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Reservoir Sedimentation in Gujarat

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Synopsis : *Dams built on rivers are subject to sediment deposition in reservoirs created on upstream and therefore provisions for extra storage in the reservoirs should be made for deposition of sediment so that the benefits do not get reduced. Various traditional as well as modern reservoir sedimentation surveying methods have been given and their applications in the capacity surveys of the reservoirs in Gujarat have been described. The new idea of the effect of various frequencies of echo-sounders and the behaviour of the return of the sound waves from the different sediment layers with various densities have been presented. Impact of different frequencies on sediment rates have been explained and it is brought out that results of sediment rates could be controversial. The need of further research in this regard is emphasised. The analysis of the silting data of reservoirs in Gujarat with reference to silting of Indian reservoirs have also been presented.*

1. Introduction

1.1 The management of water resources often requires the construction of dams, in order to control the irregularity of river discharges. All reservoirs formed by dams on sediment carrying rivers are subject to some degree of sedimentation. The problem confronting the project planner is to estimate the rate of sedimentation and the period of time before the sediment will interfere with the useful functions of reservoir. Provisions should be made for sufficient sediment storage in the reservoir at the time of design so as not to impair the reservoir function during the useful life of the project or during the period of economic analysis. Neglect in this respect would cost dearly in future, since the available water resources are limited as are the economically suitable reservoir sites within a basin.

1.2 In the operational stage of reservoirs, sedimentation surveys are conducted for various objectives. This information may be needed to :

(i) estimate the sediment yield for given watersheds or land resources areas,

(ii) evaluate sediment damage,

(iii) provide basic data to plan and design other reservoirs,

(iv) evaluate the effects of water-shed protection measures,

(v) determine the distribution of sediment in a particular reservoir, and

(vi) predict the life expectancy or period of useful operation of a reservoir.

1.3 Upon completion of the construction of a dam to impound water, regardless of the size,

a plan to monitor the resorvoir sediment accumulation should be established. This plan may vary widely depending on the size, operation, purpose or quantity of sediment inflow expected. The capacity surveys on regular intervals may be done to augment the data base of regional studies of sedimentation rates and to plan sediment control measures.

2. Reservoir Sedimentation Surveying Methods

2.1 Direct measurement yields is accomplished by either sampling the sediment load of the river or by resurveying the existing reservoirs. The general procedure for making reservoir surveys is to construct a bathymetric map of the lake bottom which can be compared to a previously constructed map to determine differences in the volume of sediment deposited There are two general methods of conducting the reservoir survey. These are the range-line survey and the contour survey. Selecting the method depends on the availability and character of previous mapping or survey records, the purpose and scope of the study objectives, the size of the reservoir, and the degree of accuracy required.

2.2 The range-line method is the most widely used for medium to large reservoirs requiring an underwater survey utilising hydrographic surveying methods. To apply the method a number of cross sections of the reservoir are surveyed before it is first filled and then periodi cally resurveyed. This method usually requires less field work and is less expensive then the contour method. On the other hand, it also is usually less accurate.

2.3 The contour method uses essentially topographic mapping procedures. This method is especially suitable for aerial surveys when flights can be scheduled for differents known pool elevations. To apply the method it is important to have a good contour map of the reservoir before filling. The contour method is usually used for small reservoirs, reservoirs which are occasionally empty or at low stage, or when the highest degree of accuracy is required.

3. Capacity Survey of Reservoirs in Gujarat

3.1 On the basis of geographical features, Gujarat State can be divided into three regions, namely (i) Gujarat Region, the main land covering the control and eastern area of the State, (ii) Saurashtra, the Peninsular Region and (iii) Kachchh Region, mostly the arid area of the State.

There are in all 17 rivers in Gujarat region. The most of the rivers of the region are inter-state rivers. These rivers flow through hilly areas till they enter the plain lands of Gujarat. There are 71 rivers in the Saurashtra region. The rivers are small but flashy during monsoon and dry up in fair season. The Kachchh region has 97 small rivulets and most of them flow radially.

