WORKSHOP

ON

RESERVOIR SEDIMENTATION ASSESSMENT USING REMOTE SENSING DATA

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Module 4

Satellite Remote Sensing Techniques for Estimation of Reservoir Sedimentation

BY

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Satellite remote sensing techniques for estimation of reservoir sedimentation.

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Abstract

Hydrographic survey of Gangapur reservoir was carried out using DGPS receivers and echo sounder. Approximately 22 Sq. Km water spread area is combed parallel to the dam axis with an offset of 100 m between the survey tracks. The depth data collected are used to estimate the current storage capacity of the reservoir. In parallel, the reservoir capacity was estimated using satellite remote sensing data collected during the past years. In this paper an attempt has been made to compare the storage volume and water spread area of the reservoir, estimated using both the techniques and the results are presented.

Introduction

Reservoir sedimentation has always been a serious problem to water managers in respect of its impact on the useful life of the reservoir. Once the reservoir is constructed and put into operation, it acts as a bowl collecting sediment and silt thereby reducing its overall performance. It is estimated that, due to sedimentation most of the Indian reservoirs are loosing storage capacity every year at a rate faster than that estimated at planning stage. This calls for quick, reliable and cost effective methods using advanced technologies for periodic evaluation of storage capacity of reservoirs.

Under National Hydrology Project, a pilot study was undertaken to estimate storage capacity of Gangapur reservoir by two methods using advanced technology. One by carrying out a hydrographic survey using Differential Global Positioning System and echosounder and the other using satellite remote sensing data over a period of one year. The DGPS survey has been carried out in December 1997 and the satellite data pertaining to the reservoir area were acquired for a period from November 1995 to May 1996. A comparison of the water spread area and storage capacity obtained from both the techniques is presented in this paper.

Methodology for DGPS based survey

Advances in space technologies can be fruitfully utilised in place of conventional techniques used for hydrographic survey of reservoirs. Information derived from navigational and/or remote sensing satellites help in completing the tasks in record times, which are otherwise time consuming and tedious when tried with conventional methods. Differential Global Positioning System (DGPS) is emerging as a useful tool for hydrographic and oceanographic surveys. Global Positioning System (GPS) uses radio frequency signals from three or more navigational satellites in the vicinity to establish the position of the GPS receiver. Due to the restrictions on the accuracy of position information available with a single receiver, differential GPS is preferred in hydrographic surveys. In differential mode operation, two GPS receivers are used; one placed stationary, acts as a reference station and the other as mobile. The position information of the mobile can then be derived and corrected with reference to that of the reference station. As the differential mode has a locational accuracy of 1m, this technique is well suited for reservoir surveys. This technique has been discussed in detail in references [1,2].

Gangapur reservoir is located near Nasik township, in Maharashtra state. The earthern dam is constructed at the confluence of Godavari and Kashyapi rivers, with a length of 3.81 km and height of 36.57 m. The FRL and MDDL of the reservoir are designed at elevations 612.35 m and 592.34 m, above mean sea level, respectively.

Sedimentation survey of Gangapur reservoir was carried out in December 1997 using a hydrographic survey system comprising two GPS receivers in differential mode for position fixing, an echo sounder for depth measurement, a commercially available hydrographic survey software and a pentium computer to coordinate various tasks. The software was used for systematising the pre-survey, survey and post survey procedures. The reference station was established by fixing one GPS receiver at the head regulator chamber and the mobile station was set up in a boat by interfacing the mobile GPS receiver and the echo sounder to the personal computer. The reservoir water spread was surveyed by moving the boat through a set of pre-decided tracks and collecting the position coordinates and depth data continuously along each track. Reservoir volumes for different levels are estimated from the grid file using Trapezoidal rule and the water spread area is computed by projecting the grid surface onto a horizontal plane passing through the corresponding bed elevation [3].

Methodology for satellite remote sensing technique

Satellite remote sensing techniques are also emerging as a quick, reliable and cost effective method with which the storage capacity of reservoirs can be estimated if cloud free data is available over non monsoon season of eight months. Remote sensing satellites can provide multitemporal and multispectral data about an area of interest with a revisit period varying from 16 to 24 days. These satellites essentially record spatial information available from the radiation reflected from a frame of earth surface of definite size kept under uniform illumination. In multispectral remote sensing, the dependence of reflected radiation on different wavelengths of electromagnetic spectrum is explored and it can be used for identification of various earth surface features. Reservoir surface can be observed as temporal variations of water spread area of the reservoir on the days of pass. As satellite remote sensing technique can provide a full synoptic view of the reservoir area, these dynamic variations can be clearly observed at regular interval. The regular interval water spread images with necessary ground truth giving reservoir level corresponding to the day of pass would enable to derive reservoir elevation vs. area. Integrated over the reservoir elevation, this would help in estimating volume of water that was stored in the reservoir corresponding to the elevation difference.

