Research Paper Engineering

Assessment of Sediment Distribution

* Hiral Shah, ** N. N. Borad, *** R. K. Jain

*, ** Department of Civil Engineering (W.R.M.),L. D. College of Engineering, Gujarat

*** Department of Civil Engineering, Vishwakarma Government Engineering College, Gujarat

ABSTRACT

Sedimentation is a complex but unavoidable natural phenomenon occurs in reservoirs and causes gradual reduction in capacity. Reservoir sediment assessment is required to estimate useful life, to predict revised area-capacity, and to calculate sedimentation rate. Revised area-capacity of reservoir can be calculated by various methods and field surveys.In present study, Empirical Area Reduction method is used to predict revised area-capacity of Deo reservoir. The sedimentation survey report of Deo reservoir, carried out in the Year 2005 by Integrated Bathymetric System, is used in this study. The comparison between the results obtained through Empirical Area Reduction method and Integrated Bathymetric System for Deo reservoir for Year 2005, is shown in this study.

Keywords : Sedimentation, Empirical Area Reduction method, Integrated Bathymetric System

1 Introduction

As a result of runoff from rainfall, soil particles of catchment area are eroded. These sediments are transported through river/stream and deposited in reservoir.The reservoir sedimentation is a global challenge [1]. Assessment of sediment distribution at regular interval of time can be helpful to achieve, the actual capacity of the reservoir and reduction in gross storage, provision and planning of sedimentation rate for new schemes, information for planning the remedial measures on sedimentation problems for better operation & management of existing reservoir [3].

2 Study Area

Deo reservoir is located across river Deo (a tributary of Dhadharriver) in Panchmahal district, Gujarat, India. Deo reservoir is situated at longitude of 73033'0" East and latitude of 22022'22" North. The Deo is medium irrigation project, mainly for irrigation purpose. Type of Deo dam is earthen and masonry. The reservoir was impounded in Year 1986. Full reservoir level (F.R.L.) is 89.65 m. and bed level is 67.30 m. The sedimentation survey was carried out in Year 2005 by Integrated Bathymetric System and provided by Gujarat Engineering Research Institute (G.E.R.I.), Vadodara.

3 Methodology

In this paper, Empirical Area Reduction method and Integrated Bathymetric System are described in detail to assess reservoir sedimentation distribution.

3.1 Empirical Area Reduction method: (EAR method)

It is the analytical method to predict sediment distribution in any reservoir at any particular time. This method was first developed from data gathered in the resurvey of 30 reservoirs and was described by Borland and Miller (1960) with revisions by Lara (1962). The method is iterative but with easy availability of computers it does not pose any problem. It is more reliable method than the other empirical methods like Trigonometric method and Area increment method. This method predicts level-wise distribution of sediment volume and gives revised area-capacity at each depth of reservoir. The classification of reservoir on the basis of depth-capacity relationship is shown in Table-1. The type of reservoir is defined by the depth to capacity relationship, where "m" is the reciprocal of the slope of the depth versus capacity plot on a logarithmic paper [2].

Reservoir Type	Classification	m
I	Lake	3.5 to 4.5
II	Flood plain-foothill	2.5 to 3.5
III	Hill	1.5 to 2.5
IV	Normally empty	1.0 to 1.5

Table-1: Classification of Reservoir

The data required for this method are Level-Area-Capacity table, Sediment volume to be distributed, F.R.L. and Bed Level.

The equations for relative sediment area are shown in Table-2 [2].The computational table for Empirical Area Reduction method is shown in Table-3.

Reservoir Type	Equation for 'Ap'
I	Ap = 5.074 p1.85 (1-p)0.35
II	Ap = 2.487 p0.57 (1-p)0.41
III	Ap = 16.967 p1.15 (1-p)2.32
IV	Ap = 1.486 p025 (1-p)1.34

Table-2: Relative Sediment Area "Ap"

Table-3: Computational Table for Empirical Area Reduction method

R.L.	Area	Capacity	Depth (d)	Relative Depth (P)	Relative Sediment Area (Ap)	Sediment Area	Sediment Volume	Accumulated volume	Revised Area	Revised Capacity
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)

The steps of this method are as below:

a) Complete columns 1, 2 and 3 of Table-3 by using given data of reduced level (R.L.), area and capacity.

