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ESTIMATION OF RESERVOIR CAPACITY LOSS OF SUKHI RESERVOIR BY REMOTE SENSING

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Abstract: To determine the loss in capacity of reservoir, assessment of sedimentation in that reservoir is essential. For the sedimentation analysis, conventional hydrographic surveys are time consuming, laborious, weather dependable, more manpower requirement and hence expensive. These drawbacks were overcome by new technological development which can be used as a tool to carry out capacity survey rapidly, frequently and economically. Thus, Satellite Remote Sensing (SRS) technique gives us directly the water spread area of reservoir. Any reduction in water spread area at specified elevation over a time period is indicative of sediment deposition at that level. This when integrated over a range of water stages helps in computing volume of storage lost through sedimentation. The present study describes capacity loss of reservoir by Satellite Remote Sensing Technique for the year 2005 (base of study) till 2010 for Sukhi Reservoir on river Sukhi and Bharaj, in Vadodara District of Gujarat, India.

Keywords: Sedimentation; Satellite Remote Sensing (SRS); water-spread area; reservoir capacity.

INTRODUCTION

The useful Life of reservoir can be determined by estimating rate of sedimentation which ultimately reduces the storage capacity of reservoir. This capacity loss of reservoir will affect adversely the planning for long term utilization of storage of reservoir for irrigation, urban water supply and flood mitigation. Some of methods presently in use for estimation/ prediction of sediment deposition in reservoir are:1) Stream measurements 2) hydrographic surveys 3) Empirical methods- Area Reduction method 4) Mathematical models 5) Satellite Remote Sensing.

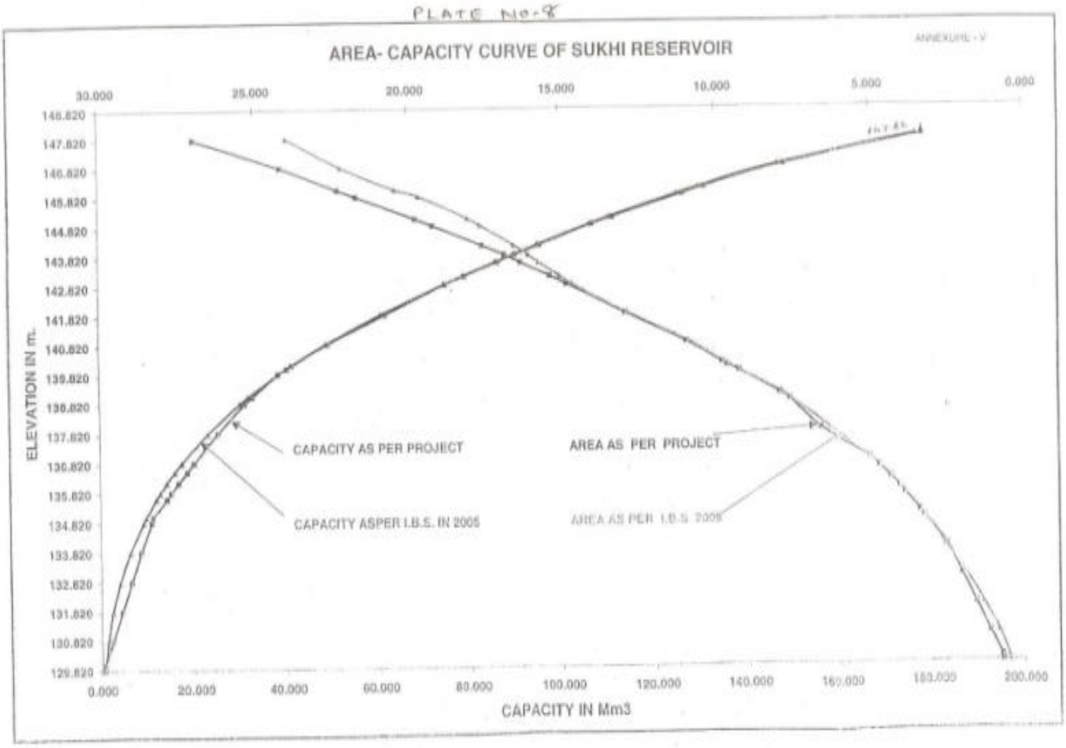
From the above methods, SRS technique offers data acquisition over a long time period and for a broad spectral range which can be considered superior to conventional methods of data acquisition. Spatial, spectral and temporal attributes of Remote Sensing data provide invaluable and timely synoptic information regarding changes in water spread area of reservoir after deposition of sediments over a period of time at particular elevation and hence by comparing the revised storage capacity at different date of satellite pass at various elevations with the original storage capacity at year of impoundment, the reservoir capacity loss can be estimated using satellite data.

