उपग्रह दूरस्थ संवेदन द्वारा
काबिनी जलाशय, कर्नाटक का अवसादन आंकलन

SEDIMENTATION ASSESSMENT OF KABINI RESERVOIR, KARNATAKA, THROUGH SATELLITE REMOTE SENSING

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Government of India
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Environment Management Organization
Remote Sensing Directorate

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SEDIMENTATION ASSESSMENT OF

KABINI RESERVOIR, KARNATAKA,

THROUGH SATELLITE REMOTE SENSING

Year of Survey 2019
Data Used 2016-2018

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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 2016-18 in the sedimentation study of Kabini 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 552.745 MCM & 453.069 MCM respectively. According to hydrographic survey conducted in 2010 the live storage capacity of reservoir was reported as 457.14 MCM. After analysis of the satellite data in the present study, it is found that live capacity of the Kabini reservoir in 2018 is 430.199 MCM witnessing a loss of 22.870 MCM (i.e. 5.048 %) in a period of 44 years during 1974 to 2018. This accounts for live capacity loss of 0.115% per annum since 1974. When compared with the recent hydrographic survey (2010) there is a loss of 26.941 MCM (i.e. 5.893 %) in a period of 08 years during 2010 to 2018. This accounts for live capacity loss of 0.737% per annum since 2010.

Since, the hydrographic survey conducted in 2010 reports increase in live storage by about 4 MCM over its capacity at the time of first impoundment i.e. 1974, it may be inferred that either the original survey or the hydrographic survey conducted in 2010 was wrong. Owing to this, in this study we have compared the results of 2018 (Remote Sensing Survey) with both the surveys i.e. original survey in 1974 and hydrographic survey in 2010.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

CWC	Central Water Commission
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
NRSC	National Remote Sensing Centre
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 KABINI RESERVOIR, KARNATAKA THROUGH SATELLITE REMOTE SENSING

1 INTRODUCTION

India – the second largest country in the world in terms of population – has about 17% of world's population, about 4% of world's water resources, and 2.5% of total geographical land area of the world. Therefore, in spite of having an average annual average precipitation to the tune of more than 1100 mm/year, the population density (lack of land resources) and per capita water resources availability make India a water-stressed country, as a whole. However, at a regional or basin level, many areas in the country are water-scarce or severely water-scarce owing to the spatial and temporal variability of water resources.

It is estimated that average annual precipitation over India is about 4000 BCM. Out of this precipitation, the average annual water resources availability of the country is about 1869 BCM, as estimated by Central Water Commission (CWC) in 1993. The water resources availability situation gets more murkier due to topographical and other constraints. Due to this, the total utilisable water resources in the country are about 1137 BCM (690 BCM of surface water and 447 BCM of groundwater). On one hand, the per-capita water resource availability is reducing due to increasing population and on the other, per-capita water usage is increasing due to industrialisation, urbanisation and change in lifestyles or dietary habits, making the available water resources still dearer.

India, has typical monsoon-based climate where more than 75% rainfall occurs in three months i.e. July, August, and September. The total number of rainy days typically are in the tune of only 20-25 days per year (100-150 hours of rain per year) for most parts of the country. As a result, the bulk of annual water (75-80%) is available in these three months only in rivers. Therefore, in order to sustain life and other activities throughout the year from a resource that is available only through 20-25 rainy days, it is absolutely essential to store the water in appropriately-sized storage structures (depending upon the topography and hydrology of the area).

So far, India has developed just 257.812 BCM as live storage capacity and 46.765 BCM is under construction. Realising the importance of storage structures, a large number of reservoirs have been built, since independence, during each plan on almost all river basins, except Ganga and Brahmaputra, to tap the available surface water and to utilize it as and when needed. The capacity of reservoirs is gradually reducing due to silting and hence sedimentation study/montioring of reservoir is of great concern for 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 (DGPS). The conventional techniques are found either time consuming or costly and require considerable manpower. Remote sensing technique to calculate the present live 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 sedimentation study of Kabini reservoir, Karnataka by Central Water Commission, New Delhi.

2. SOURCES AND MECHANISM OF SEDIMENTATION

The principal sources of sediments are:

1. Deforestation
2. Excessive erosion in the catchment
3. Disposal of industrial and public wastes
4. Farming
5. Channelisation works
6. Human activities
7. Land development, highways, and mining

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.

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).

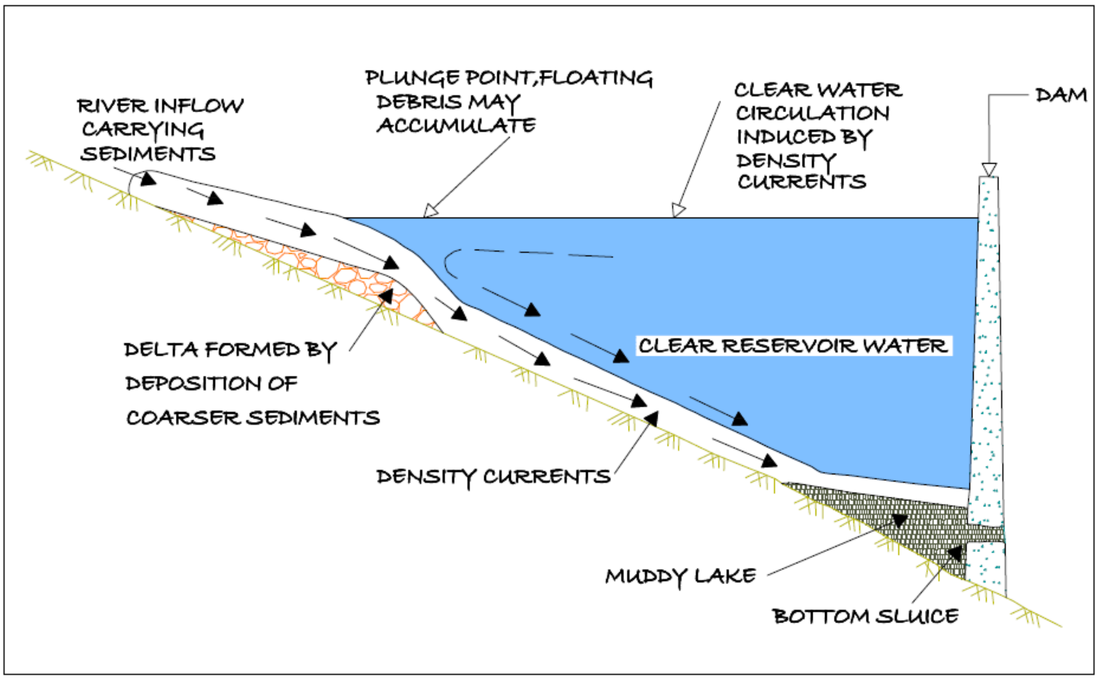


Fig. 1: Conceptual sketch of density currents in a reservoir

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.

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.

