उपग्रह दूरस्थ संवेदन द्वारा
घटप्रभा (हिडकल) जलाशय, कर्नाटक का अवसादन आंकलन

SEDIMENTATION ASSESSMENT OF GHATAPRABHA (HIDKAL) RESERVOIR, KARNATAKA, THROUGH SATELLITE REMOTE SENSING

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Government of India
Central Water Commission
Environment Management Organization
Remote Sensing Directorate

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Year of Survey 2014
Data Used 2012- 2014

STUDY TEAM

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EXECUTIVE SUMMARY

The dynamic aspects of the reservoir, mainly water spread, suspended sediment distribution and concentration requires periodical mapping and monitoring. Sedimentation in a reservoir has a bearing on the capacity of the reservoir as it affects both live and dead storages. In other words, the life of a reservoir depends on the rate of siltation. The satellite data provides opportunity to study these aspects on various scales and at different stages. The present report comprises of use of satellite remotely sensed data for the years 2012-14 in the sedimentation study of Ghataprabha reservoir. The various aspects of the reservoir sedimentation, like the process of sedimentation in the reservoir, sources of sediment, measures to check the sediment and limitations of space technology have been discussed in the report.

Multi-date satellite remote sensing data provide information on elevation contours in the form of water-spread area. Any reduction in reservoir water spread area at a specified elevation corresponding to the date of satellite data is indicative of sediment deposition. The quantity of sediment load settled down over a period of time can thus be determined by evaluating the change in the aerial spread of the reservoir at various elevations.

The original gross and live storage capacities were 1434.136 MCM & 1307.827 MCM respectively. As per Reservoir Sedimentation Dte, CWC report, Ghataprabha reservoir project work was completed in 1974 and Hydrographic Sedimentation surveys were conducted during 1974 and 2000 for this reservoir. The live storage capacity was estimated as 1228.817 MCM by Tojo-Vikas International (Pvt.) Ltd. New Delhi in 2000.

After analysis of the satellite data in the present study, it is found that live capacity of the Ghataprabha reservoir in 2014 is 1232.46 MCM witnessing a loss of 75.37 MCM (i.e. 5.76%) in a period of 53 years during 1974 to 2013. This accounts for live capacity loss of 0.144% per annum since 1974.

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ABBREVIATIONS

DSL	Dead Storage Level
FCC	False Colour Composite
FRL	Full Reservoir Level
IRS	Indian Remote Sensing
LISS	Linear Imaging Self Scanner
MDDL	Minimum Draw Down Level
MSL	Mean Sea Level
MWL	Maximum Water Level
NIR	Near Infra-Red
NRSA	National Remote Sensing Agency
SRS	Satellite Remote Sensing
N.A.	Not Available
NDVI	Normalised Difference Vegetation Index
WSA	Water Spread Area

UNITS USED

cumec	cubic metre per second
m	metre
million m^2	million square metre
million m^3 /MCM	million cubic metre
ha	hectare
Sq Km	Square Kilometre
mm/year	millimetre per year

SEDIMENTATION ASSESSMENT OF GHATAPRABHA RESERVOIR, KARNATAKA THROUGH SATELLITE REMOTE SENSING

1 INTRODUCTION

Water is a scarce resource and is becoming even scarcer with the time. It is estimated that annual precipitation over India is 4000 BCM out of which available water is 1869 BCM. Utilizable water resources account for 1123 BCM only. Out of 1869 BCM available water resources, India has developed 253 BCM as live storage capacity and 51 BCM is under construction. For sustaining the needs of increasing population and environmental ecological needs of the country, we are fast approaching the scarcity situation even when we account for water availability and requirements in totality for the country as a whole. Out of total utilizable water resources about 690 BCM of surface water and 450 BCM of ground water per year is available for use through conventional structures. The country has 20 major river basins. A large number of reservoirs have been built during each plan on almost all river basins to tap the available surface water and to utilize it as and when needed.

The country is mainly dependent on the rainfall, which is most erratic in nature. However, 50% of the total utilizable surface water has been harnessed by way of constructing large, medium and small dams till date. Due to unfavourable distribution of fresh water both in time and space, storage reservoirs are effective tools for eliminating the discrepancies in time variations of the requirement and resources. Storage reservoirs play a vital role in serving long-term benefits in many ways. The reservoirs serve the purpose of water supply, irrigation, hydropower generation, flood control, recreation and various other purposes.

All our developmental plans have given high priority to water resources projects involving construction of dams and a large number of dams have been constructed since independence. The capacity of reservoirs is gradually reducing due to silting and hence sedimentation of reservoir is of great concern to all the water resources development projects.

Correct assessment of the sedimentation rate is essential for assessing useful life of the reservoir as well as optimum reservoir operation schedule. Since 1958, when it was established that the live storage of reservoir is getting reduced due to siltation, a systematic effort has been made by various departments / organizations to evaluate the capacity of reservoirs. Various techniques like boat echo sounder, etc. being replaced by hydrographic data acquisition system (HYDAC) and HITECH method using Differential Global Positioning System (DGFS). The conventional techniques are found either time consuming or costly and require considerable manpower. Remote sensing technique to calculate the present capacity of reservoir is found to be very useful in this context due to its synoptic and repetitive coverage. The surveys based on remote sensing data are faster, economical and more reliable.

These surveys will enable selection of appropriate measures for controlling sedimentation along-with efficient management and operation of reservoirs thereby deriving maximum benefits for the society.

This report covers the study of Ghataprabha reservoir, Madhya Pradesh by Central Water Commission, New Delhi.

2. MECHANISM OF SEDIMENTATION

In order to obtain the knowledge of sedimentation in the reservoir, it is necessary to study the mechanism of sedimentation, which will help to mitigate reservoir sedimentation, prolong the life span of reservoirs and to take full benefits of reservoirs. The sediment deposition in a reservoir depends on the following:
Longitudinal and lateral valley shape
Length and shape of reservoir
Flow patterns in reservoir
Capacity to inflow volume ratio (trap efficiency)
Grain size distribution of sediment
Water and sediment discharges
Mode of reservoir operation
Nature of incoming floods

Characteristics of reservoir sedimentation include amount, distribution, configuration and composition of reservoir deposits. As water enters a reservoir, its velocity diminishes because of the increased cross sectional area of the channel. If the water stored in the reservoir is clear and the inflow is muddy, the two fluids have different densities and the heavy turbid water flows along the channel bottom towards the dam under the influence of gravity (Fig. 1). This condition is known as "stratified flow" and the underflow is called a "density current". In a general sense, a density current may be defined as a gravity flow, a fluid under, over, or through a fluid or fluids of approximately equal density. From Fig. 1 It may be seen that the depth of the turbid flow increases to the point where the density current is established after which it tends to decrease again (Varshney, 1997).

The magnitudes of these relative change and their effects upon sediments deposition depend on many factors such as reservoir shape, channel slopes, relation of outflow to inflow and density differences. As a rule, however, conditions are such that density currents move very slowly. In many respects deposits in a reservoir resemble those in a delta, made by stream where it discharges into a lake or sea. The deposits are (i) bottom set beds consisting of the fine sediments brought in by the stream, (ii) the forest beds formed of the coarser sandy sediments, (iii) top set beds consisting of coarser particles and (iv) density current deposits.

The sedimentation is a product of erosion in the catchment areas of the reservoir and hence lesser the rate of erosion, smaller is the sediment load entering the reservoir. Various factors govern the erosion, transport and deposition of sediment in the reservoir. Type of soil, drainage density, vegetation, rainfall intensity and duration, shape of catchment and land use /land cover affect the erosion. Sediment transportation depends upon slope of the catchment, channel geometry and nature of riverbank and bed. Deposition is a function of bed slope of the reservoir, length of reservoir, flow patterns, inflow - outflow rates, grain size distribution, mode of reservoir operation, etc.

