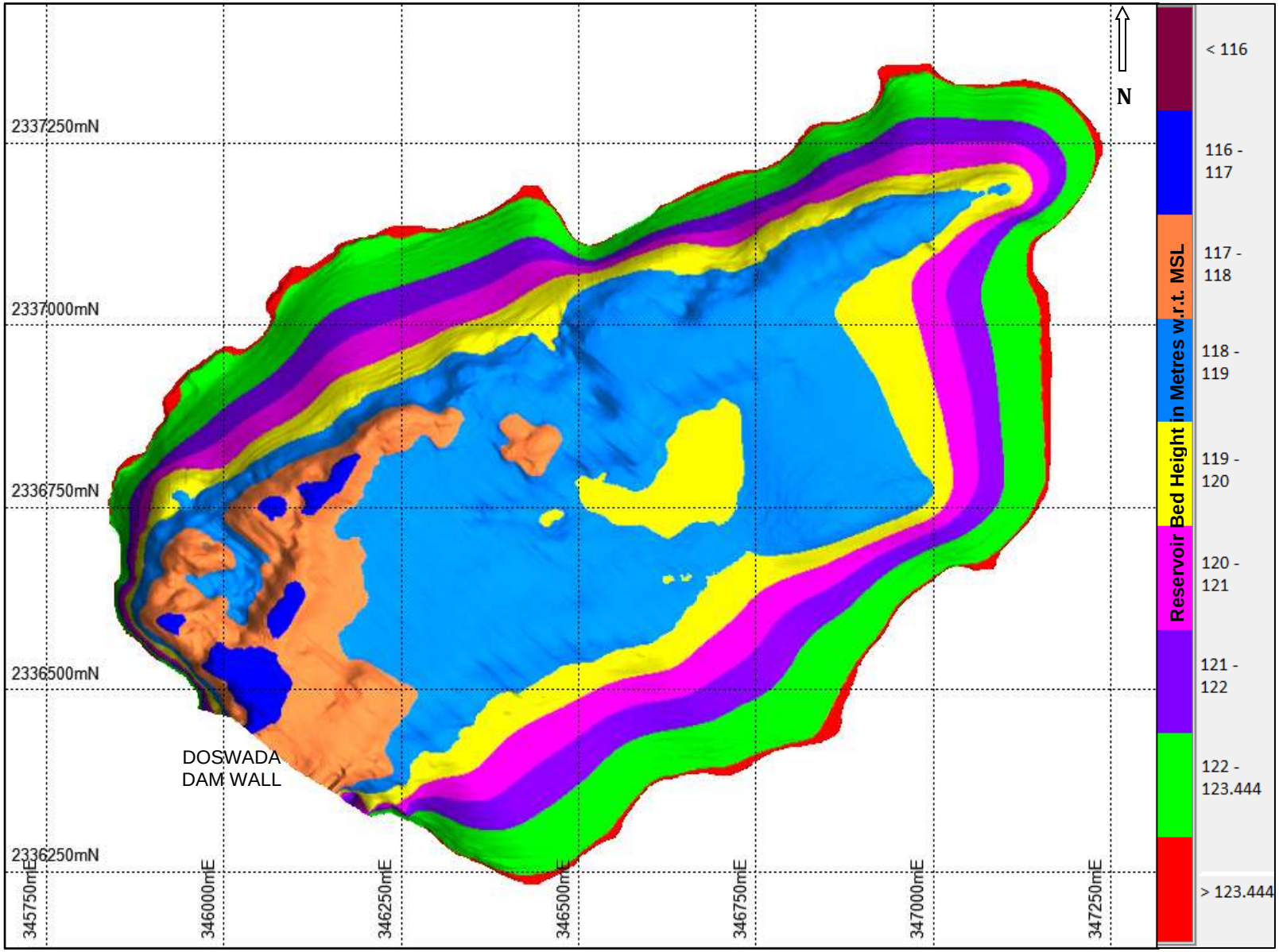


Figure 5.2: Shaded Relief Image showing gridded SBES Bathymetry and topography data of reservoir bed heights in metres from lowest bed level to FRL.

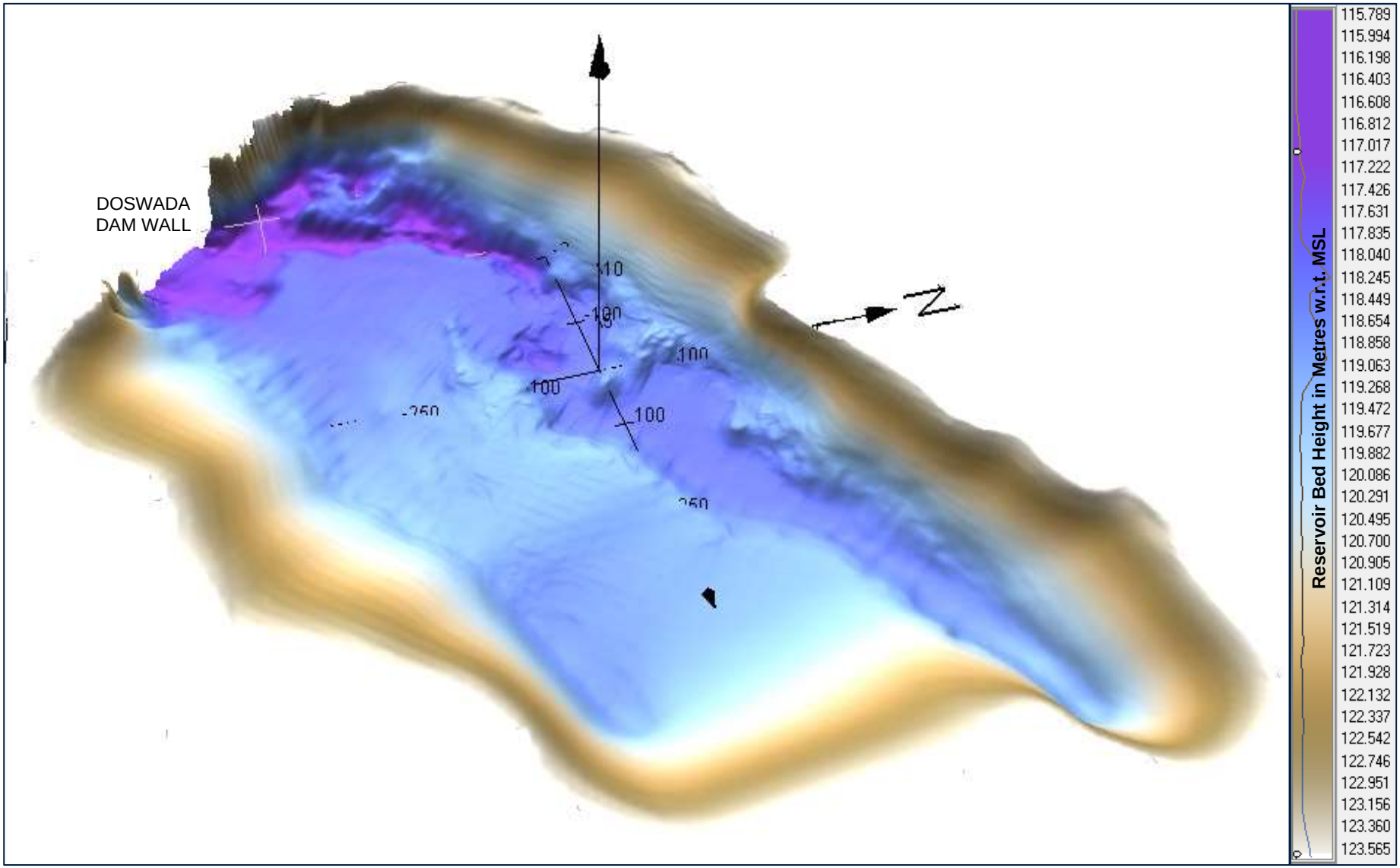


Figure 5.3: 3D view of Doswada Reservoir

Photograph A: Northernmost approachable part of Doswada Reservoir (346745 mE, 2337103 mN) with shallow water depth.

Photograph B: North-easternmost approachable part of Doswada Reservoir (346972 mE, 2336803 mN) with shallow water depth.

Photograph C: Easternmost approachable part of Doswada Reservoir (346893 mE, 2336676 mN) with shallow water depth.

Photograph D: Southernmost approachable part of Doswada Reservoir (346366 mE, 2336325 mN) with shallow water depth.

Figure 5.4: Photographs A, B, C and D showing the northern, north-eastern, eastern and southern parts within Doswada Reservoir with shallow water depths.

5.2 Elevation Area Capacity Curve (2021)

The area and capacity of the Doswada reservoir was tabulated against the respective increasing elevation starting from lowest bed elevation (i.e., 115.80 m) up to 124.00 m (above FRL of 123.44 m) at an increment of 0.1 m as shown in Table 5.1. Area capacity curve for Doswada reservoir is shown in Figure 5.5.

Table 5.1: Revised Elevation Area Capacity table at every 0.1 m interval starting from lowest bed level to FRL for the Survey Year 2021

Elevation Area Capacity Table (2021): Doswada Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
1	115.80	0.0000	0.00000	Bed level
2	115.90	0.0000	0.00000	-
3	116.00	0.0000	0.00000	-
4	116.10	0.0000	0.00001	-
5	116.20	0.0000	0.00001	-
6	116.30	0.0001	0.00001	-
7	116.40	0.0002	0.00003	-
8	116.50	0.0011	0.00009	-
9	116.60	0.0020	0.0002	-
10	116.70	0.0032	0.0005	-
11	116.80	0.0066	0.0010	-
12	116.90	0.013	0.002	-
13	117.00	0.020	0.004	-
14	117.10	0.027	0.006	-
15	117.20	0.035	0.009	-
16	117.30	0.048	0.013	-
17	117.40	0.058	0.018	-
18	117.50	0.065	0.025	-
19	117.60	0.071	0.031	-
20	117.70	0.077	0.039	-
21	117.80	0.084	0.047	-
22	117.90	0.092	0.056	-
23	118.00	0.107	0.066	-
24	118.10	0.134	0.078	-
25	118.20	0.197	0.094	-
26	118.26	0.210	0.100	MDDL
27	118.30	0.230	0.115	-
28	118.40	0.252	0.140	-
29	118.50	0.272	0.166	-
30	118.60	0.296	0.194	-
31	118.70	0.325	0.225	-
32	118.80	0.359	0.259	-
33	118.90	0.402	0.297	-

Elevation Area Capacity Table (2021): Doswada Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
34	119.00	0.451	0.340	-
35	119.10	0.494	0.387	-
36	119.20	0.515	0.438	-
37	119.30	0.526	0.490	-
38	119.40	0.535	0.543	-
39	119.50	0.543	0.597	-
40	119.60	0.550	0.651	-
41	119.70	0.559	0.707	-
42	119.80	0.567	0.763	-
43	119.90	0.574	0.820	-
44	120.00	0.582	0.878	-
45	120.10	0.591	0.937	-
46	120.20	0.599	0.996	-
47	120.30	0.608	1.056	-
48	120.40	0.618	1.118	-
49	120.50	0.627	1.180	-
50	120.60	0.636	1.243	-
51	120.70	0.645	1.307	-
52	120.80	0.655	1.372	-
53	120.90	0.665	1.438	-
54	121.00	0.675	1.505	-
55	121.10	0.685	1.573	-
56	121.20	0.694	1.642	-
57	121.30	0.703	1.712	-
58	121.40	0.714	1.783	-
59	121.50	0.725	1.855	-
60	121.60	0.735	1.928	-
61	121.70	0.744	2.002	-
62	121.80	0.754	2.077	-
63	121.90	0.764	2.153	-
64	122.00	0.774	2.230	-
65	122.10	0.784	2.307	-
66	122.20	0.795	2.386	-