This paper describes the estimation of loss of reservoir capacity of Sukhi Reservoir, one of major projects located at Sagadhra village Vadodara district, Gujarat by using multi-date Satellite imageries. The area capacity curve of year 2005 is used as a base for the assessment for the year 2010. The results of Remote Sensing survey for the period 2009-2010 are compared with the original data for the year 1987.

STUDY AREA

Sukhi Reservoir Project is one of the major Water Resources projects constructed and developed by Govt. Of Gujarat at the confluence of Sukhi and Bharaj river near village Sagadhra and Khos in Pavijetpur and Chhota-Udepur Taluka respectively of Vadodara district. The works of Sukhi Reservoir Project were started during the year 1978 and completed during the year 1987. At the time of impoundment at FRL 147.82 m corresponding capacity was 175.14 Mm^3.Total catchment area of the project is 411.81 Km^2.The Area– Elevation - Capacity curve (Fig.1) of year 2005 is taken as base for present study.

Fig.1 Area-Capacity Curve of Sukhi Reservoir

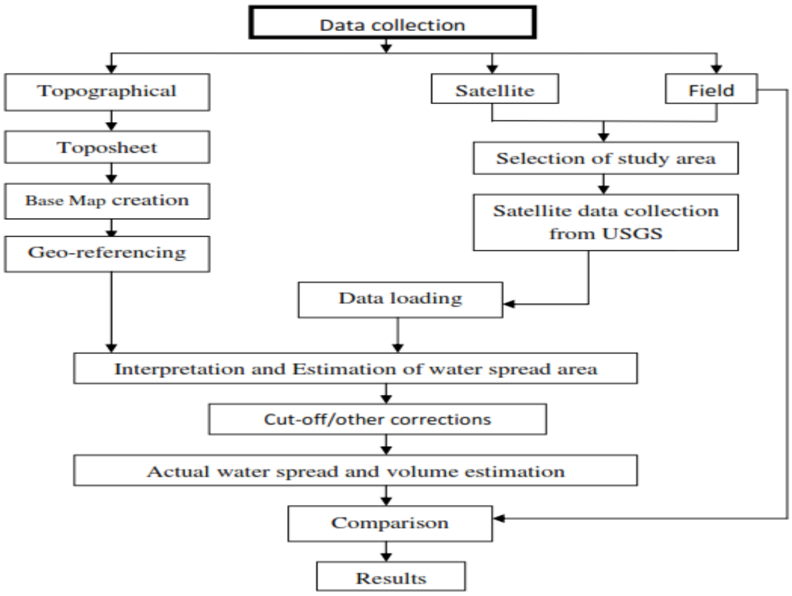


Source: Dam Management Division office, Bodeli

DATA USED

The topographical details were taken from Toposheet number F43H15 (Scale -1:50,000) obtained from Survey of India. Daily water level data for the period from 2005 to 2010 were collected from dam site. The salient features of the reservoir along with original Elevation – Area – Capacity tables, catchment area details and maps were also collected from the Sukhi Dam management division, Bodeli. The multi-spectral data of Landsat 4-5 TM sensor were collected from USGS for the year 2009-2010, and were used for this study. Five images for different date of pass were used for the analysis. The Sukhi reservoir water spread area was covered in one scene of Path 147 row 45 for LANDSAT 4-5 TM.

METHODOLOGY



The Satellite Remote Sensing (SRS) method for assessment of reservoir sedimentation uses the fact, that the water spread area of reservoir at various elevations keeps on decreasing due to sedimentation. This water spread areas of the reservoir at different levels between Full Reservoir Level (FRL) and Minimum Draw down Level (MDDL) in different months of the year could be computed from satellite imageries. Knowing the reservoir levels (as ground truth) on date of pass of the satellite, Elevation-Capacity curves could be established and compared with that at the time of impoundment of reservoir. Shift in the capacity curve will indicate extent of loss of reservoir capacity.