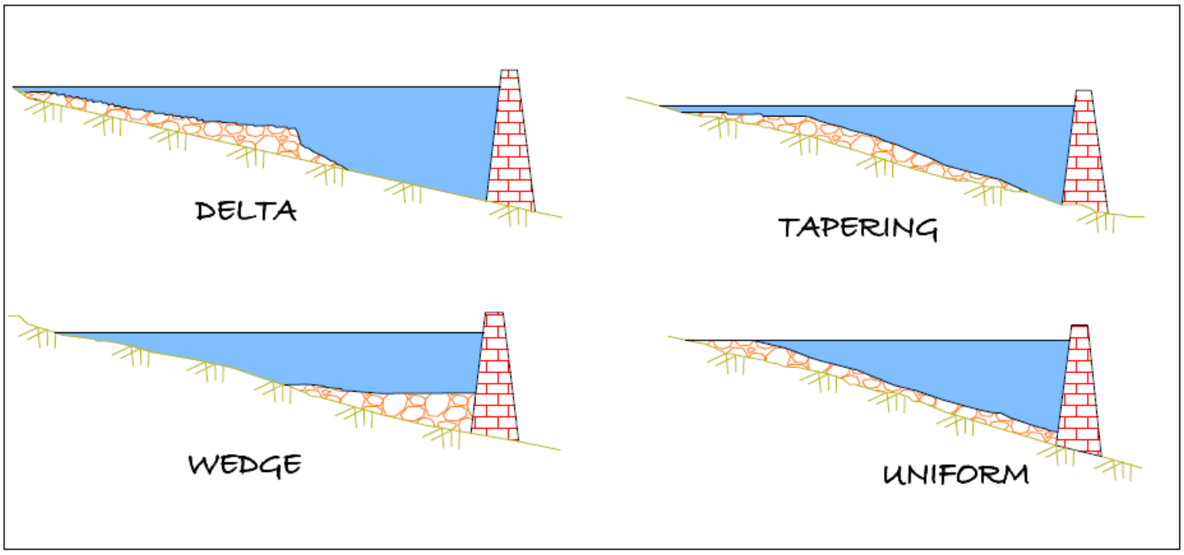


Fig. 2: Longitudinal Patterns of sediment deposition in reservoirs.

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.

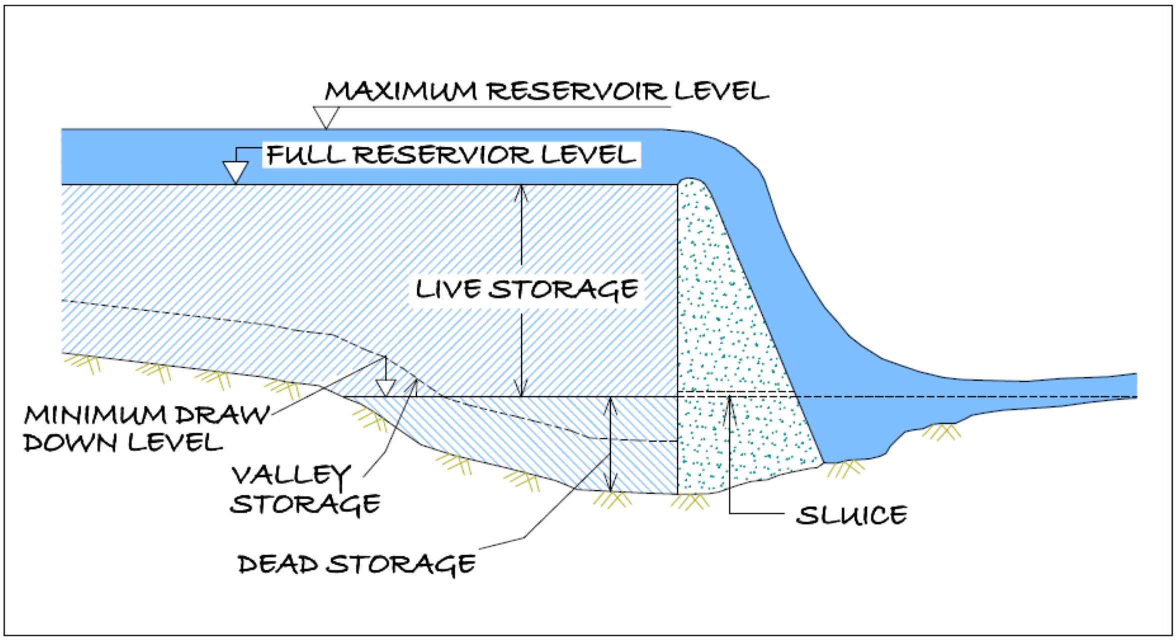


Fig. 3: Conceptual sketch of different levels in a reservoir

3. 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:

1. 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
2. Revetment and vegetation cover
3. Evacuation of sediment
4. Reservoir shoreline protection
5. Stream bank and flood plain protection
6. 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.

4. 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 Fig. 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.

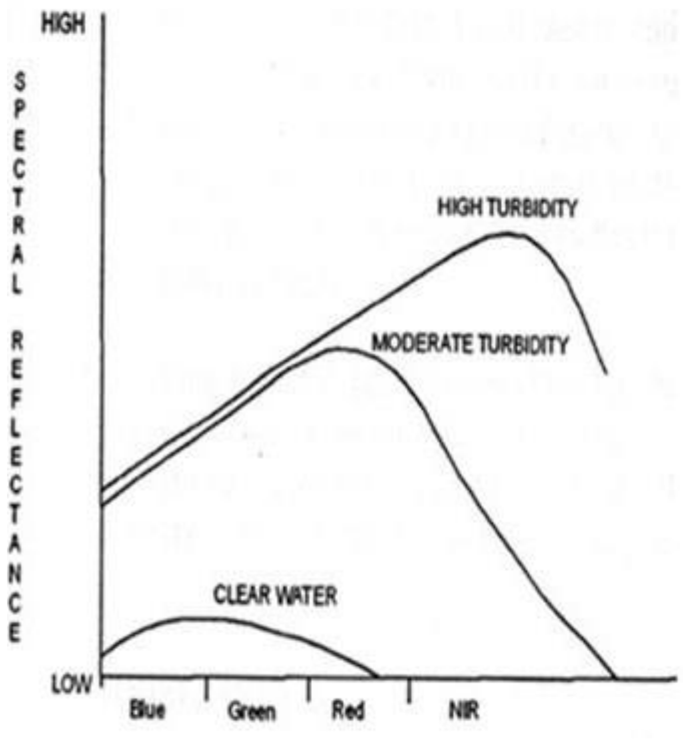


Fig. 4: Reflectance curves for Clear and Turbid water

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.

5. OBJECTIVES

The objective of the study is to estimate live capacity loss of Kabini 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

6. STUDY AREA

The Kabini dam is built on the River Kabini in the district of Mysuru. The dam is 696 meters in length and was built in 1974. The exact location of the dam is near village Beechanahally, in Taluk Heggadadevanakote, Mysuru district, latitude 11°56’27”N, longitude 76°20’17”E. The catchment area of the dam is 2,141.90 km^2. The gross, live and dead storage capacities of the reservoir are 552.630 MCM, 443.63 MCM and 99.675 MCM respectively. For the reservoir, the FRL, MDDL and DSL are 696.16m, 690.680m, and 685.50m. Salient features of Kabini reservoir is given in Appendix I and Index map of the reservoir is shown in fig. 5.