Elevation Area Capacity Table (2021): Doswada Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Capacity [Mm^3]	Remarks
67	122.30	0.804	2.466	-
68	122.40	0.815	2.547	-
69	122.50	0.826	2.629	-
70	122.60	0.835	2.712	-
71	122.70	0.845	2.796	-
72	122.80	0.855	2.882	-
73	122.90	0.866	2.968	-
74	123.00	0.876	3.055	-
75	123.10	0.886	3.143	-
76	123.20	0.897	3.232	-
77	123.30	0.910	3.322	-
78	123.40	0.921	3.414	-
79	123.44	0.925	3.430	FRL
80	123.50	0.935	3.507	-
81	123.60	0.950	3.601	-
82	123.70	0.958	3.696	-
83	123.80	0.958	3.792	-
84	123.90	0.959	3.888	-
85	124.00	0.959	3.984	-

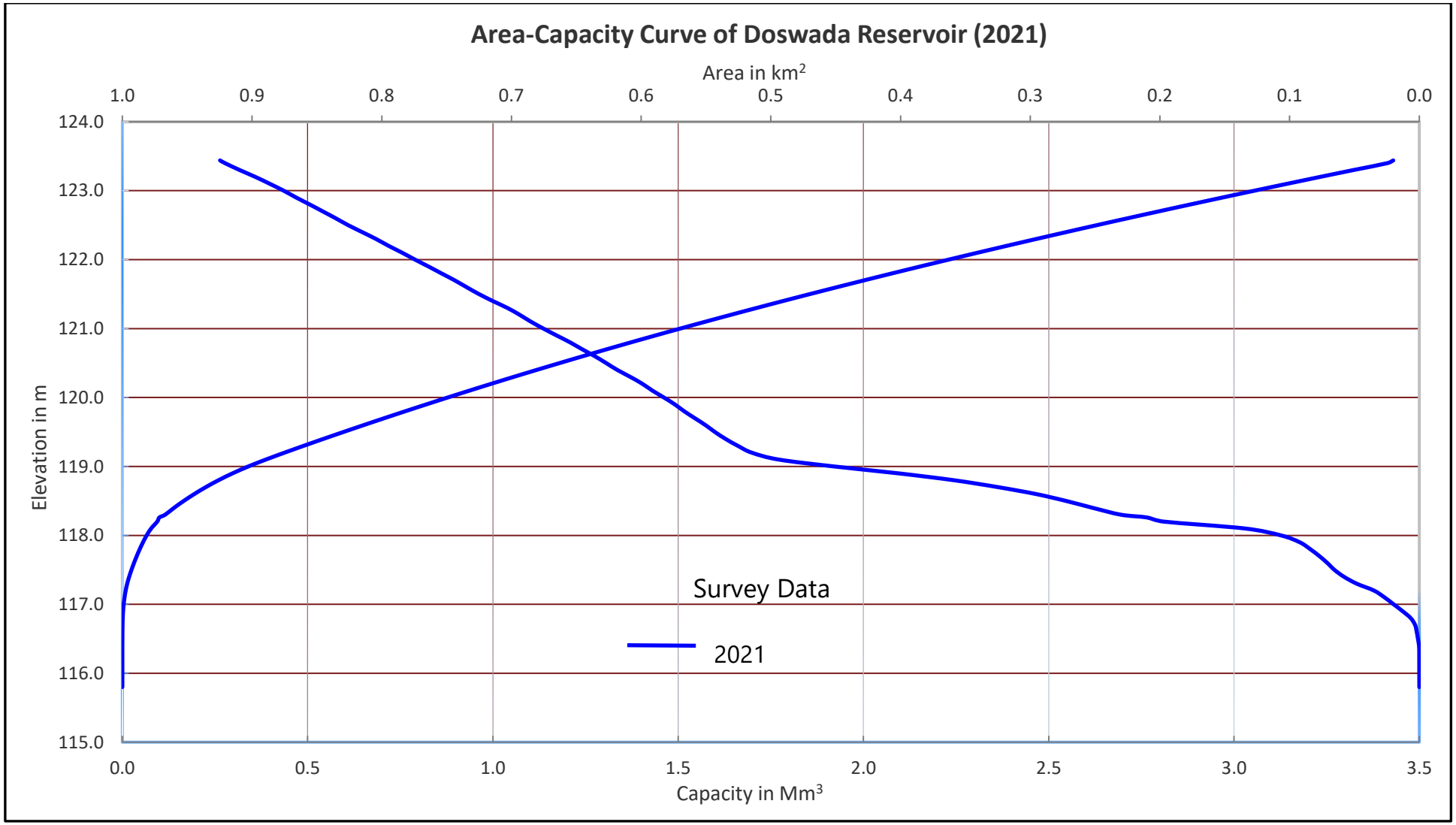


Figure 5.5: Area capacity curve for 2021 survey for Doswada Reservoir

5.3 Comparison of Elevation Area Capacity Details

Comparison of the elevation area capacity details for the year 2021 with the elevation area capacity for the previous year of 1990 is shown in Table 5.2. In addition, the comparison plots of capacity curve for the years 1990 and 2021 are shown in Figure 5.6.

In general, the 2021 survey results indicate that there is loss in gross storage capacity w.r.t. 1990 gross storage capacity.

Table 5.2: Comparison of Elevation Area Capacity details of 1990 and 2021 survey data

Sr. No	Elevation w.r.t. MSL [m]	1990 Survey		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
1	115.80	--	--	0.000	0.000
2	116.10	--	--	0.00003	0.00001
3	116.40	--	--	0.0002	0.00003
4	116.50	--	--	0.001	0.0001
5	116.80	0.002	0.0002	0.007	0.001
6	117.10	0.003	0.001	0.027	0.006
7	117.40	0.042	0.008	0.058	0.018
8	117.70	0.152	0.037	0.077	0.039
9	118.00	0.243	0.096	0.107	0.066
10	118.26	0.279	0.145	0.210	0.100
11	118.30	0.301	0.178	0.230	0.115
12	118.60	0.389	0.281	0.296	0.194
13	118.90	0.399	0.399	0.402	0.297
14	119.20	0.414	0.527	0.515	0.438
15	119.50	0.448	0.651	0.543	0.597
16	119.80	0.510	0.794	0.567	0.763
17	120.10	0.554	0.954	0.591	0.937
18	120.40	0.574	1.123	0.618	1.118
19	120.70	0.626	1.301	0.645	1.307
20	121.00	0.676	1.498	0.675	1.505
21	121.30	0.719	1.708	0.703	1.712
22	121.60	0.760	1.929	0.735	1.928
23	121.90	0.812	2.165	0.764	2.153
24	122.20	0.862	2.416	0.795	2.386
25	122.50	0.898	2.680	0.826	2.629

Sr. No	Elevation w.r.t. MSL [m]	1990 Survey		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
26	122.80	0.952	2.958	0.855	2.882
27	123.10	0.994	3.250	0.886	3.143
28	123.44	1.037	3.595	0.925	3.430

Note: Since Original area capacity curve is not available, the present survey results were compared with 1990 survey results

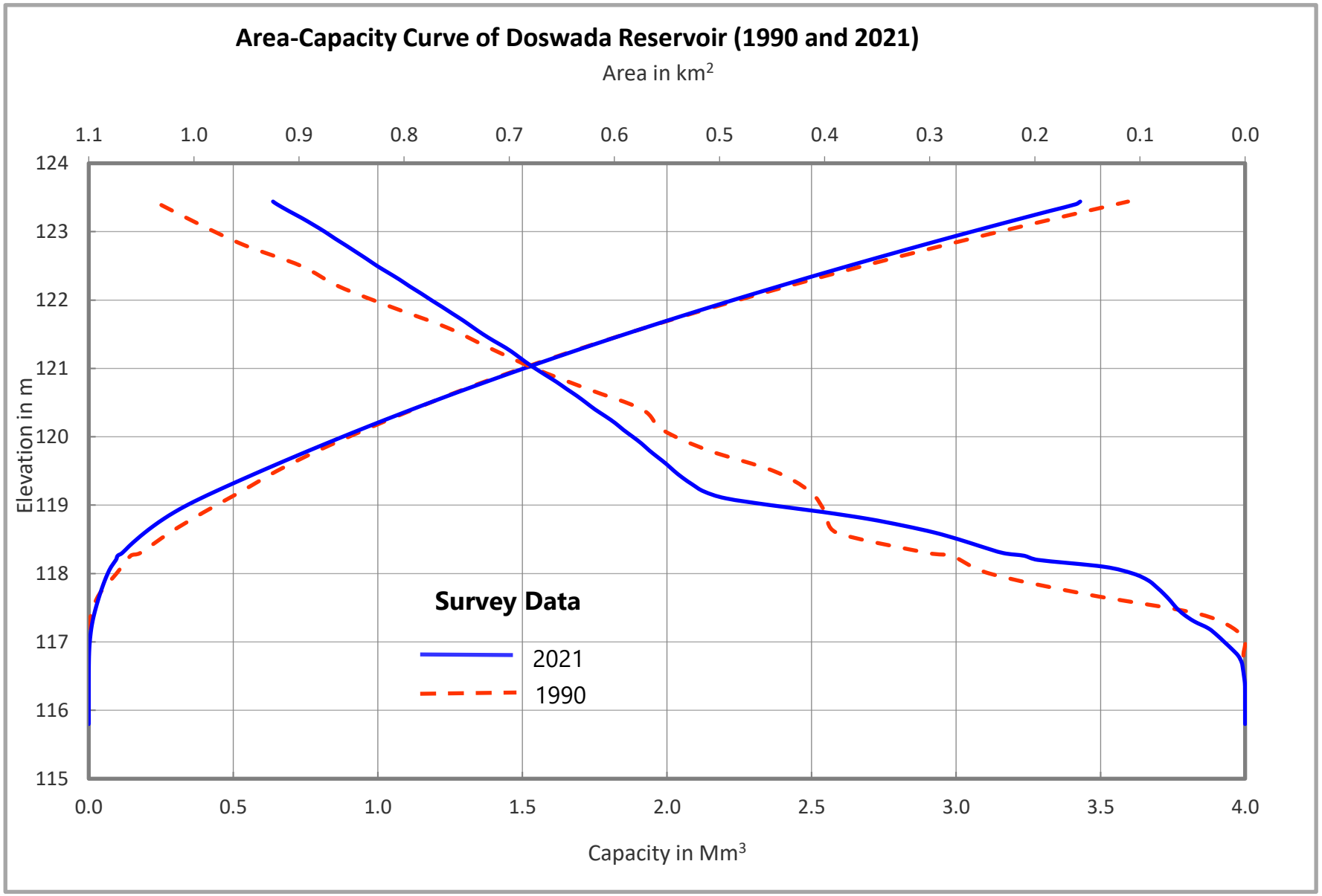


Figure 5.6: Area capacity curve for 2021 survey compared with area capacity details of 1990 survey for Doswada Reservoir

5.4 Sedimentation in Reservoir

The present survey of Doswada reservoir was carried out between April 2021 and August 2021. Previous survey was carried out in the year 1990. The catchment area considered for sedimentation studies is 62.16 km^2. In the present study, the age of the reservoir is considered as 31 years (1990 – 2021). As per 2021 survey, the total area of reservoir at FRL 123.44 m is 0.925 km^2 and the corresponding gross storage capacity is 3.430 Mm^3. Table 5.3 details the gross capacity loss, rate of sedimentation and annual % loss in gross storage capacity w.r.t. 1990 capacity survey results.

Table 5.3: Sedimentation in Doswada Reservoir

Year	1990	2021
Storage Capacity in Mm^3		
Dead	0.145	0.100
Live	3.450	3.330
Gross	3.595	3.430
Loss of Storage Capacity in Mm^3		(wrt 1990)
Dead	NA	0.045
Live	NA	0.120
Gross	NA	0.165
Sedimentation Rate in Ha m/100 km^2/Year		(wrt 1990)
Dead	NA	0.234
Live	NA	0.625
Gross	NA	0.858
Annual % loss		(wrt 1990)
Dead	NA	0.040
Live	NA	0.108
Gross	NA	0.148
Class of reservoir as per IS -12182 (1987)	As per design	Significant
Volume of sediment (w.r.t. 1990) deposited on bed in 2021= Loss of storage capacity= 0.165 Mm^3		
Note: Sign Convention: -ve sign shows desiltation and +ve sign shows siltation		

Note: Since FRL of Original (1913) data is different the same was not considered for sedimentation studies

Table 5.4 gives the results of the Trap efficiency and Sedimentation Index calculated for Doswada reservoir as per the methodology given in IS 12182-1987.