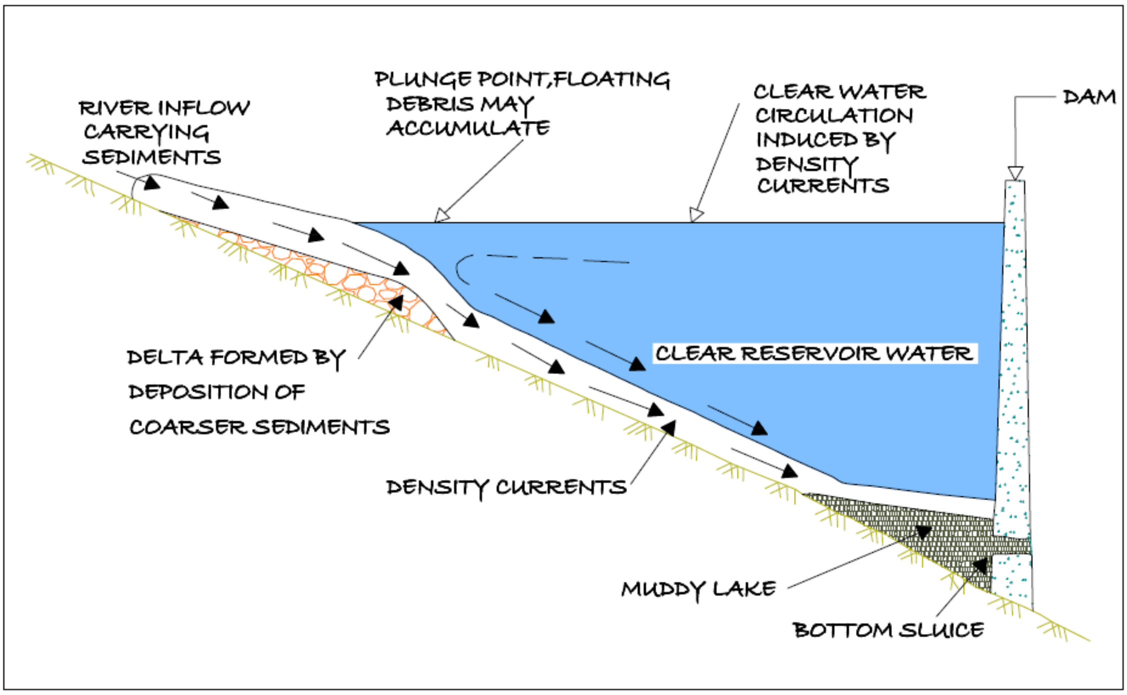


Fig. 1: Conceptual sketch of density currents in a reservoir

Earlier it was believed that sediment always gets deposited in the bottom elevations of reservoir affecting the dead storage rather than depositing throughout the full range of reservoir depth. It is now fully realized that deposition takes place throughout the reservoir reducing the incremental capacity at all elevations.

Longitudinal deposition patterns in the reservoir will vary from one reservoir to another as influenced by pool geometry, discharge and grain size characteristic of the inflowing load and reservoir operation. There can be four types of depositing patterns in the reservoir as shown in the fig 2.

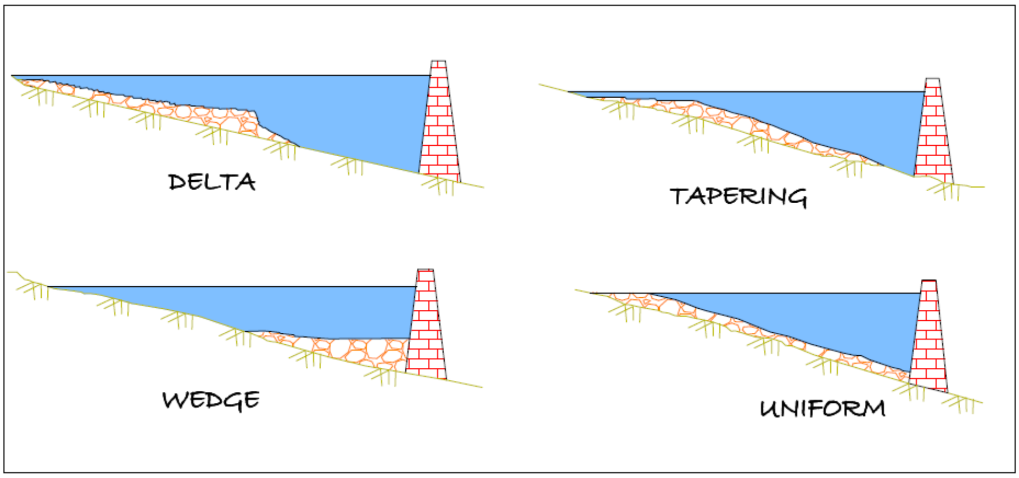


Fig. 2: Longitudinal Patterns of sediment deposition in reservoirs.

Delta deposits contain the coarsest fraction of the sediment load, which is rapidly deposited at the zone of inflow. It may consist entirely of coarse sediment or may also contain a large fraction of finer sediment such as silt. Wedge-shaped deposits are thickest at the dam and become thinner moving upstream.

This pattern is typically caused by the transport of fine sediment to the dam by turbidity currents. Wedge- shaped deposits are also found in small reservoirs with a large inflow of fine sediment, and in large reservoirs operated at low water level during flood events, which causes most sediment to be carried into the vicinity of the dam. Tapering deposits occur when deposits become progressively thinner moving toward the dam. This is a common pattern in long reservoirs normally held at high pool level, and reflects the progressive deposition of fines from the water moving toward the dam. Uniform deposits are unusual but do occur. Narrow reservoirs with frequent water level function and small load of fine sediment can produce nearly uniform deposition depths. Several factors like amount of sediment load, size distribution, fluctuations in stream discharge, shape of reservoir, stream valley slope, vegetation at the head of the reservoir, location and size of reservoir, outlets, etc., control the location of sediment deposits in the reservoir.

Figure 3 shows different levels in the reservoir where-in the capacity is affected. Reservoirs operate between Minimum Draw Down Level (MDDL), which is at sluice level to Full Reservoir Level (FRL), which is at dam level. The storage between these two levels is the live storage as shown in Fig. 3. The storage below MDDL is the dead storage. Water stored along the valley bed is known as valley storage.

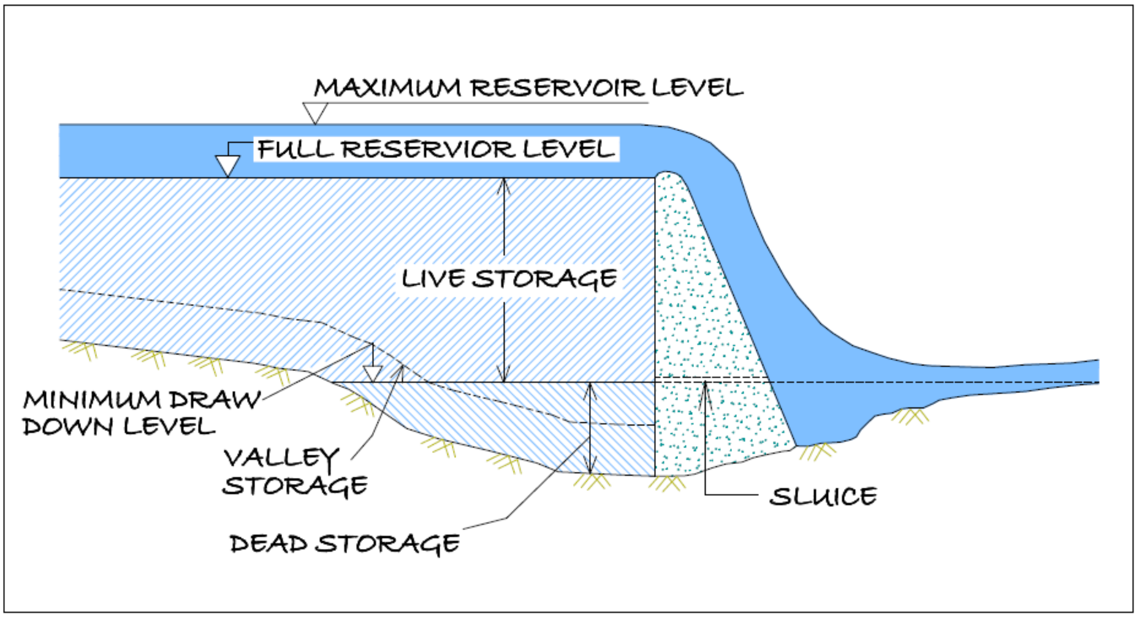


Fig. 3: Conceptual sketch of different levels in a reservoir

3. SOURCES OF SEDIMENTS

The principal sources of sediments are as follows:
Deforestation
Excessive erosion in the catchment
Disposal of industrial and public wastes
Farming
Channelisation works
Human activities
Land development, highways, and mining

4. CONTROL OF SEDIMENTATION

Due to the multiple variables involved in reservoir sedimentation, no single control measure can be considered as the most effective. The measures, which can be employed to limit sedimentation and turbidity, are as under:
Soil and water conservation measures within the drainage basin, contour ploughing, strip cropping, suitable farming practices, improvement of agricultural land, construction of small dams/ponds/terraces/check dams on gullies
Revetment and vegetation cover
Evacuation of sediment
Reservoir shoreline protection
Stream bank and flood plain protection
Ridge plantation such as pasture development and reservoir shoreline protection

Silting not only occurs in the dead storage but also encroaches into the live storage zone, which impairs the intended benefits from the reservoirs. Therefore, the problem of sedimentation needs careful consideration. Adequate provision has to be made in the reservoir for accumulation of anticipated quantities of silt. Steps are also required to be taken to ensure that the storage capacities available are not lost or get reduced by accelerated sedimentation.