It caters to the needs of around 22 villages and 14 hamlets and also a prominent source of drinking water to Bengaluru. Further significant amount of water is discharged to the Mettur reservoir in Tamil Nadu to fulfill the State's needs.

This dam also provides water to the combined system of Sagaredoddakere and Upper Nugu Dams. There is an arrangement of lifting and transfer of 28.00 TMC of water during the monsoons months from the Kabini dam to the other two smaller dams. The dam is spread over an area of 55 hectares covering forests, rivers, lakes and valleys.

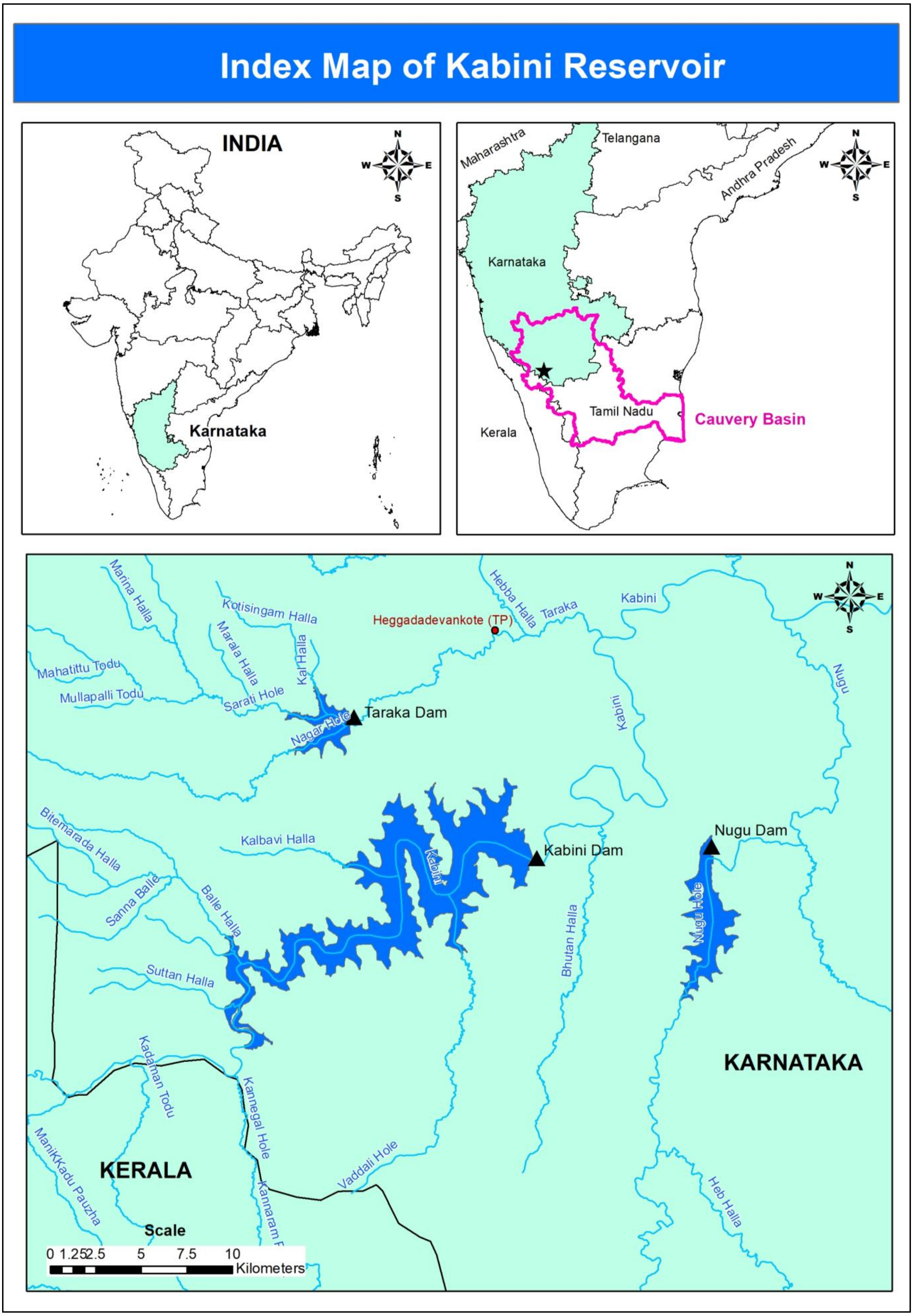


Fig. 5: Index map of the Kabini Reservoir

7. 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 DSL, water spread observations are not possible below DSL. The same are to be extrapolated from observed elevation-area curve to find out capacity below DSL. In the case of Kabini reservoir, the height difference between FRL (696.16 m) and DSL (685.50 m) is 10.66m.

8 DATA USED

8.1. SATELLITE DATA

Landsat 8 OLI/TIRS C1 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	Date of pass	Elevation (m)
Landsat 8 OLI/TIRS C1	09-SEPT-2018	696.066
Landsat 8 OLI/TIRS C1	24-OCT-2017	695.654
Landsat 8 OLI/TIRS C1	27-DEC-2017	693.310
Landsat 8 OLI/TIRS C1	06-FEB-2018	692.588
Landsat 8 OLI/TIRS C1	01-MAR-2018	690.811
Landsat 8 OLI/TIRS C1	08-DEC-2016	689.690
Landsat 8 OLI/TIRS C1	10-FEB-2017	687.650
Landsat 8 OLI/TIRS C1	24-APR-2017	685.670

8.2. FIELD DATA

The following field data has been obtained from project authorities:
Elevation - Capacity data
Salient features of Kabini reservoir levels and capacity data on specified dates

9. 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 Kabini reservoir studies, multi-date Landsat 8

OLI/TIRS C1 (08 nos. imageries) is used for the analysis. Image processing with Arc GIS software was used for the analysis. The analysis comprised,

- Geo-referenced Data base.
- Water spread area estimation.
- Estimation of reservoir capacity.
- Comparison with original capacity.

9.1. DATA BASE

The satellite data corresponding to reservoir area obtained from USGS Earth Explorer was loaded on the system. Bands 5,6,7 of the geo-referenced images for all eight different dates pertaining to study area were used for further analysis.

9.2. 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

9.2.1. 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.

9.2.2. THRESHOLDING

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 Tandula 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.

Water spread areas are extracted for all the scenes. Fig. 7 shows FCC's of different dates and Fig. 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 (30m x 30m). Table 2 shows satellite-derived reservoir water spread areas for different satellite overpass dates along with the water levels of the reservoir at the corresponding dates collected from the project authtorites.