Table 5.4: Trap Efficiency and Sedimentation Index for Doswada Reservoir

Trap Efficiency	Sedimentation Index
87%	4.835 x 10^9 sec^2/m

In Table 5.3, the survey data of 1990 has been compared with 2021 survey results to understand the sedimentation in Doswada reservoir. It may be observed that there is a reduction in the storage capacity of the reservoir due to siltation.

In comparison with 1990 survey, the present survey results indicate siltation process in the reservoir. The reason behind the present survey results showing siltation w.r.t. 1990 survey results could be due to change of upstream catchment characteristics. Also, there could be some anthropogenic activities in the catchment area which might result in siltation in the reservoir.

Table 5.5: Sedimentation Volumes from Surveys of Previous Year

Sr. No.	Year of Survey	Source of Data	Period (years)	Reservoir Capacity (Mm^3)	Loss of Gross Capacity (Since 1990 survey)			Observed Rate of Sedimentation (Since 1990 survey) (Ha m / 100 Sq km/Yr)
				Gross	Mm^3	% Cumulative	Remark	
1	1990	Govt.	-	3.595	-	-	-	-
2	2021	Present survey	31	3.430	0.165	4.600	Siltation	0.858

- As per 2021 survey results, the volume of sediment deposited or the loss in gross storage capacity w.r.t. 1990 survey data is 0.165 Mm^3.
- The rate of siltation in Doswada reservoir is 0.005 Mm^3/year.
- The average rate of siltation in the Doswada reservoir during the 31 years life span (1990 – 2021), works out to 0.858 Ha m/100 sq km/year.
- The annual % loss in Doswada reservoir during the 31 years life span is 0.148 % and hence, the reservoir is classified as "Significant" category as per IS 12182 (1987).

Trap Efficiency and sedimentation Index calculated for Doswada reservoir as per methodology give in IS 12182-1987 is 87% and 4.835 x 10^9 sec^2/m respectively. Table 5.6 gives the gross, live and dead storage capacity from bed level to FRL at 0.1 m interval.

Table 5.6: Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Doswada reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
1	115.80	0.00000	--	0.00000	Bed level
2	115.90	0.00000	--	0.00000	--
3	116.00	0.00000	--	0.00000	--
4	116.10	0.00001	--	0.00001	--
5	116.20	0.00001	--	0.00001	--
6	116.30	0.00001	--	0.00001	--
7	116.40	0.00003	--	0.00003	--
8	116.50	0.00009	--	0.00009	--
9	116.60	0.0002	--	0.0002	--
10	116.70	0.0005	--	0.0005	--
11	116.80	0.0010	--	0.0010	--
12	116.90	0.002	--	0.002	--
13	117.00	0.004	--	0.004	--
14	117.10	0.006	--	0.006	--
15	117.20	0.009	--	0.009	--
16	117.30	0.013	--	0.013	--
17	117.40	0.018	--	0.018	--
18	117.50	0.025	--	0.025	--
19	117.60	0.031	--	0.031	--
20	117.70	0.039	--	0.039	--
21	117.80	0.047	--	0.047	--
22	117.90	0.056	--	0.056	--
23	118.00	0.066	--	0.066	--
24	118.10	0.078	--	0.078	--
25	118.20	0.094	--	0.094	--
26	118.26	0.100	--	0.100	MDDL
27	118.30	0.115	0.015	0.100	--
28	118.40	0.140	0.040	0.100	--
29	118.50	0.166	0.066	0.100	--
30	118.60	0.194	0.094	0.100	--
31	118.70	0.225	0.125	0.100	--
32	118.80	0.259	0.159	0.100	--
33	118.90	0.297	0.197	0.100	--
34	119.00	0.340	0.240	0.100	--
35	119.10	0.387	0.287	0.100	--
36	119.20	0.438	0.338	0.100	--
37	119.30	0.490	0.390	0.100	--
38	119.40	0.543	0.443	0.100	--
39	119.50	0.597	0.497	0.100	--
40	119.60	0.651	0.551	0.100	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Doswada reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
41	119.70	0.707	0.607	0.100	--
42	119.80	0.763	0.663	0.100	--
43	119.90	0.820	0.720	0.100	--
44	120.00	0.878	0.778	0.100	--
45	120.10	0.937	0.837	0.100	--
46	120.20	0.996	0.896	0.100	--
47	120.30	1.056	0.956	0.100	--
48	120.40	1.118	1.018	0.100	--
49	120.50	1.180	1.080	0.100	--
50	120.60	1.243	1.143	0.100	--
51	120.70	1.307	1.207	0.100	--
52	120.80	1.372	1.272	0.100	--
53	120.90	1.438	1.338	0.100	--
54	121.00	1.505	1.405	0.100	--
55	121.10	1.573	1.473	0.100	--
56	121.20	1.642	1.542	0.100	--
57	121.30	1.712	1.612	0.100	--
58	121.40	1.783	1.683	0.100	--
59	121.50	1.855	1.755	0.100	--
60	121.60	1.928	1.828	0.100	--
61	121.70	2.002	1.902	0.100	--
62	121.80	2.077	1.977	0.100	--
63	121.90	2.153	2.053	0.100	--
64	122.00	2.230	2.130	0.100	--
65	122.10	2.307	2.207	0.100	--
66	122.20	2.386	2.286	0.100	--
67	122.30	2.466	2.366	0.100	--
68	122.40	2.547	2.447	0.100	--
69	122.50	2.629	2.529	0.100	--
70	122.60	2.712	2.612	0.100	--
71	122.70	2.796	2.696	0.100	--
72	122.80	2.882	2.782	0.100	--
73	122.90	2.968	2.868	0.100	--
74	123.00	3.055	2.955	0.100	--
75	123.10	3.143	3.043	0.100	--
76	123.20	3.232	3.132	0.100	--
77	123.30	3.322	3.222	0.100	--
78	123.40	3.414	3.314	0.100	--
79	123.44	3.430	3.330	0.100	FRL

6. Conclusions

- The reservoir topography was uneven, with reservoir bed level ranging from 115.8 m to 123.44 m w.r.t. MSL. The lowest reservoir bed level 115.80 m was found near the upstream face of the dam boundary and it becomes shallower as we go further upstream from the dam face. Also, the reservoir bed tends to get shallower as we go further in north-east, south-east & north-west directions away from the dam wall within the survey area.
- Current survey results indicate that the loss of gross storage capacity (w.r.t. 1990 survey data) due to siltation in Doswada reservoir is 0.165 Mm^3. The probable reasons for the decrease of gross storage capacity could be change in hydrodynamics due to change of upstream discharges as sediment carrying capacity of the river and its tributaries. Moreover, the cause of changes could be anthropogenic intervention towards siltation of the reservoir.
- In comparison with 1990 survey results, 2021 results indicate decrease in storage capacity due to siltation. The annual % loss in gross storage capacity is 0.148 % and hence, the reservoir is classified as "Significant" category as per IS 12182 (1987).
- The sedimentation volumes, sedimentation rates, loss of storage capacity, trap efficiency, sedimentation index have been reported in the study. Moreover, the tables for gross, live and dead storage capacity of reservoir at every 0.1 m interval from lowest bed level to FRL have been provided.

7. References

- Bengtsson, L., Herschy, R. W., & Fairbridge, R. W. (2012). *Encyclopedia of Lakes and Reservoirs (Encyclopedia of Earth Sciences Series)* (2012th ed.). Springer.
- Bureau of Indian Standards. (1987). *Guidelines for determination of effects of sedimentation in planning and performance of reservoirs* (IS 12182 : 1987 ed.). Bureau of Indian Standards.
- Bureau of Indian Standards. (1999). *Indian Standard Fixing the Capacities of Reservoirs Methods Part 1 General Requirements* (IS 5477 Part 1: 1999). Bureau of Indian Standards.
- Devi, Sunita. (2013-2014). *Groundwater Brochure Tapi District Gujarat*. Ministry of Water Resources Central Ground Water Board West Central Region Ahmedabad, Government of India.
- Directorate of Census Operations, Gujarat. (2011), *District Census Handbook Tapi*. Census Organization. Series-25, Part-XII-A.
- Gujarat Social Infrastructure Development Society (GSIDS). (2015). *District Human Development Report: Tapi*. Gujarat Social Infrastructure Development Society (GSIDS)
- India-WRIS. (2014). *West Flowing Rivers from Tapi to Tadri Basin* (Version 2.0 ed.). Ministry of Water Resources, Government of India.
- Schellenberg, G., Donnelly, R. C., Holder, C., & Ahsan, R. (2017). Dealing With Sediment - Effects on Dams and Hydropower Generation. *HRW Hydro Review Worldwide*, *25*(1), 6–13.
- Schleiss, A. J., Franca, M. J., Juez, C., & de Cesare, G. (2016). Reservoir sedimentation. *Journal of Hydraulic Research*, *54*(6), 595–614. https://doi.org/10.1080/00221686.2016.1225320
- Shiferaw, M., & Abebe, R. (2020). Examining Reservoir Sedimentation and Estimating Dam Stockpiling Limit Utilizing Bathymetry Overview: A Contextual Investigation of Abrajit Dam, North Gojjam Sub-basin, Blue Nile basin, Ethiopia. *Journal of the Indian Society of Remote Sensing*, *48*(9), 1313–1323. https://doi.org/10.1007/s12524-020-01159-8

Appendix A

Diary of Events

(01 page)

Diary of Events (Bathymetry and Topography Survey)	
Date	**Events**
Bathymetry Survey	
19 April 2021	Survey personnel and equipment along with survey boat 'Fugro Zodiac' reached Doswada reservoir.
20 April 2021	Fugro Zodiac deployed on Doswada reservoir and DGPS observation at both TBMs carried out
21 April 2021	Levelling at TBM carried out. Mobilization and Calibration/verification commenced and completed.
22 April 2021	Bathymetry survey commenced.
23 April 2021	Bathymetry Survey completed.
24 April 2021	Survey team reached Lakhigam dam for site visit and carried out reconnaissance survey.
25 April 2021	Demobilization completed at Doswada reservoir
Topography Survey	
9 August 2021	Topography survey team with equipment reached Doswada Dam. Mobilisation and calibration commenced and completed. Topography survey commenced and completed

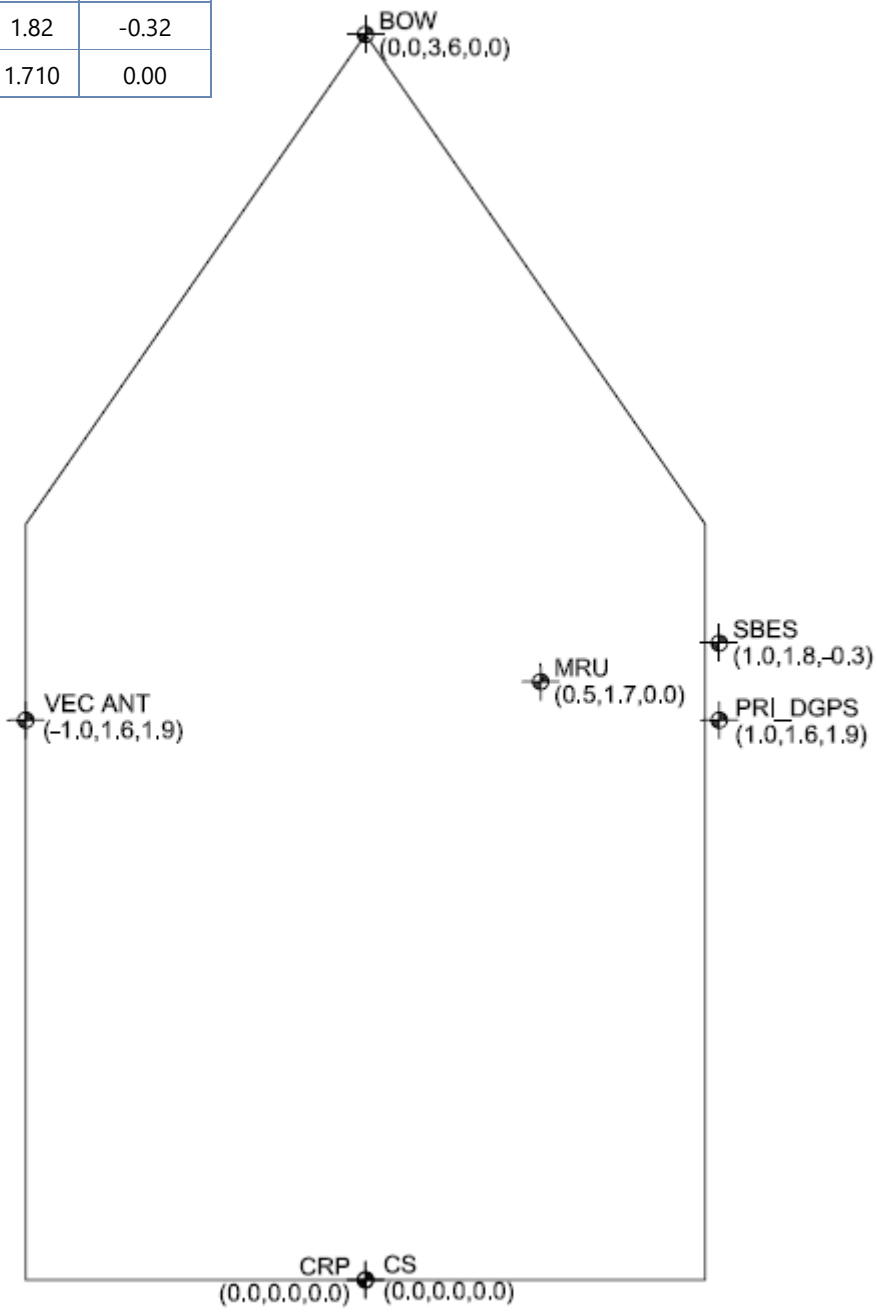
Appendix B

Survey Vessel Sensor Offsets

(01 Page)