5. REMOTE SENSING IN RESERVOIR SEDIMENTATION

Remote sensing is the art and science of collecting information about earth's feature without being in physical contact with it. Various features on earth surface reflect or emit electromagnetic energy depending upon their characteristics. The reflected radiation depends upon physical properties of the terrain and emitted radiation depends upon temperature and emissivity. The radiations are recorded by the sensor on-board satellite and then are transmitted back to earth. Difference between features depends on the fact that response from different features like vegetation, soil, water is different and discernable. Data received at ground stations, is digitally or visually interpreted to generate thematic maps.

The data from satellites such as Landsat, SPOT and IRS are more useful for mapping and monitoring the surface water bodies and other land resources based on which, better water management strategies could be planned. Water is one of the most easily delineable features on the satellite data due to high contrast between land and water bodies in NIR band. Water absorbs all the incident energy in NIR region depending upon nature and status of water body. Land features reflect more energy in NIR region. The Figure 4 shows the reflectance curves for clear and turbid water categories.

Spectral response of water is affected by variables like time of the year, sun elevation angle, water vapour content in the atmosphere, roughness of water surface, water colour, turbidity, type and concentration of suspended particles, depth of water, characteristics of bottom material and submerged or emergent vegetation.

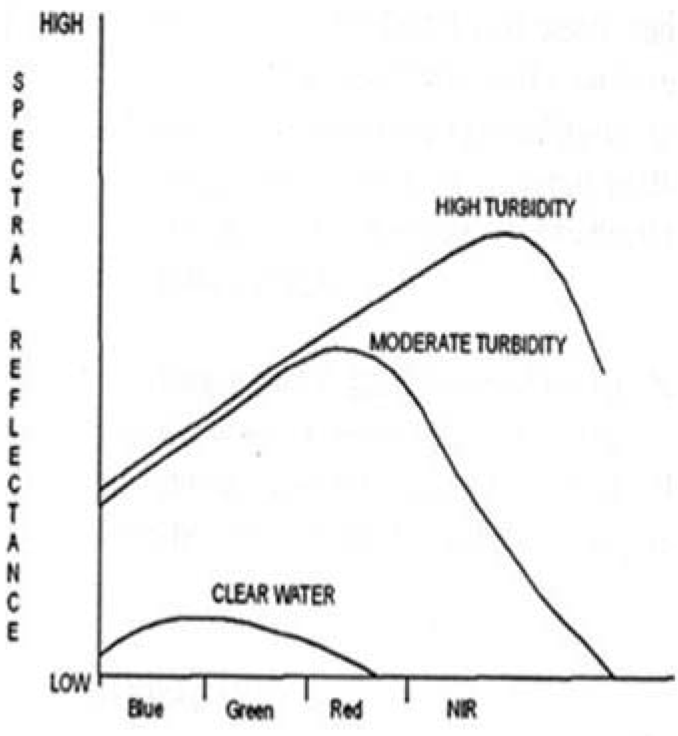


Fig. 4: Reflectance curves for Clear and Turbid water

Reservoir sedimentation surveys are essentially based on mapping of water-spread area at the time of satellite over pass. Multi-date satellite data is needed which covers the operating level of reservoir at close interval. Water spread area is nothing but water level contour at that level. Using different contours, capacity between them is calculated. With the sedimentation, the water spread area of the reservoir reduces at different levels. The water spread area and the elevation information is used to calculate the volume of water stored between different levels. These capacity values are then compared with the previously calculated capacity values to find out the change in capacity between different levels.

Remote Sensing based reservoir capacity estimation has certain limitations. The capacity estimation works between MDDL and FRL only as these are the levels between which reservoir operates. Thus changes can be estimated only in live capacity of reservoir. For capacity estimation below MDDL corresponding to dead storage other methods like hydrographic survey are to be used. Availability of cloud free data throughout reservoir operations also poses limitation in the analysis. This is overcome by combining data from different water years to get full operative range. This technique gives accurate estimates for fan shaped reservoir where there is a considerable change in water spread area with change in water level.

6. OBJECTIVES

The objective of the study is to estimate live capacity loss of Ghataprabha reservoir due to sedimentation through Satellite Remote Sensing. Following objectives will be achieved in the study.

a. Updation of Elevation - Area - Capacity curve using satellite data in live storage zone.

b. Estimation of storage loss due to Sedimentation

7. STUDY AREA

The Ghataprabha river with its main tributaries viz., the Hiranyakeshi, the Taamraparani, the Markandeya is one of the principal rivers of the northern part of the Karnataka state. It is one of the major inter-state tributaries of the Krishna river. At present, there are two major/medium irrigation schemes in the basin. These projects are the Ghataprabha Stage -1 and Ghataprabha Stage – 2. As a part of Ghataprabha Stage – 2, The dam at Hidkal was conceived for providing storage requirements for the entire Ghataprabha Valley by a single storage reservoir. The project was finally taken up for implementation in 1960 as a multipurpose project with benefits of irrigation and hydropower generation and completed in stages. The project consists of a composite dam across the river Ghataprabha near Hidkal village (reservoir is named after this village), about 19km upstream of Dhupdal weir. The dam is 8841m long and 53.35m in height. The original gross storage capacity of the reservoir was around 1434.136 MCM. The canal system on both banks of the river, taking off from the dam provide irrigation in districts of Belgaum and Bijapur. The head available at Hidkal dam and the irrigation releases are used for power generation at the dam Power House on the right bank. Power house has installed capacity of 32 MW. The index map of the reservoir is shown in Figure – 5.

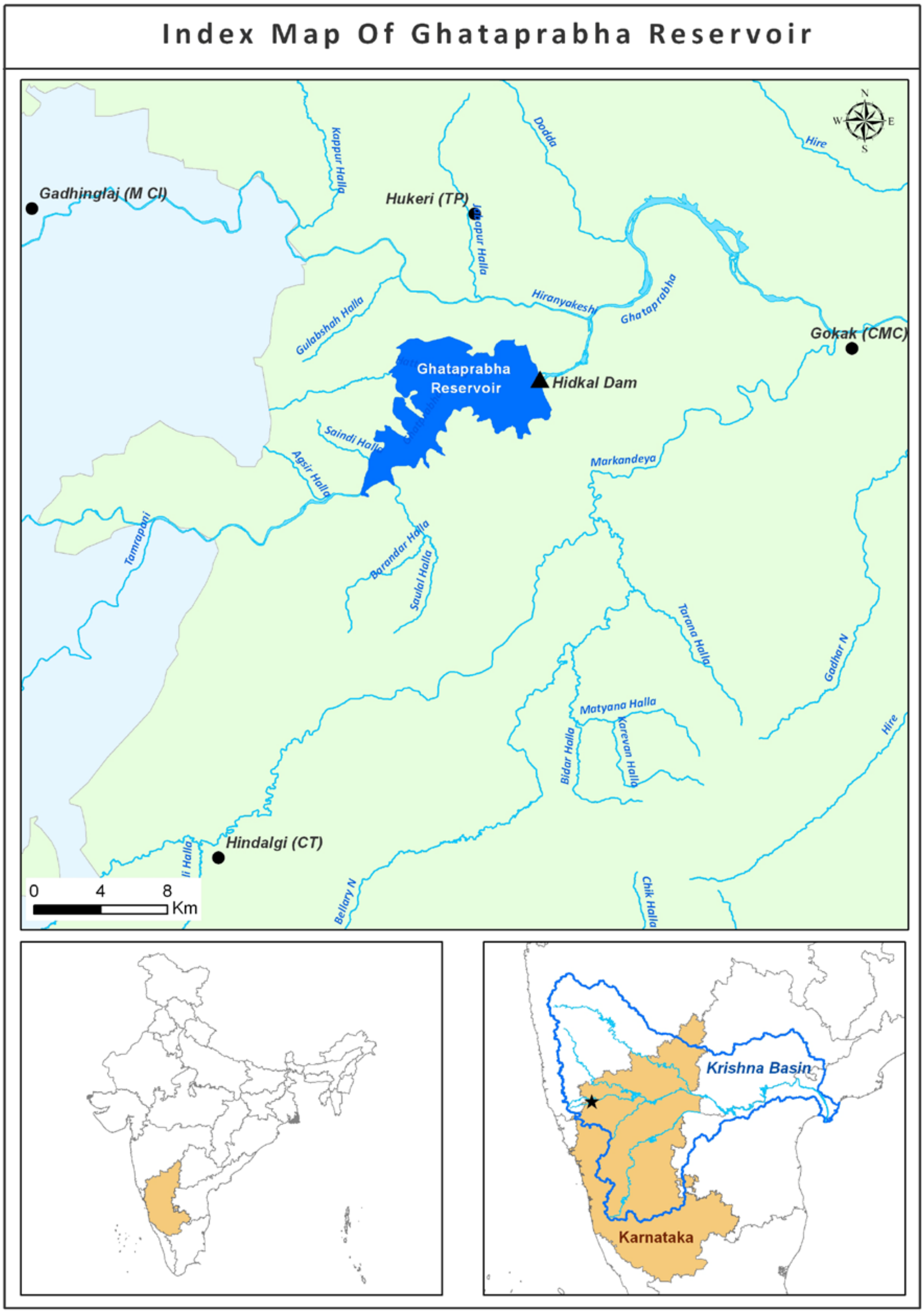


Fig. 5: Index map of the Ghataprabha Reservoir

8. PREVIOUS SURVEYS

Gross storage capacity of Ghataprabha reservoir was originally assessed as 1434.136 M. cum, with full reservoir level which is same as Maximum Water Level, at 662.940 m. In all subsequent publications, above gross storage is considered as original gross capacity.