3.2 Drought is a common and frequently phenomenon experienced by the north Gujarat, Saurashtra and Kachchh regions of Gujarat. Saurashtra and Kachchh regions suffered from severe drought conditions four times during the last two decades, in 1969-70, 1972-73, 1974-75 and chronic drought coditions during 1985-86 and 1986-87.

Sedimentation survey was not made in any of the reservoir in Gujarat State before 1974. During the scarcity years of 1974 and 1986, the medium sized reservoirs of the Saurashtra and Kachchh regions became almost empty. Appreciating the problem of sedimentation of reservoirs and its urgent necessity, the State Government took this opportunity and planned the reservoir bed surveys (contour surveys) of some of the reservoirs of Saurashtra and Kachchh regions. The siltation phenomenon was studied in 15 reservoirs during the year 1974 and in 23 reservoirs during the year 1986.

3.3 Realising the crucial role that silting plays in the proper design and planning of storage reservoirs systems, the C.B.I.P. included this subject under the Research scheme applied to River Valley Projects and work on selected reservoirs was initiated. For carrying out sediment survey of Ukai and Kadana reservoirs of Gujarat, sponsored under CBIP programme, one sub-division under GERI, Vadodara was opened since 1979. The systematic surveys started only after that. Looking to the importance of the problem and vast data required to be collected and analysed for other big reservoirs of Gujarat State, a separate division under GERI, Vadodara for sedimentation survey was sanctioned in 1986. The hydrographic survey of 12 reservoirs have been carried out by GERI since then.

4. Hydrographic Survey in Gujarat

The present methods of conducting sedimentation Survey in the reservoirs involves the use of conventional equipments such as (i) Motor boat with out-board engine of 3.5 to 20 H.P. (ii) Echo-Sounders with transducer or echo-track (iii) currentmeter and (iv) Tellurometer or Distomate.

4.1 Gujarat Govt. procured 4 Echo-sounders from U.S.A. through World Bank for sedimentation survey in Ukai, Damanganga and Dharoi Dam reservoirs. The echo-sounders have the following specifications :

DE - 719C
Fathometer - Echosounder
Precision Survey Depth Recorder

SPECIFICATIONS

Depth	0-55, 50-105, 100-155, 150-205 Feet 0-16.5, 15-31.5, 30-41.5, 45-61.5 Meters
Sounding Rate	534 Soundings per minute
Voltage Input	12 Vdc
Current Input	2.5 Amperes
Accuracy	± 0.5% ± 1″ of indicated depth
Operating Frequency	208 kHz
Transducer	Barium titanate-Model 200 T5HAD Optional Model 7245A
Transducer Beam width	8° at the half power points
Chart Paper Speed	1, 2, 3, 4, inches per minute
Chart Paper	7 inches x 60 feet
Recorder Dimensions	Height (including handle)--18″ Width 15-3/″ Depth 9-1/16″
Net Weight	Recorder w/transducer and rigging 47 lbs. Recorder only - 38 lbs.

SPECIFICATION

7245A Transducer

Operating Frequency	204 to 210 kHz
Transducer Impedance	50 ohms + J18 + 20% at operating frequency