Table – 2: Water Spread Areas estimated from Satellite Images

Date of pass	Elevation (m)	Area (M Sqm)
09-SEPT-2018	696.066	61.8313
24-OCT-2017	695.654	60.3613
27-DEC-2017	693.310	51.4796
06-FEB-2018	692.588	49.4354
01-MAR-2018	690.811	43.1184
08-DEC-2016	689.690	35.9421
10-FEB-2017	687.650	25.9366
24-APR-2017	685.670	13.5623

9.2.3. NDVI ANALYSIS STEP BY STEP:

1. Add images in Band 1 to 7 in ArcMap
2. Stack the bands using Composite bands tool
3. Remove unwanted layers
4. Convert Composite image into FCC image
5. Clip satellite image as per reservoir area approximately
6. Generate NDVI image from FCC image
7. Export NDVI image in output folder
8. Build raster attribute table for NDVI image
9. Picking pixels representing water from image
10. Mark all pixels representing water
11. Reclassify the image using reclassification tool
12. Raster to vector conversion
13. Create AREA field in attribute table
14. Calculate the water spread area using calculate geometry tool

The methodology adopted in this analysis is shown in the flow chart (Fig. 6).

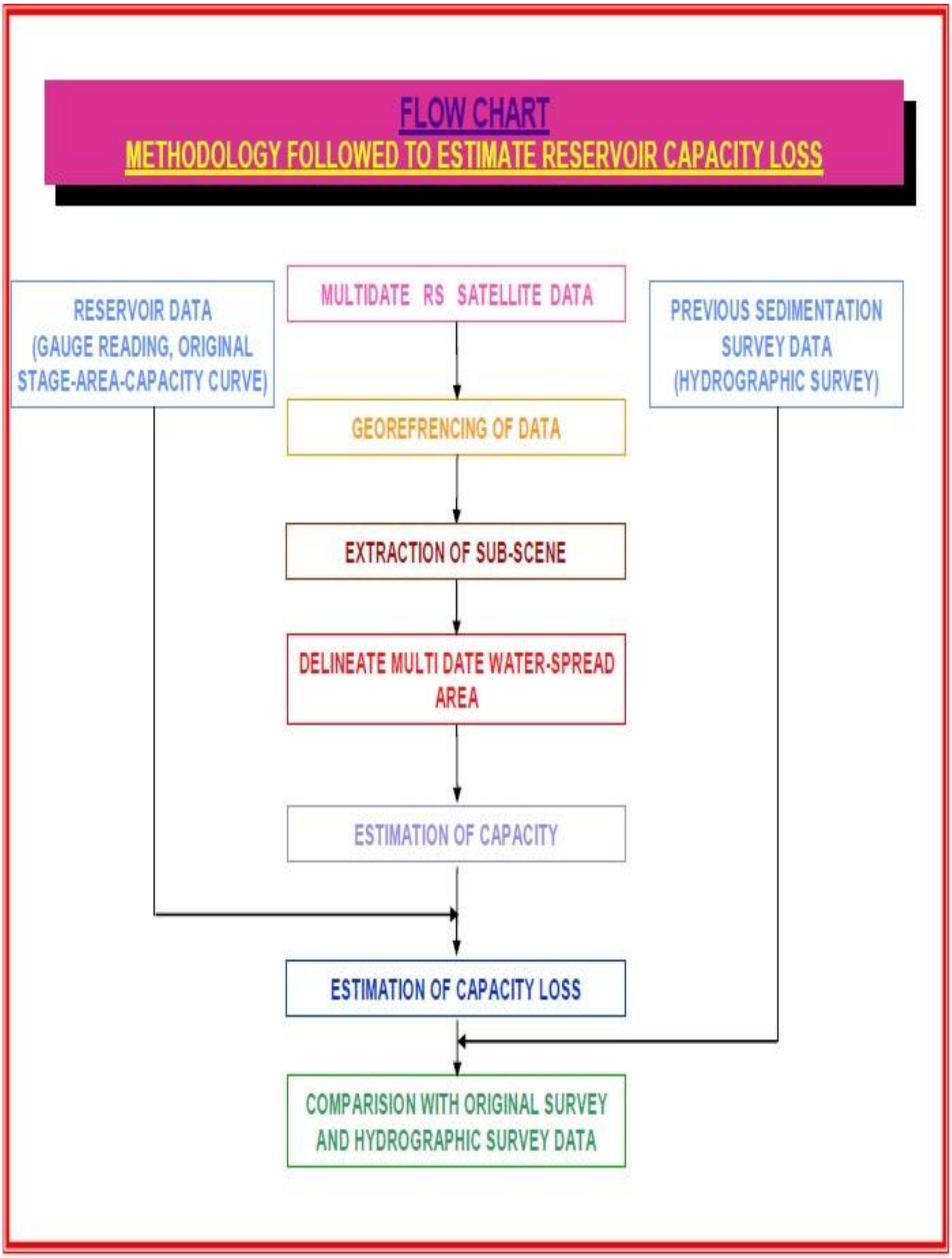
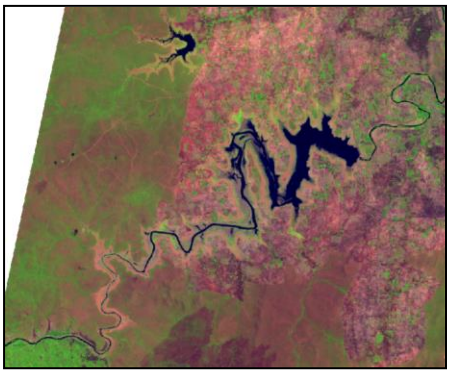
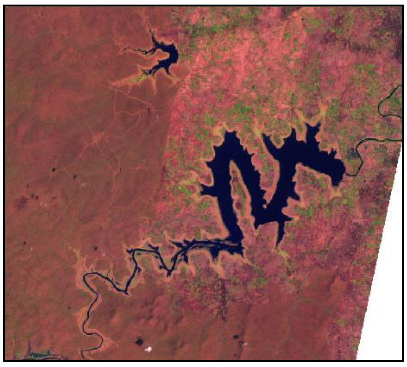


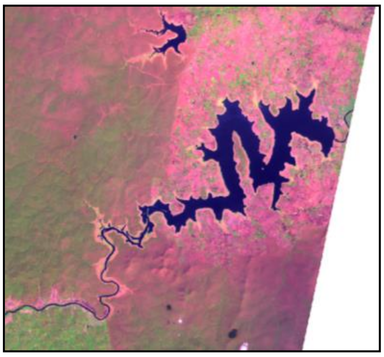
Fig 6 : Flow chart showing methodology followed to estimate reservoir capacity loss



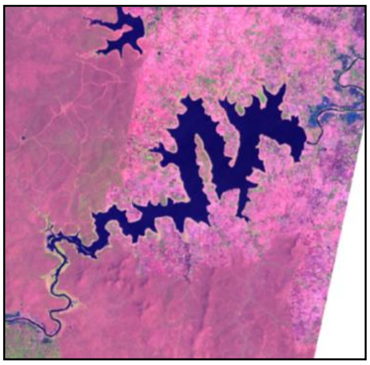
24-Apr-2017(685.670m)