The first impoundment of the reservoir took place in 1974 and since then reservoir studies have been carried by satellite imagery in 1989 and 1996. A hi-tech hydrographic and topographic surveys was done in 2000 by Tojo-Vikas International (Pvt). Ltd. which estimated the total sedimentation upto 2000 A.D. at 115.524 M.Cum. upto FRL. According to that report, the gross capacity has reduced 8.1% in 26 years from 1434.136 M.Cum to 1318.612 M.Cum. The live storage above MDDL was 1228.817 M.Cum.

The surveys conducted by various methods from time to time have indicated progressive reduction of storage capacity as under :

Period of Project	Planning Stage	Gross capacity (M. Cum)	Live Storage Capacity above MDDL (M.Cum)	Storage Capacity at MDDL (M.Cum)
1974	Original Survey	1434.136	1307.827	126.309
1989-90	Satellite Imageries Analysis	1343.50	1243.671	99.869
1996-97	Satellite Imageries Analysis	1327.618	1232.763	94.855
2001	Hydrographic & Topographic Survey	1318.612	1228.817	89.795

Dead Storage provision of 68 MCum has been made at the planning stage with Dead Storage level at RL 629.070 m. Entire provision for sedimentation was made in the dead storage zone exclusively provided upto RL 629.07 m. Minimum drawdown level has been kept at 633.292 m.

9. APPROACH FOR PRESENT STUDY

Remote Sensing technique makes use of water-spread of the reservoir between maximum and minimum operating level during the observation period. Since the reservoir levels generally do not go below the MDDL, water spread observations are not possible below MDDL. The same are to be extrapolated from observed elevation-area curve to find out capacity below MDDL. In the case of Ghatprabha reservoir, the height difference between FRL (662.94 m) and MDDL (633.292 m) is 29.648 m and the use of satellite remote sensing in the present study has been restricted in live storage.

10 DATA USED

10.1. SATELLITE DATA

IRS P6- LISS III data for eight (08) dates has been used in the analysis. Table 1 depicts the Path and Row index along with date of pass of satellite.

Table – 1: Date of pass for satellite data

Satellite	Path	Row	Shift	Date of pass	Elevation (m)
IRS-P6 LISS III	96	61	50%	09th Nov, 2014	661.705
IRS-P6 LISS III	96	61	50%	19th Nov, 2012	658.65
IRS-P6 LISS III	96	61	50%	13th Dec, 2012	653.96
IRS-P6 LISS III	96	61	50%	06th Jan, 2013	651.42
IRS-P6 LISS III	96	61	50%	30th Jan, 2013	647.65
IRS-P6 LISS III	96	61	50%	25th Jan, 2014	640.47
IRS-P6 LISS III	96	61	50%	18th Feb, 2014	638.20
IRS-P6 LISS III	96	61	50%	07th Apr, 2014	635.60

10.2. FIELD DATA

The following field data has been obtained from project authorities:
Elevation – Area - Capacity data (Original and 2000 survey)
Salient features of Ghataprabha reservoir, reservoir levels on specified dates

11. METHODOLOGY

Digital analysis has an edge over visual analysis in identifying water spread and turbidity levels in detail and more accurately because of minimizing human error or subjectivity. Digital image analysis using Image Processing System on computer mainly, edge enhancement ratios (B/NIR. B/R, R/G), principle component (PC) and classification were found very good for mapping water spread, turbidity levels and surgical aquatic vegetation. For Ghataprabha reservoir studies, multi-date IRS– P6 LISS III data (08 nos. imageries) is used for the analysis. Image processing with ERDAS imagine software was used for the analysis. The analysis comprised,

- Data base geo-referencing.
- Water spread area estimation.
- Estimation of reservoir capacity.
- Comparison with previous surveys.

The methodology adopted in this analysis is shown in the flow chart (Fig6).

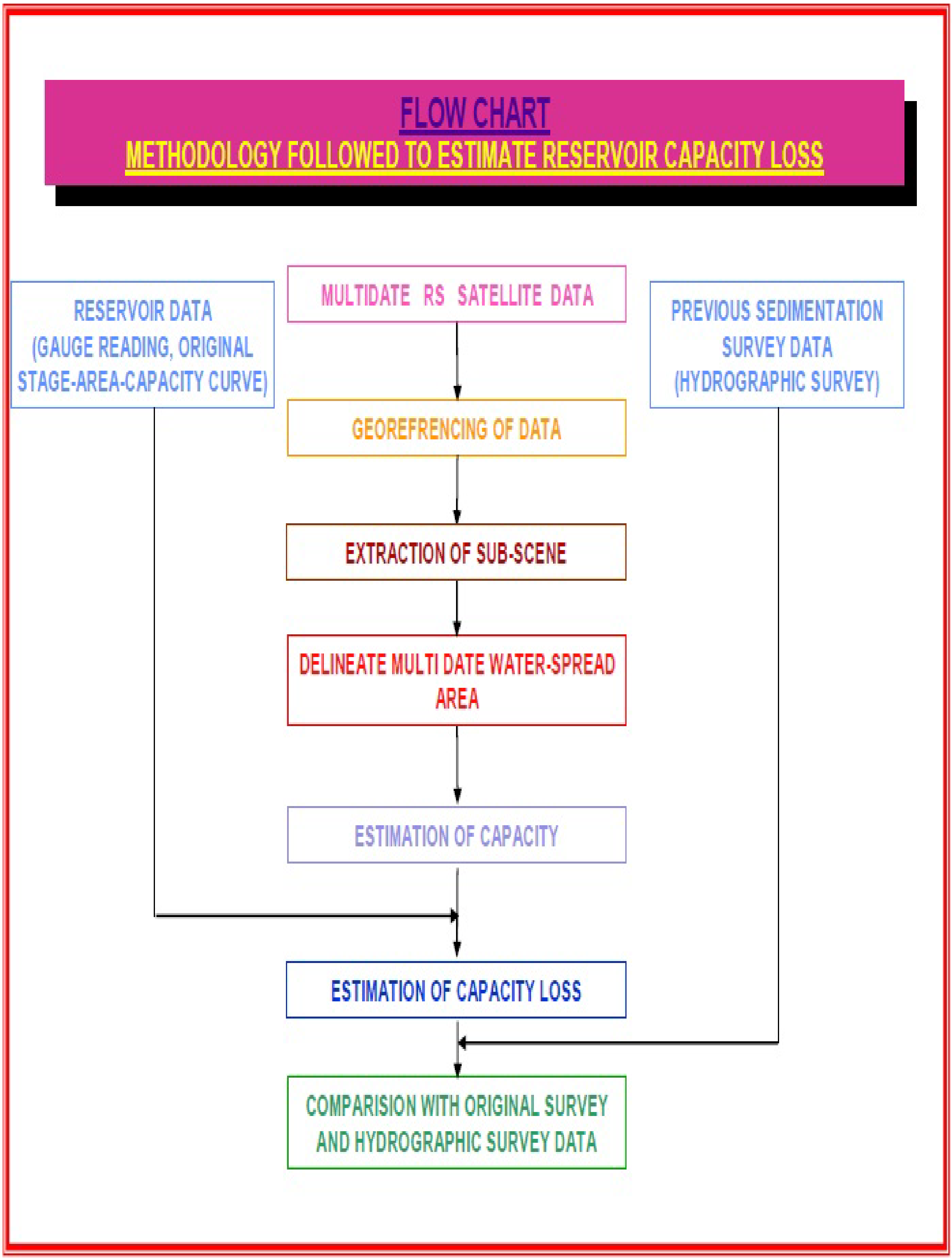


Fig 6 : Flow chart showing methodology followed to estimate reservoir capacity loss

11.1. DATA BASE GEO-REFERENCING

The satellite data corresponding to reservoir area obtained from NRSC DATA CENTRE was loaded on the system. The scene of 19th Nov, 2012 was taken as reference image for all other seven images for geo-referencing using image-to-image registration techniques. The geo-referenced images for all eight different dates pertaining to study area were used for further analysis.