b) Compute depth "d" at each level, as in (1) and complete column 4 of Table-3.
Depth = Level – Bed Level (1)
c) Compute relative depth "P" at all levels, as in (2) and complete column 5 of Table-3.
Relative Depth = Depth / Depth at F.R.L. (2)
d) Compute relative sediment area "Ap" from Table 2 and complete column 6 of Table-3.
e) Assume New Zero Elevation (N.Z.E.). This is the elevation up to which the entire capacity will be filled with sediment.
f) Compute "k" in supplement, as in (3).
k = Area at assumed N.Z.E. / Ap at assumed N.Z.E. (3)
g) Compute sediment area at each depth by multiplying the values in column 6 by "k" and complete column 7 of Table-3.
h) Compute sediment volume at each depth in column 8 of Table-3,using areas from column 7. Use average end area method, as in (4).
V = h/2 (A1+A2) (4)
Where, V = Volume of segment, h = Height of segment, A1 and A2 = Areas at the end of segment.
i) Sediment volume is added bottom upwards to give accumulated sediment volume at each depth. If the accumulated sediment volume does not match with design sediment volume then, the assumed N.Z.E. was not correct. A new N.Z.E. is assumed and steps up to this point are repeated. This process is continued till computed accumulated sediment volume agrees with design sediment volume within acceptable limits of error. Finally accumulate the values in column 8 to complete column 9 of Table-3.
j) Complete column 10 of Table-3 as difference between column 2 and 6.
k) Complete column 11 of Table-3 as difference between column 3 and 9.
l) A new set of area-capacity curves representing the situation after any years can be drawn from the data in columns 10 and 11.

2.2 Integrated Bathymetric System: (IBS)

It is the field survey method to predict revised area-capacity of any reservoir. It has been found as an ideal solution to earlier conventional method.

An automated data collection system consists of, field computer with GEODOS software, differential Global Positioning System (GPS), and echo-sounder. The GARMIN GPS35 with GPS L1 antenna being mounted on the tripod at a point with known coordinates (Northing, Easting and Elevation). The rover being fixed at 2 m height on wooden pole mounted on the side of the boat. More than 10,000 data points being traced during surveying. At an average boat speed of 2.5 km/h, data (X, Y, and Z) being collected at every 5 m along the survey track lines. Figure-1 shows Base Station & Survey Boat being used in this system.

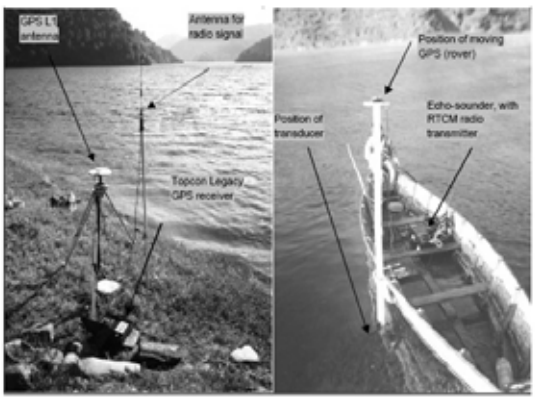

Figure-1: Base Station & Survey Boat

A bathymetric map of reservoir being created by using Surfer Golden Software and ESRI ArcMap programmes. The bathymetric data being gridded and modelled into three-dimensional surface in the Surfer programme. In this method, the basic procedure is the determination of bed elevation at many known locations on reservoir.

These measurements are always made by measuring water depth beneath a boat and exact location of the boat on the lake's surface. The simplest way of measuring water depth is to use sounding equipment which is preferred on most reservoirs. The depth recording devices can be used to provide continuous record or chart of bottom profile.

3 Analysis

As per sedimentation survey report of Deo reservoir for Year 2005, original area-capacity data and curvesare shown in Table-4 and Figure-2,3.

Table-4: Original Area-Capacity Data of Deo Reservoir for Year 1986

R.L. (m)	Original Area (Km2)	Original Capacity (Mm3)
89.65	16.68	84.09
88.00	12.12	60.02
86.00	8.84	39.13
84.00	6.31	24.04
82.00	3.80	14.03
80.00	2.50	7.76
78.00	1.63	3.66
76.00	0.69	1.40
74.00	0.32	0.56
72.00	0.11	0.17
67.30	0.00	0.00

