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"Estimation of Revised Capacity for Deo Reservoir of Gujarat, India"

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ABSTRACT

Reservoir sedimentation is a serious problem because it leads to the loss of storage capacity of reservoir. Assessment of reservoir sedimentation is essential to determine and check the current status of storage capacity and water body area for better operation of reservoir, to draw new level-area and level-capacity curves, to determine reservoir trap efficiency and useful life, to verify percentage of sediment settled in reservoirs, to determine percentage loss in gross capacity of reservoir etc. Various methods and models are available for the estimation, analysis and prediction of reservoir sedimentation process. However, these methods and models differ in terms of their complexity, inputs and computational requirements. In present study, the Empirical Area Reduction method is used to predict revised capacity of Deo reservoir. The sedimentation survey report of Deo reservoir - 2005, is used in this study. It was carried out by Integrated Bathymetric System and provided by Gujarat Engineering Research Institute. As per the sedimentation survey report of Deo reservoir, its original capacity in the Year 1986 was 84.09 Mm3. As per the Empirical Area Reduction method, the revised capacity of Deo reservoir in the Year 2011 is 68.43 Mm3. The loss in gross storage capacity is 18.62 %.

Keywords : Reservoir sedimentation, Deo reservoir, Empirical Area Reduction method.

1 Introduction

The dams are being constructed across the rivers and reservoirs are being formed on its upstream side. Reservoirs are the key infrastructures for mankind and well-being. The reservoirs have primary purposes such as irrigation, water supply, flood Control, power generation, navigation, fishery, and recreation [1]. Despite the benefits realized, reservoirs are not without their drawbacks such as reservoir sedimentation, water quality degradation etc. As a result of runoff from rainfall, soil particles of catchment area are eroded. These sediment particles are transported through river or stream system and eventually deposited in reservoir [4].Reservoirs become a natural means for retention of transported sediments. Reservoirs get silted day by day because of sedimentation phenomena. The reservoir sedimentation is a global challenge [2]. Assessment of reservoir sedimentation is essential for taking up appropriate measures in controlling the sediment inflow, to obtain current status of storage capacity and useful life of reservoir, and to decide on the optimum reservoir operation schedule [5].

2 Study Area

Deo reservoir is located across river Deo (a tributary of Dhadhar river), near village Kuberpura of Halol taluka in Panchmahal district, Gujarat state, India, as in Figure-1. Deo reservoir is situated at a longitude of 730 33'0" East and latitude of 220 22' 22" North. Type of Deo dam is earthen and masonry. The Deo is a medium irrigation project, mainly for irrigation purpose. The reservoir was impounded in Year 1986 with the initial gross storage capacity of 84.09 Mm3. Out of which Dead storage allocation was to the extent of 7.76 Mm3. The full reservoir level (F.R.L.) is 89.65 m. and bed level is 67.30 m. The reser[illegible]

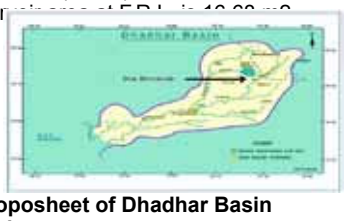

Figure-1: Toposheet of Dhadhar Basin

3 Methodology

In this paper, Empirical Area Reduction method is used for the estimation of revised capacity for Deo reservoir of Gujarat, India. This method helps to predict sediment distribution in any reservoir at any particular time.

This analytical 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. The method recognizes that, the sediment distribution mainly depends upon, the manner in which the reservoir is to be operated, the texture and size of deposited sediment particle, shape of the reservoir, and volume of sediment deposited in the reservoir. As this method is the analytical one and does not require costly survey equipment, it is the cheapest and reliable method for assessment of reservoir sedimentation at regular interval of time.

This method predicts level-wise distribution of sediment volume and gives revised area & revised capacity at each depth of reservoir. It does not predict the distribution of sediment in length and breadth of the 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 [3]. The equations for relative sediment area are shown in Table-2 [3]. The data required for this method are Level-Area-Capacity table, Sediment volume to be distributed, Full Reservoir Level (F.R.L.) and Bed Level. The computational table for Empirical Area Reduction method is shown in Table-3.

Table-1: Classification of Reservoir

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

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.

4 Analysis

As per the sedimentation survey report of Deo reservoir which carried out in the Year 2005 and provided by Gujarat Engineering Research Institute-Vadodara, original area-capacity data of Deo reservoir for the Year of 1986 is shown in Table-4.

Table-4: Original Area-Capacity 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

For theoretical computation of reservoir sediment distribution, Empirical Area reduction method is employed in this paper. The revised capacity obtained through this method for Year 2011 is shown in Table-5.

Table-5: Theoretical Sediment Distribution by Empirical Area Reduction Method for Year 2011

R.L.(m)	Original Area (Km2)	Original Capacity (Mm3)	Depth 'd' (m)	Relative Depth 'P' (m)	Relative Sediment Area '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	0.018	15.66	16.68	68.43
88.00	12.12	60.02	20.70	0.93	0.03	0.022	0.166	15.65	12.10	44.37
86.00	8.84	39.13	18.70	0.84	0.20	0.144	0.498	15.48	8.70	23.65
84.00	6.31	24.04	16.70	0.75	0.49	0.354	0.975	14.98	5.96	9.06
82.00	3.80	14.03	14.70	0.66	0.86	0.621	1.523	14.01	3.18	0.02
80.00	2.50	7.76	12.70	0.57	1.25	0.903	2.058	12.48	1.60	0.00
78.00	1.63	3.66	10.70	0.48	1.60	1.155	2.476	10.43	0.47	0.00
76.00	0.69	1.40	8.70	0.39	1.83	1.321	2.664	7.95	0.00	0.00
74.00	0.32	0.56	6.70	0.30	1.86	1.343	2.520	5.29	0.00	0.00
72.00	0.11	0.17	4.70	0.21	1.63	1.177	2.766	2.77	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= 15.664			

In this method, area-capacity data of the Year 1986 has been selected as base data. In the Year 2011, the new zero elevation of Deo reservoir changes from R.L. of 67.30 m to R.L. of 80 m. It means that, no storage would be available below 80 m. and reservoir capacity below this level is lost. The capacity curves of Deo reservoir for Year 1986 and Year 2011 are shown in Figure-2. The comparison between the capacity of

Year 1986 and Year 2011 is shown in Table-6 and Figure-3.

Figure- 2: Capacity Curves for Year 1986 and Year 2011

Table-6: Comparison between the Capacity of Year 1986 and Year 2011

R.L. (m)	Original Capacity (Mm3) for Year 1986	Revised Capacity by E.A.R. method (Mm3) for Year 2011
89.65	84.09	68.43
88.00	60.02	44.37
86.00	39.13	23.65
84.00	24.04	9.06
82.00	14.03	0.02
80.00	7.76	0.00
78.00	3.66	0.00
76.00	1.40	0.00
74.00	0.56	0.00
72.00	0.17	0.00
67.30	0.00	0.00

Figure- 3: Comparison between the Capacity of Year 1986 and Year 2011

5 Conclusion

As per the sedimentation survey report of Deo reservoir, its designed gross storage capacity in the Year 1986 at the R.L. of 89.65 m. was 84.09 Mm^3. As per the Empirical Area Reduction method, the revised capacity of Deo reservoir in the Year 2011 at the R.L. of 89.65 m. is 68.43 Mm^3. The loss in gross storage capacity is 18.62 %. The revised capacity of any reservoir at any interval of time can be estimated by using Empirical Area Reduction method.

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