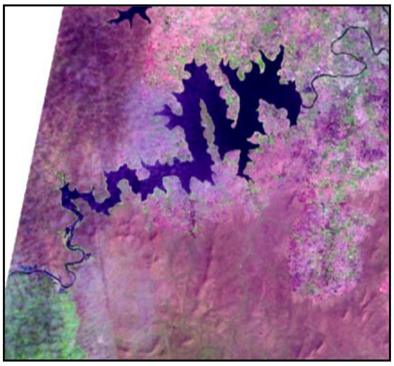
10-Feb-2017(687.650m)



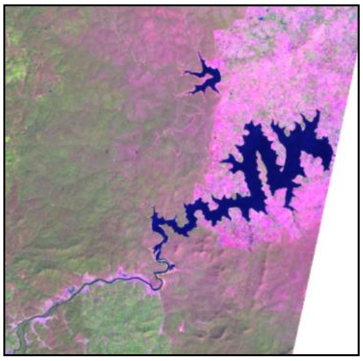
08-Dec-2016(689.690m)



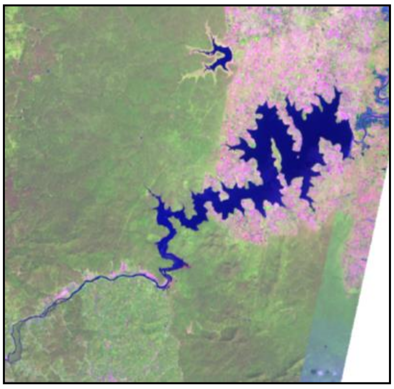
01-Mar-2018(690.811m)



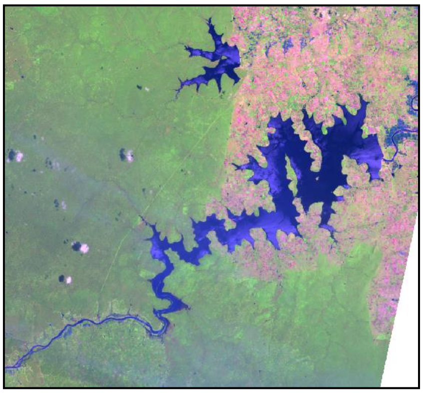
06-Feb-2018(692.588m)



27-Dec-2017(693.310m)



24-Oct-2017(695.654m)



09-Sept-2018(696.066m)

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

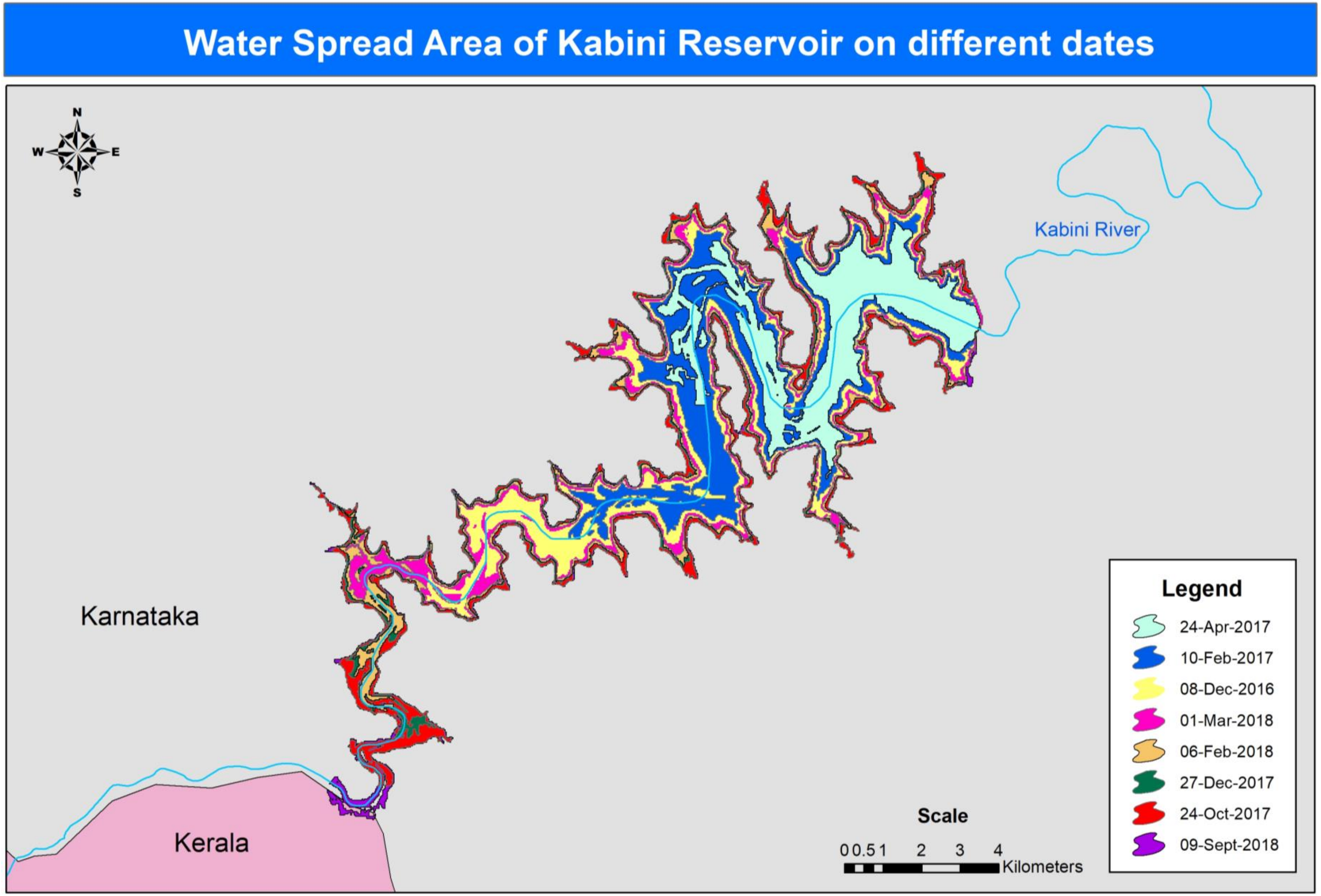


Fig. 8: Kabini Reservoir Water Spread Area on different dates

The Satellite Images for the Kabini reservoir have been obtained from USGS Earth Explorer. The analysis has been carried out using Digital Image Processing software Arc GIS. The digitally processed images of Kabini Reservoir showing its water spread area for eight overpass dates such as 09-Sept-2018, 24-Oct-2017, 27-Dec-2017, 06-Feb-2018, 01-Mar-2018, 08-Dec-2016, 10-Feb-2017, 24-Apr-2017 are shown in fig. 9.

The water elevation 696.066 for 09th Sept, 2018 is near the Full Reservoir Level (FRL) of 696.16m and water elevation 685.67m for 24th April, 2017 is above the Dead Storage Level (DSL) of 685.50m.