Survey Vessel 'Fugro Zodiac' Sensor Offset Diagram

Sensor Offsets: Fugro Zodiac			
Starfix.Suite Name	**X [m]**	**Y [m]**	**Z [m]**
Centre Stern (CS)	0.00	0.00	0.00
Bow	0.00	3.56	0.00
PRI_GPS	1.01	1.60	1.90
VEC_ANT	-0.97	1.60	1.90
SBES	1.01	1.82	-0.32
MRU	0.50	1.710	0.00

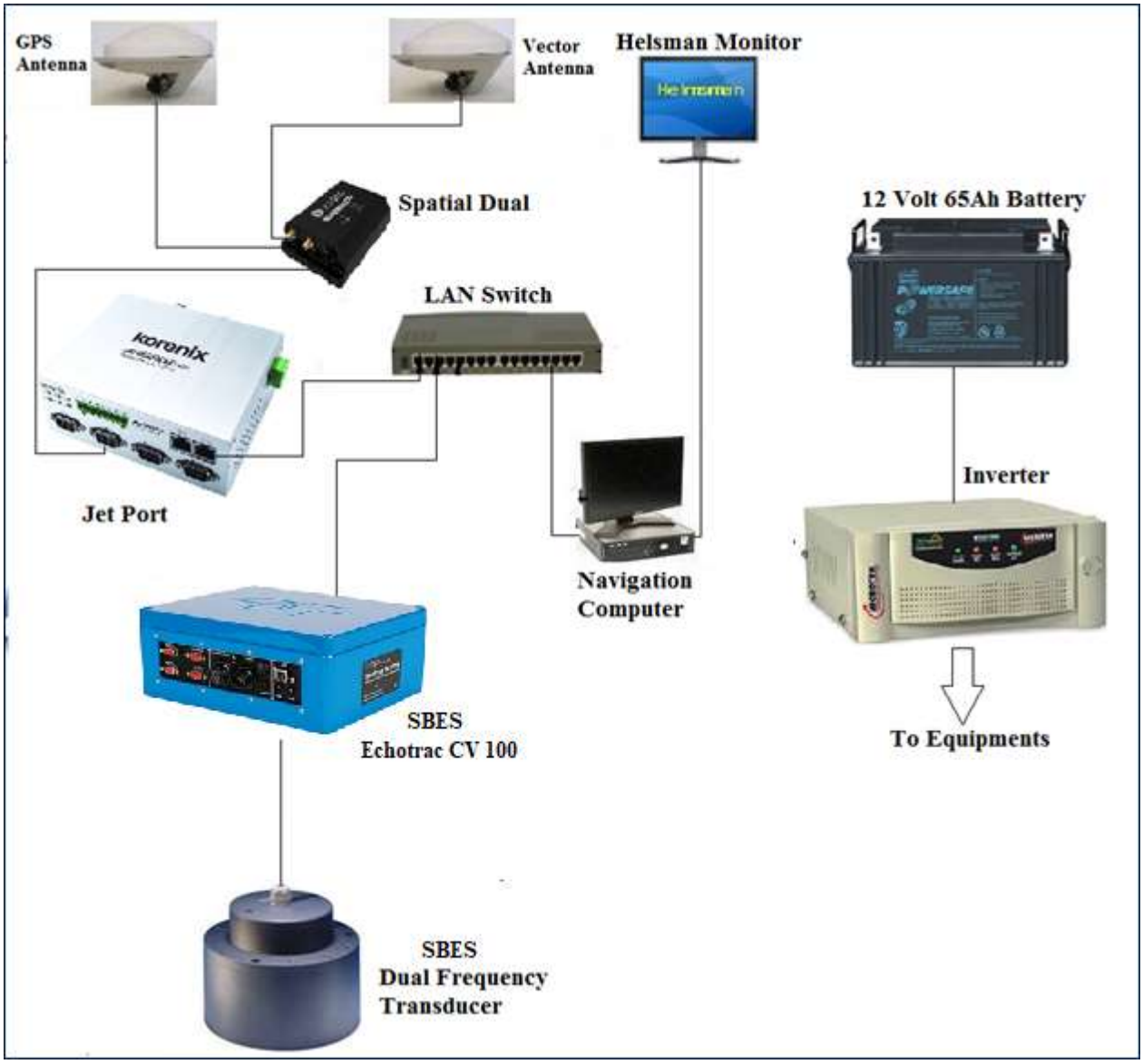


Appendix C

Equipment Layout Diagram

(01 Page)

Equipment Layout Diagram onboard Fugro Zodiac



Appendix D

Results of Field Calibrations / Verifications

(26 pages)

FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of DOSVADA DAM TBM1

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	DOSVADA DAM TBM1	**Location:**	DOSVADA DAM, Gujarat
Party Chief :	Pritam Seth	**Job Engineer/Surveyor :**	Atul Bhoyte.
Date of Observation: (Date & Time)	20-04-2021 & 17:41hrs	**End of Observation: (Date & Time)**	20-04-2021 & 18:11hrs

1. Station Name: DOSVADA DAM TBM1**.**

Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
TRIMBLE BX992 RECEIVER	025-00009601	PRI_DGPS	Mean position report	FBF	NA	0.01

A=Center Point of DOSVADA DAM TBM1 Height from MSL 126.322m

B= Antenna Height from BM 1.730m (Measure by Tape)

Ellipsoidal height of Antenna= 62.570m

Ellipsoidal Height of BM 62.570m - 1.730m=60.840m

Position Of Antenna:-

Latitude: 21°07’23.394”N, Longitude: 073°30’59.601”E

Easting: 3,45,941.429m E, Northing: 23,36,497.587m N

Prepared By: Pritam Seth.

BATHYMETRY SURVEY
MEAN POSITION REPORT

Project ID	J-HYD-20-174630-DOSVADA DAM		
Location	DOSVADA, CENTRAL GUJRAT		
Client	GOVERMENT OF GUJRAT	**Vessel**	Tripod
Comment	DOSVADA DAM TBM1 STN HT 1.730m		

Session Name: MPR-20210420113513-v1 Records Used: 1399 of 1798

Start Time: 20 Apr 2021, 17:41:03+05:30 End Time: 20 Apr 2021, 18:11:02+05:30 Session Length: 00:29:59

Mean Position for Tripod CommonReferencePoint		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	21°07'23.39446"N	21°07'23.39446"N
Longitude	073°30'59.60168"E	073°30'59.60168"E
Height	62.570m Ell.	62.570m Ell.
Easting	3,45,941.429m E (SD: ±0.01m)	
Northing	23,36,497.587m N (SD: ±0.01m)	
Height	124.616m Ort. (SD: ±0.04m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	342.23°T 342.77°G	±61.1°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

DOSVADA DAM TBM1 STN HT 1.730m

Mean Position to Waypoint	
Waypoint	TBM2
Easting	3,45,874.276m E
Northing	23,36,548.162m N
Range	84.08m Geodetic
Bearing TO	306.45°True
Bearing FROM	126.45°True

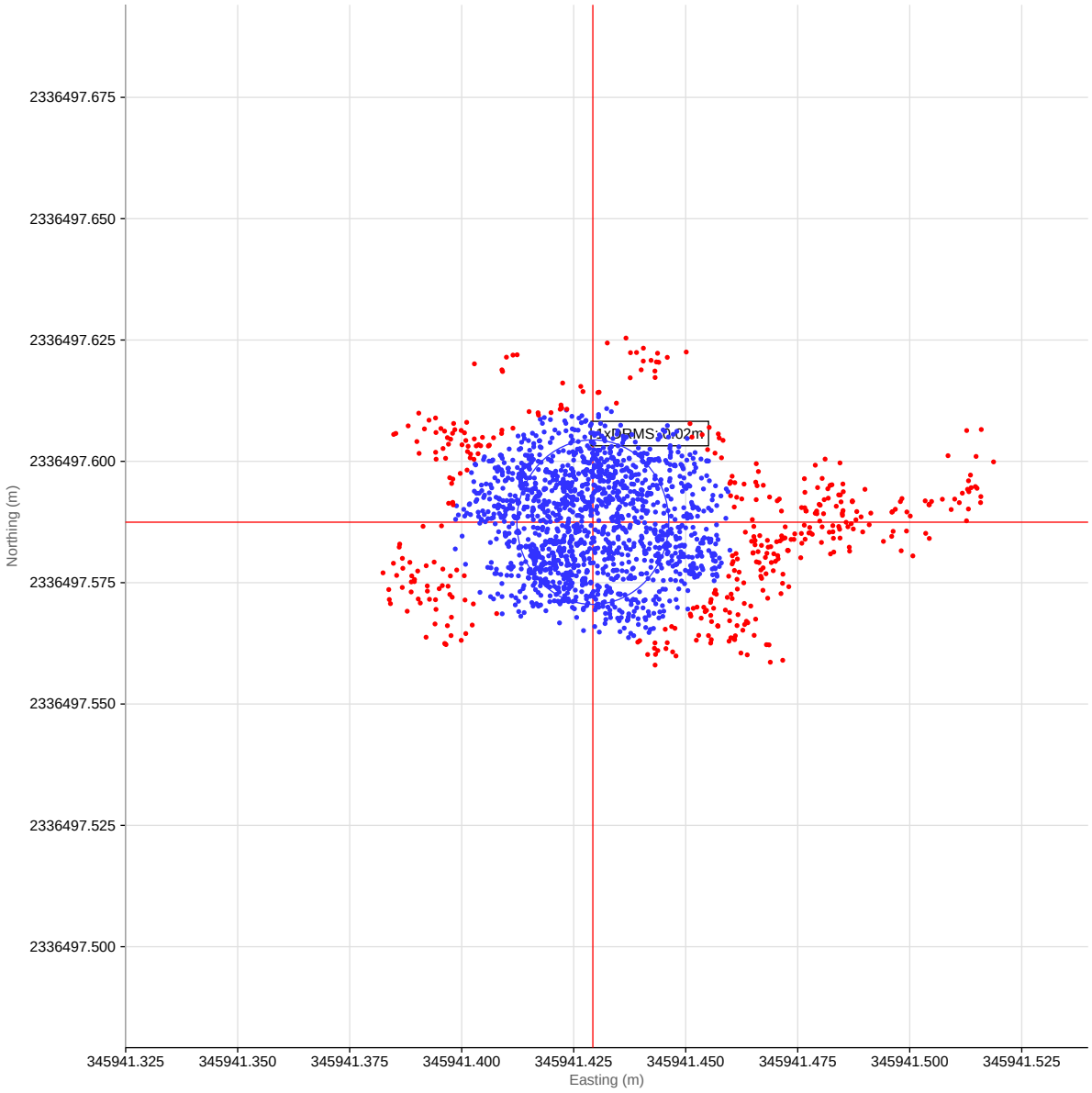
PRITAM SETH
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Deputy Executive Engineer
DOSWADA DAM
Govt. of Gujrat