11.2. WATER SPREAD AREA ESTIMATION

Reduction in capacity of reservoir at different levels is depicted by reduction in water-spread area (WSA) at different water levels. Estimation of water-spread area is done using various digital image processing (DIP) techniques. Various techniques adopted for water-spread area estimation are as follows:

- Generation of False Color Composite (FCC) and analysis of histogram
- Thresholding and modeling

11.2.1. GENERATION OF FCC AND ANALYSIS OF HISTOGRAM

FCC is generated from three spectral bands of satellite data, generally NIR, Red and Green bands, where water features appear in shades of black and blue depending upon depth and turbidity. Histogram, which is graph between grey values and the frequency of occurrence, is plotted for individual bands. NIR band information is more useful in identification of WSA. The spectral separability between features is more in NIR band. The water pixels are identified and range of grey values is recorded. Under normal conditions when there is no effect of cloud and shadow, water generally occupies lower range of histogram.

11.2.2. THRESHOLDING AND MODELLING

The areas where clear water/ land demarcation is there, density slicing is successfully used for delineation of water spread areas. Density slicing is a technique where the entire grey values of pixels occurring in the image are divided into a series of analyst specified intervals. All the grey values falling within a range are grouped in one grey value, which is displayed in output. This process divides the image into water and land pixels. From the study of histogram peaks, minimum and maximum value for water pixels is identified and image is then density sliced. Thresholding can be performed on single and or combination of bands. Band ratioing is the technique of enhancing a particular feature or class from the satellite data. Different ratio indices are available to enhance water, vegetation, soil etc. Normalised Difference Vegetation Index (NDVI) is one such index, which enhances vegetation and water.
For estimation of water spread area of Ghataprabha reservoir, use of NDVI has been made. NDVI has been generated using 8-Bit unsigned channel with the help of formula given below:

$$NDVI = (NIR - R) / (NIR + R)$$

Where 'NIR' is digital number in near infrared band and 'R' is digital number in red band. The rationed image is then density sliced. Water pixels generally occupy lower range of histogram in ratioed image.

Table 2 shows Range of NDVI (digital number) for water body delineated and noted for different imageries of Ghataprabha Reservoir as per date of pass.

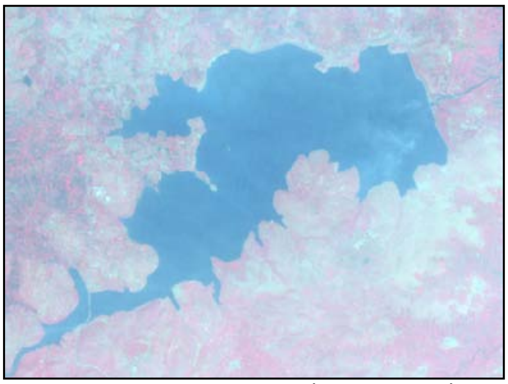
Table – 2: Range of NDVI for satellite data

Date of pass	Range of NDVI (Threshold values)	
	Minimum	**Maximum**
09th Nov, 2014	-0.176251	-0.0458555
19th Nov, 2012	-0.430462	-0.0869994
13th Dec, 2012	-0.519903	-0.162136
06th Jan, 2013	-0.388832	-0.198583
30th Jan, 2013	-0.40118	-0.207317
25th Jan, 2014	-0.460938	-0.179688
18th Feb, 2014	-0.420616	-0.191803
07th Apr, 2014	-0.351563	-0.171875

Using the above range of values, Water spread areas are extracted for all the scenes. Figure 7 shows FCC's of different dates and figure 8 shows the superimposed reservoir water spreads for different dates. Water spread area has been calculated by multiplying number of pixels with area of each pixel (24m x 24m). The water-spread area estimated from Satellite Images for different dates corresponding to the levels are shown in Table 3.

Table – 3.: Water Spread Areas estimated from Satellite Images

Date of pass	**Elevation (m)**	**Area (Million m^2)**
09th Nov, 2014	661.705	69.510
19th Nov, 2012	658.65	63.065
13th Dec, 2012	653.96	53.310
06th Jan, 2013	651.42	48.405
30th Jan, 2013	647.65	40.080
25th Jan, 2014	640.47	32.121
18th Feb, 2014	638.20	27.716
07th Apr, 2014	635.60	23.220



09-Nov-2014 (661.705m)

19-Nov-2012 (658.65m)

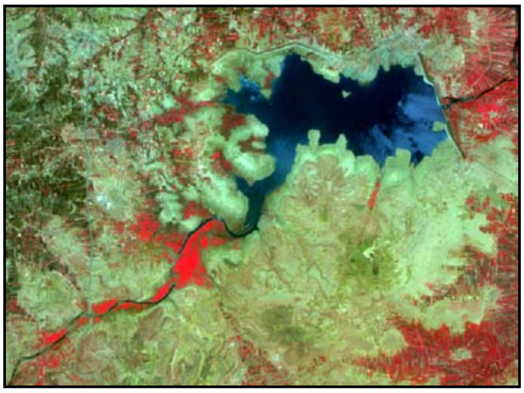
13-Dec-2012 (653.96m)

06-Jan-2013 (651.42m)

30-Jan-2013 (647.65m)

25-Jan-2014 (640.47m)

18-Feb-2014 (638.20m)



07-Apr-2014 (635.60m)

Fig 7 : False Colour Composites(FCCs) showing water spreads at different dates

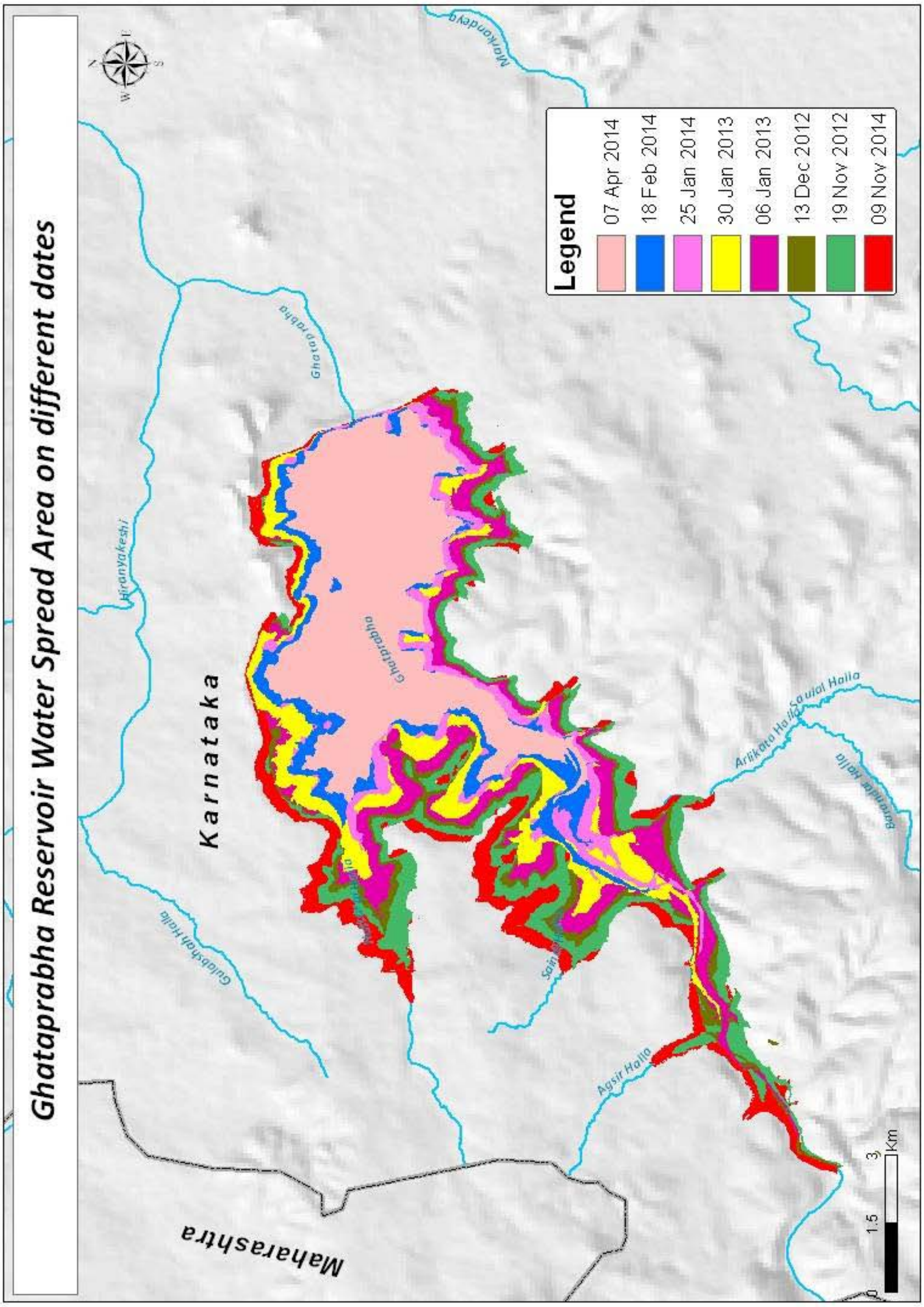


Fig. 8: Ghataprabha Reservoir Water Spread Area on different dates

The water elevation 661.705m for 09th Nov, 2014 is near the Full Reservoir Level (FRL) of 662.94 and water elevation 635.60m for 07th April, 2014 is well above the Minimum Draw Down Level (MDDL) of 633.292 m.