Storage capacity of the Gangapur reservoir has been estimated using satellite remote sensing data. Remote sensing data from sensors LISS-II and LISS-III on board Indian Remote Sensing Satellites IRS 1B and IRS 1C respectively. for eight passes, during a period from November 1995 to May 1996 were used for computations. The satellites record data about the reservoir area in four bands of electromagnetic spectrum namely, blue (0.45 to 0.52 microns), green (0.52 to 0.59 microns), red (0.62 to 0.68 microns) and infrared (0.77 to 0.86 microns). It is known that the reflectance of water is less in infrared band than that in green band. The digital data have been geometrically corrected and a band ratioing (Infrared/Green) has been done to ascertain the water spread. The water level recorded during the date of pass of the satellite along with the water spread area computed from the satellite data are employed in the prismoidal formula for estimating the volume of the reservoir between the recorded water levels. The total storage capacity is estimated as the cumulative sum of the sliced volumes [4].

Results

Figure 1 shows the contour plan of Gangapur reservoir. Table 1 gives the details of the water spread area for different reservoir levels. Table 2 gives cumulative storage volume computed for the selected reservoir water levels using both the techniques.

Present storage capacity of the reservoir has been estimated by cumulative addition of the volume between the levels. Since the lowest water level for which remote sensing data is available is 599.58 m, the volume obtained from the survey data for this level is used for cumulative addition of volumes from remote sensing data also. Figure 2 shows the water spread area and Figure 3 shows the cumulative volume for different water levels,- estimated using both the techniques. Present storage capacity of the reservoir upto the level of 610.93 is estimated as 144.78 MCM from DGPS based survey data and the same is estimated as 155.70 MCM from the satellite remote sensing data analysis.

Discussions

Storage capacity and water spread area of Gangapur reservoir obtained from DGPS survey and satellite remote sensing have been compared. Although the difference in estimates of level wise volume and water spread area obtained from both techniques are very small, it can be observed that the estimates from satellite remote sensing data are higher in values compared to the estimates from DGPS survey data. Higher estimates from satellite data could be attributed to the following points.

1. As satellite data give a full synoptic view of the reservoir area, in addition to the reservoir water spread, it can cover the water spread in tail waters, outlet canals as well as small ponds around the reservoir. Gangapur reservoir has two such long back water tails, an outlet canal, and a few small ponds in the neighbourhood, which could not be physically surveyed due to inaccessibility. This could be a reason for the higher estimates obtained from remote sensing data.

2. The water spread area has been computed by analysis of gray values of pixels of definite size. Gray values are numerical realisation of reflected radiation from pixelised earth surface. For LISS - II sensor a pixel represents an area of 36.2m x 36.2m on the earth surface. During the analysis the pixels are to be classified into different classes such as land, water and land use/land cover, by analysing the gray values. The problem arises during the classification of pixels when they fall at the land-water boundary, as the gray values of these pixels could be midway between the gray values for the land and water. This can introduce a difference of a minimum of +/- 1 pixel size all along the water boundary for the estimations. This could also be a reason for higher estimates using satellite data.

Conclusion

Water spread area and storage volumes for different reservoir levels obtained for Gangapur reservoir using DGPS survey and satellite remote sensing data have been compared. The results show very good match between the estimates obtained using these two techniques. In DGPS survey, the storage capacity is estimated from the data collected during a short period, hence the estimate can directly represent the current capacity. On the other hand remote sensing data are obtained from the data archived over a period of eight months. There could be additional sedimentation occurred during and after these data collection period. Hence it is suggested that this method needs further calibrations to obtain faithful estimates of the current storage capacity, the remote sensing data used should be of recent past. To minimise the errors from digital image processing, satellite data of better resolution could be used. Most of the remote sensing satellites are scheduled to acquire data at around 9:30 AM to 10:30 AM local time. Daily recording of reservoir level can be carried out at this time, so as to minimise errors due to fluctuations in the water levels. This procedure after calibration would be useful in estimating reservoir capacity, identify siltation rate and zone etc. Periodical satellite data of reservoir area is necessary and should be cloud free. This is generally available in the states of Maharashtra, Mandhya Pradesh, Karnataka, Orissa and Utter Pradesh. In short the method of estimating reservoir capacity by remote sensing techniques looks promising and attractive from economic considerations.

