CRITICAL ANALYSIS OF SEDIMENTATION ASSESSMENT OF RESERVOIRS OF NAGPUR REGION DONE BY SATELLITE REMOTE SENSING

Er. S. R. Mandwar¹, Dr. H. V. Hajare², Dr. A. R. Gajbhiye³

¹Assistant Engineer Gr-1, Water Resources department Maharashtra Nagpur.
²Professor and H.O.D., Priyadarshani College of Engineering, Nagpur Maharashtra
³Professor and H.O.D., Yeshvantrao Chavan College of Engineering, Nagpur Maharashtra

ABSTRACT

To evaluate the performance of Reservoirs in Nagpur region, Water Resources Department of Maharashtra has conducted Satellite Remote Sensing (SRS) Survey of several reservoirs in the region. This paper elaborated the facts of sedimentation status of reservoirs in the Nagpur region in Vidarbha. Maharashtra Engineering Research Institute (MERI) Nashik, have conducted capacity assessment of several Major and Medium reservoirs of Nagpur Region by satellite Remote Sensing technique. The average rate of sedimentation in the reservoirs of Nagpur region has been observed as 5.22 Ha.m / 100 km² / year. In this paper a little attempt have been made to analyze the critical assessment of rate of sedimentation considering design criteria for sedimentation, geology of catchment, and the rate of sedimentation arrived from SRS.

Keywords: Climate Zone, Design of Dams, Life of Dams, Limitations of SRS, Rate of Sedimentation, Satellite Remote Sensing.

1. INTRODUCTION

Remote Sensing based reservoir capacity assessment survey is essentially based on mapping of water-spread areas at the time of satellite over pass. The fact that the water-spread area of the reservoir is reduced with the sedimentation at at different levels was used to evaluates the present capacity of reservoir. The water-spread area and the elevation information are used to evaluate the volume of water stored between different levels. These capacity values are then compared with the originally calculated designed capacity values to find out change in capacity between two different levels. Reservoirs constructed on rivers are subjected to sedimentation. Reservoir sedimentation is a natural phenomenon. All the reservoirs are bound to suffer a loss in their storage potential because of silt load, over a period of time. The specific site conditions, land use, topography, morphology, and
rainfall intensity affects the rate of sedimentation. In this paper a little attempt has been made to focus the factors affecting the rate of sedimentation of reservoirs in Nagpur region.

The literature review in this regard shows that in India, about 5334 M Tones of soil (about 16.35 t / Ha.) is eroded annually (Narayan and Ram Babu, 1983), out of which about 10% gets deposited in the reservoirs. As per the ISO-erosion map (Gurmel Singh, Ram Babu, Pratap Narain) the rate of sedimentation in Vidarbha is in the range of 5-10 tones / ha / year (7.5- 15 Ha.m / 100 km²/year). As per the State of the Art report of Central water Commission Ministry of Water Resources Govt. of India, on Development of Hydrological Design Aids (surface water) under Hydrology project –II (November 2010) the most of the area of Vidarbha region is under Decan peninsular east flowing rivers including Godavari and South Indian rivers where the average rate of sedimentation is 7.43 ham/100 km² / year and the medium value of sedimentation is 4.65 ham/100km²/year. In the report it has been mentioned that the little portion of Narmada and Tapi basin has the average rate of sedimentation as 7.29 ham/100km²/year and the medium based value as 7.5 ham / 100 km²/year.

II. STUDY AREA AND CHARACTERISTICS OF CATCHMENT AREA OF RESERVOIRS

The major and medium projects of Nagpur region have been surveyed for study of sediments accumulation and capacity evaluation using SRS technique. Major projects viz. Pench, Itiadow, Lower wunna, Bor, Erai and Medium projects Dham, and Kolar have been selected for study, and the details of rainfall, soils of the region, and geology of the catchment area have been shown in fig. no.1 The details of location of projects, Basin and sub basins of catchments of reservoirs are shown in fig. no.2. The details of Rainschet and soils have been taken from Maharashtra Irrigation Commission Report 1999. District wise average rainfall data have been taken from MERI – Nashik. Location map of Nagpur Region has been taken from Water Resources Department, Nagpur. Drainage properties of soils and Lithology have been taken from Maps prepared by Maharashtra Remote Sensing application Center, Nagpur. The features of each of factors have been elaborated as below. 

![Fig-1: VIDARBHA REGION SOILS AND RAINFALL](source:- Maharashtra Irrigation Commission 1999)

![Fig-2: RESERVOIRS IN NAGPUR REGION](source:- Maharashtra Irrigation Commission 1999)
A. RAINFALL

The mean Annual rainfall of the region ranges 750 mm to 1500 mm. Bhandara, Gondia, Chandrapur, and Gadchiroli districts of the Eastern Vidarbha falls under heavy rainfall zone with an average rainfall above 1250 mm. Nagpur and Wardha districts are under medium rainfall zone, ranges 875 mm to 1250 mm. The monthly average district wise rainfall of Nagpur region is shown in Fig no.3.

