

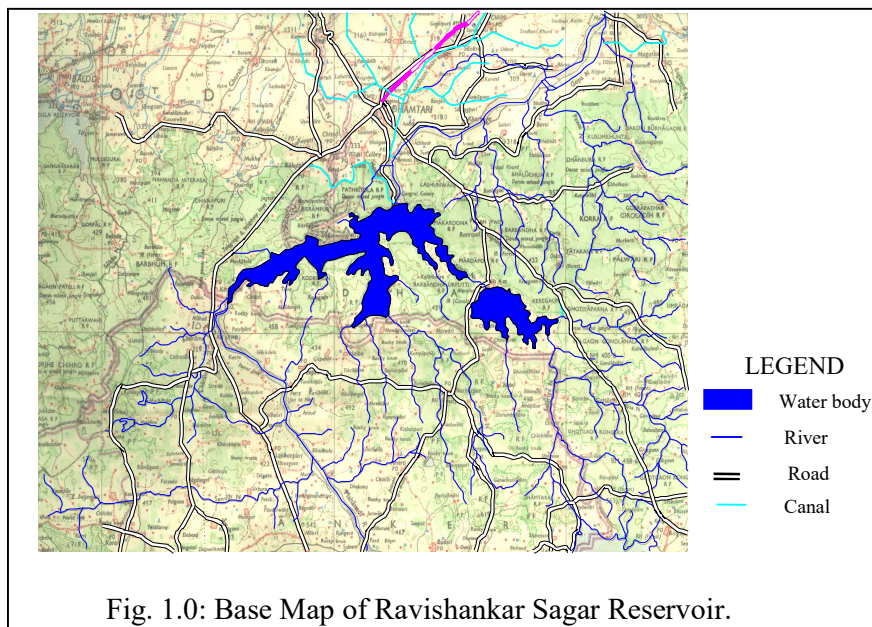
**ASSESSMENT OF RESERVOIR SEDIMENTATION IN  
RAVISHANKAR RESERVOIR USING REMOTE SENSING & GIS**

**NATIONAL INSTITUTE OF HYDROLOGY  
JAL VIGYAN BHAVAN  
ROORKEE - 247 667 (INDIA)**

## 1.0 STUDY AREA

The Ravishankar Sagar dam is situated in Dhamtari district of Chhattisgarh state. The dam is constructed on river Mahanadi. The Ravishankar Sagar dam is one of the major dams of Multipurpose Mahanadi project, which consists of Pairi, Ravishankar Sagar, Moorumsilli, Dudhawa, Sondur and Sikasar reservoir. The base map of the study area has been presented in Fig 1.0. The Ravishankar Sagar Reservoir project was designed with the following objectives:

- Supplying annually 61 Mm<sup>3</sup> water to municipal requirements of Dhamtari town and Raipur City.
- Converting existing 'Protective' Irrigation of Kharif paddy in about 1,82,500 hectare (1,47,500 hectare in Mahanadi old command and 35,000 hectare New area) to 'Productive' irrigation by providing timely, reliable and equitable supply of water of the land to boost present per hectare Yield of 1.4 tonnes to about 3 tonnes.
- Expanding irrigation in new area of 1,56,500 hectare.
- Increasing irrigation intensity in the CCA for present 72% to 100% in Kharif and 1% to 35% in Rabi season.
- Additional agricultural production of 11.95 lakhs tonnes values at Rs. 152 Crores at 1990 prices.
- Generating farm and non-farm employment to about 1, 80,000 persons.



## 1.1 Mahannadi River System

The River Mahanadi is an interstate river system between Chhatisgarh, Maharashtra, Bihar and Orissa. The river rises in Raipur district at an elevation of about 442.00 m. above m. s. l. at latitude 20°-20'N and longitude 82°-0'-30"E near Nagri village. Initially the river flows in west direction up to Kanker, where it takes a sharp turn to northeast direction. After the confluence with one of its major tributary Sheonath, the river takes an easterly course and continues to flow in this direction till it leaves Chhatisgarh and enters Orissa. The basin lies between longitude 83°30'E and 84°50'E and latitude 19°20'N and 23°35'N. The total length of the river is 851.00 kms and the catchment area of the river is about 1, 41, 589 sq. kms. The Chhatisgarh state contributes the maximum drainage area in river Mahanadi. The distribution of catchment areas in different states has been presented below:

S.N.	State	Drainage Area (Sq. Km)	Percentage
1.	Chhatisgarh	75,136	53.06
2.	Orissa	65,580	46.32
3.	Bihar	635	0.45
4.	Maharashtra	238	0.17

The river has 25 major tributaries with catchment area exceeding 250 sq. km out of which 18 lies wholly in Chhatisgarh. The river Seonath is the longest tributary which is 383 km long and lies partly in Chhatisgarh and Maharashtra with a catchment area of 30,523 sq. km.