Table 1

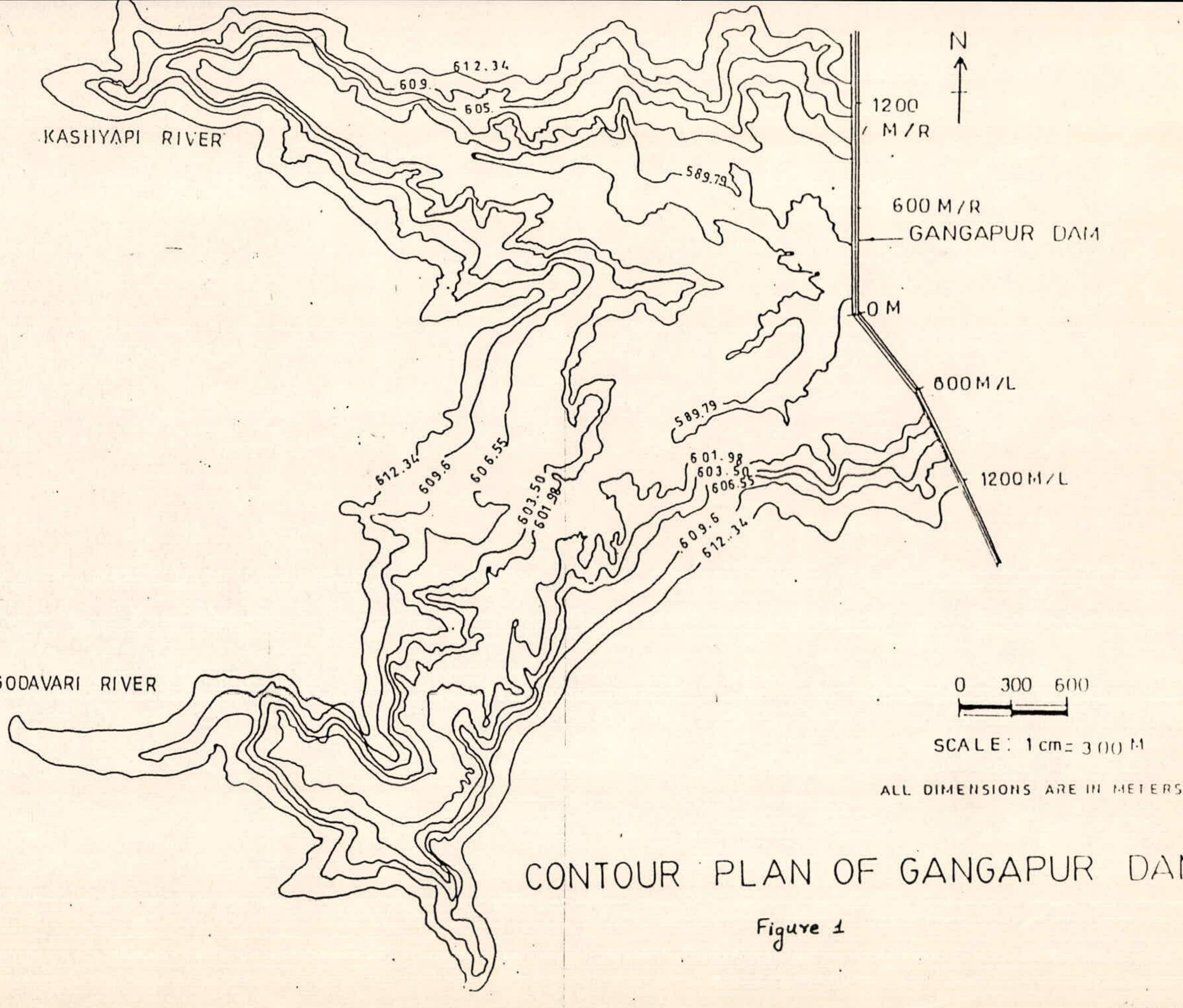
Water spread area for different water levels

Reservoir Level	Water spread area DGPS survey	Remote sensing
(m)	(Sq. Km)	
610.93	17.61	17.79
609.03	14.66	15.92
607.93	13.51	15.03
607.53	13.14	14.21
606.33	12.03	14.04
604.82	10.55	10.58
602.05	7.50	8.24
599.58	4.82	6.63