B. SOILS OF THE NAGPUR REGION

The Eastern part of Nagpur district, Chandrapur, Gadchiroli, Bhandara, and Gondia districts are covered with much earlier geological formations such as Granite of the Cambian age, and sand stones of the Vindhyan age, several Metamorphic rocks such as Gneiss, Schist, Pegmatite marbles, etc. The plains in Nagpur, Bhandara, Gondia, chandrapur, and Gadchiroli districts have been covered with Yellowish brown soil. The Western part of Nagpur district and Wardha district have the Black Cotton soil. Soil texture, erosion property, soil type of the reservoirs surveyed by remote sensing in Nagpur Region are tabulated as Table-1.
Table-1: SOILS OF THE NAGPUR REGION

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name of Project</th>
<th>District</th>
<th>Soil Type</th>
<th>Soil Texture</th>
<th>Erosion Property</th>
<th>Sub-Basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pench</td>
<td>Nagpur</td>
<td>Yellowish Brown soil mixed origin on high level and plains</td>
<td>Gravelly sandy clay loams</td>
<td>Slight to Moderate</td>
<td>Wainganga</td>
</tr>
<tr>
<td>2</td>
<td>Lower wunna</td>
<td>Nagpur</td>
<td>Shallow depth medium B.C. soil, hilly area.</td>
<td>Clayey loams</td>
<td>Moderate</td>
<td>Wardha</td>
</tr>
<tr>
<td>3</td>
<td>Bor</td>
<td>Wardha</td>
<td>Shallow to medium deep B.C. soil</td>
<td>Clayey loams, clayey.</td>
<td>Moderate to Severe</td>
<td>Wardha</td>
</tr>
<tr>
<td>4</td>
<td>Dham med. Pro.</td>
<td>Wardha</td>
<td>Shallow to medium deep B.C. soil</td>
<td>Gravelly clay loams.</td>
<td>Moderate to Severe</td>
<td>Wardha</td>
</tr>
<tr>
<td>6</td>
<td>Itiadoh</td>
<td>Gondia</td>
<td>Yellowish Brown soil (mixed origin) on plains</td>
<td>Gravelly sandy clay loams.</td>
<td>Moderate</td>
<td>Wainganga</td>
</tr>
<tr>
<td>7</td>
<td>Erai</td>
<td>Chandrapur</td>
<td>Deep to Medium B.C. Soil</td>
<td>Clayey, Clay loams.</td>
<td>Severe to very Severe</td>
<td>Wardha</td>
</tr>
</tbody>
</table>

C. BASIN OF NAGPUR REGION

The basin of Nagpur region is Godavari basin and Sub-basins are Wainganga, and Wardha. The details of soil and rainfall of the region are shown in Fig. 1.

III. NECESSITY OF RE-SURVE OF RESERVOIRS AND METHODOLOGY

A. NECESSITY

The efficient use and management of available water in the reservoirs is the demand of time. Day by day the uncertainty of climatic changes and increasing population, creating pressure on available water resources. Hence the critical assessment of each of the major and medium reservoirs became essential, so that proper planning for available water storage and if any catchment area treatment needed can be implemented in time.

The life span of the reservoir is governed by the rate of sedimentation, which gradually reduces its storage capacity. The loss in storage capacity affects planning for long term utilization of water for irrigation, domestic use and flood control activities. To increase the life span of reservoirs and to use the available storage to its optimum is the challenge for the Engineers working in the field of water resources.

The process of sedimentation in the reservoirs and the rate of sedimentation is governed by various factors such as land use, topography, lithology, hydrology, and climatic conditions of the catchment area of reservoirs. The rate of sedimentation obtained using Satellite Remote Sensing techniques is the physical database to analyze the factors governing the rate of sedimentation. The consideration of accuracy of rate of sedimentation on the basis of single SRS survey report may be inadequate for future planning. On the basis of two or three successive SRS survey at the interval of five years are essential to established the accurate rate of sedimentation.

A Reservoir Sedimentation Committee under Ministry of Water Resources, Government of India, was set up in 1978 has recommended that the capacity survey of reservoirs be conducted at the interval of five years.
B. METHODOLOGY

Maharashtra Engineering Research Institute, Nashik has conducted the Satellite Remote Sensing survey of several reservoirs in Nagpur region. For this following field data for each of the reservoirs have been collected.

1. Water levels in the reservoir on different dates of the Satellite pass over the reservoir.
2. The water spread area at different levels and volume as per the project report.
3. The original Elevation Area capacity table.
4. Details of submergence area on contour Index map.
5. Latitude/Longitude location of the reservoir.