11.3. Estimation of Reservoir Capacity

Area elevation curve has been plotted using these above eight (08) water-spread areas for different water level in the reservoir and a best-fit polynomial equation of second order as given below has been derived.

Y = 0.0081*X^2 – 1.7052 * X + 13.93

R^2 = 0.9993

Where X is Elevation in meters

Y is Water Spread Area in Million m^2

Elevation - area curve using this equation has been plotted and shown in Fig-9. Water spread areas derived from satellite data for various dates are also marked on the curve.

Computation of the reservoir capacity at various elevations was made using following formula

V = h/3{A1+A2 + sqrt. (A1*A2)}

Where,

'V' is the reservoir capacity between two successive elevations h1 and h2,

'h' is the elevation difference (h1-h2),

'A1 & A2' are areas of reservoir water spread at elevations h1 & h2.

Table 4 gives the values of Live storage capacity and submergence areas at a regular interval of 2.0 m have been worked out using this best-fit polynomial equation at different elevations.

The modified elevation – area –capacity curves are plotted and shown in Fig-11.

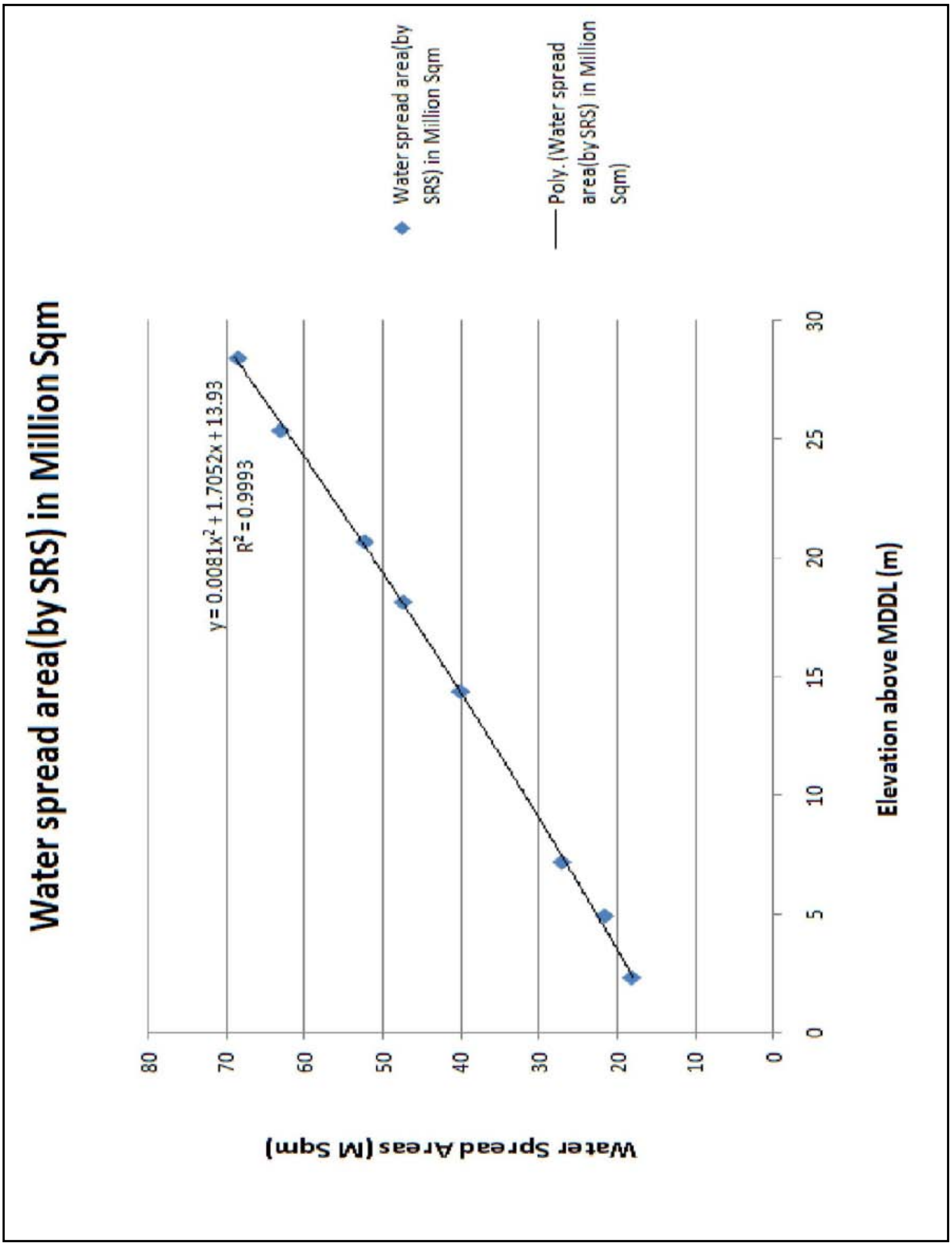


Fig. 9: Water spread Area of Ghatprabha Reservoir

Table-4: Aerial extent of reservoir at regular interval (2.0m) using SRS Survey 2014

Reservoir water level in Metre		Water spread area by trend line	Segmental Live Capacity (Mcm) by SRS technique	Cumulative Live capacity (Mcm) by SRS technique
MDDL	633.292	13.930	0	0
	635	16.866	26.260	26.260
	637	20.364	37.175	63.435
	639	23.927	44.244	107.679
	641	27.555	51.439	159.118
	643	31.247	58.764	217.882
	645	35.005	66.217	284.099
	647	38.827	73.799	357.898
	649	42.714	81.510	439.408
	651	46.666	89.350	528.758
	653	50.682	97.320	626.078
	655	54.764	105.419	731.497
	657	58.910	113.648	845.145
	659	63.121	122.006	967.151
	661	67.396	130.494	1097.645
FRL	**662.94**	71.606	134.811	1232.456

