COMPARATIVE STUDY OF THE RESERVOIRS

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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OF

MASTER OF TECHNOLOGY

IN

HYDRAULICS AND WATER RESOURCES ENGINEERING

Submitted By

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DECLARATION

I, Pradeep Sharma, Roll No. 2K16/HFE/12 of M.Tech. Hydraulics and Water Resources Engineering, hereby declare that the project Dissertation titled **"COMPARATIVE STUDY OF RESERVOIRS"** which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of technology, is original and has been done by myself under the general supervision of my supervisor. This work has not been submitted to any other Institute for the award of any Degree or Diploma.I have followed the guidelines provided by the institute in writing the report and conformed to the norms and guidelines given in the ethical code of conduct of the institute.

Place-Delhi **PRADEEP SHARMA**

Date:

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CERTIFICATE

I hereby certify that the Project Dissertation titled **"COMPARATIVE STUDY OF THE RESERVOIRS"** by **Pradeep Sharma**, Roll No. **2K16/HFE/12**, Department of Civil Engineering, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge, this work has not been submitted in parts or full for any Degree or Diploma to this University or elsewhere.

Place- Delhi

Date:

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ABSTRACT

Reservoir sedimentation affects the availability of water storage and thus impairs sustainable water resources management. A reservoir is, of course, merely an artificial lake, and all reservoirs are gradually dying from loss of their capacity caused by deposition of sediment, most of which is transported by inflowing streams. Thus it is seen that though most of the dams are constructed to last almost indefinitely, they will become largely useless from silting long before the dams themselves reach a stage of significant deterioration. Reservoir storage diminishes gradually, without causing instant disaster. Damages become appreciable in a more or less distant future: energy production may drop, irrigation falter, overshadowed by more urgent social issues. The problem of sedimentation of reservoirs and its effect on the useful life of reservoirs is complex. The phenomenon of sedimentation and the concept of life of a reservoir and its estimation have been studied in depth over many years.

The most obvious effect of reservoir sedimentation is the depletion of water storage capacity in the reservoir. The decrease of storage capacity prevents the reservoir from supplying the services for which it was designed, thus disturbing the economic life of the region or community which it serves.

This project deals with the analysis of the data that was obtained after the sedimentation studies carried out by CWC for the Salaulim Reservoir on the Salaulim River in Goa State,the Ranapratap sagar Reservoir on Chambal river in Rajasthan state and the Bhima(Ujjani) Reservoir on Bhima river in Maharastra state.

Reservoir sedimentation assessments have, over the years, been carried out by Hydrographic surveys. However, it evolved into a specialized technique with the development of Differential Global Positioning Techniques (DGPS) in recent years. This technique, which is now increasingly being adopted for the siltation studies of reservoirs in India, enables collection of enough data to map the entire reservoir bottom and then using the standard topographic and mapping programmes evaluate the changes in the reservoir sedimentation.The Hydrographic and topographic surveys of the above discussed Reservoirs were carried out by CWC, in accordance with the prescribed Terms of Reference, using High Technology equipment, namely integrated

Hydrographic Survey System comprising recording type echo-sounder and computer software for interfacing and recording the position and depth data in real time.In this project,we will briefly discuss the methodology of field investigation adopted by CWC to study the reservoir behaviour.

The trap efficiency is one of the most important properties of a pond or reservoir.The reservoir trap efficiency is defined as the ratio of deposited sediment to the total sediment inflow for a given period within the reservoir economic life time. Trap efficiency is influenced by many factors,of which primarily factors are: the sediment fall velocity ,the flow rate through the reservoir and the reservoir operation rules.In this project,using the Elevation capacity table (furnished by CWC) at different elevations for the reservoirs taken in a study we will obtain a trap efficieny of each reservoir.

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LIST OF ABBREVIATIONS

Cu.km…………………….Cubic kilometre

Th.cu.m…………………..Thousand cubic Metre

M.cu.m…………………… Million cubic Metre

Ha.m………………………..Hectare Metre

Sq.km. ……………………..Square kilometre

mm …………………………Millimetre

cm…………………………..Centimetre

m …………………………...Metre

C.A………………………… Catchment area

DSL…………………………Dead storage level

MDDL……………………... Maximum draw down level

FRL…………………………Full reservoir level

MWL……………………… Maximum water level

m/s………………………….Metre per Second

m^3/s ……………………….Cubic metre per second

GPS………………………..Global positioning system

DGPS………………………Differential Global Positioning System

CHAPTER – 1
INTRODUCTION

1.1 BACKGROUND

Performance and economics of the reservoir projects calls for a serious study and research effort to understand the phenomenon of reservoir sedimentation.This phenomenon is analysed in terms of rate of siltation,loss of gross storage capacity ,loss of dead storage capacity and loss of live storage capacity of reservoirs during their designed life span.

It is well established that reservoir, formed by construction of a dam across a river, decreases the water surface gradient resulting in reduction of the velocity of flow, which interalia causes a reduction in the capacity of the river channel to transport sediment.Consequently deposition of sediment in the full range of reservoir depth occurs. This process progressively reduces the utility of the reservoir requiring attention not only at the project planning stage but also during operation stage.

Keeping the above aspects in view, a realistic assessment of the siltation rate and the loss of storage due to siltation that has been recorded in various existing reservoirs and which has enabled fixing the norms for new projects.

The trap efficiency is one of the most important properties of a pond or reservoir. The reservoir trap efficiency is defined as the ratio of deposited sediment to the total sediment inflow for a given period within the reservoir economic life time. Trap efficiency is influenced by many factors,of which primarily factors are: the sediment fall velocity ,the flow rate through the reservoir and the reservoir operation rules.

1.2 OBJECTIVES OF THE STUDY

The Objectives of the study set forth are discussed as under:

- To estimate the Rate of Siltation and siltation in different zones of the reservoir namely (a) dead storage (b) live storage and (c) flood storage, if any.
- To estimate the Trap Efficiency of the Salaulim Reservoir(Goa),Ranapratap Sagar Reservoir(Rajasthan) and Bhima Reservoir(Maharastra) .
- To compare the obtained results of the Salaulim Reservoir(Goa),Ranapratap sagar Reservoir(Rajasthan) and Bhima Reservoir(Maharastra) .
- To analyse the data of vertical sediment distribution(furnished by CWC) of the Salaulim Reservoir(Goa),Ranapratap Sagar Reservoir (Rajasthan) and Bhima Reservoir(Maharastra) and plot the graph corresponding to the data of each reservoir taken in a study.
- To estimate and plot the graph of the sediment deposit of the Salaulim Reservoir(Goa),Ranapratap Sagar Reservoir(Rajasthan) and Bhima Reservoir(Maharastra).

1.3 SCOPE OF STUDY

A. Data Analysis and Preparation of Tables

After obtaining the data of capacity survey from CWC, the survey data shall be analysed to obtain the following:

1. Estimation of sedimentation in different zones of reservoir

Loss of storage capacity and rate of sedimentation may be worked out in each vertical zone separately, viz., dead storage, live storage and flood storage, If any.