Table 2

Storage volume for different water levels

Reservoir Level	Cumulative volume DGPS Survey	Remote Sensing
(m)	(mcm)	
610.93	144.78	155.70
609.03	114.41	123.69
607.93	98.86	106.67
607.53	93.51	100.83
606.33	78.36	83.88
604.82	61.24	65.36
602.05	36.06	39.37
599.58	21.04	21.04



CONTOUR PLAN OF GANGAPUR DAM

Figure 1

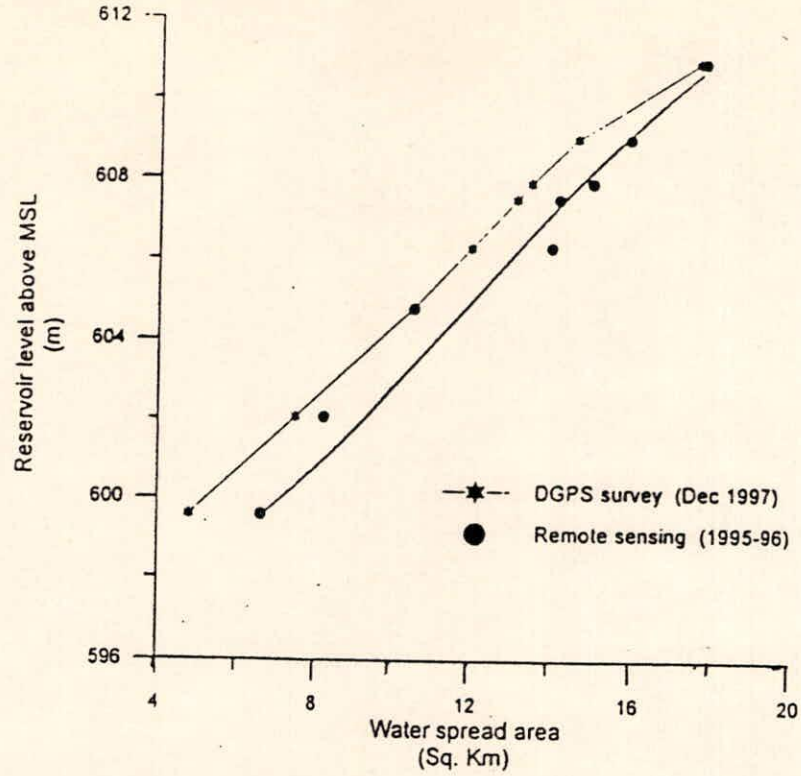


Figure 2 Comparison of water spread area.

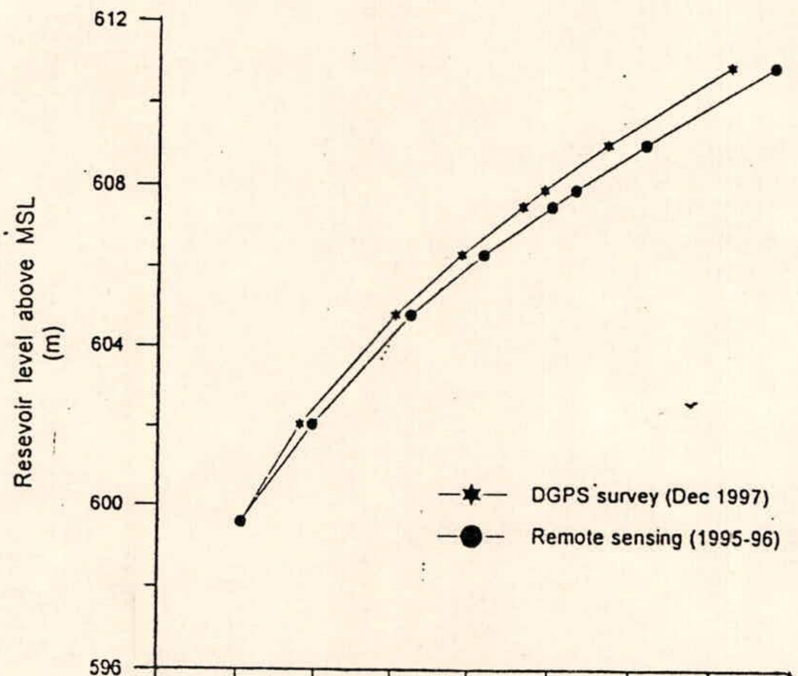


Figure 3 Comparison of storage capacity

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