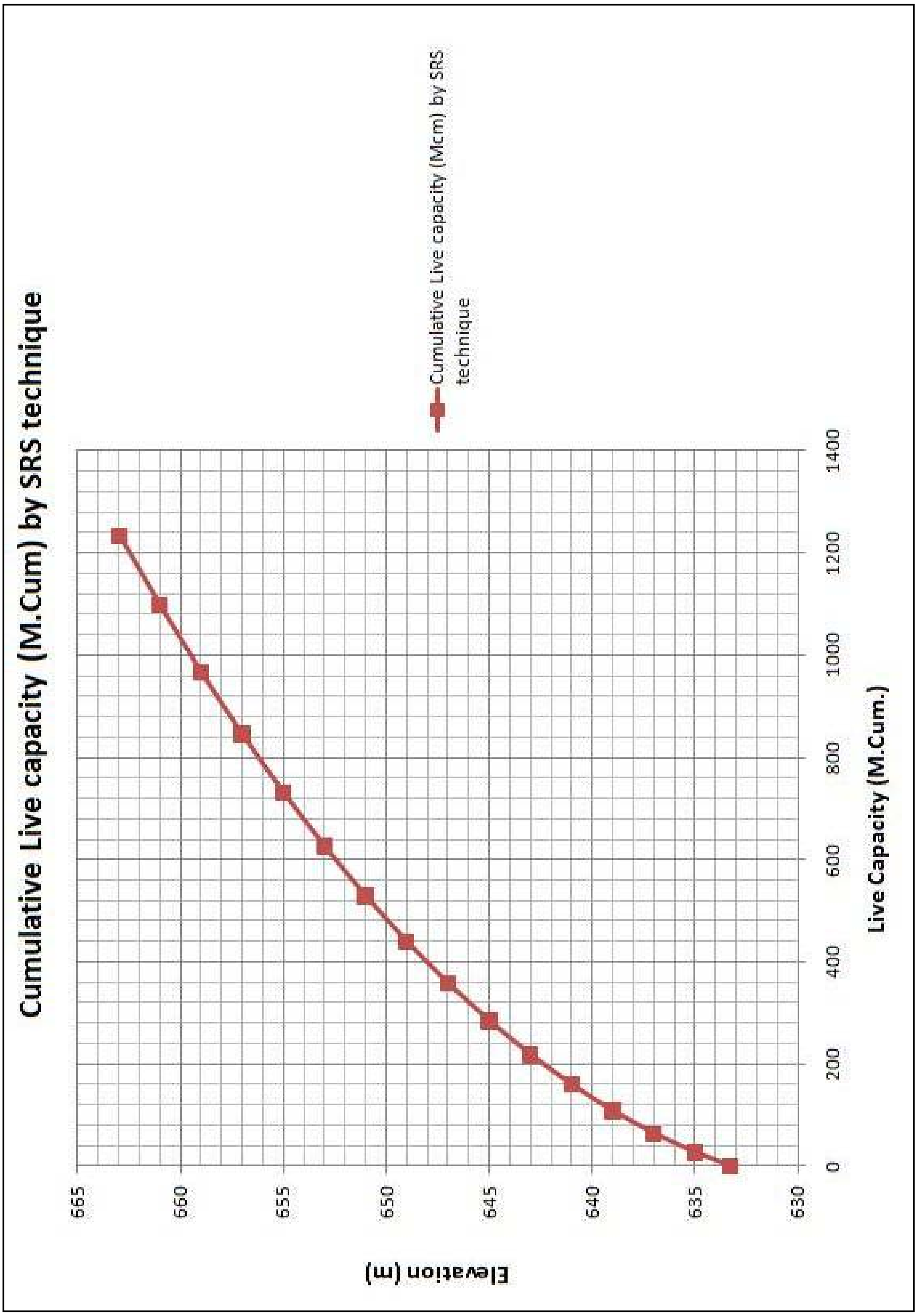


Fig. 10 : Modified live capacity - elevation curve (SRS technique)

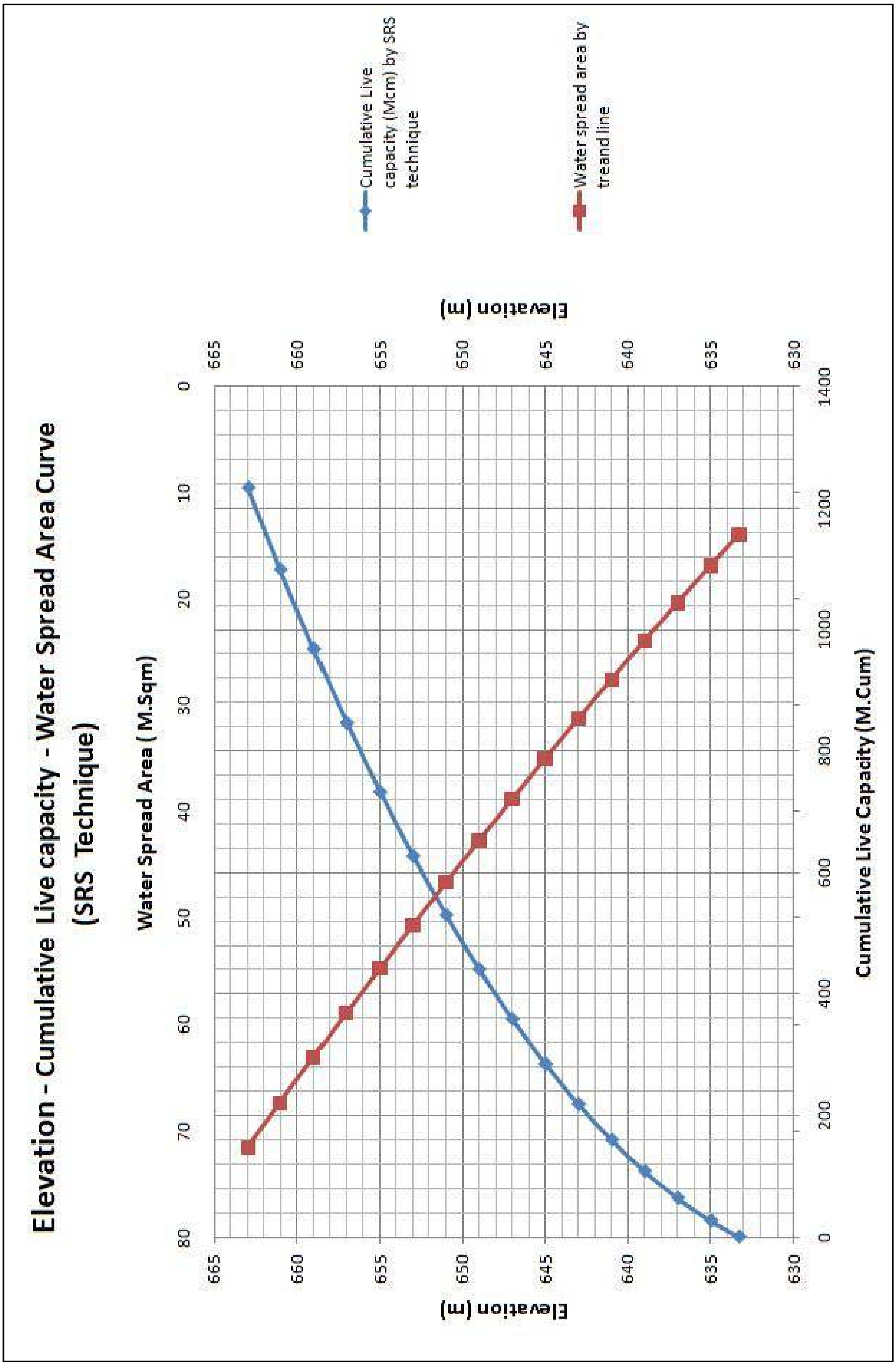


Fig. 11 : Elevation – Area- Capacity Curve

11.4. COMPARISON WITH ORIGINAL SURVEY

Table-5 & 6 as given below show the comparison of water spread areas and live storage capacity of SRS survey with original at various elevations respectively. Curve showing comparison of water spread areas and live capacity of SRS survey with previous survey is drawn in Figure- 9 & 10.

Table -5: Comparison of Water Spread Areas (Million m^2)

	Elevation (m)	**Area (Original)**	**Area (SRS)**
MDDL	633.292	16.90	13.93
	635	19.65	16.87
	637	23.72	20.36
	639	28.22	23.93
	641	31.88	27.55
	643	34.36	31.25
	645	38.12	35.00
	647	41.79	38.83
	649	45.23	42.71
	651	48.47	46.67
	653	51.68	50.68
	655	55.99	54.76
	657	60.20	58.91
	659	65.20	63.12
	661	69.21	67.40
FRL	662.94	72.59	71.61