2. Estimation of Trap efficiency of:

(a) Salaulim Reservoir

(b) Ranapratap Sagar Reservoir

(c) Bhima(Ujjani) Reservoir

B. Data Analysis and preparation of Graphs

After obtaining the data of vertical sediment distribution from CWC, the data shall be analysed to obtain the following:

1. **Plotting of Graphs corresponding to Vertical sediment distribution data of:**
   (a) Salaulim Reservoir
   (b) Ranapratap Sagar Reservoir
   (c) Bhima(Ujjani) Reservoir

2. **Estimation of Sediment Deposit and plotting of Graphs corresponding to Estimated Sediment Deposit of:**
   (a) Salaulim Reservoir
   (b) Ranapratap Sagar Reservoir
   (c) Bhima(Ujjani) Reservoir

1.4 REPORT

1. Salaulim Reservoir

This project deals with the sedimentation studies carried out for the Salaulim Reservoir on the Salaulim River (also called Sanguem River, a tributary of Zuari River in the Western Ghats in Goa State.The field investigations were carried out from December 23, 2010 to January 10, 2011(Data furnished by CWC).

2. Ranapratap Sagar Reservoir

This project deals with the sedimentation surveys and studies carried out for the Ranapratap sagar Reservoir on the Chambal (a tributary of the Yamuna River) in the Rajasthan state.The fiels investigations were carried out from January 12,2011 to March 23,2011(Data furnished by CWC).

3. Bhima(ujjani) Reservoir

This project deals with the sedimentation surveys and studies carried out for the Bhima (Ujjani) on the Bhima River.The field investigations were carried out from April 4, 2011 to October 24, 2011.(Data furnished by CWC)

CHAPTER – 2
LITERATURE REVIEW

2.1 GENERAL

Reservoirs are built either as single or multipurpose reservoirs. Most reservoirs are multi purpose .Most reservoirs are multipurpose schemes combining two or more of the following requirements: irrigation, hydropower, water supply, flood control ,navigation, fishery, recreation and environmental issues. Sedimentation within reservoirs or ponds is a problem as it decreases the storage capacity and hence makes the structure less efficient .Especially for small pond or reservoir sedimentation can become a severe problem as the rate of siltation is generally much higher in comparison to large dams. Reservoir trap efficiency is defined as the ratio of deposited sediment to the total sediment inflow for a given period within the reservoir economic life time.Trap efficiency is influenced by many factors,of which primarily factors are: the sediment fall velocity,the flow rate through the reservoir and reservoir operation rules.

2.2 DEFINITIONS

Reservoir-A water supply scheme drawing water directly from a river or a stream may fail to satisfy the consumers demands during extremely low flows,while during high flows it may become difficult to carry out its operation due to devastating floods,a barrier in the form of dam is therefore constructed across the river ,so as to form a pool of water on the upstream side of the dam is known as a reservoir.

Full Reservoir Level (FRL): It is the level corresponding to the storage which includes both inactive and active storages and also the flood storage, if provided for. In fact, this is the highest reservoir level that can be maintained without spillway discharge or without passing water downstream through sluice ways.

Dead storage level(DSL): Below the level, there are no outlets to drain the water in the reservoir by gravity.

Maximum water level(MWL): This is the water level that is ever likely to be attained during the passage of the design flood. It depends upon the specified initial reservoir level and the spillway gate operation rule. This level is also called sometimes as the Highest Reservoir Level or the Highest Flood Level.

Live storage: This is the storage available for the intended purpose between Full Supply Level and the Invert Level of the lowest discharge outlet. The Full Supply Level is normally that level above which over spill to waste would take place. The minimum operating level must be sufficiently above the lowest discharge outlet to avoid vortex formation and air entrainment. This may also be termed as the volume of water actually available at any time between the Dead Storage Level and the lower of the actual water level and Full Reservoir Level.

Dead storage: It is the total storage below the invert level of the lowest discharge outlet from the reservoir. It may be available to contain sedimentation, provided the sediment does not adversely affect the lowest discharge.

Outlet Surcharge or Flood storage: This is required as a reserve between Full Reservoir Level and the Maximum Water level to contain the peaks of floods that might occur when there is insufficient storage capacity for them below Full Reservoir Level.

Buffer storage: This is the space located just above the Dead Storage Level up to Minimum Drawdown Level. As the name implies, this zone is a buffer between the active and dead storage zones and releases from this zone are made in dry situations to cater for essential requirements only. Dead Storage and Buffer Storage together is called Interactive Storage.

Reservoir trap efficiency: Reservoir trap efficiency is defined as the ratio of deposited sediment to the total sediment inflow for a given period within the reservoir economic life time.

TYPES OF RESERVOIR

- **Auxiliary or Compensatory Reservoir:** A reservoir which supplements and absorbed the spill of a main reservoir.

- **Balancing Reservoirs:** A reservoir downstream of the main reservoir for holding water let down from the main reservoir in excess of that required for irrigation, power generation or other purposes.

- **Conservation Reservoir:** A reservoir impounding water for useful purposes, such as irrigation, power generation, recreation, domestic, industrial and municipal supply etc.

- **Detention Reservoir:** A reservoir where in water is stored for a relatively brief period of time, past of it being retained until the stream can safely carry the ordinary flow plus the released water. Such reservoirs usually have outlets without control gates and are used for flood regulation. These reservoirs are also called as the Flood Control Reservoir or Retarding Reservoir.

- **Distribution Reservoir:** A reservoir connected with distribution system a water supply project, used primarily to care for fluctuations in demand which occur over short periods and as local storage in case of emergency such as a break in a main supply line failure of a pumping plant.

- **Impounding or Storage Reservoir:** A reservoir with gate-controlled outlets wherein surface water may be retained for a considerable period of time and released for use at a time when the normal flow of the stream is in sufficient to satisfy requirements.

- **Multipurpose Reservoir:** A reservoir constructed and equipped to provide storage and release of water for two or more purposes such as irrigation, flood.

2.3 REVIEWS ON RESERVOIR SEDIMENTATION AND TRAP EFFICIENCY

M.A. Eizel-Din, M.D. Bui & P. Rutschmann(2010):

The reservoir trap efficiency is defined as the ratio of deposited sediment to the total sediment inflow for a given period within the reservoirs economic life time. The curves presented by Brune are still widely used to estimate the reservoir trap efficiencies. These curves are based on data collected from 40 normal ponded reservoirs in the USA. In the Nile River, the transported sediment is mainly cohesive material from which about 85% to

95% are suspended sediment. Data from the Roseires Reservoir on the Blue Nile show that trap efficiency decreased from 45.5% after 10 years to 26% after 30 years of operation. However, by applying Brune's curves the estimated trap efficiency is about 79%. Recently, Siyam (2000) showed that Brune's curves are a special case of a more general trap efficiency function which can be described by an exponential decay function. The so-called sedimentation factor β which is integrated in the equation of Siyam reflects the reduction in reservoir storage capacity. The upper and lower Brune's trap efficiency curves can be well described with β=0.0055 and β=0.015 respectively for normal ponded reservoirs. Siyam (2000) provided an explanation for Brune's extreme data in the semi-dry reservoirs (β=0.75) and de-silting basins (β=0.00012). The observed trap efficiency in the Roseires reservoir can be well estimated using a value of β=0.056. The simulation of the long-term morphological changes in the Nile River due to construction of Merowe and Shereik dams in Sudan using 1D numerical morphological model revealed that the trap efficiencies of these reservoirs did not follow Brune's curves for normal ponded reservoirs. The calculated sedimentation factor β has a range between 0.015 and 0.056. In addition, the relation between trap efficiency and years of operation in these reservoirs is presented.