Geodetic Parameters

Name : WGS 84 / UTM zone 43N		
EPSG Code	EPSG::32643	
Local Geodetic Datum Parameters		
Datum	World Geodetic System 1984	EPSG::6326
Ellipsoid	WGS 84	
Semi major axis	a = 63,78,137.000 m	
Inverse flattening	1/f = 298.257223563	
Local Projection Parameters		
Map Projection	Transverse Mercator	
Grid System	UTM zone 43N	EPSG::16043
Latitude Origin	00° 00’ 00.000” N	
Central Meridian	075° 00’ 00.000” E	
Scale Factor on Central Meridian	0.9996	
False Easting	500 000 m	
False Northing	0 m	

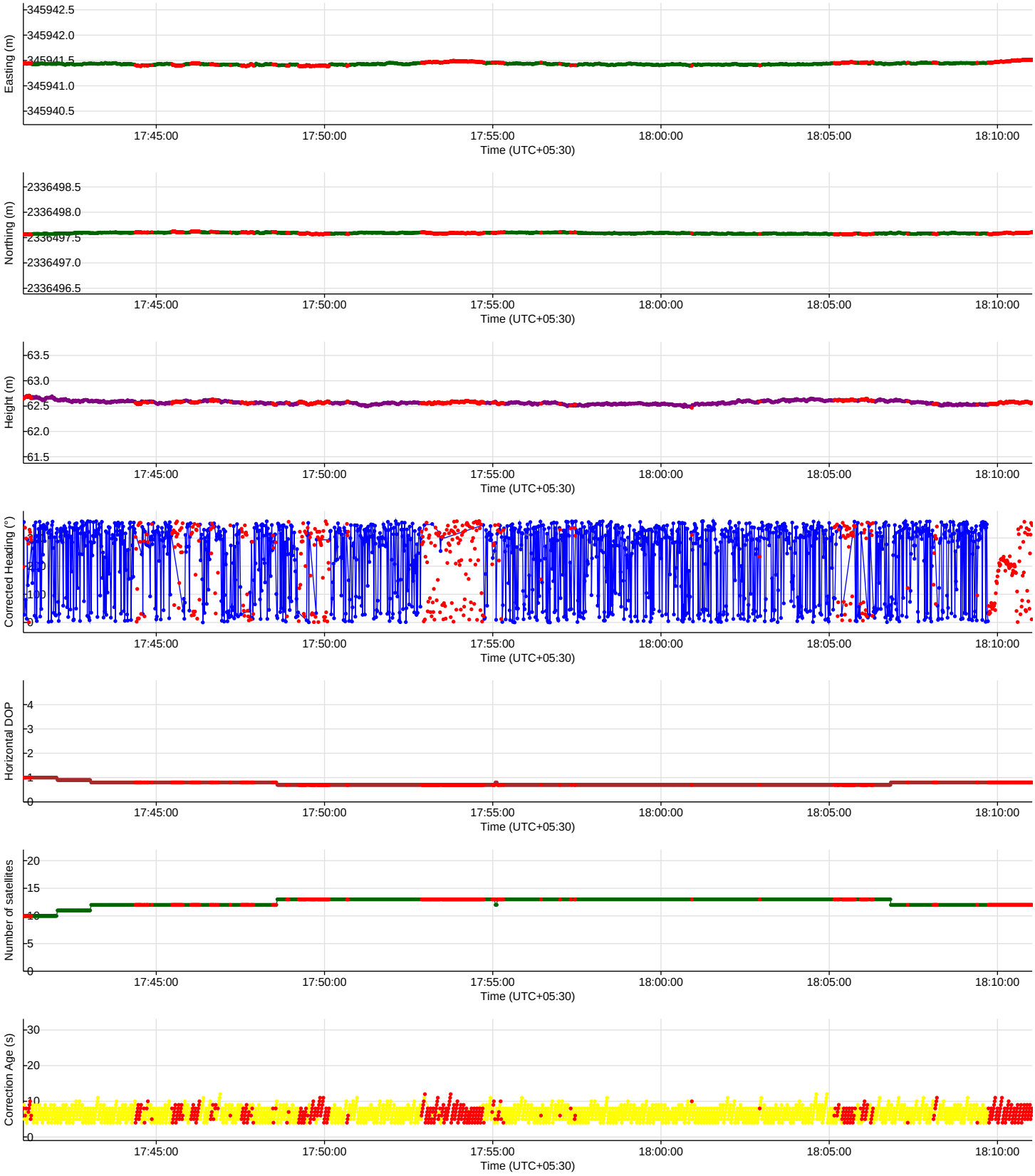
Scatter Plot



Mean Position

	Easting	Northing
Tripod	3,45,941.429m E	23,36,497.587m N

Time Series Plots for Tripod



FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of DOSVADA DAM TBM1

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	**DOSVADA DAM TBM1**	**Location:**	DOSVADA DAM, Gujarat
Party Chief :	Pritam Seth	**Job Engineer/Surveyor :**	Atul Bhoyte.
Date of Observation: (Date & Time)	20-04-2021 & 18:34hrs	**End of Observation: (Date & Time)**	20-04-2021 & 19:04hrs

1. Station Name: DOSVADA DAM TBM1.

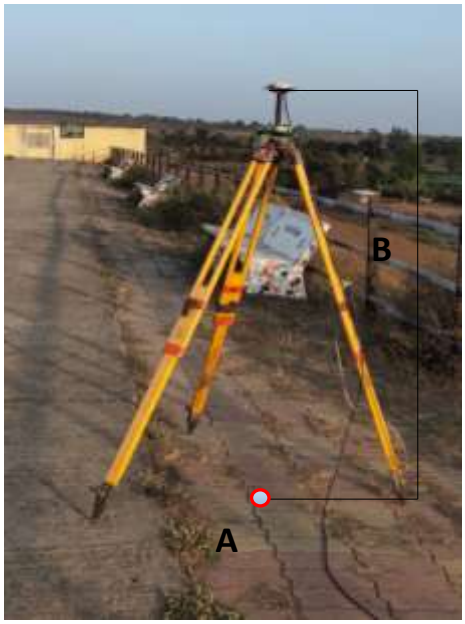
Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
SATIAL DUAL RECEIVER	025-00006405	PRI_DGPS	Mean position report	FBF	NA	0.01

A=Center Point of **DOSVADA DAM TBM1** Height from MSL 126..322m

B= Antenna Height from BM 1.685m (Measure by Tape)

Ellipsoidal height of Antenna= 62.731m

Ellipsoidal Height of BM 62.731 - 1.685m=61.046m



Position Of Antenna:-

Latitude: 21°07’23.393”N, **Longitude:** 073°30’59.603”E

Easting: 3,45,941.494m E**, Northing:** 23,36,497.560m N

Prepared By: Pritam Seth.

BATHYMETRY SURVEY
MEAN POSITION REPORT

Project ID	J-HYD-20-174630-DOSVADA DAM		
Location	DOSVADA, CENTRAL GUJRAT		
Client	GOVERMENT OF GUJRAT	**Vessel**	Tripod
Comment	DOSVADA DAM TBM1 STN HT 1.685mSD		

Session Name: MPR-20210420124920-v1 Records Used: 1578 of 1800

Start Time: 20 Apr 2021, 18:34:39+05:30 End Time: 20 Apr 2021, 19:04:38+05:30 Session Length: 00:29:59

Mean Position for Tripod CommonReferencePoint		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	21°07'23.39359"N	21°07'23.39359"N
Longitude	073°30'59.60393"E	073°30'59.60393"E
Height	62.731m Ell.	62.731m Ell.
Easting	3,45,941.494m E (SD: ±0.02m)	
Northing	23,36,497.560m N (SD: ±0.01m)	
Height	124.777m Ort. (SD: ±0.04m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	0.00°T 0.00°G	±0.0°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

DOSVADA DAM TBM1 STN HT 1.685m

Mean Position to Waypoint	
Waypoint	TBM2
Easting	3,45,874.276m E
Northing	23,36,548.162m N
Range	84.14m Geodetic
Bearing TO	306.44°True
Bearing FROM	126.44°True

PRITAM SETH
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Deputy Executive Engineer
DOSWADA DAM
Govt. of Gujrat

Geodetic Parameters

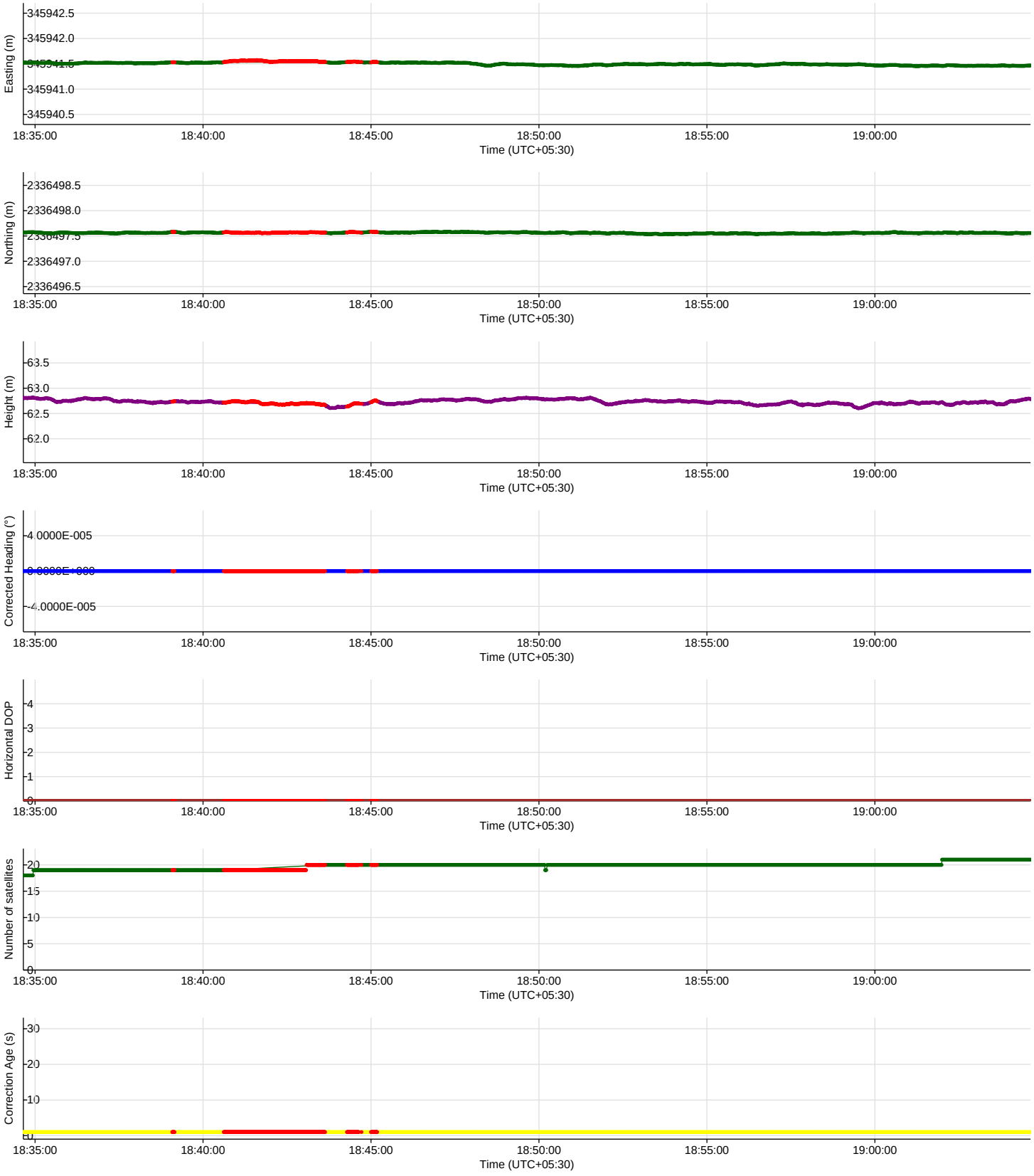
Name : WGS 84 / UTM zone 43N		
EPSG Code	EPSG::32643	
Local Geodetic Datum Parameters		
Datum	World Geodetic System 1984	EPSG::6326
Ellipsoid	WGS 84	
Semi major axis	a = 63,78,137.000 m	
Inverse flattening	1/f = 298.257223563	
Local Projection Parameters		
Map Projection	Transverse Mercator	
Grid System	UTM zone 43N	EPSG::16043
Latitude Origin	00° 00’ 00.000” N	
Central Meridian	075° 00’ 00.000” E	
Scale Factor on Central Meridian	0.9996	
False Easting	500 000 m	
False Northing	0 m	