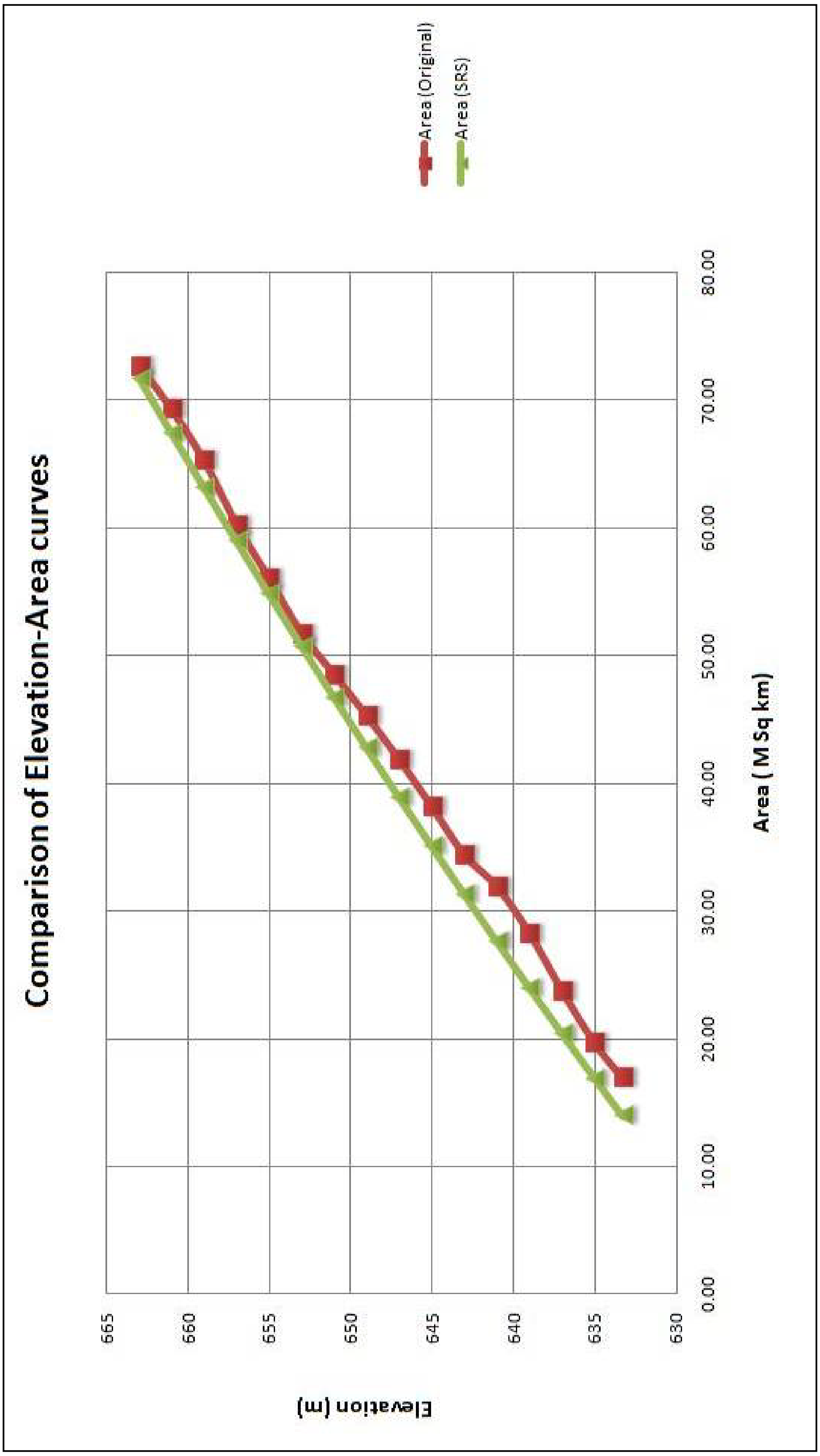


Fig. 12 : Comparison of Elevation – Area Curves

Table -6: Comparison of Live Storage Capacity (Million m³)

	Elevation (m)	Live Capacity (Original) 1960	Live Capacity (Hydro graphic survey) 2001	Live Capacity (SRS) 2014
MDDL	633.292	0.000	0.000	0.000
	635	32.839	26.899	26.260
	637	75.948	64.099	63.435
	639	127.839	108.320	107.679
	641	187.961	158.359	159.118
	643	271.563	215.543	217.882
	645	326.489	279.251	284.099
	647	406.525	351.672	357.898
	649	493.540	431.957	439.408
	651	587.360	520.168	528.758
	653	687.245	616.679	626.078
	655	794.903	721.925	731.497
	657	911.144	836.080	845.145
	659	1035.713	959.714	967.151
	661	1170.223	1092.289	1097.645
FRL	**662.94**	1307.827	1228.718	1232.456

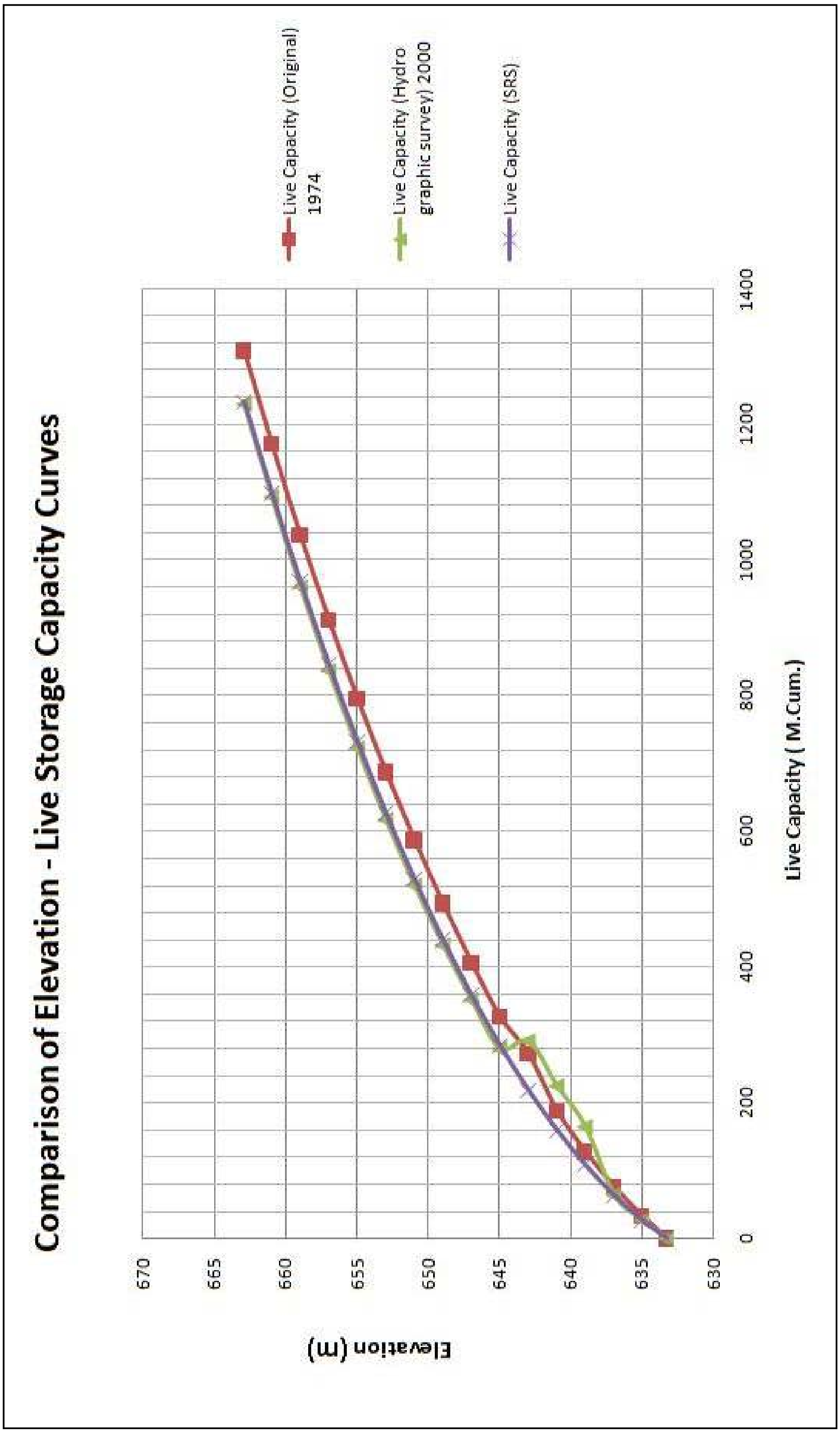


Fig 13: Comparison of Elevation - Live Storage Capacity curves (Million m^3)

12 RESULT AND DISCUSSIONS

The loss in live storage capacity of the reservoir due to sedimentation since original survey has been shown in Table 7.

Table-7: Live storage capacity loss due to sedimentation

Details	Original (1960)	SRS (2014) CWC
Live Capacity in Million m^3	1307.827	1232.456
Loss in live capacity in Million m^3	-	75.31
% Live capacity loss (since 1974)	-	5.76
Annual % live capacity loss	-	0.144

13 CONCLUSION

The following conclusions emerge from the present study, however subject to the limitations stated in following paragraphs.

- The live storage capacity of Ghataprabha reservoir has been found to be 1232.456 Million m^3 in 2014 against the original live storage capacity of 1307.827 Million m^3 in 1974.

There is a live capacity loss of 75.31 M cum in 40 years which is 5.76 % of original live capacity. Annual live capacity loss is 0.144%.

14 LIMITATIONS

As the reservoir operates in between DSL and FRL, the satellite data is available for this region only. The satellite remote sensing based reservoir capacity estimation works between DSL and FRL in live storage.
Remote sensing techniques give accurate estimate for fan shaped reservoir where there is considerable change in water-spread area with change in water level.
Data from two to three water years was combined to get the required data set.
General error can creep in the identification of tail end of reservoir, particularly in the rainy season.

SALIENT FEATURES

Annexure-I

1.	**Name of Reservoir**	Ghataprabha Reservoir
2.	**Location**: a. District b. State c. Longitude d. Latitude e. Year of completion	 Belgaum district Karnataka $74^0 34'$ to $74^0 39'$ $16^0 03'$ to $16^0 09'$ 1977
3.	**Average Annual Rainfall**	921 mm
4.	**Type**	Composite (Masonry, Rockfill and Earth dam)
5.	**River** (on which located)	Ghataprabha
6.	**Year of First Impounding**	1974
7.	**Total catchment area** up to dam site	1411.55 Sq Km
8.	**Salient Levels**: i. Maximum Water Level ii. FRL iii. MDDL	 662.94 m 662.94 m 633.292 m
9.	**Designed storage capacity** i. Gross Storage ii. Live Storage iii. Dead Storage	 1434.136 MCM 1366.136 MCM 68.0 MCM
10	**Total Water spread area at FRL**	72.588 sq Km
11	**(a) Dam Details**	
	(i) Length of dam at top	4481 m
	(ii) Max. Height	668.10 m
	(b) Spillway a) Length of Spillway b) Type, No. & Size of gates c) Type of Spillway	 149.39m (Central Spillway) Radial, 10 nos. , 12.19m x 7.62m Ogee Type Spillway

GROUND TRUTH PHOTOGRAPHS

<u>Annexure-II</u>

Photo 1 : Spillway of Ghatprabha Dam

Photo 2 : Downstream channel

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