Gert Verstraeten and Jean Poesen(2000):

Throughout the world, several millions of small ponds exist for water supply, irrigation, flood control or to control water quality downstream. The reduced flow velocity in these ponds causes sedimentation of tranported particles. For most ponds this is a negative impact as their retention capacity decreases due to sedimentation processes. Sediment volumes in small ponds can be used to reconstruct sediment yield values and to study the spatial variation in sediment yield over large areas. Especially in developing countries, this technique can be very helpful in establishing large data sets on sediment delivery as there are often no resources for expensive monitoring programmes. However, when such studies are undertaken, one has to take into account the efficiency of the pond in trapping sediments. This trap efficiency is dependent on the characteristics of the inflowing sediment and the retention time of the water in the pond, which in turn are controlled by pond geometry and runoff characteristics. Because trap efficiency is one of the most important properties of a pond or reservoir, it has been studied for quite some time. This article provides an overview of the different methods available to estimate the trap efficiency of reservoirs and ponds. The first set of methods are empirical models that predict trap efficiency, mostly of normally ponded large reservoirs using data on a mid to long-term basis. These models relate trap efficiency to a capacity/watershed ratio, a capacity/annual inflow ratio or a sedimentation index. Today, these models are the most widely used models to predict trap efficiency, even for reservoirs or ponds that have totally different characteristics from the reservoirs used in these models. For small ponds, these models seem to be less appropriate. They also cannot be used for predicting trap efficiency for a single event. To overcome these restrictions, different theoretical models have been developed based on sedimentation principles. These can be very simple, such as the overflow rate method, but also very complex when runoff and sediment are routed through a pond with incremental timesteps. The theoretical-based models are probably more capable of predicting trap efficiency for small ponds with varying geometric characteristics, and some of them also provide data on effluent sediment concentrations and quality. However, when reconstructing sediment yield.

M. M. A. shahs(1993):

The flow of water in many African rivers is regulated through storage reservoirs. The service life of some of these reservoirs is exercising a continuous reduction due to the unexpectedly high rate of siltation. Sedimentation of six reservoirs together with their operation rules are reviewed. These are the reservoirs formed by the old and the High Aswan dams in Egypt, the Sennar, the Roseires and the Khashm el-Girba in the Sudan, and the Koka in Ethiopia. The present paper emphasizes the effectiveness of the operation rules as a means of reducing reservoir sedimentation. Six storage reservoirs are reviewed in this paper. These are the reservoirs formed by the old and the High Aswan dams on the Main Nile, Egypt, the Sennar and the Roseires on the Blue Nile and the Khashm el-Girba on the Atbara, all three in the Sudan, and the Koka on the Awash, Ethiopia.

Revel ,Ranasiri ,Rathnayake and Pathirana(2015):

Reservoir sedimentation has become one of the major problems facing water resources development projects in many countries around the world. However, only a limited number of studies have been reported in this field, particularly addressing the trap efficiency of reservoirs. In addition, even the available studies in this area have considered only few parameters governing reservoir sedimentation. As a result, the available knowledge on trap efficiency is not very well defined. The Brune curve is being widely used for estimating trap efficiency of reservoirs at present, but it has several limitations, as it considers only the reservoir capacity and inflow ratio for estimating the trap efficiency. The objective of this study is to formulate an improved methodology for estimating reservoir sedimentation through laboratory experiments. A small-scale laboratory model was set-up to represent a reservoir and a series of tests were conducted by varying the inflow rate, inflow sediment concentration, reservoir capacity and the outflow rate. The experimental results were compared with values obtained from available theories and it was found that they are not very much in agreement with many of the existing theories which are mostly based on a limited number of parameters. A comprehensive data analysis was performed using dimensional analysis to develop an improved relationship to estimate reservoir sedimentation incorporating many parameters governing the problem. However, the applicability of the proposed method is still limited only to reservoirs with continuous spilling conditions. In addition, only one type of sediment gradation (d50) was used in the experimental runs and thus, the effect of sediment sizes is not well represented in this method. However, the relationship developed in this study could be further improved by conducting more experimental runs by varying few other parameters which have not been considered in the present study.

CHAPTER – 3

PROJECT BACKGROUND

3.1 SALAULIM RESERVOIR

3.1.1 THE SALAULIM RIVER BASIN

The Salaulim Dam is located on the Sanguem (Salaulim or Guleli River), a tributary of the Zuari River in Goa. It is an integral component of the Salaulim Irrigation Project which envisages benefits of irrigation and drinking water supply to South Goa.

3.1.2 SALAULIM RESERVOIR

The project is located at Pajimol-Xelpen in the Zuari River Basin, which is drained by the Zuari River which in turn is formed after the confluence of Sanguem (Salaulim) and Uguem Rivers in Sanguem Taluk. The Salaulim dam is located on the Sanguem River near the Sanguem town. The river drains a catchment area of 209 sq.km.

The dam is a composite structure of earth-cum-masonry type of 42.50 m height above the deepest foundation level. The length of dam at the crest is 1003.83 m and the reservoir water spread area (within Goa without any inter-state implications) is 29.64 sq km. The dam structure has a volume content of 2.714 M.Cu.m. The gross storage capacity of the reservoir is 234.36 M.Cu.m. with the live or effective storage capacity fixed at 227.16 M.Cu.m.

The spillway which is of the unique Duckbill type (Morning Glory type) is an ungated structure located in the gorge section with a length of 44 m.

Out of the total live storage of about 234.36 M.Cu.m, live storage is 227.16 M.Cu.m (144.66 M.Cu.m is for irrigation and the balance 82.50 M.Cu.m is earmarked for domestic and industrial water use. As a result, 220 MLD of water is available for industrial and domestic use in South Goa, in addition to 160 MLD originally provided in the approved project.

3.1.3 RESERVOIR SUBMERGENCE

The reservoir water spread at Full Reservoir Level EL 41.15m is 29.64 sq. km (2964 ha) (as per reports of the Water Resources Department of Goa). The reservoir submergence involved 29 villages which were partially or fully submerged. 3000 people were displaced and resettled. Mining areas were also submerged for which compensation was provided. The total storage capacity of the reservoir at FRL is 234.36 M.Cu.m. of which the effective (live) storage is 227.16 M.Cu.m. The dead storage is 7.20 M.Cu.m. at dead storage level. The Elevation-Area- Capacity Table (1990) furnished by CWC is indicated in **Table 3.1.**

Table - 3.1: Pre-Impoundment Elevation-Area-Capacity Table

Elevation(m)	Area (Sq.Km.)	Capacity(M.Cu.m)
10	0.000	0.000
11		0.150
12		0.300
13		0.450
14		0.600
15	0.098	1.540
16		1.650
17		1.800
18		3.000
19		4.200
20	1.214	6.480
21		7.800
22		10.800
22.5	2.430	12.300
23		13.800
24		17.400
25	4.250	21.890
26		26.400
27		32.400
28		38.400
29		46.800
30		54.890
31		65.400
32		78.000
33		91.800
34		106.800
35	14.340	116.570
36		138.000
37		156.000
37.5	18.210	165.286
38		174.600
39		193.200
40	22.610	212.1509
41		231.6009
41.15		234.0009

42		247.760
42.5	27.920	271.365
43		308.350
45.8		

3.1.4 APPROACHES TO THE PROJECT

The Salaulim reservoir in Goa state is the second largest multipurpose project in the state, after the Tillari Irrigation Project, which is an interstate project. It is approachable by road from Sanguem town at a distance of 5 km.