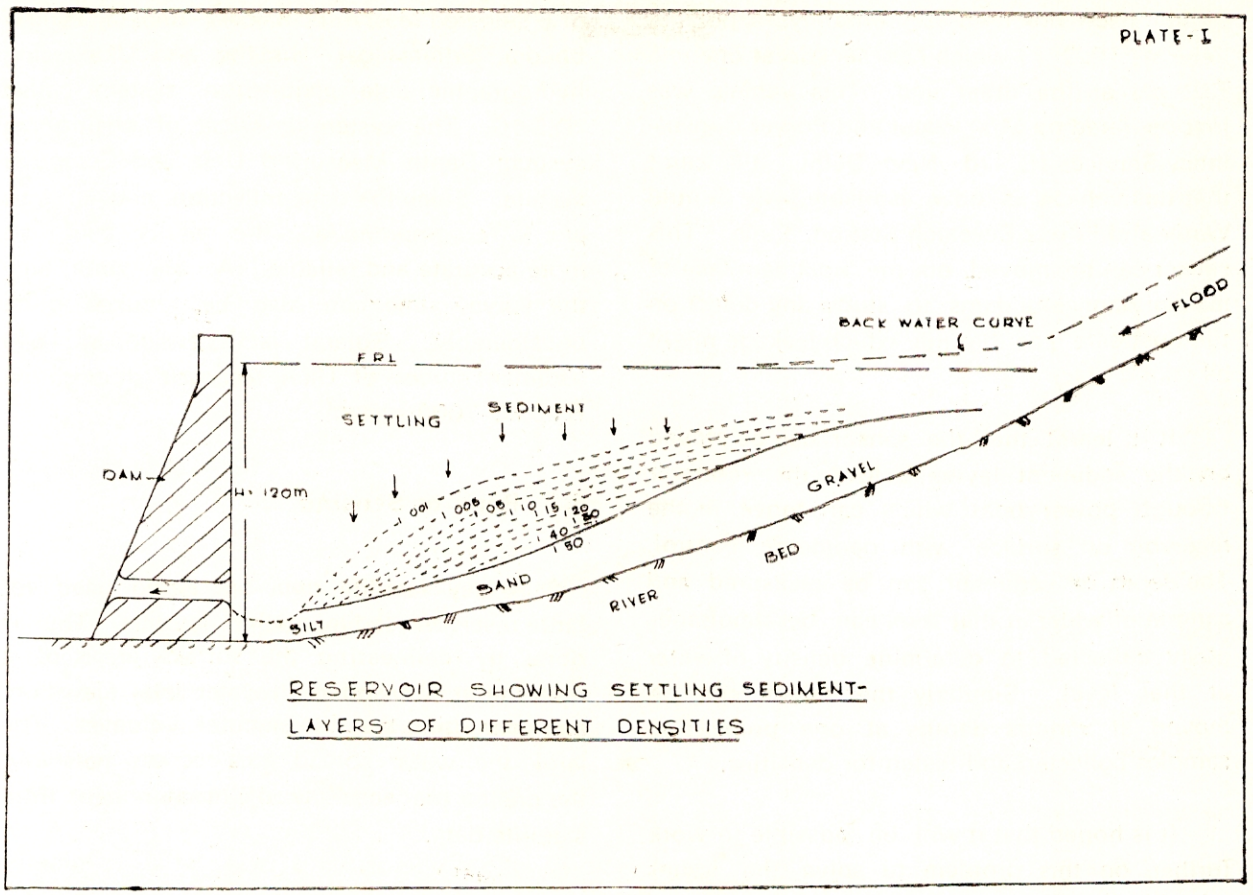
Transducer Beam Width	2.75 inclusive at – 3 dB points 3.5 inclusive at – 6 dB points. 4 degrees inclusive at – 10 dB points.
Minor Lobes	First lobes down at least 11 dB, peaking 4.5° either side of center, all minor lobes beyond 10 down at least 21 dB, and beyond 35 down at least 40 dB.
Cable	Supplied with 30' of 2 conductor # 18 shielded and neoprene jacked cable, having O.D. of 3/8". Supplied with Cannon type XLR–3–12C connector plug for use with DE–719C Survey Recorder Additional cable up to 1500' In length may be used.
Housing Material	Silicon bronze housing with sound window of polyurethane.
Mounting	The mounting stem should be vertical within 1° of the bottom for best resolution.

200T5HAD Transducer

Operating Frequency	208 kHz
Transducer Impedance	The impedance at 200 kHz with the transducer immersed in water shall be in the range of 50 ohms ± 15%.
Transducer Beam Width	Peak response within 2° of mechanical axis. — 3 dB points not more than 10° apart. —10 dB points not more than 18° apart.
Minor Lobes	First sidelobes at least 15 dB below in axis response. Outside ± 35° off axis, the response must be at least 20 dB below on axis at any angle including sides and rear.
Cable	The cable is shielded twin with stranded copper shield, all tin plated. Each conductor is the equivalent of 16 strands of # 31 AWG. The total cable length is 30' ± 6".
Housing Material	Red brass housing
Mounting	Same as 7245A.