Scatter Plot

Mean Position

	Easting	Northing
Tripod	3,45,941.494m E	23,36,497.560m N

Time Series Plots for Tripod



FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of DOSVADA DAM TBM2

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	**DOSVADA DAM TBM2**	**Location:**	DOSVADA DAM, Gujarat
Party Chief :	Pritam Seth	**Job Engineer/Surveyor :**	Atul Bhoyte.
Date of Observation: (Date & Time)	20-04-2021 & 14:02hrs	**End of Observation: (Date & Time)**	20-04-2021 & 14:32hrs

1. Station Name: DOSVADA DAM TBM2.

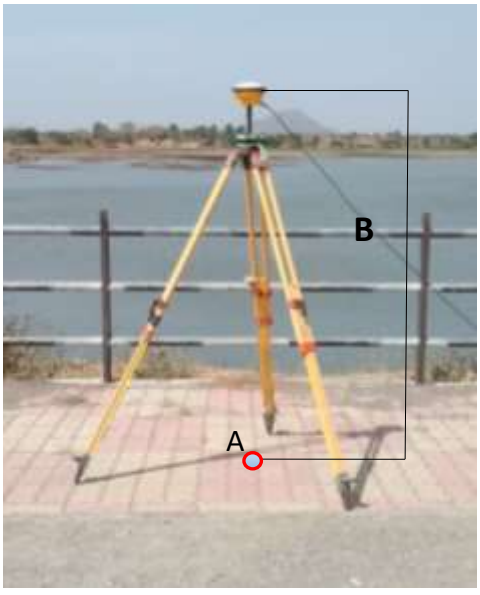
Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
Trimble BX 992 RECEIVER	025-00009601	PRI_DGPS	Mean position report	FBF	NA	0.03

A=Center Point of DOSVADA DAM TBM2 Height from MSL 126.393m

B= Antenna Height from BM 1.735m (Measure by Tape)

Ellipsoidal height of Antenna= 62.698m

Ellipsoidal Height of BM 62.698m - 1.735m=60.963m



Position Of Antenna:-

Latitude: 21°07’25.018”N, **Longitude:** 073°30’57.257”E

Easting: 3,45,874.266m E**, Northing:** 23,36,548.161m N

Prepared By: Pritam Seth.

BATHYMETRY SURVEY
MEAN POSITION REPORT

Project ID	J-HYD-20-174630-DOSVADA DAM		
Location	DOSVADA, CENTRAL GUJRAT		
Client	GOVERMENT OF GUJRAT	**Vessel**	Tripod
Comment	DOSVADA DAM TBM 2 BX982 STN HT 1.735		

Session Name: MPR-20210420073053-v1 Records Used: 1214 of 1798

Start Time: 20 Apr 2021, 14:02:19+05:30 End Time: 20 Apr 2021, 14:32:18+05:30 Session Length: 00:29:59

Mean Position for Tripod CommonReferencePoint		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	21°07’25.01856”N	21°07’25.01856”N
Longitude	073°30’57.25770”E	073°30’57.25770”E
Height	62.698m Ell.	62.698m Ell.
Easting	3,45,874.266m E (SD: ±0.03m)	
Northing	23,36,548.161m N (SD: ±0.01m)	
Height	124.742m Ort. (SD: ±0.04m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	0.00°T 0.00°G	±0.0°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

DOSVADA DAM TBM 2 BX982 STN HT 1.735

PRITAM SETH
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Deputy Executive Engineer
DOSWADA DAM
Govt. of Gujrat

Geodetic Parameters

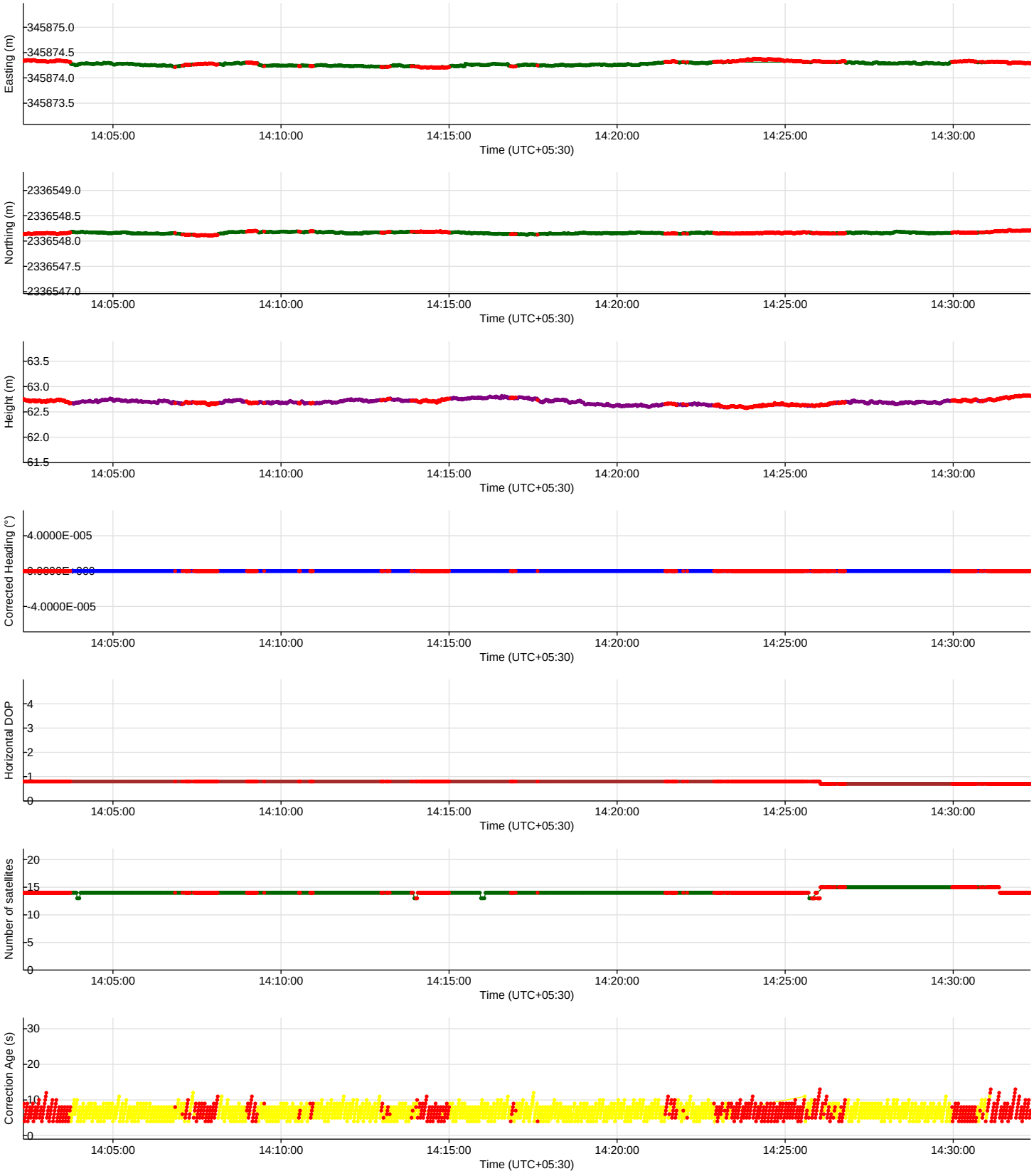
Name : WGS 84 / UTM zone 43N		
EPSG Code	EPSG::32643	
Local Geodetic Datum Parameters		
Datum	World Geodetic System 1984	EPSG::6326
Ellipsoid	WGS 84	
Semi major axis	a = 63,78,137.000 m	
Inverse flattening	1/f = 298.257223563	
Local Projection Parameters		
Map Projection	Transverse Mercator	
Grid System	UTM zone 43N	EPSG::16043
Latitude Origin	00° 00’ 00.000” N	
Central Meridian	075° 00’ 00.000” E	
Scale Factor on Central Meridian	0.9996	
False Easting	500 000 m	
False Northing	0 m	

Scatter Plot

Mean Position

	Easting	Northing
Tripod	3,45,874.266m E	23,36,548.161m N

Time Series Plots for Tripod



FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of DOSVADA DAM TBM2

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	**DOSVADA DAM TBM2**	**Location:**	DOSVADA DAM, Gujarat
Party Chief :	Pritam Seth	**Job Engineer/Surveyor :**	Atul Bhoyte.
Date of Observation: (Date & Time)	20-04-2021 & 16:06hrs	**End of Observation: (Date & Time)**	20-04-2021 & 16:36hrs

1. Station Name: DOSVADA DAM TBM2.

Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
SATIAL DUAL RECEIVER	025-00006405	PRI_DGPS	Mean position report	FBF	NA	0.01

A=Center Point of **DOSVADA DAM TBM2** Height from MSL 126.393m

B= Antenna Height from BM 1.725m (Measure by Tape)

Ellipsoidal height of Antenna= 62.846m

Ellipsoidal Height of BM 62.846 - 1.725m=61.121m

Position Of Antenna:-

Latitude: 21°07’25.018”N, **Longitude:** 073°30’57.263”E

Easting: 3,45,874.421m E**, Northing:** 23,36,548.161m N

Prepared By: Pritam Seth.

BATHYMETRY SURVEY
MEAN POSITION REPORT

Project ID	J-HYD-20-174630-DOSVADA DAM		
Location	DOSVADA, CENTRAL GUJRAT		
Client	GOVERMENT OF GUJRAT	**Vessel**	Tripod
Comment	DOSVADA DAM TBM2 ANT HT 1.725 SD		

Session Name: MPR-20210420094811-v1 Records Used: 1401 of 1799

Start Time: 20 Apr 2021, 16:06:53+05:30 End Time: 20 Apr 2021, 16:36:52+05:30 Session Length: 00:29:59

Mean Position for Tripod CommonReferencePoint		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	21°07’25.01862”N	21°07’25.01862”N
Longitude	073°30’57.26308”E	073°30’57.26308”E
Height	62.846m Ell.	62.846m Ell.
Easting	3,45,874.421m E (SD: ±0.01m)	
Northing	23,36,548.161m N (SD: ±0.01m)	
Height	124.889m Ort. (SD: ±0.04m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	0.00°T 0.00°G	±0.0°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

DOSVADA DAM TBM2 ANT HT 1.725

PRITAM SETH
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Deputy Executive Engineer
DOSWADA DAM
Govt. of Gujrat