3.1.5 SALIENT FEATURES OF SALAULIM RESERVOIR

SALAULIM RESERVOIR (Data furnished by CWC)

1.	**LOCATION**	
	State	Goa
	Tehsil	Sanguem
	River	Sanguem (Gulati Nadi)
	Site of Dam	Lat. 15º 13' – N
		Log 74º 11' – E
2.	**HYDROLOGY**	
	Catchment area	209 sq.km (78.sq. miles)
	Mean Annual Rainfall (Monsoon Rainfall)	3665mm (144.3)
	Maximum Design Flood	2883 m³/s (1,00,000 cusecs)
	Maximum routed Flood	1450 m³/s (51,200 cusecs)
3.	**RESERVOIR**	
	Maximum Water Level	RL 45.8m
	Full Reservoir Level	RL 41.15m
	Minimum draw down Level	RL 20.42m
	Gross storage capacity	234.36 M.Cu.m

	Dead storage capacity	7.20 M.Cu.m
	Live storage capacity	227.16 M.Cu.m
4.	**DAM**	
	Type of Dam	Composite Dam (Central Duckbill masonry spillway with earthen dam on right and left Banks)
	Top of Dam	RL 47.65 m
	Length of dam	1003.83m at top
	Height of dam above deepest river bed	42.50 m
5.	**SPILLWAY**	
	Type of Spillway	Ungated duckbill spillway
	Maximum head over the crest	4.65m
	Crest Level	RL 41.15m
6.	**CANALS**	
	(Left bank contour only)	
	Design discharge of the main canal	13.6 cumecs
	Designed for	14.0 cumecs in initial reaches
	Length of the Left Bank main canal	25.73 km (15.99 miles)
7.	**IRRIGATION**	
	Gross Command Area	23876 Ha (59000 acres)
	Culturable command area	9686 Ha. (23934 acres)
	Annual Irrigation	14326 Ha (35400 acres)
8.	**WATER USAGE**	
	Irrigation	144.66 M.Cu.m
	Water Supply	82.50 M.Cu.m
9.	**SUBMERGENCE**	
i)	Total Area under submergence	2964 Ha (29.64 sqkm)
ii)	Cultivable area under submergence	1240 Ha
iii)	Area of forest submergence	706 Ha

3.1.6 FIELD PHOTOGRAPH

View of s Salaulim Dam,Goa

View of a Salaulim Reservoir,Goa

3.2 RANAPRATAP SAGAR RESERVOIR

3.2.1 THE CAMBAL RIVER BASIN

The rana pratap sagar dam is the second in the series of chambal valley projects,located 56 km downstream of the Gandhi sagar dam in Madhya Pradesh .it is built across the Chambal river in rajasthan .The dam was completed in the year 1970.

The Chambal river rises from mahu in the northern ranges of vindhyachal,flows north northeast through Madhya Pradesh ,before entering rajasthan forming the boundary between rajasthan and Madhya Pradesh ,then turns southeast to the join the Yamuna river in uttar Pradesh .The total catchment area up to the dam is 25305 sq. km. of which only 956 sq. km(data furnished by CWC). in rajasthan.

3.2.2 RANAPRATAP SAGAR RESERVOIR

The 54 m high Ranapratap sagar masonry dam is located at Rawat Bhata in Chittorgarh district of rajasthan ,about 56 km down stream of the Gandhi sagar dam and 48 km upstream of the kota barrage.The pre-impoundment elevation-area- capacity Table(1970) as furnished by CWC is given in **Table 3.2**.

Table 3.2: Pre-Impoundment Elevation-Area-Capacity Table

Elevation(m)	Area (Sq.Km.)	Capacity(M.Cu.m)
317.75	0.00	0.00
319.27	2.61	4.62
320.80	5.22	14.18
322.32	7.81	22.69
323.84	10.44	31.21
325.37	19.47	73.76
326.89	28.57	119.28
328.42	37.43	167.50
329.94	46.54	224.24
331.46	55.85	298.50
332.99	65.08	388.91
334.51	74.06	496.47
336.04	83.17	621.66
337.56	93.49	762.28
339.08	104.61	917.69
340.61	114.13	1075.58
342.13	124.65	1245.80
343.66	131.16	1418.48
345.18	145.41	1638.03

346.70	155.81	1860.06
348.23	166.36	2074.68
349.75	177.06	2331.24
351.28	187.79	2601.63
352.80	199.00	2904.80(FRL)
354.17	214.37	3204.59(MWL)

3.2.3 APPROACHES TO THE PROJECT

The Ranapratap sagar Reservoir in rajasthan state is one of the largest multipurpose projects in the state .it is approachable by road from jaipur via kota city.

3.2.4 SALIENT FEATURES OF RANAPRATAP SAGAR RESERVOIR

RANAPRATAP SAGAR RESERVOIR (Data furnished by CWC)

1.	Location	Latitude :24 º53 Longitude :75 º41
2	Type of Dam	Straight Gravity Dam
3	Lowest bed level at dam site	317.75m
4	Height of dam above deepest bed level	177'/53.95m
5	Catchment area	2280 Sq.km(free catchment)
6	Total length of dam at top	3750'/1143m
7	MDDL	343.00
8	FRL	352.80
9	MWL	354.17m
10	Storage capacity at MDDL	1344.25 M.cu.m
11	Live storage capacity at FRL	1560.55 M.Cu.m
12	Gross storage capacity at FRL	2904.80 M.Cu.m
13	Area of submergence at FRL	199.00 Sq.km
14	Length of spillway	1190'/362.71m
15	Spillway gates	Vertical Lift gates 17 Nos. 18.288m *8.534m
16	Pen stockes	4 Nos. 6.096m dia
17	Power generation	Installed capacity 172 MW 4 units of 43 MW each

3.2.5 FIELD PHOTOGRAPH

View of Ranapratap Sagar Reservoir

View of Ranapratap Sagar Dam

3.3 BHIMA (UJJANI) RESERVOIR

3.3.1 THE BHIMA RIVER BASIN

The Bhima River rises from Bhimashankar hills in the western ghats, also known as the Sahyadri hill range. The river flows for a length of 725 km till it meets the Krishna river at Narsingpur in Solapur district. Bhima river basin has many tributaries of which the major ones are the Kundali, Kumandale, ghod, Bharma, Indrayani, Mula, Mutha Pavna, Sina, Man, Bhogwati, and Nira. The total drainage area of 48631 Sq.km of Bhima river basin, covers both Maharashtra (75%) and Karnataka (25%) state, out of which 14858 Sq.km drains into the Bhima (Ujjani) reservoir created by the Bhima (Ujjani) dam.