9.3. 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 = -0.1675*X^2 +6.3936 * X + 12.678

R^2 = 0.9985

Where X is Elevation in meters

Y is Water Spread Area in M Sqm

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 3 gives the values of Live storage capacity and submergence areas at a regular interval of 1.0 m have been worked out using this best-fit polynomial equation at different elevations.

The Modified live capacity - elevation curve and modified elevation – area –capacity curves are plotted and shown in Fig-10 and Fig-11 respectively.

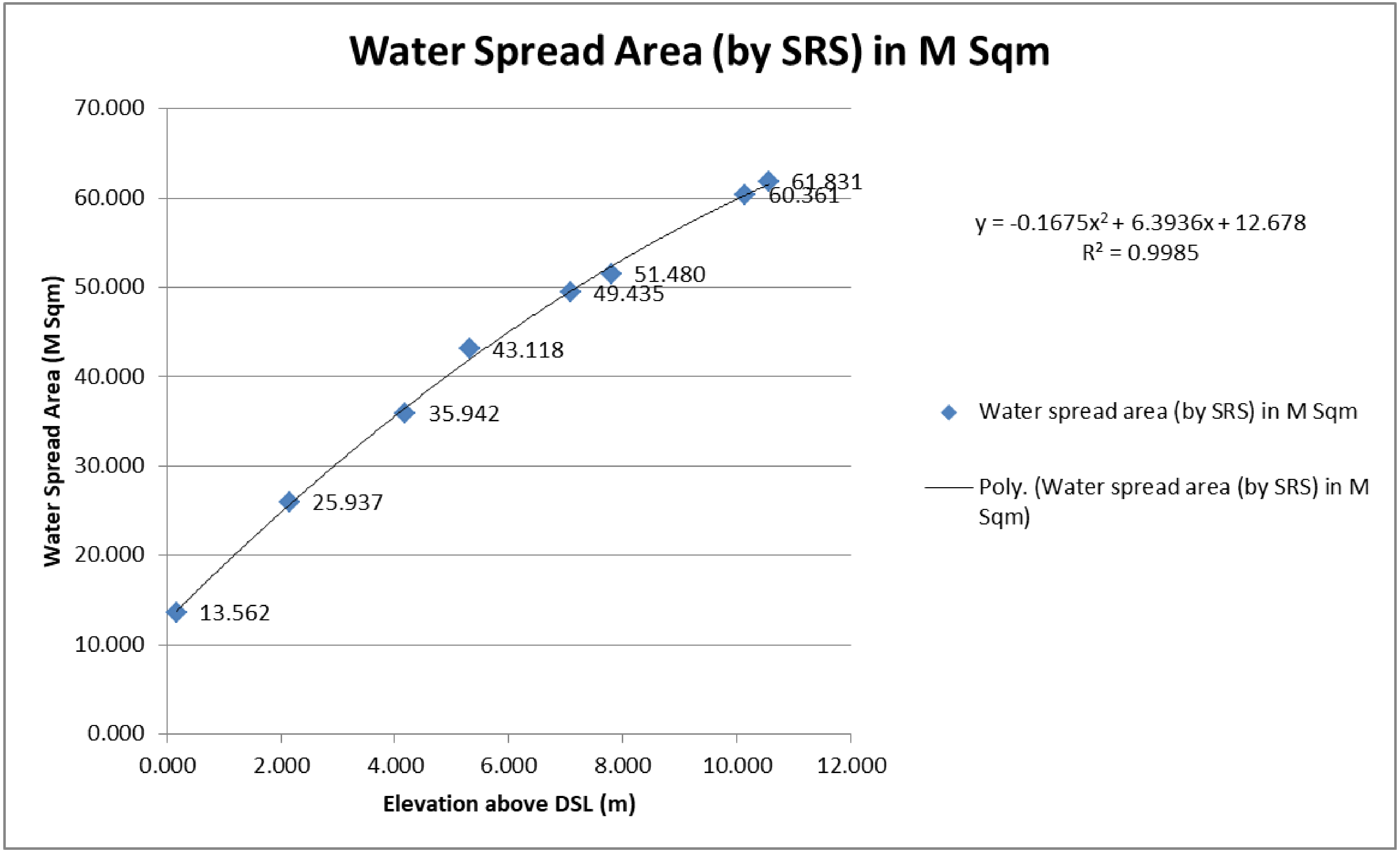


Fig. 9: Water spread Area of Kabini Reservoir

Table-3: Aerial extent of reservoir at regular interval (1.0m) using SRS Survey 2018

Reservoir water level in Metre		Water spread area by trend line (M Sqm)	Segmental Live Capacity (MCM) by SRS technique	Cumulative Live Capacity (MCM) by SRS technique
DSL	**685.50**	12.678	0	0
	686.00	15.833	7.113	7.113
	687.00	21.892	18.781	25.894
	688.00	27.615	24.698	50.592
	689.00	33.004	30.269	80.861
	690.00	38.057	35.501	116.362
	691.00	42.776	40.394	156.755
	692.00	47.160	44.950	201.705
	693.00	51.208	49.170	250.875
	694.00	54.922	53.054	303.929
	695.00	58.300	56.603	360.532
	696.00	61.344	59.816	420.348
FRL	**696.16**	61.800	9.851	430.199