Geodetic Parameters

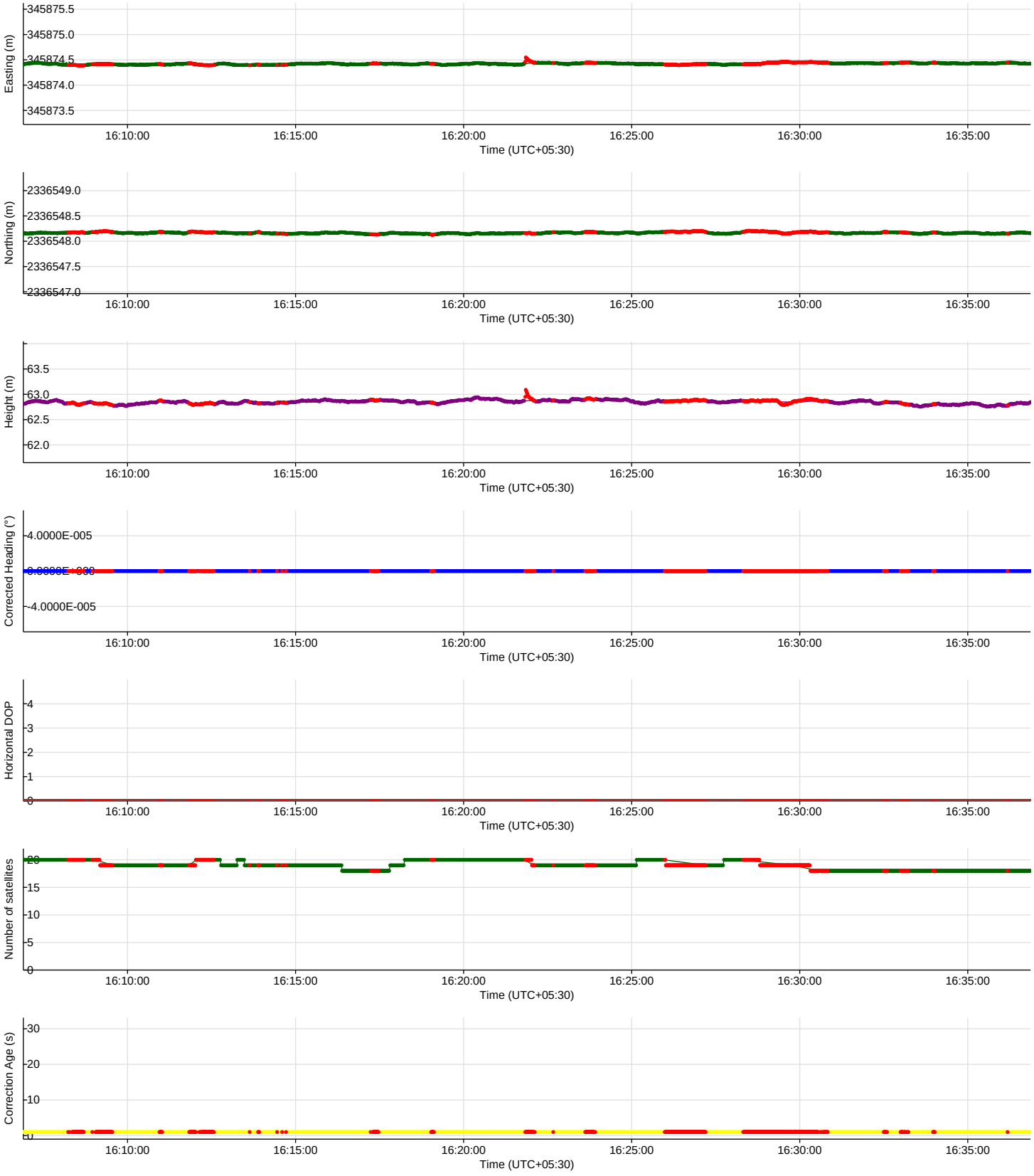
Name : WGS 84 / UTM zone 43N		
EPSG Code	EPSG::32643	
Local Geodetic Datum Parameters		
Datum	World Geodetic System 1984	EPSG::6326
Ellipsoid	WGS 84	
Semi major axis	a = 63,78,137.000 m	
Inverse flattening	1/f = 298.257223563	
Local Projection Parameters		
Map Projection	Transverse Mercator	
Grid System	UTM zone 43N	EPSG::16043
Latitude Origin	00° 00’ 00.000” N	
Central Meridian	075° 00’ 00.000” E	
Scale Factor on Central Meridian	0.9996	
False Easting	500 000 m	
False Northing	0 m	

Scatter Plot

Mean Position

	Easting	Northing
Tripod	3,45,874.421m E	23,36,548.161m N

Time Series Plots for Tripod



Station Name: DOSVADA DAM

Positioning System Verification With BX-992 Reciever and Spatial Dual						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Easting mE**	**Northing mN**	**Latitude**	**Longitude**	**Ellipsoidal height (m)**
TRIMBLE BX992 RECEIVER	025-00009601	345,941.429	2,336,497.587	21°07’23.39446”N	073°30’59.60168”E	62.57
Spatial Dual	025-00006405	345,941.494	2,336,497.560	21°07’23.39359”N	073°30’59.60393”E	62.731
	Difference	**-0.065**	**0.027**	**--**	**--**	**-0.161**

FUGRO

Station Name: DOSVADA DAM

Positioning System Verification With BX-992 Reciever and Spatial Dual						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Easting mE**	**Northing mN**	**Latitude**	**Longitude**	**Ellipsoidal height (m)**
TRIMBLE BX992 RECEIVER	025-00009601	345,874.27	2,336,548.161	21°07'25.01856"N	073°30'57.25770"E	62.698
Spatial Dual	025-00006405	345,874.421	2,336,548.161	21°07'25.01862"N	073°30'57.26308"E	62.846
	Difference	**-0.155**	**0**	**--**	**--**	**-0.148**

SBES Calibration

SBES Barcheck Correction Table

Project No.	Project Title:	Vessel:	Place:
J-HYD-20-174630	**Bathymetry Survey**	**FUGRO ZODIAC**	**DOSVADA DAM**
Date:	Time:	Client:	
21-Apr-21	**18:30**	**GOV. OF GUJRAT**	
Observed By: PRITAM SETH		Echo Sounder Model and SL. No.	Area Depth
Project No. J-HYD-20-174630		**ODOM ECHOTRAC CV 100/ 007169**	**3**

Echo Sounder Settings

Draft HI	Draft LO	Sound Velocity	
		Average	**Upto Depth**
0.32	**0.32**	**1500**	**3**
Barcheck Frequency selected	**Survey Frequency:**	Manufacturer's Accuracy	
High 210 KHz	**33 and 210 KHz**	0.10 % of Depth	0.00 m

Observations while lowering			Observations while hoisting		
Bar Depth (m)	ES Reading (m)	Difference (m)	Bar Depth (m)	ES Reading (m)	Difference (m)
1	0.99	0.01	2.5	2.51	-0.01
2	2.01	-0.01	2	2.01	-0.01
2.5	2.51	-0.01	1	1.01	-0.01

Average	0.00	Average	-0.01
Std. Dev	0.0115	Std. Deviation	0.0000
		Cumulative Average	-0.01
		Cumulative Std. Deviation	0.0082

Partychief
Pritam Seth
FSINPVT

Deputy Executive Engineer
DOSWADA DAM
Govt. of Gujrat

Report No:	Rev No:	Prepared	Checked	Client Rep.
###	0			

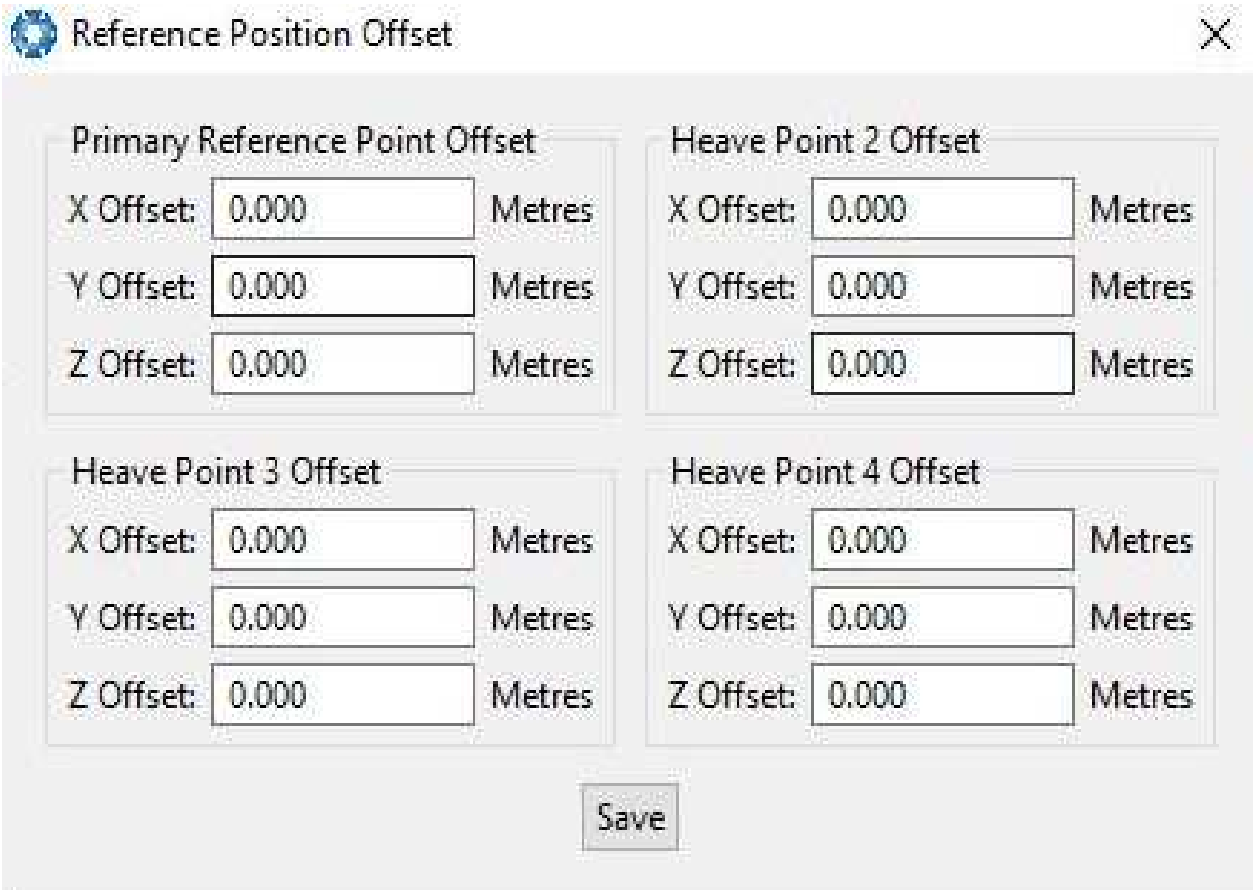
Report on Motion Sensor Calibration at sea by 'Free-Float' Method

Job No:	**J-HYD-20-174630**
Job Title:	**Bathymetric Survey**
Vessel Name:	**Fugro Zodiac**
Client Name:	**Govt. Of Gujarat**

Spatial Dual Set up:-

The instrument was placed on a plain surface Near Single beam Echosunder of the vessel and secured firmly in place.
Instrument has kept for 5 minutes to acquire accurate solution. Spatial Dual's Motion is always on fully automatic.