3.3.2 BHIMA(UJJANI)RESERVOIR

The Bhima (Ujjani) dam, also known as Bhima (Ujjani) dam on Bhima river, a tributary of the Krishna River, is an earth fill cum Masonry gravity dam located near Bhima village of Madha Taluk in Solapur district of the state of Maharashtra. The Bhima (Ujjani) valley with its tributaries and streams, has 22 dams built on it and Bhima (Ujjani) dam is the terminal dam on the river and is the largest in the valley. The total catchment area of the reservoir is 14,858 sq.km, out of which 5,092 sq.km is intercepted by u/s reservoirs. The construction of the dam including the canal system started in 1969 and completed in June, 1980. But the first impounding took place in the year 1977. It is a multi purpose project for irrigation, power generation, drinking and industrial water supply and fisheries development.The Elevation–Area-Capacity Table as per pre-impoundment survey -1977 furnished by CWC is given in **Table 3.3**.

Table 3.3: Pre-Impoundment Elevation-Area-Capacity Table

Reservoir Level (m)	Area (M.Sq.m)	Cumulative Capacity (M.Cu.m)
458	0.00	0.00
459	0.84	0.28
460	1.27	1.328
461	1.42	2.672
462	2.12	4.430
463	2.54	6.757

464	3.54	9.783
465	4.24	13.668
466	5.31	18.433
467	7.08	24.607
468	8.49	32.381
469	11.56	42.367
470	20.20	58.047
471	22.80	79.534
472	25.40	103.622
473	28.80	130.705
474	33.40	161.776
475	38.80	197.843
476	44.00	239.215
477	49.40	285.889
478	55.20	338.162
479	61.60	396.533
480	68.00	461.307
481	74.20	532.384
482	82.80	610.845
483	91.40	697.910
484	100.00	793.577
485	110.20	898.636
486	120.80	1014.096
487	134.00	1141.438
488	148.00	1282.381
489	163.40	1438.017
490	178.80	1609.059
491	197.00	1796.886
492	216.00	2003.313
493	236.00	2229.239
494	261.20	2477.738
495	286.80	2751.633
496	312.00	3050.944
497	340.00	3377.450
498	368.60	3731.654

3.3.3 APPROACHES TO THE PROJECT

The dam is approachable from Pune city which is 160 km away. The dam is about 8 km u/s of the bridge across the Bhima River on the Pune- Solapur road.

3.3.4 SALIENT FEATURES OF BHIMA(UJJANI) RESERVOIR

BHIMA(UJJANI) RESERVOIR (Data furnished by CWC)

1.	**GENERAL**	
	State	Maharashtra
	District	Solapur
	Village/Town	Ujjani
	Location	Latitude – 18º 04' 24'' – N Longitude – 75º 07' 15'' – E
	Purpose of the Project	Irrigation, Power Generation & Water Supply.
	Year of Completion	1980
	Year of first impoundment	1977
2.	**HYDROLOGY**	
	Basin	Krishna
	River	Bhima
	Catchment area	14,858 Sq.km (including intercepted catchment of 5,092 Sq.km)
	Average annual rainfall near the dam site	500mm
	Maximum observed flood discharge at the dam site	8720 Cumecs
	Spillway design flood	15,010 Cumecs
	Probable Maximum flood	22,656 Cumecs
3.	**DAM**	
	Type	Earth fill cum Masonry Gravity Dam
	Top of dam i) Masonry ii) Earthen	501.40m 499.87m
	Maximum Water Level (MWL)	497.58m
	Full Reservoir Level (FRL)	496.83m
	Spillway Crest Level	490.83m
	Minimum Draw Down Level (MDDL)	491.03m
	Irrigation Outlet Sill Level i) Left Bank Canal ii) Right Bank Canal	 487.20m Offtaking in Km. No.20 of U.L.B.C
	Power Outlet Sill Level	483.32m

	River Sluice Sill Level	470.00m
	Deepest Foundation Level	446.05m
	Max. Height of Dam below the Lowest Bed Level	56.40m
	Max. Height of Dam above Lowest Bed Level	43.23m
	Height of Dam above the Spillway Crest Level	10.57m
	Max. Width of Foundation	46.23m
	Width of Dam at the Top	6.70m
4.	**RESERVOIR**	
	Gross Storage Capacity	3320 M.Cu.m
	Live Storage Capacity	1517.20 M.Cu.m
	Dead Storage Capacity	1802.80 M.Cu.m
	Surcharge Storage Between MWL & FRL	259.42 M.Cu.m
	Submergence Area at MWL	357 Sq.km
	Submergence Area at FRL	336.50 Sq.km
	Maximum Length of the Reservoir	*134 Km.*
	Maximum Width of the Reservoir	8 Km.
	Length of Periphery	670 Km.
	Lowest Bed Level	458.17m
5.	**IRRIGATION**	
	Gross Command Area	1,56,860 Ha.
	Culturable Command Area	1,25,488 Ha.
	Irrigable Command Area	1,12,940 Ha.
	Length of Canal a. Left Bank **b.** Right Bank	 126 Km. 112 Km.
6.	**POWER**	
	Type of Power House	Circular Type
	Installed Capacity	12 MW
	No. of Units	One
	Plant Load Factor	20%

3.2.5 FIELD PHOTOGRAPH

View of the Bhima (Ujjani) Reservoir, Maharashtra

View of Bhima (Ujjani) Dam, Maharashtra

CHAPTER – 4

METHODOLOGY

4.1 GENERAL METHODOLOGY

Reservoir sedimentation assessments have, over the years, been carried out by Hydrographic surveys. However, it evolved into a specialized technique with the development of Differential Global Positioning Techniques (DGPS) in recent years. This technique, which is now increasingly being adopted for the siltation studies of reservoirs in India, enables collection of enough data to map the entire reservoir bottom and then using the standard topographic and mapping programmes to evaluate the changes in the reservoir sedimentation.In this chapter,we are going to discuss briefly about the methodology of field investigation adopted by the CWC to study the reservoir behaviour.

4.2 HYDROGRAPHIC SURVEY

1. Salaulim Reservoir

The work involved hydrographic and topographic survey of the Salaulim Reservoir(survey done by CWC) area upto the Maximum Water Level (MWL) EL. 45.8m.

2. Ranapratap Sagar Reservoir

The work involved hydrographic and topographic survey of the Ranapratap Sagar reservoir(survey done by CWC) area up to the Full Reservoir Level EL 352.80 m and MWL 354.17 m of the reservoir.

3. Bhima(ujjani) Reservoir

The work involved hydrographic and topographic survey of the Bhima (Ujjani) reservoir(survey done by CWC) area up to the FRL/MWL of 496.83 m/ 497.58m of the reservoir.

Surveys were conducted using State-of-the Art technology. The survey system basically comprised of three components:

•	Positioning System	Global Positioning system in Differential Mode.
•	Depth Measurement Unit	Digital Echo-Sounder / Bathymeter / Transducer for depth measurement.
•	Computer interface	GPRSV7 (utility of GEOSOFT) software for data logging and processing of positioning data with contour plots.

4.2.1 Positioning System

To position the survey with high accuracy, Global Positioning System in differential mode (DGPS) was used.

4.2.1.1 Global Positioning System

GPS is a satellite-based global navigation system created and operated by the United States Department of Defense (DOD).Originally intended solely to enhance military defense capabilities, GPS capabilities have expanded to provide highly accurate position information for many civilian applications.

An in-depth study of GPS is required to fully understand how it works, but simply stated: more than thirty two satellites in six orbital paths circle the earth twice each day at an inclination of approximately 55 degrees to the Equator. This constellation of satellites continuously transmits coded positional and timing information at high frequencies in the 1500-Megahertz range. GPS Receivers with antennae located in strategic positions to clearly view the satellites, pick up these signals, and use the coded information to calculate a given position in an earth co-ordinate system.