## 1.2 Topography & Geology

The Mahanadi basin is saucer shaped basin has boundary on north by the Baghelkhand plateau (*Sarguja and shahdol*) and central India hills; on the south and east by the Dandakarnya plateau and the Eastern Ghats and on the west by Satpura Maikala Ranges. The highest level in this northern plateau is about 1500m but most of the area is at an elevation of about 600m. The Chhatisgarh plains are fan Shaped and lie between elevations of 200m to 400m. There are some small hill ranges unevenly located in this region.

The basin contains rocks belonging to age ranging from Pleistocene to Archaens, represented by laterites, basalt, lime stones sand stone, dolomite, gneiss schist, phyllites, quartzite, granites, etc. However, the alluvial deposits belong to the recent age.

## 1.3 Hydrometeorology

The basin is fed by both south west and south east monsoon. The rains commence by

second week of June and last till the end of September. Average annual rainfall is 142 cms. About 90% rainfall occurs during the monsoon month (June to September) and the balance 10% is distributed in the winter and summer months. The rainfall pattern within the basin indicates decreasing trend towards central portion, as compared to north and southern region. In the entire basin, the rainfall varies from 100 cm to 150 cm. The temperature in the basin varies between 8.0°C to 44.0 °C.

The 75% dependable yields from Mahanadi catchment have been assessed for the project are given below:

Location	Catchment area Sq. km.	75% dependable yield	
		Mm3	MAF
Upstream of Hirakud	72629	29933	24.27
Downstream of Hirakud	2507	929	0.75
Total	75136	30862	25.02

#### **1.4 Ravishankar Sagar Dam**

The dam is a unique by non-over flow masonry dam accommodating the head regulator of Mahanadi feeder canal and four penstocks of the powerhouse. The length of main earth dam, masonry dam including spillway and non- over flow blocks and rock-fill dam is 1246, 454 and 130 meters respectively. The saddle earth length is 1050 meter. The maximum height of masonry dam above river bed level is 28.7 meters and of the masonry dam above the foundation is 28.2 m. The masonry dam is founded on Chandrapur sand stone overlying granites. The foundation treatment comprises of consolidation grouting to render the foundation homogeneous to receive the load of dam, curtain grouting to render the foundation water tight and a shear key in the downstream to prevent any sliding due to presence of horizontal joints in the material. Drainage holes discharging into the foundation gallery are provided to release the uplift pressure on the foundation.

The cut-off trench of the earth dam is founded on rock at the left and right flanks. In the river portion, where the rock level is about 16 m. below the bed, two rows of rein-forced concrete diaphragm walls 60 cm thick separated by 40 m. are provided. The RCC walls are keyed into rock. The joints of the RCC wall panels and the junction with rock at the foundation are all grouted to ensure water rightness across the walls and along foundation contact. The concrete walls are provided with a cap of plastic soil around and at the top and about 3 meter deep below the ground level to render them safe against any settlement of the earth dam that might take

place.

The earth dam is homogeneous in section with an impervious soil core with ½:1 side slope in the centre. To facilitate drainage of the up stream slope during draw down condition, horizontal filters terminating in the filter behind the rip-rap are provided to bring down the pheratic line and render the downstream slope free from saturation, a vertical chimney filter starting from MWI and going down to join the filter blanket medium at G.I. in the section is also provided. The downstream slope is protected by rock toe and pitching.

The spillway comprising of 14 no. radial gates of 15 m. x 10 m. with common bonded anchorages to release flood discharge of 18,000 cumecs corresponding to speak inflow of 23,500 cumecs. The remaining length of gorge is plugged by the earth dam. The Masonry spillway is connected with earth dam by non- overflow transition masonry blocks and key-walls and wrap rounds, there is a low saddle dam on the right flank separated from the main dam by a long ridge. The salient features of Ravishankar Sagar Reservoir are given below:

#### GENERAL

S.N.	Feature	Description
1.	Across River	: Mahanadi
2.	Village	: Gangrel
3.	Taluka	: Dhamtari
4.	District	: Dhamtari
5.	Location	: 20°37.016' N & 81° 33.808" E
6.	Nearest Railway Station and distance	: Raipur, 90 kms.