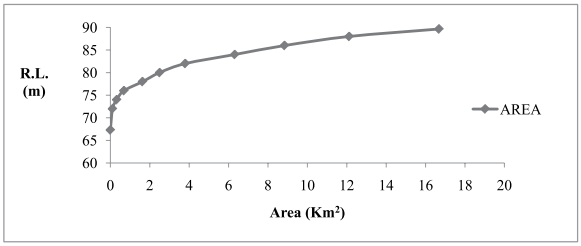

Figure-2: Area-Curve for Year 1986

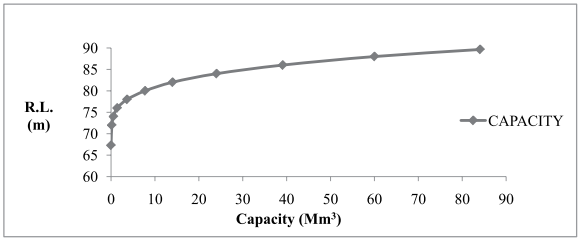

Figure-3: Capacity-Curve for Year 1986

As per that report, revised area-capacity data and curves of Deo reservoir for Year 2005 are shown in Table-5 and Figure-4,5.

Table-5: Revised Area-Capacity Data of Deo Reservoir for Year 2005 by IBS

R.L. (m.)	Revised Area (Km2)	Revised Capacity (Mm3)
89.65	13.723	67.546
88.00	9.203	45.791
86.00	6.875	29.633
84.00	4.514	18.225
82.00	2.796	11.047

80.00	1.779	6.594
78.00	1.085	3.794
76.00	0.618	2.128
74.00	0.340	1.209
72.00	0.185	0.701
67.30	0.000	0.000

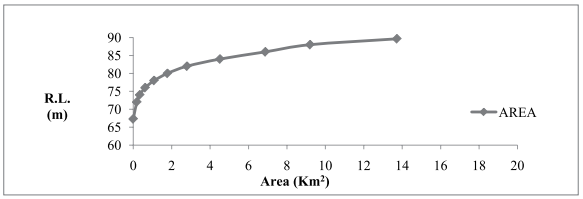

Figure-4: Area-Curve for Year 2005 by IBS

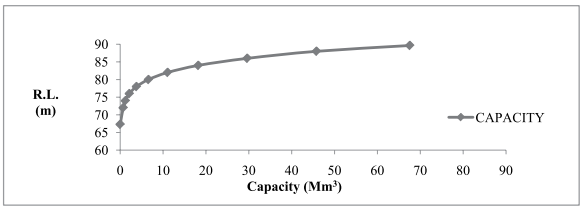

Figure-5: Capacity-Curve for Year 2005 by IBS

For theoretical computation of reservoir sediment distribution, Empirical Area reduction method is employed in this paper. The revised area-capacity data and curves obtained through this method for Year 2005 are shown in Table-6 and Figure-6,7.

In this method, area-capacity data of Year 1986 has been selected as base data. In Year 2005, N.Z.E. of Deo reservoir changes from R.L. of 67.30 m to R.L. of 78m. It means that, no storage would be available below 78m. and reservoir capacity below this level is lost.

Table-6: Revised Area-Capacity Data of Deo Reservoir for Year 2005 by EAR Method

R.L. (m.)	Original Area (Km2)	Original Capacity (Mm3)	d (m)	P (m)	AP (Km2)	Sediment Area (Km2)	Sediment Volume (Mm3)	Accumulated Volume (Mm3)	Revised Area (Km2)	Revised Capacity (Mm3)
89.65	16.68	84.09	22.35	1.00	0.00	0.000	0.012	10.63	16.68	73.46
88.00	12.12	60.02	20.70	0.93	0.03	0.015	0.113	10.62	12.11	49.40
86.00	8.84	39.13	18.70	0.84	0.20	0.098	0.338	10.51	8.74	28.62
84.00	6.31	24.04	16.70	0.75	0.49	0.240	0.662	10.17	6.07	13.87
82.00	3.80	14.03	14.70	0.66	0.86	0.421	1.034	9.51	3.38	4.52
80.00	2.50	7.76	12.70	0.57	1.25	0.613	1.397	8.47	1.89	0.71
78.00	1.63	3.66	10.70	0.48	1.60	0.784	1.681	7.08	0.85	0.00
76.00	0.69	1.40	8.70	0.39	1.83	0.897	1.808	5.40	0.00	0.00
74.00	0.32	0.56	6.70	0.30	1.86	0.911	1.710	3.59	0.00	0.00
72.00	0.11	0.17	4.70	0.21	1.63	0.799	1.877	1.88	0.00	0.00
67.30	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.00	0.00
							Total=10.631			