Position accuracy depends on the Receiver's ability to calculate accurately the time it takes for each satellite signal to travel to earth. This is where the problem lies. There are primarily four sources of errors, which can affect the Receiver's calculation. These errors consist of (1) ionosphere and troposphere delays on the radio signal, (2) signal multi-path, (3) receiver clock biases, (4) orbital errors, also known as ephemeris errors of the satellite's exact location. These errors can be reduced or eliminated through a technique known as "Differential".

4.2.1.2 Differential Global Positioning System

DGPS works by placing a high-performance GPS receiver (reference station) at a known location. Since the receiver knows its exact location, it can determine the errors in the satellite signals. It does this by measuring the ranges to each satellite using the signals received and comparing these measured ranges to the actual ranges calculated from its known position. The difference between the measured and calculated range is the total error. The error data for each tracked satellite is formatted into a correction message and transmitted to GPS users. The correction message format follows the standard established by the Radio Technical Commission for Maritime Services, Special Committee 104 (RTCM-SC104). These differential corrections are then applied to the GPS calculations, thus removing most of the satellite signal error and improving accuracy. The level of accuracy obtained is a function of the GPS receiver. Sophisticated receivers like the Starlink DNAV-212 and INVICTA 210 series can achieve accuracy of the order of 1 meter or less.

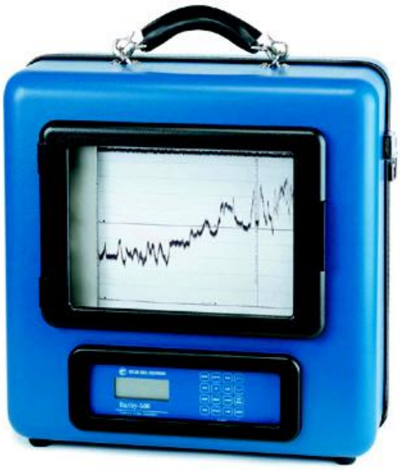
4.2.2 Depth Measuring Unit

Most modern hydrographic surveys are conducted using electronic echo-sounders. The bathymeter is installed on a survey boat. The depth is derived from time measurements of the return trip of the acoustic pulse from source to bottom and return.

The principle of the method is to send an acoustic signal and measure the travel time to derive a depth. This depth conversion process is done by first measuring the velocity of sound in the lake water at different depths. This calibration should be done twice a day to ensure a good accuracy in trip of the acoustic pulse from surface to bottom and return. Since the depth of acoustic sound wave is mainly influenced by water temperature and salinity, calibration of the instrument is essential. This has been done by depth conversion process by just measuring the velocity of sound in the lake at different depths. (The speed of sound in water can vary from 1400 m/s to 1600 m/s).

The digital echo sounder was used as far as possible. However, the digital system has a limitation of not being accurate at water depths less than one meter. In such case, an analogue method of pole sounding was used to maintain the accuracy of the data.

IHO(International Hydrographic organization) standards Special9Publication9No. 44 was used for hydrographic survey, which also incorporates procedure for elimination of doubtful data, and thus maintaining a high level of accuracy.



Bathymeter (Bathy – 500)

4.2.2.1 Transmission Point

The echo-sounder transmission point was set to read the depth of the transducer of the boat such that the depths read are the actual depths from the surface to the bottom. The transmission point was constantly monitored while sounding was in progress and during echo-sounding calibration.

4.2.2.2 Sounding Calibration

To ensure the required accuracy in Bathymetry survey, the echo sounder was calibrated at least twice a day and at any other time as deemed necessary. All calibrations were recorded and filed. The speed of sound in water can vary from 1400m/s to 1600m/s. Systematic procedures were, therefore, required to ensure the determination of the proper speed of sound in order to determine the true depth.

4.2.2.3 Bar, Plate and Cone Check

These methods consisted of lowering a steel bar plate, to known depths at maximum intervals of 10 meters below the water surface. Usually the plate was lowered to the maximum depth from the survey boat. The echoes from the plate determine the required corrections to be applied to the measured depths to obtain the true depths.The calibration was performed on the day of survey in the area where the survey was to be conducted because of potential changes in water temperature and salinity throughout the area.

4.2.3 Computer Interface

The output from GPS is available at every second interval, whereas a Bathymeter can take sounding at much higher frequencies; the computer program monitors the GPS serial port for incoming data, and every time a GPS data string is received, the program immediately retrieves a depth reading from the second serial port. The speed of the boat was controlled is such a way that it was possible to collect data along the line at 2m interval. The survey software has many other capabilities. They are listed below.

- Fixing grid line on screen.
- Display of boat position, speed, direction, heading angle etc. on screen in real time.
- Interfacing with bathymeter and DGPS and writing of output in X,Y,Z format.
- Display of depth and depth chart in real time.
- Selection of base line for survey.
- Display of coordinates.
- Display of chainage being covered.
- Display of offset from the selected line.

a) Data collection

- The bathymetric equipments for the Hydrographic survey comprising the GPS, Echo sounder and the interface modulator along with the laptop computer were mounted on the boat.
- On a chosen segment the boat was parked as close to the bank as would the draft for the boat practically allows generally up to 0.6m to 0.9m depths.
- Distance from water edge to boat measured and recorded.
- The boat run on a course as close to the segment as practically possible.
- The depth and position data recorded at every 2m interval.
- As the boat run would automatically cease at such a distance along the segment in the close proximity of the periphery where draft would be about

0.9m/1.2m, the uncovered length form the end of the run to the water edge on the segment was measured and recorded.

- Wherever mounts are encountered during the process of data collection, the periphery of the mounts was covered by running the boat close to the water edge.
- The above steps were repeated along the pre planned segments drawn on the digitized water spread plan configuration.
- Islands, rocks and other important bench mark points, as and when encountered, was marked with their latitude/longitude and name on the water spread plan configuration with the help of a symbol was set up, which would extremely help in cruising the boat safely and to identify the positions on the water spread during the subsequent Hydrographic surveys.
- Water levels were recorded at the beginning and end of the survey day daily.
- Maximum number of segments as practicable was covered on a given survey day and during the return journey, the boat run collecting the data longitudinally across the segments covered for that day and then reach the starting point.
- The starting point was changed to another identified landmark when the travel time to reach the starting point at the end of the survey day exceeded one hour.

Fore mentioned procedure; with appropriate modification as and when encountered was adhered to till the completion of the entire survey and of course with appropriate approvals to any modification.

4.3 TOPOGRAPHIC SURVEY

Topographic survey was conducted in the area between existing water level at the time of survey upto MWL of the reservoir area. The survey of the exposed land area of the reservoir was carried out at grid interval of 50m x 50m(for salaulim reservoir) and 100m x 100m(for Ranapratap Sagar Reservoir and Bhima Reservoir). However, at certain locations where narrow features were observed, closer samples were taken to have truly representative data. Electronic Total Station Leica 1103 series was used for this purpose. The instrument has an internal memory to store upto 10,000 data points. Data transfer on PC was achieved with the RS 232 C interface cable. Leica Total Station series meets the 'IPX4' water resistance performance based on IEC 529 International Standards that makes it the most reliable and durable "Total Station" in its class. Degree of protection for the Leica 1100 series is equivalent to IPX4, which is defined as "'Water splashed against the enclosure from any direction shall have no harmful effect".The land survey accuracy and quality was enhanced by setting up control stations using DGPS all along the periphery of the reservoir, and data was cross checked at these control points. During the surveys, all features of the project were picked up.