The frequency of these echo-sounders is 200 kHz. It is learnt that these echo-sounders are manufactured with different values of frequencies viz. 200, 100, 50 kHz. Further it is learnt that lower the frequency, greater is the depth that sound can travel in water. The rebound of sound takes place from the layer of water having certain density.

It is well-known that the flood waters with all sizes of sediment enter the reservoirs every year and process of settlement of sand particles, silt particles and clay particles go on indefinitely in the body of water of the reservoirs. The reservoirs thus at any time of the year has different layers of waters having different densities. The upper layers will have lower densities and lower layers will have higher densities as clay particles will be at the highest level and silt and sand particles will be at middle levels and lower layers respectively. These densities of different layers may be of the following values from upper layers to lower layers : [see plate I attached].



RESERVOIR SHOWING SETTLING SEDIMENT-LAYERS OF DIFFERENT DENSITIES

Reservoir Depth from F.R.L.	Probable densities
15 m	1.001
25 m	1.005
30 m	1.05
40 m	1.10
50 m	1.15
60 m	1.20
70 m	1.30
90 m	1.40
100 m	1.50

The sound wave released from echo-sounder with frequency of 200 kHz will travel below FRL say down to a water layer having density of 1.15. While sound Wave released from echo-sounder with frequency of 50 kHz may travel say, down to a water layer having density of 1.30. Thus the frequency of the echo-sounder plays very important role in deciding depth of sedimentation from the F.R.L. Based on this survey, we decide depth of sedimentation in reservoirs. It is suggested that research stations in the Country may carry out experiments on this behaviour of return of sound wave vis-a-vis the water layer having certain density below which the water become not useful because of higher density and we call that level as top of sediment layer in the reservoirs.

Recently Ministry of Water Resources, New Delhi has procured "Remotely Operated Vehicle" (R.O.V.) which has sensor at one end T.V. set at the other end. This vehicle was first operated by M/s Water and Power Consultancy Services (I) Ltd New Delhi. It is learnt that this vehicle is now available with Central Water and Power Research Station, Pune. This sensor can be moved on the upstream face of masonry/concrete dams to study any defect on the upstream face through which leakage might be taking place.

It is learnt that the sensor can be moved on the sediment layers below the reservoir through power boat which can move in the reservoir on surface with geometric control. The depth of sediment can be measured and sample of water at that level can be simultaneously collected to determine density of water at that level. Similarly the sensor can be moved at various depths at one point and samples collected and tested for densities.

It is hoped that it will be possible to work further on this problem to solve the issues raised in the above paragraphs of the effect of frequency of echo-sounders.

5. Modern Methods

The basic procedure for executing sediment surveys has changed little for many years, but there have been great advance in the development of accurate and labour-saving equipment to carry out the basic procedure.

5.2 HYDAC System

In order to improve the technique of sedimentation surveys of reservoirs, presently a scheme is under implementation in Reservoir Sedimentation Directorate, C.W.C., New Delhi with the assistance of UNDP. Under this scheme it is proposed to conduct hydrographic surveys of 5 selected reservoirs namely Bhakra, Tungabhadra, Sriramsagar, Hirakud and Ukai using hydrographic data acquisition system called HYDAC. The system consists of positioning system, Depth Measuring Unit and Computer system. Since the data collection and analysis are fully computersied, the results could be more accurate and reliable. At the same time the survey time can also be reduced quite coosiderably. Gujarat is fortunate to have sediment survey of Ukai reservoir through the HYDAC-2000 system.

5.3 Remote Sensing

To-day satellite data are being used for large reservoir sedimentation studies. This is done by delineating the surface areas of a reservoir at corresponding water level elevation, and computing the incremental volumes. The larger the water spread area of the reservoir, the greater the accuracy of measurement from satellite data.