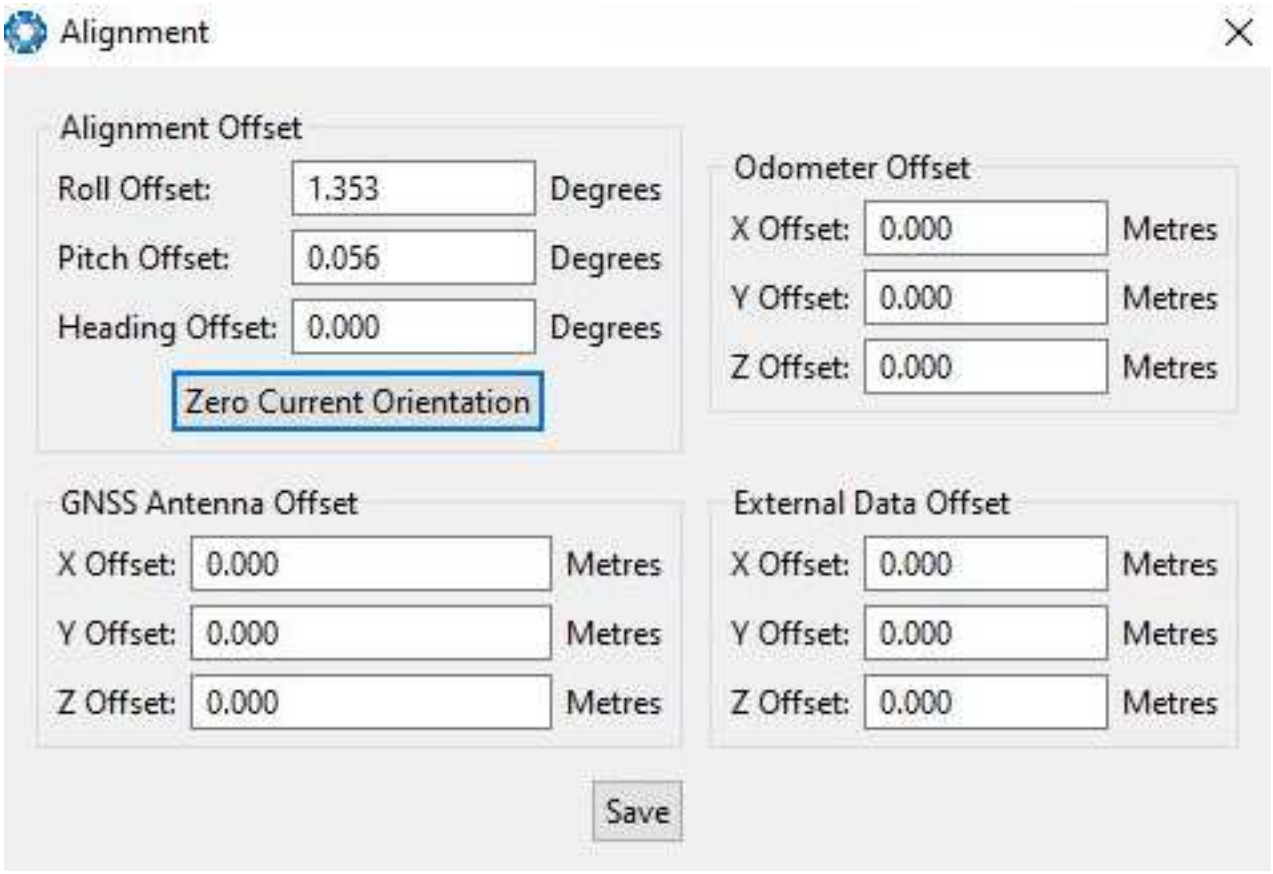
Screen Shot of Spatial Dual Manager software



Calibration by 'Free-Float' Method:-

Spatial Dual Manager Terminal progam was choosen to observe the sensor.
The vessel was then allowed to float freely for 15 minutes and the data output by the motion sensor was observed.

Pre Zero-Orientation Screen Shot of the Spatial Dual Alignment



Spatial Dual Motion has been "Zero-Oriented" by clicking "Zero current Orientation" Option in Spatial Dual manager software.

Pritam Seth
FSINPVT Party Chief
Date: 21/04/2021

Atul Bhoyte
Engineer
Date: 21/04/2021

Location Name:	Doswada Dam	Date:	09/08/2021	Instrument Name	CHC
Work:	RTK Observation by Topography Team			Model no.	I 80

Station Name		Observation Duration	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)	Remarks
TBM-2	By rover 1	2 sec	345874.266	2336548.161	126.393	XYZ Value generated by RTK of Topography Team, Base station was on Doswada Dam TBM-1 (Fugro provided XYZ value)
TBM-2	By rover 2	2 sec	345874.373	2336548.176	126.392	XYZ Value generated by RTK of Topography Team, Base station was on Doswada Dam TBM-1 (Fugro provided XYZ value)
TBM-2	By rover 3	2 sec	345874.374	2336548.187	126.391	XYZ Value generated by RTK of Topography Team, Base station was on Doswada Dam TBM-1 (Fugro provided XYZ value)

		Fugro Provided XYZ Value							Difference With Fugro Provided XYZ Value		
Station Name	Remarks	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)	Station Name	Remarks	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)
TBM-2	Fugro Provided Value	345874.266	2336548.161	126.393	TBM-2	Check by Rover 1	345874.266	2336548.161	126.393	0.000	0.000	0.000
					TBM-2	Check by Rover 2	345874.373	2336548.176	126.392	-0.107	-0.015	0.001
					TBM-2	Check by Rover 3	345874.374	2336548.187	126.391	-0.108	-0.026	0.002

Note: Client has confirmed that Doswada Dam the TOD value(123.44) is from Mean Sea Level, TBM-1 RL value is shifted from TOD(top of dam) of the Dam
Note: Base station was on Doswada Dam TBM-1, TBM-1 value used to setup base (Fugro provided XYZ value), 3 reading taken for 2 sec each on TBM-2 by 3 rovers on pole mounted.

Prepared by Rambabu Sah

Appendix E

Benchmark Descriptions

(3 pages)

Fugro Survey (India) Pvt. Ltd.
D-222/30, TTC Industrial Area,
MIDC, Nerul, Navi Mumbai
Pin - 400 075 (India)

Station / Bench Mark Description

Job No. :	**J_HYD_20_174630**	**Station Name:**
Client :	**Govt. Of Gujarat**	
Location :	DOSVADA DAM	**DOSVADA DAM TBM1**
Observed By:	Pritam Seth,Atul Bhoyte	
Date:	20-04-2021	

Brief Description of the Method Adopted

1. Purpose of Establishing the station :- Ref. Station for Bathymetric Survey of Reservoir and Topography survey.
2. Equipment Deployed :- Trimble BX992 Receiver
3. Method Used :- 30 minutes Mean Position for Tripod Centre Of Gravity

Final Coordinates in WGS84 Datum/UTM zone-43N

GEOGRAPHICAL COORDINATES:		**UTM COORDINATES:**		CM: 75° E
LATITUDE:	21°07'23.39446"N	EASTING:	3,45,941.429m E	σ = +/- 0.01 m
LONGITUDE :	073°30'59.60168"E	NORTHING:	23,36,497.587m N	σ = +/- 0.01 m
ELLIPSOIDAL HEIGHT:	60.840m Ell	CONVERGENCE :	-0.5347 Degrees	
HEIGHT ABOVE LAT/CD:	NA	TBM VALUE:	126.322 w.r.t MSL	

LOCATION & ACCESS : Its established in Entrance rod of Dosvada Dam. 40m from Dam Gate.40m NW side from Old Banyan Tree.

STATION MARKING : DOSVADA DAM TBM1 establised by Fugro. And point is marked with Yellow paint.

Expected durability of the Station (Years) : 05 years

DETAILED DIAGRAM :

Note:-

Coordinates are measured by DGPS observation.
Client hasn't supplied any X,Y Value

Pritam Seth
Party chief (FSINPVT)

Deputy Executive Engineer
DOSVADA DAM
GOVT. OF GUJRAT

Fugro Survey (India) Pvt. Ltd.
D-222/30, TTC Industrial Area,
MIDC, Nerul, Navi Mumbai
Pin - 400 075 (India)

Station / Bench Mark Description

Job No. :	**J_HYD_20_174630**	**Station Name:**
Client :	**Govt. Of Gujarat**	
Location :	DOSVADA DAM	**DOSVADA DAM TBM2**
Observed By:	Pritam Seth,Atul Bhoyte	
Date:	20-04-2021	

Brief Description of the Method Adopted

1. Purpose of Establishing the station :- Ref. Station for Bathymetric Survey of Reservoir and Topography survey.
2. Equipment Deployed :- Trimble BX992 Receiver
3. Method Used :- 30 minutes Mean Position for Tripod Centre Of Gravity

Final Coordinates in WGS84 Datum/UTM zone-43N

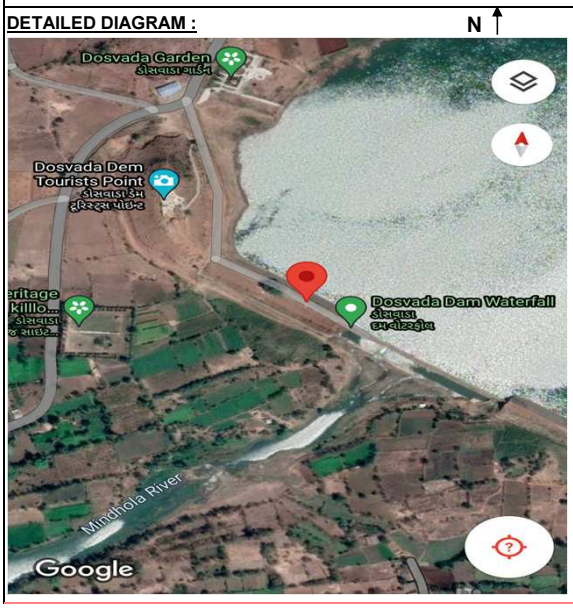
GEOGRAPHICAL COORDINATES:		**UTM COORDINATES:**		CM: 75° E
LATITUDE:	21°07'25.01856"N	EASTING:	3,45,874.266m E	σ = +/- 0.03 m
LONGITUDE :	073°30'57.25770"E	NORTHING:	23,36,548.161m N	σ = +/- 0.01 m
ELLIPSOIDAL HEIGHT:	60.963	CONVERGENCE :	-0.53495 Degrees	
HEIGHT ABOVE LAT/CD:	NA	TBM VALUE:	126.393 w.r.t MSL	

LOCATION & ACCESS : Its established in Entrance rod of Dosvada Dam. 120m from Dam Gate.30m NE side from Old Banyan Tree.

STATION MARKING : DOSVADA DAM TBM2 establised by Fugro. And point is marked with Yellow paint.

Expected durability of the Station (Years) : 05 years

DETAILED DIAGRAM :



Note:-

Coordinates are measured by DGPS observation.
Client hasn't supplied any X,Y Value

Pritam Seth
Party chief (FSINPVT)

Deputy Executive Engineer
DOSVADA DAM
GOVT. OF GUJRAT

LEVELLING RECORD FROM FRL DOSWADA DAM TO ALL TBM POINTS

Job No :	J-HYD-20-174630	Client Name :	GOVT. OF GUJARAT
Levelling Equpt Used:	AUTO LEVEL	Equipment Serial/Asset No:	256726
Area/Location Name:	DOSWADA DAM	Date of Observation:	21/04/2021
Observer's Name:	Pritam Seth	Staff Holder's Name:	Atul Bhoyte

TOP OF DAM TBM TO DOSWADA DAM TBM1

BACK SIGHT	FORE SIGHT	RL Value	Point Name
		123.44	TOP OF DAM
3.755	0.873	126.322	DOSWADA DAM TBM1
0.864	3.746	123.44	TOP OF DAM
Miscloser value	0		

DOSWADA DAM TBM1 TO DOSWADA DAM TBM2

BACK SIGHT	FORE SIGHT	RL Value	Point Name
		126.322	DOSWADA DAM TBM1
1.492	1.421	126.393	DOSWADA DAM TBM2
1.424	1.495	126.322	DOSWADA DAM TBM1
Miscloser value	0		

NOTE-	TOP OF DAM Value 123.44m/405.00ft w.r.t MSL Provided by Client
	DOSWADA DAM TBM1 Value 126.322m. Established by Fugro.
	DOSWADA DAM TBM2 Value 126.393m. Established by Fugro.

PRITAM SETH
PARTY CHIEF
FSINPVT

Deputy Executive Engineer
DOSWADA DAM
GOVT. OF GUJRAT

Appendix F

List of Charts

(1 page)

List of Reports / Documents to be Submitted

Sr. No.	Type of Report / Document	Reporting Schedule	No. of Copies (Hard)	Remarks
1	Survey Procedure (QA Document)	01 December 2020	1	Submitted
2	Mobilisation Report (With Results of Calibration)	26 October 2020	--	Fugro Office copy only
4	Draft Report	30 days from completion of survey	1	Submitted
5	Final Report on Survey	1 week from receipt of client's comments	10	**This document**

Details of Charts Accompanying this Report

Details of Charts							
Sl. No.	Charts showing Results of Bathymetry and Topography Survey at Doswada Reservoir	Sheet No.	Encl. No.	Drawing No.: JHYD-20-174630/WRD/GUJARAT/BS/	Rev. No	HS	VS
1	Reservoir Bed and Topographic Heights	01 of 01	01 of 03	B/01/9627	0	1:2000	-
2	Contour Map of Doswada Reservoir	01 of 01	02 of 03	B/01/9701	0	1:2000	-
3	Shaded Relief Image Prepared from SBES Data	01 of 01	03 of 03	I/01/9702	0	1:2000	-
Details of Other Deliverables							
1	L-section	Soft copy					
2	C-section at every 100 m	Soft copy					