4.3.1 Total Station Survey

The system incorporates an electronic Theodolite, electronic distance measuring device and a computer as a unit.The capability of the system to retain data in memory, carry out calculation using its own processor and finally able to create X, Y, Z files directly transferable to the computer.

4.3.2 Electronic Computerized Total Station

Total Station is the most modern instrument being used for topographical surveys worldwide. The system incorporates an electronic theodolite, an electronic distance measurement device and a computer as one unit. The capability of the system to retain data in memory, carry out calculation using its own processor, and finally ability to create X, Y, Z files directly transferable to the computer, makes the survey process very fast and accurate.

Topographical data is arranged using utility software by LIECA and TOPCON ARRANGE.

Arrange data come in the following format:

Point # Northing Easting Elevation Code

X, Y, Z are extracted from this data using in-house software and then merged with the bathymetry data for girding and contouring operations.

4.3.3 Auto Level

Auto level is used to accurately transfer the Z co-ordinate from the bench mark to control points.

4.4 FIELD WORK

In compliance of the work schedule, the team for hydrographic and topographic surveys, collection of data, and interaction with the project authorities was deputed immediately and the team arrived at the respected project location and completed the surveys from December 23,2010 to January 10,2011 for salaulim reservoir,from January 12,2011 to March 23,2011 for Ranapartap Sagar Reservoir and from 4 April, 2011 to 24 October, 2011 for Bhima(Ujjani) Reservoir.

Discussions were held with the authorities of the Water Resources Department of States on various aspects of surveys and studies proposed to be done for sedimentation assessments. The authorities extended full support to the field teams and no difficulties were encountered in the field work.

The survey of respected Reservoirs was conducted in a rapid and efficient manner in accordance with the prescribed specifications. The reference station was positioned on the left Bank of the dam. The latitude & longitude of the reference station were determined using Self-survey with GPS to fix the Longitude and Latitude. The water level gauge, from which daily water levels are observed, was the reference B.M for the survey.The maximum and minimum water levels observed during the period of survey are 41.13m and 40.86m respectively for Salaulim Reservoir,347.874 m and 345.36 m respectively for Ranapartap Sagar Reservoir and 847.110m and 845.660m respectively for Bhima Reservoir.

The bathymetric equipment for the hydrographic survey comprising the DGPS rover station, the digital echo sounder and the interface modulator along with the laptop computer were all mounted on the boat. The reference station for the DGPS was first established at the dam site as mentioned above and surveys were started with this station as the base station for positioning. The base station was shifted as the survey progressed depending on the line of sight visibility for positioning and tracking the boat for the hydrographic surveys.

The Base stations and the subsequent reference stations used for the hydrographic surveys were used for the topographic surveys also to ensure that the merging of the two sets of data is done accurately.

The Bathymetric Surveys were carried out in a grid of 50mx50m (for salaulim reservoir) and 100m x 100m (for Ranapratap Sagar Reservoir and Bhima Reservoir)for the reservoir area under water. For area not covered under water, topographic survey was carried out with a grid of 50mx50m using Total Station. However, at certain locations where narrow features were observed, closer samples were taken to have truly representative data.

The land survey accuracy and quality was enhanced by setting up control stations using DGPS all along the periphery of the reservoir, and data was cross checked at these control points. During the surveys, all features of the project like the dam, the spillway, dykes, outlets etc., were picked up. Wherever Island formation was noticed the levels of the islands exposed upto the MWL were also surveyed.

4.5 DATA PROCESSING

Bathymetry data recorded in the file is in X, Y, Z format with Z being the depth of the bed. Data is first transferred to reduced levels format. The bathymeter files are merged with the land survey data for the entire duration of the survey using Geosoft utility XYZMERGE. The XYZ file is then subjected to grid operation using Geosoft utility RANGRID. The software allows user to select various parameters like cell size (dependent on the survey grid), search radius (for smooth data between two surveyed locations) etc., which are set by the user depending on the final contour requirements, grid of the survey, data density etc. The output grid is then filtered to remove noise from the data using GEOSOFT utility GRIDHANN. The grid is then used for contouring using GEOSOFT utility CONTUR. Software allows for selection of contour intervals, lowest and highest contour, pen color and width selection, label formatting, density selection etc.

Final contour file is in "plt" format, which is transferred to "dxf" format to be imported in AutoCAD, using Geosoft utility PLTDXF.

Final dxf file is then imported in AutoCAD for plotting and formatting.

From the grid data, using the Geosoft utilities, reservoir areas and capacity at required elevation interval was generated.

CHAPTER – 5

DATA ANALYSIS & RESULTS

5 5.1 SALAULIM RESERVOIR

5.1.1 EARLIER CAPACITY SURVEY

The Elevation – Capacity table / Curve of pre–impoundment survey (**1990**) and salient data of the project have been furnished by the CWC.

5.1.2 RATE OF SILTATION – PLANNING STAGE

The practice in vogue before the eighties was to provide dead storage to accommodate 100 years of sedimentation. Entire sediment was assumed to deposit at the lowest level. The assumption that sediment would settle within dead storage only, was found to be not valid and the reservoir surveys indicated that the sedimentation took place throughout the reservoir with different rates in live and dead storages. The period required for complete sedimentation of the dead storage thus would be normally more than the “planned life” of the reservoirs planned prior to 1987.It is not appropriate to compare the assumed sedimentation rate at the planning stage of these old reservoirs with the average rate obtaining in the first 10 or 30 years after impoundment and conclude that the actual rate of sedimentation is “alarming” (Ref: CWC-Compendium on silting of Reservoirs in India, 2001). Comparison of the assumed rate at planning stage with the 100 - year average rate based on trend line obtaining during operation stage is appropriate; if at all a comparison is needed. Better alternative would be to compare the “assessed life” of reservoir based on reservoir sedimentation survey data with “planned life”.

5.1.3 CAPACITY SURVEY (2011)

The capacity survey of the Salaulim Reservoir was carried in between December 2010 and January 2011 by CWC.Elevation-Area-Capacity tables have been generated using the grid generated from XYZ file. Geosoft utilities, GRIDVOL and GRIDSTAT have been used to compute capacities and areas at various levels from the lowest bed level at.Values of area and capacity as per 2011 –Survey corresponding to reservoir elevations at 0.1 m interval are given in **Tables 5.1 & 5.2(Data furnished by CWC)** for ready reference.

Table - 5.1:Elevation Area Table(2011) of Salaulim Reservoir

Unit: Sq.km.