#### HYDROLOGY

S.N.	Feature	Description
1	Catchment area at the dam site	: 3670 Sq.kms.
2	C.A. Considered for Yield	: 777.00 Sq.kms.
3	Free C.A. at Dam site	: 336.70Sq.kms
4	Average annual Rainfall	: 1196 mm.
5	Maximum Rainfall	: 1426 mm.
6	Minimum Rainfall	: 234 mm.
7	Mean annual runoff	: 1479.988 M.Cum.
8	Yield at	

	50% reliability	:	1735 M.Cum.
	75% reliability	:	1557 M.Cum.
	90% reliability	:	1307 M.Cum.
9	Maximum probable flood	:	23500 Cumecs
10	Moderated out flow	:	6230 Cumecs (Easte-weir) (2,20,000 Cumecs) 1444 Cumecs (G.B. ddl.w.w.)(51,000Cumecs)

---

## RESERVOIR

S.N.	Feature	Description
1	Full Reservoirs Level	: 348.70M
2	Maximum Water Level	: 350.70M
3	Dead storages	: 336.21M
4	Flood lift	: 7.50M
5	Length of rock fill Dam	: 130 M
6	Length of spillway	: 252.25 M
7	Low water level	: 127.85 M
8	Tail water level	: 133.65 M
9	Gross capacity at F.R.L.	: 909.32 M.Cum.
10	Dead storages at L.W.L.	: 143.00M.Cum.
11	Live storages	: 766.32M.Cum.
12	Gross Utilisation	: 126.00 M.Cum. (4450 Mcft.)
13	Net Utilisation	: 101.00 M.Cum. (3567 Mcft.)
14	Evaporation Losses	: 25.00 M.Cum. (883 Mcft.)
15	Carry over	: 50.00 M.Cum. (1766 Mcft.)

## DAM

### A. Masonry Dam

S.N.	Feature	Description
a.	Left Non Over Flow Dam	
i	Top of Dam	: 353.00 m
ii	Length of NOF Dam	: 132.00 m

iii	Length of right Transition	:	70.00m
iv	Length of left Transition	:	53.495 m
b.	Over Flow Dam		
i.	Top of Dam	:	353.00 m
ii	Length of spillway	:	252.25 m
iii	Maximum height above foundation	:	14.70 m
iv	No. of sizes of crest gates	:	14 Nos, 15 m x10 m (50'x33')
v	Crest level	:	338.70 m
vi	Top width of Dam	:	7.50 m.

### **B Earth Dam**

S.N.	Feature		Description
i	Top of Dam	:	353.00 m
ii	Length of left flank Dam	:	1245.75 m
iii	Length of right rock fill Dam	:	130.00 m
iv	Minimum height from the deepest foundation of the spillway crest	:	30.50 m
v	Top width of Dam	:	7.50 m.

### **C. Saddle Dam**

S.N.	Feature		Description
1	Length of Dam	:	1050.00 m

### **SUBMERGENCE**

S.N.	Salient Feature		Description
1	Area under Submergence at F.R.L.	:	9517 Ha
2	Area under Submergence at M.W.L.	:	10674 Ha
3	Agricultural land under Submergence at FRL	:	5370.59 Ha
4	Grain Area under Submergence at FRL	:	6589.78 Ha
5	Total population affected at M.W.L.	:	5060 Souls

## 2.0 DATA USED

For estimation of sedimentation in a reservoir with the help of remote sensing and GIS, the original as well as revised (present) area of water spread at different interval is required. The original water spread at any interval can be obtained from the elevation-area-capacity curve and the revised area may be extracted from satellite data. The Dead Storage Level (D.S.L.) and the Full Supply Level (F.S.L.) of the Ravishankar Sagar reservoir are 336.21 m. and 348.70 m respectively. The LISS III data of IRS 1D (Path 58, Row 102) of ten different dates have been purchased from NRSA, Hyderabad, India to cover the whole range of live storage at regular interval. The satellite data used in the analysis has been given in the Table 1.0. The original elevation-area-capacity curve/table and the reservoir level of year 2001 to 2003 have also been used in the analysis. The original elevation-area-capacity table of the Ravishankar Sagar has been presented in Table 2.0.

**Table 1.0: Satellite data used for estimation of water spread area**

Sl. No.	Date of Pass	Elevation (meters)	Satellite	Sensor
1	23-May-01	337.59	IRS 1-D	LISS-3
2	30-Apr-01	338.16	IRS 1-D	LISS-3
3	06-Dec-03	339.55	IRS 1-D	LISS-3
4	18-May-03	340.65	IRS 1-D	LISS-3
5	29-Mar-03	341.46	IRS 1-D	LISS-3
6	30-Oct-02	342.83	IRS 1-D	LISS-3
7	8-May-02	344.62	IRS 1-D	LISS-3
8	13-Apr-02	345.32	IRS 1-D	LISS-3
9	09-Dec-01	346.41	IRS 1-D	LISS-3
10	09-Nov-03	348.72	IRS 1-D	LISS-3