The basic concept is to find the water spread area from satellite data for different water levels between Maximum Draw Down Level (MDDL) to Full Reservoir Level (FRL). The difference between aerial spread of water between current year and earlier years is the aerial extent of silting at these levels. Series of observations as imageries for different selected cloud free days of satellite over pass have been recorded and the capacity table has been prepared and compare with original capacity table. Difference in capacity treated as accumulated sediments.

IV. SEDIMENTATION ASSESSMENT OF RESERVOIRS IN NAGPUR REGION BY SRS

The Maharashtra Engineering Research Institute (MERI), Nashik has conducted the Satellite Remote Sensing Survey of major projects viz. Pench, Itiadoh, Lower wunna, Bor, Erai and Medium projects Dham, and Kolar in Nagpur region. The LISS III sensor of IRS 1C, 1D, and P6 satellite have put an immense contribution in SRS based sedimentation studies of reservoirs in the Nagpur region. The LISS III sensor resolution of 24 m is more or less grid size of 30 m x 30 m has been adopted in actual field survey. The Observations of the study are tabulated as Table-2.

Table-2: SEDIMENTATION ASSESSMENT OF RESERVOIRS IN NAGPUR REGION BY SRS

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name of Project</th>
<th>Catchment Area Km²</th>
<th>Designed L. S. Mm³</th>
<th>As per SRS L. S. Mm³</th>
<th>Total Loss in L. S. Mm³</th>
<th>Percentage Loss in Live Storage Mm³</th>
<th>Period of Sedimentation In year</th>
<th>Rate of Sedimentation in Ham/100 Km²/Yr.</th>
<th>Annual % Loss.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pench Totladoh</td>
<td>4273</td>
<td>1091</td>
<td>1017</td>
<td>74.07</td>
<td>6.79</td>
<td>24</td>
<td>7.22</td>
<td>0.283</td>
</tr>
<tr>
<td>2</td>
<td>Pench Navegaon Khairy</td>
<td>388</td>
<td>181</td>
<td>141.39</td>
<td>39.3</td>
<td>21.72</td>
<td>34</td>
<td>7.40</td>
<td>0.639</td>
</tr>
<tr>
<td>3</td>
<td>Lower Wunna Vadgaon</td>
<td>854.5</td>
<td>136</td>
<td>134.9</td>
<td>1.19</td>
<td>0.81</td>
<td>13</td>
<td>0.99</td>
<td>0.062</td>
</tr>
<tr>
<td>4</td>
<td>Bor Proj.</td>
<td>380</td>
<td>127.4</td>
<td>123.2</td>
<td>4.21</td>
<td>3.30</td>
<td>44</td>
<td>2.51</td>
<td>0.075</td>
</tr>
<tr>
<td>5</td>
<td>Dham Proj.</td>
<td>371</td>
<td>62.51</td>
<td>59.5</td>
<td>3.03</td>
<td>4.84</td>
<td>24</td>
<td>3.40</td>
<td>0.202</td>
</tr>
<tr>
<td>6</td>
<td>Kolar Proj.</td>
<td>176</td>
<td>31.32</td>
<td>31.32</td>
<td>0.90</td>
<td>2.87</td>
<td>26</td>
<td>1.96</td>
<td>0.111</td>
</tr>
<tr>
<td>7</td>
<td>Itiadoh</td>
<td>704</td>
<td>318.82</td>
<td>329.27</td>
<td>-</td>
<td>-</td>
<td>40</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Erai proj.</td>
<td>550</td>
<td>193</td>
<td>144.8</td>
<td>48.2</td>
<td>24.97</td>
<td>22</td>
<td>39.82</td>
<td>1.135</td>
</tr>
</tbody>
</table>

Source:- WRD, Nagpur
V. DESIGN PARAMETERS OF THE RESERVOIRS

The major and medium reservoirs are designed for the 75% dependability whereas the minor reservoirs are designed for 50% dependability. The life of reservoirs and the rate of sedimentation for major, medium, and minor reservoirs for the purpose of design considered as below as Table 3.

Table 3: DESIGN PARAMETERS OF THE RESERVOIRS.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Type of Reservoir</th>
<th>Prescribed rate of Sedimentation ham/100km²/yr.</th>
<th>Life of dam in Year</th>
<th>Dependability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Major</td>
<td>3.57</td>
<td>100</td>
<td>75%</td>
</tr>
<tr>
<td>2</td>
<td>Medium</td>
<td>2.38</td>
<td>75</td>
<td>75%</td>
</tr>
<tr>
<td>3</td>
<td>Minor</td>
<td>1.67</td>
<td>60</td>
<td>50%</td>
</tr>
</tbody>
</table>

As per the MI manual of Water Resources Department of Maharashtra (1987) the rate of sedimentation for minor irrigation projects is recommended as 1.67 ham/100km²/year. On observations it was found that the rate of siltation for minor irrigation projects much more higher than the recommendations in MI manual, hence as per circular of Government of Maharashtra (BKS 1091/(468/91)/IMP dt. 5th May 1992) the rate of sedimentation was recommended as 6.0 ham/100km²/year. And the pattern of distribution of silt is 50% in live storage and 50% in dead storage.