SATELLITE DATA ANALYSIS

The digital satellite data was processed and analyzed using Digital Image Processing software, ERDAS/IMAGINE. On visual analysis, the pixels representing water spread area (except at the periphery) of the reservoir were quite distinct and clear in the FCC. The reservoir area and its surroundings (area of interest) were separated out from the full scenes from all the imageries. These imageries were georeferenced using SOI toposheets. All images were geometrically corrected and transformed into the standard cartographic projection and scale so that any measurement made on the image will be accurate with those made on the base map and ground. (Lillesand, T. M. and Kiefer R.W., 1987). The geometric corrections enable the imageries to be represented in their latitudinal and longitudinal coverage.

IDENTIFICATION OF WATER PIXELS

In the visible region of the spectrum (0.4-0.7 urn), the transmittance of water is significant and the absorptance and reflectance are low. The absorptance of water rises rapidly in the NIR band, where both the reflectance and transmittance are low. At NIR wavelengths, water apparently acts as a black body absorber. Though the spectral signatures of water are quite distinct from other land uses such as vegetation, built-up areas and soil surfaces, the identification of water pixels at the water/soil interface is very difficult and depends on the interpretative ability of the analyst. Deep water bodies have quite distinct and clear representation as compared to shallow water. Shallow water can be mistaken for soil, while saturated soil can be mistaken for water, especially along the periphery of the reservoir. To differentiate water pixels from the adjacent wet land pixels, comparative analysis of the digital numbers in different bands was carried out. The methodologies commonly used in digital processing are classification, thresholding and modeling. After analyzing the spectral reflectance of water pixels in various imageries, an algorithm was used to identify water pixels using data of different bands. The algorithm matches the digital number (DN) value of a pixel with that of water and then identifies whether a pixel represents water or not. In addition, it also checks for the normalized difference water index, NDWI, which can be defined as:

$$NDWI = \frac{(Green - NIR)}{(Green + NIR)}$$

A separate NDWI image of the area is created. In all the images, it was found that the NDWI value for water is either equal to or greater than 0.44. The algorithm checks for the following condition for each pixel: "If the digital number of NIR band of a pixel is less than the digital number of the red band and the green band, and the NDWI is >0.44, then it is classified as water, otherwise not" In other words, if the condition is satisfied, then the pixel is recorded as water, otherwise not.

Since the absorptance of electromagnetic radiation by water is at a maximum in the NIR spectral region, the DN value of water pixels will be appreciably less than those of other land cover pixels. Even if the water depth is very shallow, the increased absorptance in the NIR band causes the DN value to be less than that of red and green bands. This algorithm differentiates water pixels from other pixels and was applied in the form of a model in the ERDAS/IMAGINE software; model runs were taken with images of different dates. The resulting images of water pixels were compared with the NIR images and the standard FCC. The results were found to be satisfactory in all the cases. The biggest advantage of this method was that it avoided the necessity of selecting different limits in different images as required in density slicing.

CALCULATION OF REVISED CAPACITY

After finalizing the water-spread areas of all the images, the histograms were analysed and the water pixels in each image were recorded. The water-spread area at any elevation was obtained by multiplying the number of water pixels by the size of one pixel (24 m x 24 m). The reservoir capacity between two consecutive reservoir elevations was computed using the prismoidal formula:

$$V = \frac{h}{3} \times (A1 + A2 + \sqrt{A1 \times A2})$$

Where V is the volume between two consecutive elevations 1 and 2, and $A1$ and $A2$ are the contour areas and AH is the difference between elevations 1 and 2. From the original elevation-capacity table, the original capacity at the intermediate elevations (reservoir elevations on the dates of satellite pass) was obtained by linear interpolation. The revised volume was compared with the original volume in each zone and the difference between the two gave the capacity loss due to sedimentation.

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RESULTS AND DISCUSSION

The difference between the cumulative capacities of original (2005) and latest (2010) surveys represents loss of capacities in different zones. The comparative capacity-elevation curves for the year 2005 and year 2010 is shown in fig 2.