**Table 2.0: The original elevation-area-capacity Table of Ravishankar Sagar Reservoir**

S.N.	Elevation (m)	Area (km <sup>2</sup> )	Capacity (M. m <sup>3</sup> )
1.	332.28	19.340	40.44
2.	333.20	21.540	62.93
3.	334.11	24.200	83.54
4.	335.33	28.080	112.29
5.	336.24	32.000	143.61
6.	337.26	35.110	174.90
7.	338.38	40.550	216.73
8.	339.29	45.160	260.49
9.	340.21	49.370	304.24
10.	341.12	53.090	348.00
11.	341.73	56.250	381.53
12.	342.09	57.790	400.48
13.	343.26	63.900	476.26
14.	344.17	68.110	533.10
15.	345.09	73.655	600.29
16.	346.00	79.281	672.33
17.	347.22	86.606	768.50
18.	348.13	91.875	851.09
19.	348.74	95.412	909.54

### 3.0 METHODOLOGY

The basic principal of revised capacity estimation using remote sensing and GIS is that when the sedimentation occurred in a reservoir its water spread reduced with respect to its original area before impoundment. The IRS 1D, LISS III data of ten different dates have been obtained and digital image analysis have been carried out in ILWIS 3.0 GIS software. All the images have been geo-referenced with the help of Survey of India toposheets so that they can be overlaid and linked with the latitude and longitude and the geographical area also can be determined directly in sq. m. After geo-referencing, all the images have been cut down to small sizes to cover the water spread area of the reservoir and its surroundings.

In the visible region of the spectrum (0.4 - 0.7  $\mu\text{m}$ ), the transmittance of water is significant and the absorption and reflectance are low. The reflectance of water in the visible region scarcely rises above 5%. The absorption of water rises rapidly in the near-IR where both, the reflectance and transmittance are low. The normalised difference water index (NWDI) has

been used to identify the water pixels in the images. The NWDI can be written as:

$$NWDI = \left[ \frac{GREEN - NIR}{GREEN + NIR} \right] \quad \dots 1.0$$

The slicing operation of the NDWI images has been carried out to extract the water pixels from the rest. The revised areas obtained from this operation may be used to estimate the revised volume between two consecutive elevations with the help of cone formula. In the cone formula, the volume of water (V) between two consecutive spread  $A_1$  and  $A_2$  can be expressed as:

$$V = \frac{h}{3} (A_1 + A_2 + \sqrt{A_1 A_2}) \quad \dots 2.0$$

Where, h is the height between two elevations.

The revised cumulative capacities have been obtained by adding the revised volumes between consecutive intervals. For comparison, the original cumulative capacities on different stage of pass have been obtained from the original elevation-area-capacity curve.

#### 4.0 ANALYSIS AND RESULTS

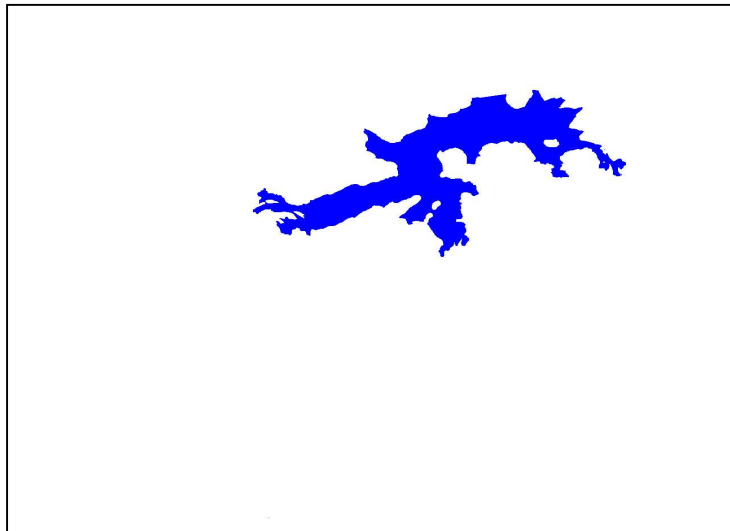
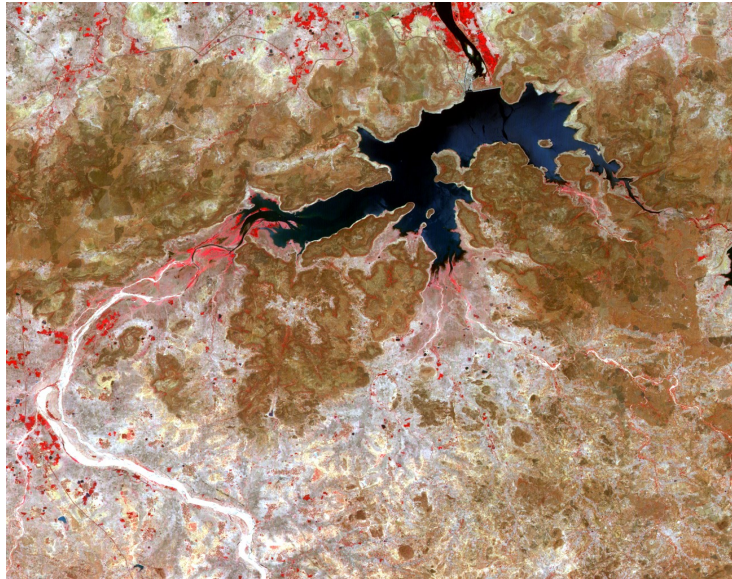
The satellites data of ten different dates have been analysed to determine the revised water spread areas of Ravishankar Sagar reservoir. The false colour composite and the masked out water spread area of some selected dates have been presented in Figure 2.0 to 4.0. The satellite data at D.S.L. i.e. 336.21 m and at F.S.L., i.e. 348.70 m were not available. To compute the revised spread area at these levels, a graph has been prepared between reservoir elevation and spread area. A best fit line has been plotted and the revised water spread at 336.21 m and 348.70 m have been computed as 3022.98 hectare and 9018.7 hectare respectively. The revised water spread area and corresponding volume at different elevations have been worked out and given in the Table 3.0.