As per IS: 12182 (1987), the present practices have following main features:

1. The sedimentation rate is to be decided on the basis of observations of river sediment flow and reservoir surveys.
2. Methodologies for trapping efficiency and sediment distribution have been specified for distribution of sediment within the reservoir depths, empirical area reduction method is preferred.
3. The live storage is to be so planned that the benefits do not reduce for a period of 50 years for irrigation or 25 years for hydropower projects.
4. The live storage is to be so planned that sedimentation beyond the outlet, causing operational problems, would not occur for 100 years for irrigation projects and 75 years for hydropower projects.
5. If the annual loss of capacity of reservoirs is less than 0.1 percent it is insignificant. If it is 0.1 to 0.5 percent it is significant, the simulation or working study may be done to ensure full service time of reservoir. And if this annual rate of loss of capacity is more than 0.5 percent, it considered as serious and catchment area treatment become essential to ensure full service life of reservoir.

VI. LIMITATIONS OF THE SATELLITE REMOTE SENSING

1. The Remote Sensing based capacity estimation, works between FRL and the minimum water level in the reservoir only. Thus changes can be estimated only in this zone of reservoir. For the capacity estimation below minimum water level in reservoir, other method like hydrographic survey is to be conducted.
2. Availability of cloud free dates through reservoir operation period is the problem. Hence data from different year was selected.
3. Remote Sensing technique gives accurate estimation for fan shaped reservoir where there is a considerable change in water-spread area for incremental change in water level.
4. Another source of general error lies in the identification of tail end of reservoir particularly, in rainy season.

VII. RESULTS AND DISCUSSION

The rate of sedimentation of catchment area of reservoirs in Wainganga sub basin have been observed more than that of catchment area of Wardha sub basin. In Wainganga sub basin soils are yellowish/redish brown colour clayey sandy loams which are slight to moderate in drainage, whereas the soil of Wardha sub basin is B.C. soil deep to moderate depth and severe to moderate in drainage. The average rate of sedimentation in Nagpur region have been observed as \(5.22 \text{ ham/100km}^2/\text{year}\) which is more than the design parameters for design the life of reservoirs as tabulated in table 4. This rate of siltation is alarming and demands the catchment area treatment. After Satellite Remote survey, it has been observed that the storage capacity of Itiadoh reservoir in Gondia district is more than the design capacity it mean there were lacunae in original capacity assessment. The rate of annual loss of capacity of Erai dam in Chandrapur district has been observed as 1.135% which is seems to be very serious and it is very essential to take remedial treatment to reduce the annual rate of sedimentation. There is a thermal power plant on Erai Reservoir hence to assure maximum life of reservoir, catchment area treatment is necessary for Erai dam. The rate of annual loss in Pench Navegaon Khairy Reservoir has been observed as 0.639 is also serious matter it demands catchment area treatment to increase the life of reservoir. In case of other reservoirs stimulation study for capacity is became essential. Except Pench project, the Satellite Remote Sensing survey of other reservoirs in Nagpur region have been conducted once Hence the rate of sedimentation observed in the single SRS report could not be implemented rationally. The correctness of the estimation of rate of sedimentation by SRS method is fully dependent on the correctness of the original area capacity table. If the original capacity table is incorrect and has some errors, then conclusion about rate of sedimentation based on comparison of with SRS based survey may not give correct picture of sedimentation in the reservoirs.

VIII. CONCLUSIONS

The average rate of sedimentation of Nagpur region \(5.22 \text{ ham/100km}^2/\text{year}\) is quite less than the rate given in ISO EROSION Map by Gurmel Singh, Ram Babu, and Pratap Narain (1978). The rate of sedimentation has been observed in the Nagpur region is alarming and demands catchment area treatment of reservoirs. The rate of sedimentation on the basis of single Satellite Remote Sensing Survey may not be taken for future planning of the reservoir storage as permanent solution. The detail analysis of catchment area considering, soil texture, slope of land, land use, topography, lithology, and hydrology are required to asses the rate of sedimentation. To predict soil loss the Rivised Universal Soil Loss Equation (RUSLE) module can be used. Atleast two to three SRS survey each of the reservoirs at the interval of five years span may be required for accurate assessment of rate of sedimentation. In addition to this Hydrographic survey can be conducted to assess the accurate rate of sedimentation of the reservoirs.

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X. REFERENCES