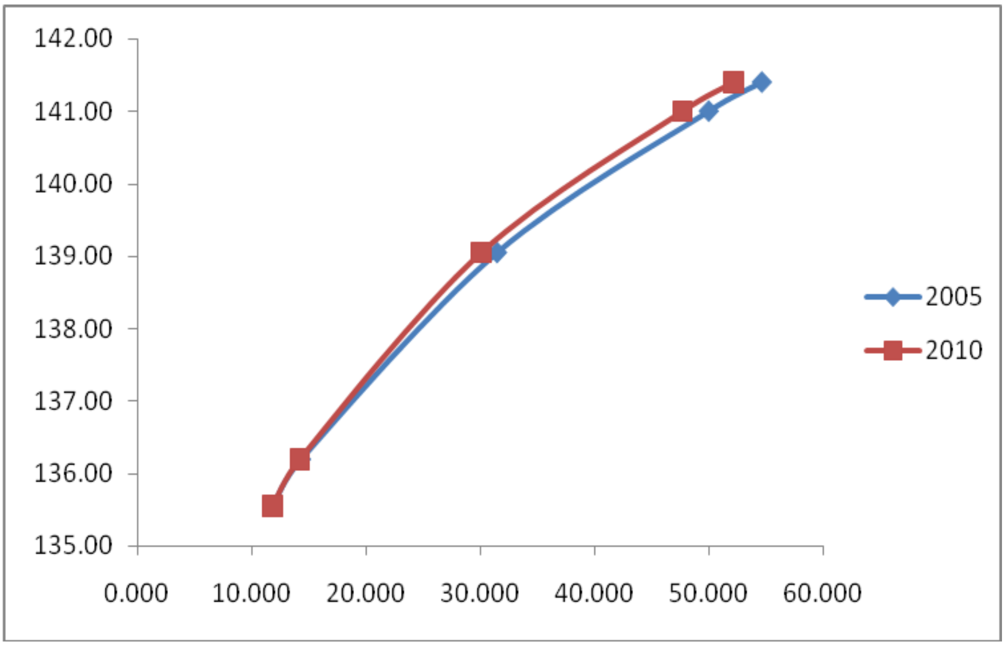

Fig 2. Capacity- Elevation curves for year 2005 and 2009/10

The cumulative revised capacity of the reservoir at the lowest observed level (135.55 m) was assumed to be the same as the original cumulative capacity (10.00 M m³) at this elevation. Above this level, the cumulative capacities between the consecutive levels were added together to arrive at the cumulative revised capacity at the maximum observed level (141.40 m). The calculation is presented in Table 1

Table 1: Calculation of Reservoir Capacity loss

Date of satellite pass	Reservoir Elevation (m)	Original area (Mm^2)	Revised area using RS data (Mm^2)	Original Volume (Mm^3)	Revised Volume using RS data (Mm^3)	Original cumulative volume (Mm^3)	Revised cumulative volume (Mm^3)
25th Mar 2010	135.55	3.407	3.582			11.804	11.804
21st Feb 2010	136.20	4.344	3.8248	2.513	2.4	14.317	14.204
20th Jan 2010	139.05	7.858	7.528	17.142	15.883	31.459	30.087
03rd Dec 2009	141.00	11.226	10.6514	18.509	17.637	49.968	47.724
17th Nov 2009	141.40	12.019	11.837	4.648	4.498	54.616	52.222

From Table 1, it is observed that there is capacity loss of 16.221 Mm³ during 2005 to 2010 (5 years).

CONCLUSIONS

- The gross storage capacity of Sukhi reservoir was estimated to be 52.222 Mm³ during 2010.
- The capacity loss of reservoir is 3.244 Mm³/year from 2005 to 2010.
- Thus Remote Sensing is an effective way for calculation of reservoir capacity loss.

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REFERENCES

[01] Saumitra Mukherjee, et.al. "Sedimentation Study of Hirakud Reservoir through Remote Sensing Techniques" Journal of Spatial Hydrology Vol.7, No.1, Spring 2007, 122-130

[02] Kamuju Narasayya, et. al. **"**Assessment of Reservoir Sedimentation Using Remote Sensing Satellite Imageries" Asian Journal of Geoinformatics, Vol.12, No.4 (2012).

[03] Sanjay K. Jain, et.al. "Assessment of sedimentation in Bhakra Reservoir in the western Himalayan region using remotely sensed data" Hydrological Sciences-Journal 47(2) April 2002

[04] M. K. Goel, et.al. "Assessment of sediment deposition rate in Bargi Reservoir using digital image processing" Hydrological Sciences-Journal 47(S) April 2002

[05] Roman, Uday C. Suneeta, Jatwa, Singh, M. N. Selvan, S. "Reservoir Capacity Loss Estimation Using Satellite Data – A Case Study" Indian Geotechnical Conference – *2010*, Geotrendz, December 16–18, 2010