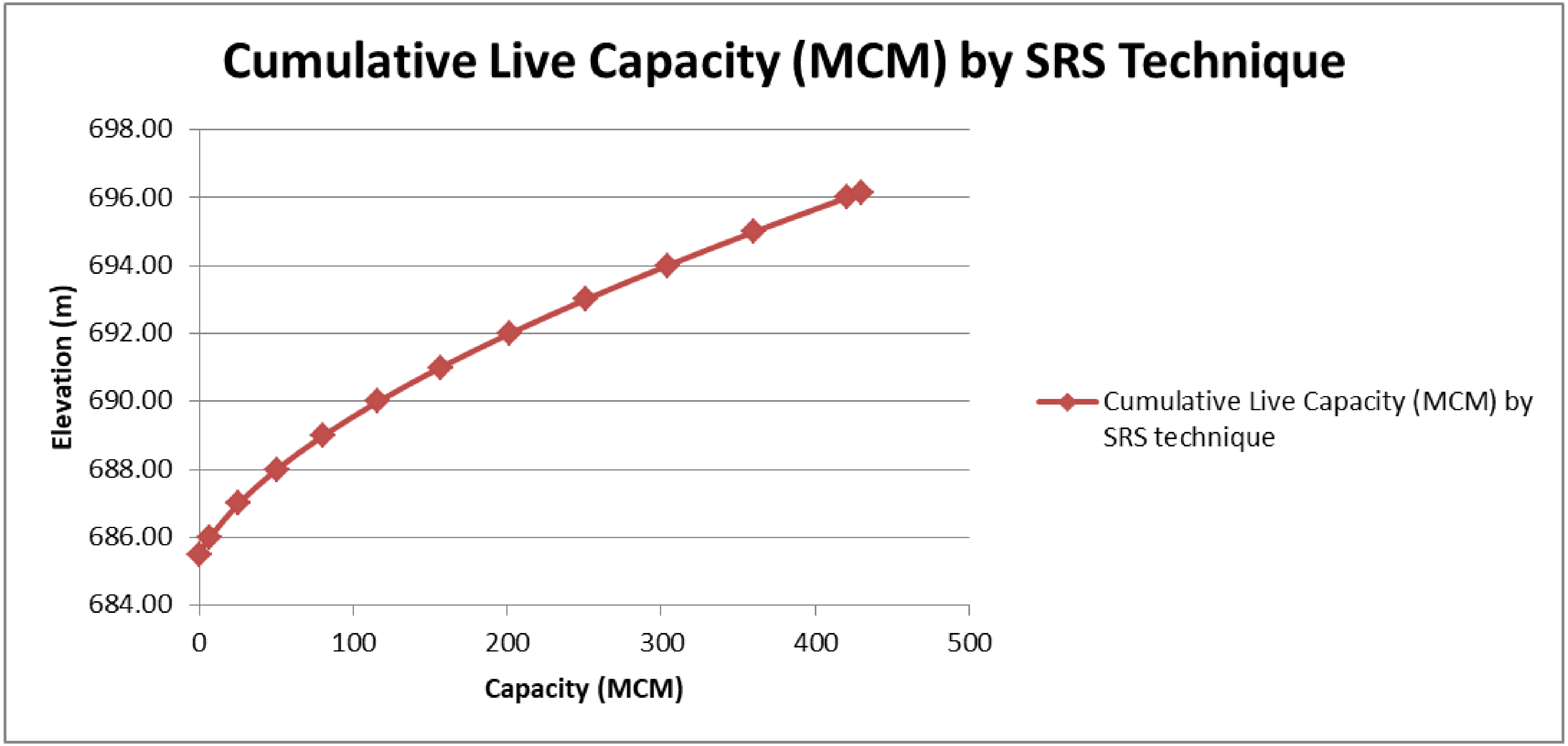


Fig. 10: Modified live capacity - elevation curve (SRS technique)

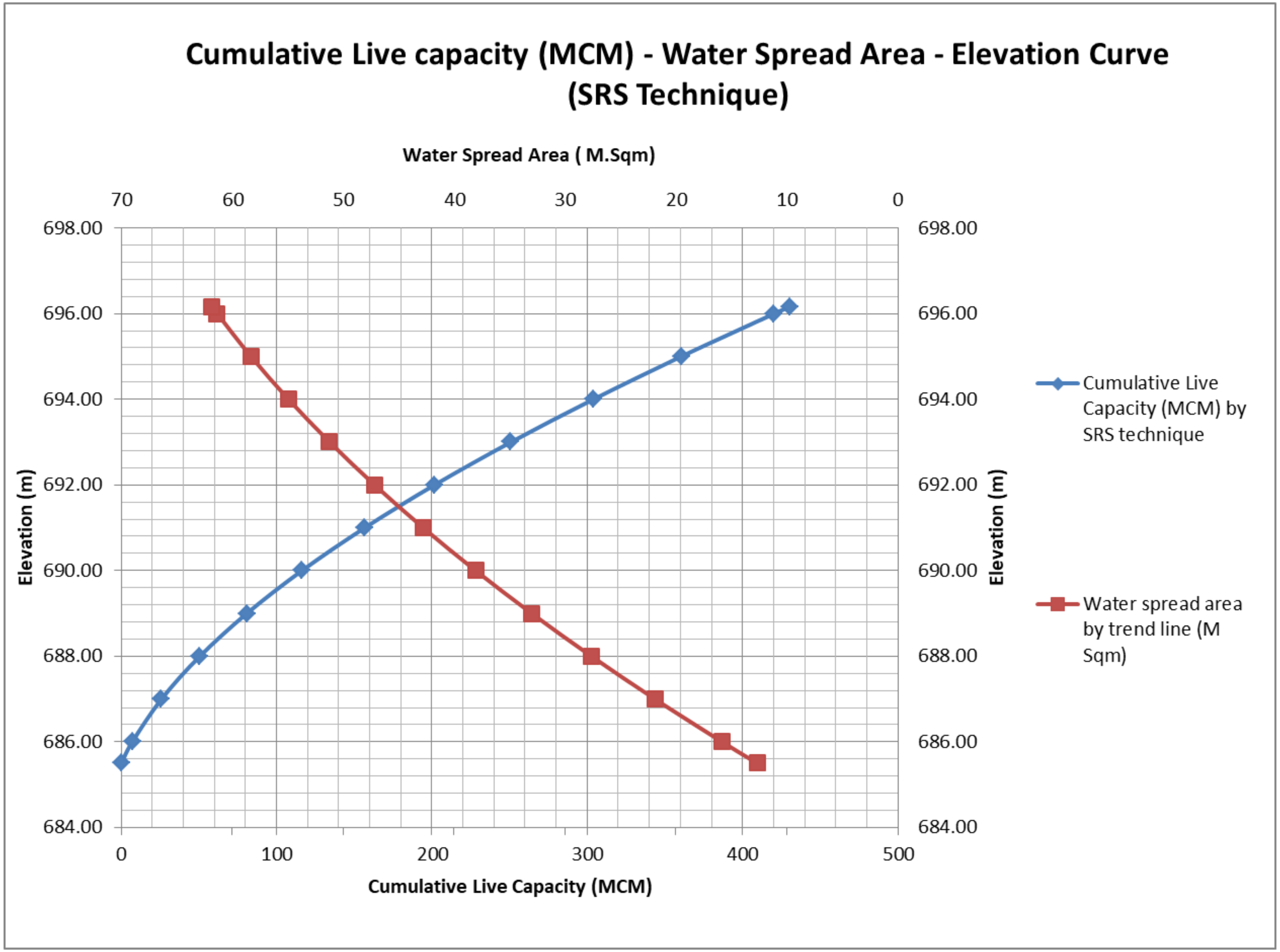


Fig. 11: Elevation – Area- Capacity Curve

9.4. COMPARISON WITH ORIGINAL SURVEY

Comparison of live storage capacity of SRS survey with hydrographic survey 2010 at various elevations respectively is given below in Table 4. Curve showing comparison of live capacity of SRS survey with hydrographic survey 2010 is drawn in Fig-12.