The application of Remote Sensing is in experimental stage for many of the reservoirs in the country and it may take some time to operationalise the technique. To begin with, the GERI, Vadodara has taken up such studies in Ukai reservoir.

6 Silting of Reservoirs in Gujarat

6.1 The details of sedimentation surveys in respect of the reservoirs of Gujarat State as mentioned herein-above have been collected and analysed. It is unfortunately not possible to present all the information of all reservoirs here. The most useful available information has been extracted for inclusion here and given in Annex-I.

Annexure – I

Statement showing the rates of reservoir sedimentation in some of the reservoirs of Gujarat State

Sr. No.	Name of the reservoir	Silting rate w.r.t. original survey & first capacity survey (Ha. m./ 100 Sq, km/year)	Sr. No.	Name of the reservoir	Silting rate w.r.t. first and second capacity surveys (Ha. m./ 100 sq. km. / year)
(I)	**Gujarat Region**				
1.	Dantiwada	12.57	1.	Kadana	2 61
2.	Hathmati	9 90	2.	Ukai	8.90
3.	Meshwa	17.45			
4.	Patadungri	13.58			
5.	Waidy	1.34			
II	**Saurashtra Region**				
1.	Gema	10.80	1.	Rojki	6.72
2.	Ghandali	6.13	2.	Rangola	12.92
3.	Fulzar-II	8.37	3.	Bhimdad	25.23
4.	Sorthi	14.25	4.	Ghelo (I)	17.93
5.	Sasoi	6.70	5.	Ghelo (S)	15.39
6.	Puna	11.26	6.	Khodiyar	4.55
7.	Sapada	9.98	7.	Moj	6.70
8.	Fulzar-I	6.46	8.	Surajwadi	10.00
9.	Vartu	4.25	9.	Limd Bhegave	5.02
10.	Dhatarwadi	12 54	10.	Ghee	3.14
11.	Mahuvanti	8.32	11.	Wadhwan Bhegave-II	2.02
12.	Wadhawan Bhogave	2.36			
13.	Dadar	13.40			
14.	Demi-II	11 57			
15.	Chhaparwadi (L)	7.16			
16.	Hiran-I	8.42			
17.	Vijarakhi	0.35			
18.	Brahmni	7.20			
19.	Vachhapari	6.20			

III Kachchh Region

1.	Kaila	9.27	1.	Sanadre	28.84
2.	Suvi	10.37			
3.	Rudramata	3.94			
4.	Nara	4.86			
5.	Kaswati	6.01			
6.	Godhatad	4.31			
7.	Kankawati	6.37			

6.2 The sediment rates in major reservoirs of Gujarat region have been observed to vary from 1.34 to 17.45 Ha. m/100 sq. km/year. Similarly the sedimentation rates in the reservoirs of Saurashtra region vary from 0.35 to 25.23 Ha. m/100 sp. km/year and the same in the reservoirs of Kachchh region vary from 3.94 to 28.84 Ha. m/100 sq. km year.

6.3 The analysis shows a wide variability in sedimentation rates of reservoirs. It is observed that the siltation rates in some of the reservoirs are higher than the rates assumed at the planning stage. It is pertinent to note that enough reliable data were not available for assuming the sedimentation rates of reservoirs at their planning stage and therefore, the observed rates seem to be higher than considered in planning.

Further, the silting rates in many reservoirs were estimated by computing the first capacity survey with the original survey as the second capacity survey was not done.

7. Conclusion

Reservoirs are a vital part of every water resources project, built or planned for important social and economic purposes. Though the ultimate fate of all reservoirs is to become filled with sediment, it is necessary that the reservoir planning must therefore include considerations of probable rate of sedimentation for effective functioning of the reservoir during its economic life. From observations of sedimentation rates in various reservoirs in India and abroad, it is seen that the sedimentation rate increases for first 15 to 20 years and then rate falls significantly. The overall life of all major dams constructed in India and abroad is thus more than 200 years, and even after 200 years, the benefits of irrigation and power continue with some reduced values.