Using revised water spread areas, the revised cumulative capacity and percentage loss in grass storage at different levels have been estimated. The computation of percentage loss in storages of Ravishankar Sagar Dam has been depicted in Table 4.0. The graphical representation of the elevation v/s original and revised cumulative capacities of Ravishankar Sagar reservoir has been presented in Fig. 5.0.

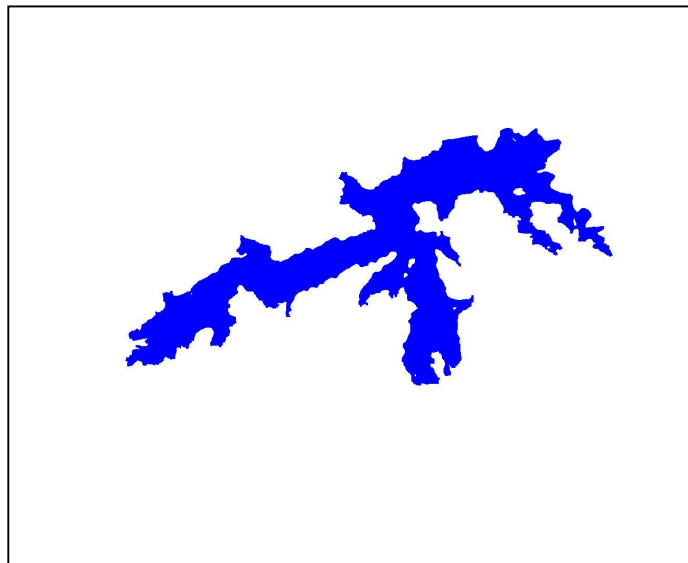
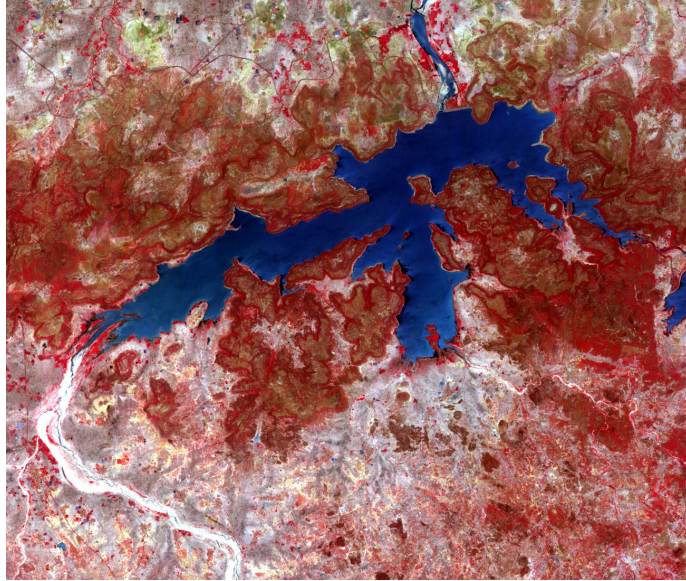
From the analysis of the results, it has been observed that 45.93 M. cum of gross storage and 31.00 M. cum. of live storage have been lost in last 24 years (1979 to 2003). If the rate of sedimentation in the reservoir is assumed as constant over the period of 24 years, the rate of silting may come out as 1.91 M. cum/year or 191 ha-m/year. The catchment area up to the dam

site of the Ravishankar Sagar reservoir being 3670 sq. km, the silting rate in commonly unit is computed to be 5.20 ha-m/100 km<sup>2</sup>/year. It has been observed that the present rate of sedimentation is higher than the adopted rate of Mahanadi project which is 3.4 ha-m/100 km<sup>2</sup>/year. In Mahanadi project report, it has been assumed that the 4.5% of the live storage may be lost in 50 years due to sedimentation. The live storage of the dam is 766.32 M. cum. The sedimentation in 50-years may be computed as 34.48 M. cum. The present study shows that in the last 24 years, 31.00 M. cum of the live storage has been lost due to sedimentation, therefore it is necessary to take corrective measures in the catchment area to reduce entry of silt in the reservoir.