Table -4: Comparison of Live Storage Capacity (MCM)

	Elevation (m)	**Live Capacity (Hydrographic survey) 2010**	**Live Capacity (SRS) 2018 (MCM)**
MDDL	**685.50**	0.000	0.000
	686.00	11.714	7.113
	687.00	39.279	25.894
	688.00	70.673	50.592
	689.00	103.404	80.861
	690.00	141.377	116.362
	691.00	182.429	156.755
	692.00	226.688	201.705
	693.00	274.000	250.875
	694.00	324.762	303.929
	695.00	377.167	360.532
	696.00	433.586	420.348
FRL	**696.16**	443.750	430.199

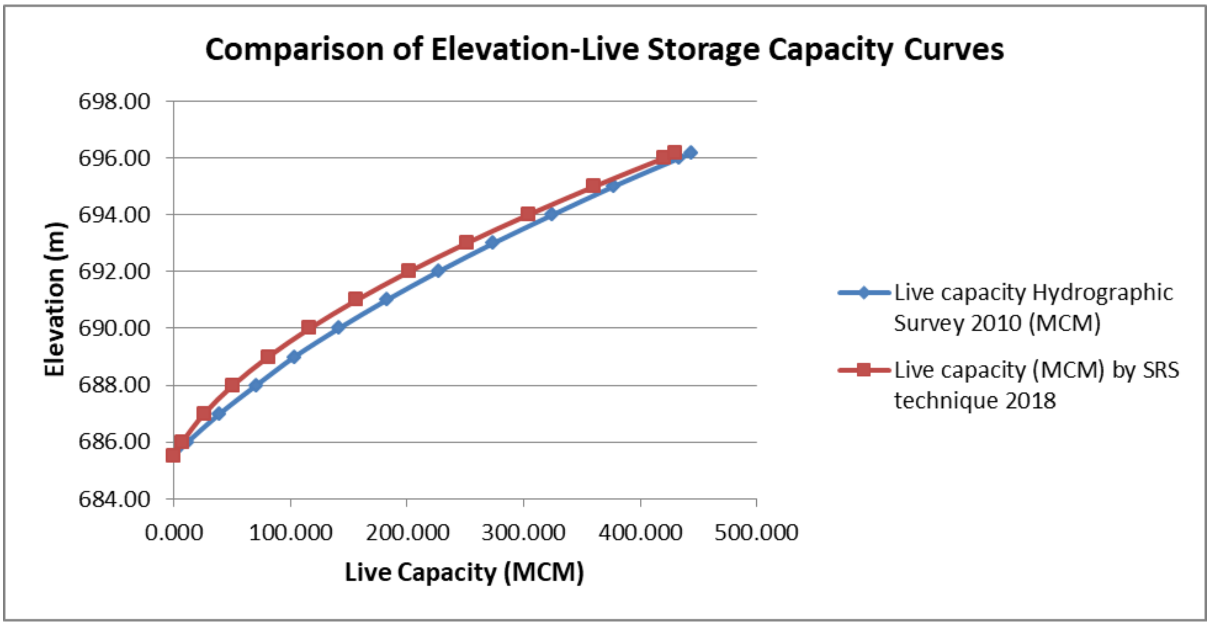


Fig 12: Comparison of Elevation - Live Storage Capacity curves (MCM)

10 RESULT AND DISCUSSIONS

The loss in live storage capacity of the reservoir due to sedimentation since original survey and hydrographic survey 2010 has been shown in Table 5 and table 6 respectively.

Table-5: Live storage capacity loss due to sedimentation as per Original survey (1974)

Details	Original (1974)	SRS (2018) CWC
Live Capacity in MCM	453.069	430.199
Loss in live capacity in MCM	-	22.870
% Live capacity loss (since 1974)	-	5.048
Annual % live capacity loss	-	0.115

As per the original survey live capacity of Kabini was 453.069 MCM [4]. However, according to hydrographic survey conducted in 2010 the live capacity of Kabini was reported as 457.14 MCM showing an increase in live capacity by about 4 MCM which is not possible unless the original capacity assessment was faulty [5]. In the present study the live capacity of Kabini resevoir is found to be 430.199 MCM. Thus, according to original survey there is a loss of 22.870 MCM (i.e. 5.048 %) in a period of 44 years during 1974 to 2018. This accounts for live capacity loss of 0.115% per annum since 1974.

Table-6: Live storage capacity loss due to sedimentation as per Hydrographic Survey (2010)

Details	Hydrographic Survey (2010)	SRS (2018) CWC
Live Capacity in MCM	457.14	430.199
Loss in live capacity in MCM	-	26.941
% Live capacity loss (since 2010)	-	5.893
Annual % live capacity loss	-	0.737

As per Hydrographic Survey (2010), there is loss of 26.941 MCM (i.e. 5.893 %) in a period of 08 years during 2010 to 2018. This accounts for live capacity loss of 0.737% per annum since 2010.

11 CONCLUSION

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

- The live storage capacity of Kabini reservoir has been found to be 430.199 MCM in 2018 against the original live storage capacity of 453.069 MCM and 457.14 MCM as per hydrographic survey (2010).
- In view of above, it is recommended that one more hydrographic survey be conducted preferably by 2020 i.e. after 10 years of the last survey so as to have a better confidence level regarding its capacity vis-à-vis the original survey.

12 LIMITATIONS

- As the reservoir operates in between DSL and FRL, the satellite data is available for this range 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 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.

Annexure-I

Salient features of Reservoir	
1. Name of Reservoir	Kabini Reservoir
2. Location	Located across River Kabini near village Beechanahally
Latitude	11^{o} 50' 30" N
Longitude	76^{o} 20' 17" E
Taluk	Heggadadevanakote
District	Mysuru
Basin	Cauvery
Sub-basin	C-2 Kabini Sub-basin
3. Catchment area (in Sq.kms)	2141.90
4. Design yield at 50% dependability (in TMC)	97.70
5. Storage (in MCM)	
i) Gross	552.745
ii) Dead	99.675
iii) Live	453.069
iv) Carry over	-NIL-
6. Reservoir Evaporation Loss (MCM)	96.28
7. i) Filling period	From June to November
ii) Depletion period	From November to May
8. Submersion (in M Sqm)	Karnataka Kerala
Total Area	64.021 0.57
i) Forest area	28.12
ii) Cultivable area	35.89
iii) Fallow lands	Nil
iv) No.of villages / hamlets	22 villages / 14 hamlets
9. Level Of Storage	
i) Full Reservoir Level (FRL)	RL 696.16 m
ii) Minimum drawn down level (MDDL)	RL 689.115 m (RL 690.68m for Right Bank Canal, RL 687.63m for Left Bank Canal)
iii) Dead Storage Level	RL 685.50 m
iv) Sill level of canal sluice	RL 685.495 m
a) Right Bank Canal Sluice	RL 685.495 m

b) Left Bank Canal Sluice	RL 685.495 m
v) Sill level of river sluice	RL 676.351 m
10. **Silt charge per year (Mcft/sq.km of catchment area)**	
i) Designed	0.0001
ii) Actual	Not assessed
11. Ayacut (in M Sqm)	**Flow Canals** **Lift Canals**
i) Left Bank Canal	12.141 -
ii) Right Bank Canal	445.154 421.68
12. General characteristics of soil in the Command Area	In the upper reaches of both Right Bank Canal and Left Bank Canal Red Soil is predominant while black soil are more predominant in its lower reaches.
13. a) Installed power in MW	32 M.W. Contemplated.
b) Annual Power Generation in MU	280.32

Annexure-II

PHOTOGRAPH OF RESERVOIR

Photo 1: Kabini Reservoir [5]

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