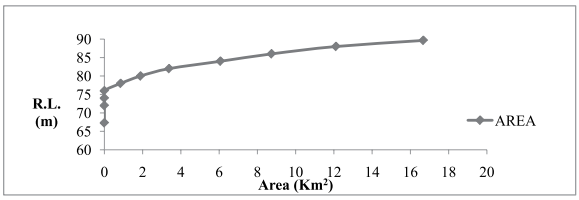

Figure-6: Area-Curve for Year 2005 by EAR method

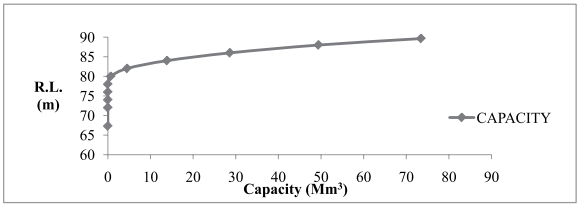

Figure-7: Capacity-Curve for Year 2005 by EAR method

The comparison of area by IBS and EAR method for Year 2005 is shown in Table-7 and Figure-8,9.

Table-7: Comparison of Area by IBS and EAR method for Year 2005

R.L. (m.)	Area (Km2)	
	IBS	EAR
89.65	13.723	16.68
88.00	9.203	12.11
86.00	6.875	8.77
84.00	4.514	6.13
82.00	2.796	3.48
80.00	1.779	2.03
78.00	1.085	1.03
76.00	0.618	0.00
74.00	0.340	0.00
72.00	0.185	0.00
67.30	0.000	0.00

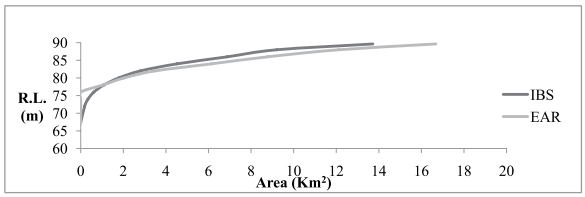

Figure-8: Area-Curves by IBS and EAR method for Year 2005

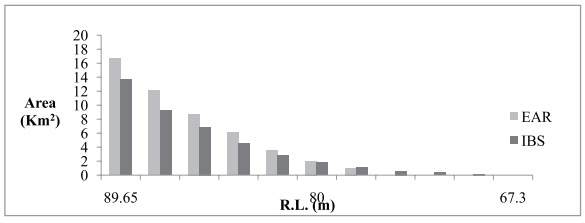

Figure-9: Comparison of Areas by IBS and EAR method for Year 2005

The comparison of capacityby IBS and EAR method for Year 2005 is shown in Table-8 and Figure-10,11.

Table-8: Comparison of Capacity by IBS and EAR method for Year 2005

R.L. (m)	Capacity (Mm3)	
	IBS	EAR
89.65	67.546	75.91
88.00	45.791	51.85
86.00	29.633	31.05
84.00	18.225	16.22
82.00	11.047	6.72
80.00	6.594	1.24
78.00	3.794	0.00
76.00	2.128	0.00
74.00	1.209	0.00
72.00	0.701	0.00
67.30	0.000	0.00

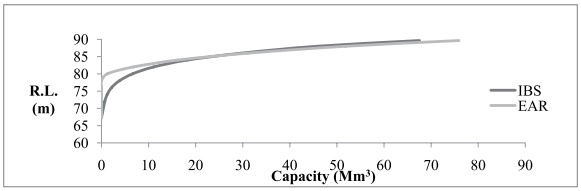

Figure-10: Capacity-Curves by IBS and EAR method for Year 2005

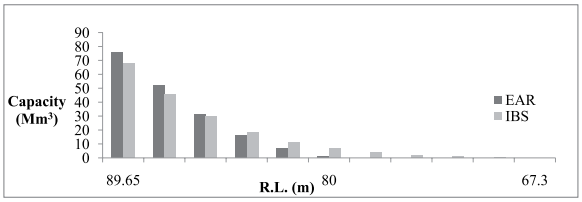

Figure-11: Comparison of Capacities by IBS and EAR method for Year 2005

4 Conclusion

The revised area-capacity for Deo Reservoir for the Year 2005, estimated by IBS were 13.72 Km2 and 67.54 Mm3 respectively, and the same calculated by EAR method are 16.68 Km2 and 73.46 Mm3 respectively at the R.L. of 89.65 m. As the Empirical Area Reduction method is the analytical one and does not require costly survey equipment, as required in Integrated Bathymetric System, it is the cheapest and reliable method for reservoir sedimentation assessmentat regular time interval.

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