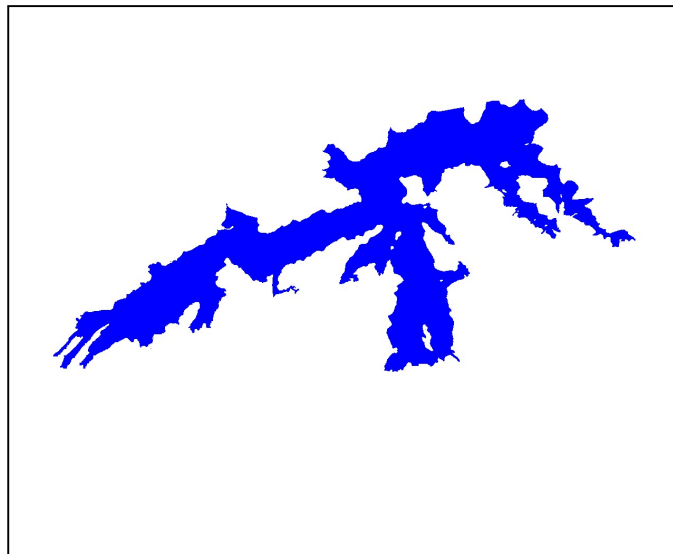
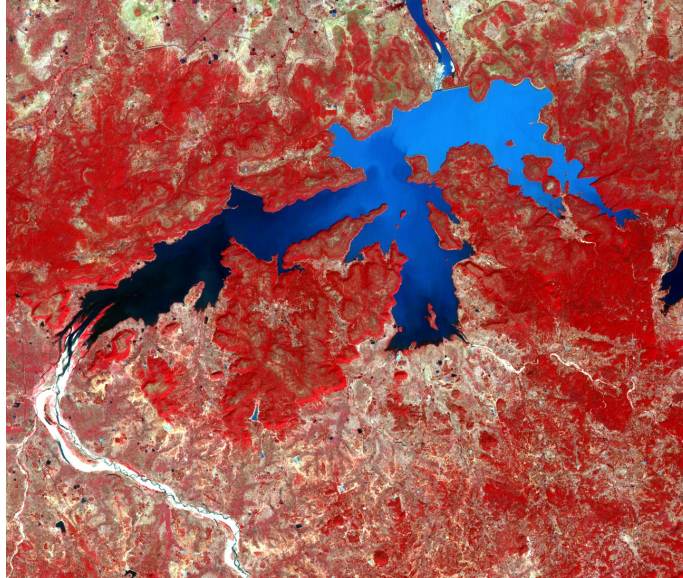
A hydrographic survey of Ravishankar Sagar dam has also been conducted in the year 2003. The cumulative capacities at different levels obtained from the remote sensing analysis have been plotted on a graph and a best-fit line has been plotted. Using this best-fit line, the revised cumulative capacities at smaller intervals have been computed. The cumulative capacities of original, revised and 2003-hydrographic survey have been presented in Table 5.0. From the observation of the table, it may be concluded that the remote sensing approach for estimation of reservoir sedimentation can be used conveniently economically at regular interval.



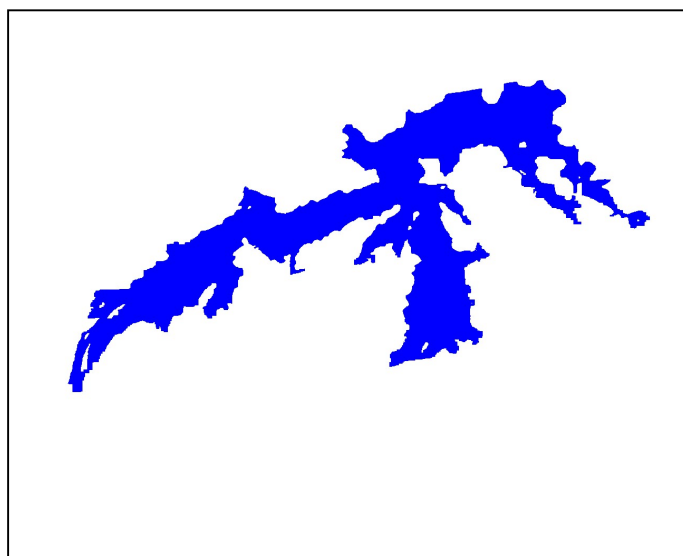
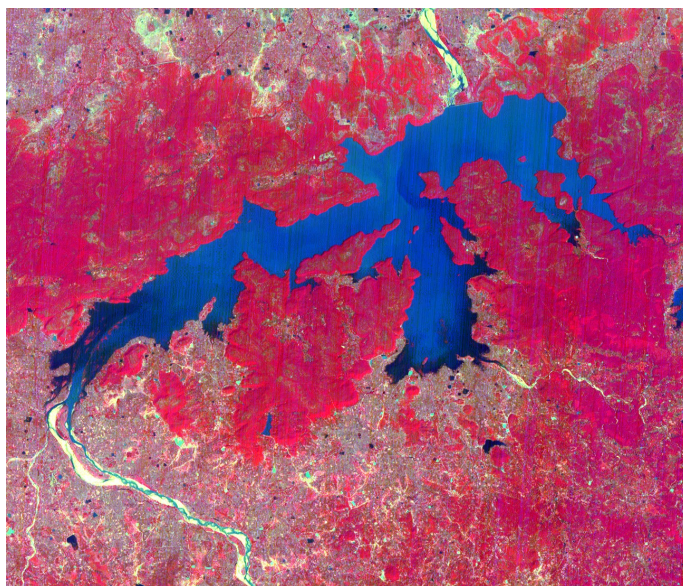
**Fig 2.0: False colour composite and water spread area of Ravishankar Sagar reservoir on April 30, 2001.**



**Fig 3.0: False colour composite and water spread area of Ravishankar Sagar reservoir on May 08, 2002.**



**Fig 4.0: False colour composite and water spread Area of Ravishankar Sagar reservoir on Dec 09, 2001.**



**Fig 5.0: False colour composite and water spread area of Ravishankar Sagar reservoir on Nov 09, 2003.**

**Table 3.0: Revised elevation-area-capacity table for Ravishankar Sagar Reservoir**

Date of Pass	Reservoir Elevation (meter)	Number of Water Pixel	Revised Area (hectare)	Revised Volume (M cu.m)	Original Cumu. Capacity (M cu.m)	Original Volume (M cu.m)	Loss in Volume (M cu.m)	% Loss in Volume
River Bed	323.50		0.00		0.000			
				128.074		143.000	14.926	10.44
DSL *	336.21		3022.98		143.000			
				43.772		44.225	0.453	1.02
23-May-01	337.59	57694	3323.2		187.225			
				20.243		21.288	1.045	4.91
30-Apr-01	338.16	65705	3784.6		208.513			
				56.996		61.689	4.693	7.61
6-Dec-03	339.55	76816	4424.6		270.202			
				51.269		55.197	3.928	7.12
18-May-03	340.65	85090	4901.2		325.399			
				40.746		41.290	0.544	1.32
29-Mar-03	341.46	89596	5160.7		366.689			
				77.139		81.720	4.581	5.61
30-Oct-02	342.83	106145	6114.0		448.409			
				116.110		117.556	1.446	1.23
8-May-02	344.62	119210	6866.5		565.965			
				49.657		52.533	2.876	5.47
13-Apr-02	345.32	127147	7323.7		618.498			
				83.820		86.151	2.331	2.71
9-Dec-01	346.41	139965	8062.0		704.649			
				197.274		204.891	7.617	3.72
9-Nov-03	348.72	156720	9027.1		909.540			
FSL *	348.70		9018.7	195.566	909.320	204.671	9.105	4.45



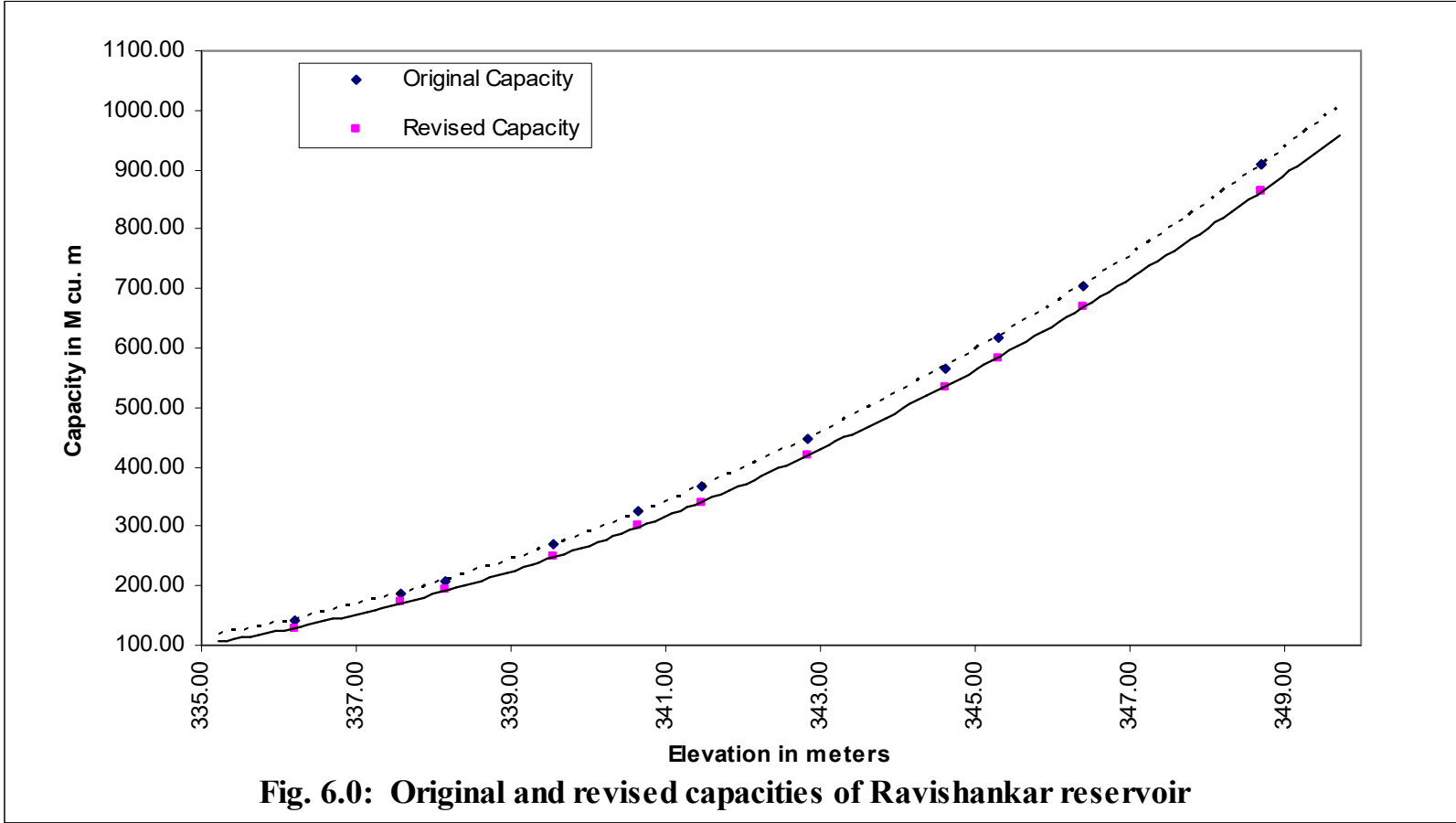
**Table 4.0: Estimation of loss in storage of Ravishankar Sagar reservoir**

Elevation (meter)	Original Capacity (ha-m)		Revised Capacity (ha-m)		Loss in Cum. Capacity (ha-m)	% Loss in Cumulative Capacity
	Volume	Cumulative Capacity	Volume	Cumulative Capacity		
323.50*	143.000	143.000	128.074	128.074	14.926	10.44
326.21**	44.225	187.225	43.772	171.846	15.379	8.21
337.59	21.288	208.513	20.243	192.089	16.424	7.88
338.16	61.689	270.202	56.996	249.085	21.117	7.82
339.55	55.197	325.399	51.269	300.354	25.045	7.70
340.65	41.290	366.689	40.746	341.100	25.589	6.98
341.46	81.720	448.409	77.139	418.240	30.169	6.73
342.83	117.556	565.965	116.110	534.350	31.615	5.59
344.62	52.533	618.498	49.657	584.007	34.491	5.58
345.32	86.151	704.649	83.820	667.826	36.823	5.23
346.41	204.891	909.540	197.274	865.100	44.440	4.89
348.72	204.671	909.320	195.566	863.392	45.928	5.05
348.70***						

\* River bed level

\*\* Dead storage level

\*\*\* Full supply level



**Table5.0: The original capacity, revised capacity and capacity obtained from 2003-hydrographic survey of Ravishankar Sagar Reservoir.**

S.N.	Level (m.)	Cumulative capacity (M. cum.)		
		Original	Revised	2003-survey
1.	336.24	143.61	130.57	124.75
2.	337.46	185.38	167.20	176.53
3.	339.60	272.07	249.81	251.02
4.	340.21	304.24	277.66	282.72
5.	340.82	333.41	307.40	311.61
6.	341.43	354.00	339.04	331.89
7.	342.09	400.48	375.42	378.00
8.	343.87	514.16	484.63	489.52
9.	344.48	552.80	525.78	527.56
10.	345.39	624.24	590.70	597.81
11.	346.00	672.33	636.59	645.96
12.	346.61	720.41	684.38	693.92
13.	347.22	768.50	734.08	741.81
14.	347.83	821.86	785.67	795.01
15.	348.44	880.31	839.17	852.92
16.	348.74	909.54	866.81	881.34