Elevation (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
14	0.000	0.004	0.008	0.012	0.016	0.020	0.024	0.029	0.033	0.037
15	0.041	0.050	0.060	0.069	0.078	0.088	0.097	0.106	0.116	0.125
16	0.135	0.144	0.153	0.163	0.172	0.182	0.191	0.200	0.210	0.219
17	0.228	0.238	0.247	0.257	0.266	0.275	0.285	0.294	0.304	0.313
18	0.322	0.336	0.349	0.363	0.376	0.390	0.403	0.417	0.430	0.443
19	0.457	0.476	0.494	0.513	0.531	0.550	0.568	0.587	0.605	0.624
20	0.643	0.665	0.687	0.710	0.732	0.755	0.777	0.800	0.822	0.845
21	0.867	0.898	0.928	0.959	0.989	1.020	1.051	1.081	1.112	1.142
22	1.173	1.209	1.245	1.281	1.317	1.354	1.390	1.426	1.462	1.498
23	1.534	1.572	1.610	1.648	1.686	1.724	1.762	1.800	1.838	1.876
24	1.914	1.967	2.020	2.074	2.127	2.181	2.234	2.288	2.341	2.395
25	2.448	2.503	2.558	2.613	2.668	2.723	2.778	2.834	2.889	2.944
26	2.999	3.057	3.115	3.174	3.232	3.291	3.349	3.407	3.466	3.524
27	3.582	3.641	3.700	3.759	3.818	3.877	3.936	3.995	4.054	4.113
28	4.172	4.235	4.298	4.362	4.425	4.488	4.551	4.614	4.678	4.741
29	4.804	4.888	4.971	5.055	5.139	5.222	5.306	5.390	5.473	5.557
30	5.641	5.752	5.864	5.976	6.087	6.199	6.311	6.422	6.534	6.646
31	6.758	6.904	7.051	7.198	7.345	7.492	7.639	7.786	7.933	8.080
32	8.227	8.412	8.596	8.781	8.965	9.150	9.334	9.519	9.703	9.888
33	10.073	10.277	10.481	10.685	10.889	11.093	11.297	11.501	11.705	11.909
34	12.113	12.310	12.507	12.705	12.902	13.099	13.297	13.494	13.691	13.889
35	14.086	14.246	14.405	14.565	14.725	14.884	15.044	15.204	15.363	15.523
36	15.683	15.855	16.027	16.200	16.372	16.545	16.717	16.890	17.062	17.235
37	17.407	17.566	17.725	17.884	18.043	18.202	18.361	18.520	18.679	18.838
38	18.998	19.164	19.331	19.498	19.665	19.832	19.999	20.166	20.333	20.500
39	20.667	20.836	21.005	21.175	21.344	21.513	21.682	21.851	22.020	22.189
40	22.358	22.481	22.604	22.727	22.850	22.973	23.096	23.219	23.342	23.465
41	23.588	23.712	23.951	24.064	24.177	24.291	24.404	24.517	24.631	24.744
42	24.857	24.985	25.112	25.240	25.367	25.495	25.622	25.750	25.877	26.005
43	26.132	26.258	26.383	26.509	26.634	26.760	26.885	27.011	27.136	27.262
44	27.387	27.495	27.603	27.711	27.819	27.928	28.036	28.144	28.252	28.360
45	28.468	28.592	28.716	28.839	28.963	29.087	29.210	29.334	29.458	

Area at MDDL of 20.42m = 0.737 Sq. km

Area at FRL of 41.15m = 23.84 Sq. km

Table - 5.2:Elevation Capacity Table(2011) of Salaulim Reservoir

Unit: M.Cu.m

Elevation(m)	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900
14	0.000	0.000	0.001	0.002	0.003	0.005	0.007	0.010	0.013	0.017
15	0.020	0.025	0.030	0.037	0.044	0.053	0.062	0.072	0.083	0.095
16	0.108	0.122	0.137	0.153	0.169	0.187	0.206	0.225	0.246	0.267
17	0.290	0.313	0.337	0.362	0.389	0.416	0.444	0.473	0.502	0.533
18	0.565	0.598	0.632	0.668	0.705	0.743	0.783	0.824	0.866	0.910
19	0.955	1.001	1.050	1.100	1.152	1.206	1.262	1.320	1.380	1.441
20	1.505	1.570	1.638	1.707	1.779	1.854	1.930	2.009	2.090	2.174
21	2.259	2.348	2.439	2.533	2.631	2.731	2.835	2.941	3.051	3.164
22	3.279	3.398	3.521	3.647	3.777	3.911	4.048	4.189	4.333	4.481
23	4.633	4.788	4.947	5.110	5.277	5.447	5.622	5.800	5.982	6.167
24	6.357	6.551	6.750	6.955	7.165	7.380	7.601	7.827	8.058	8.295
25	8.537	8.785	9.038	9.297	9.561	9.830	10.105	10.386	10.672	10.964
26	11.261	11.564	11.872	12.187	12.507	12.833	13.165	13.503	13.847	14.196
27	14.551	14.912	15.280	15.653	16.031	16.416	16.807	17.203	17.606	18.014
28	18.428	18.849	19.275	19.708	20.148	20.593	21.045	21.504	21.968	22.439
29	22.916	23.401	23.894	24.395	24.905	25.423	25.949	26.484	27.027	27.579
30	28.139	28.708	29.289	29.881	30.484	31.099	31.724	32.361	33.009	33.668
31	34.338	35.021	35.719	36.431	37.158	37.900	38.657	39.428	40.214	41.015
32	41.830	42.662	43.513	44.381	45.269	46.175	47.099	48.041	49.003	49.982
33	50.980	51.998	53.035	54.094	55.172	56.271	57.391	58.531	59.691	60.872
34	62.073	63.294	64.535	65.795	67.076	68.376	69.695	71.035	72.394	73.773
35	75.172	76.589	78.021	79.470	80.934	82.415	83.911	85.423	86.952	88.496
36	90.056	91.633	93.227	94.839	96.467	98.113	99.776	101.457	103.154	104.869
37	106.601	108.350	110.114	111.895	113.691	115.504	117.332	119.176	121.036	122.912
38	124.804	126.712	128.637	130.578	132.536	134.511	136.503	138.511	140.536	142.578
39	144.636	146.711	148.803	150.912	153.038	155.181	157.341	159.517	161.711	163.921
40	166.149	168.391	170.645	172.912	175.191	177.482	179.785	182.101	184.429	186.769
41	189.122	191.487	193.870	196.271	198.683	201.106	203.541	205.987	208.445	210.913
42	213.393	215.886	218.390	220.908	223.438	225.982	228.537	231.106	233.687	236.282
43	238.888	241.508	244.140	246.785	249.442	252.111	254.794	257.488	260.196	262.916
44	265.648	268.392	271.147	273.913	276.689	279.477	282.275	285.084	287.904	290.734
45	293.576	296.429	299.294	302.172	305.062	307.964	310.879	313.806	316.746	

Capacity at MDDL of 20.42m = 1.822 M.Cu.m

Capacty at FRL of 41.15m = 192.67 M.Cu.m

5.1.4 LOSS OF STORAGE

Two sets of pre-impoundment capacity tables were provided, one prepared by S.O.I. and the other being followed by the project. There is substantial difference in the capacities at FRL between the tables. The capacity at FRL of 41.15m as per S.o.I. table is 196.01 M.Cu.m, whereas it is 234.36 M.Cu.m as per the table being followed by the project. It is learnt that the table was first prepared by Survey of India and the table being followed by the project was prepared by m/s WAPCOS, later. Hence for sedimentation study purpose the table being followed by the project has been used. The areas/capacities at various elevation as per the table by the project authorities, corrected as explained above and obtained as per 2011 survey are given at **Table 5.3(Data furnished by CWC)** and elevation-area-capacity curve superimposed over the curve of pre-impoundment survey is at **Figure 5.1(figure furnished by CWC)**.

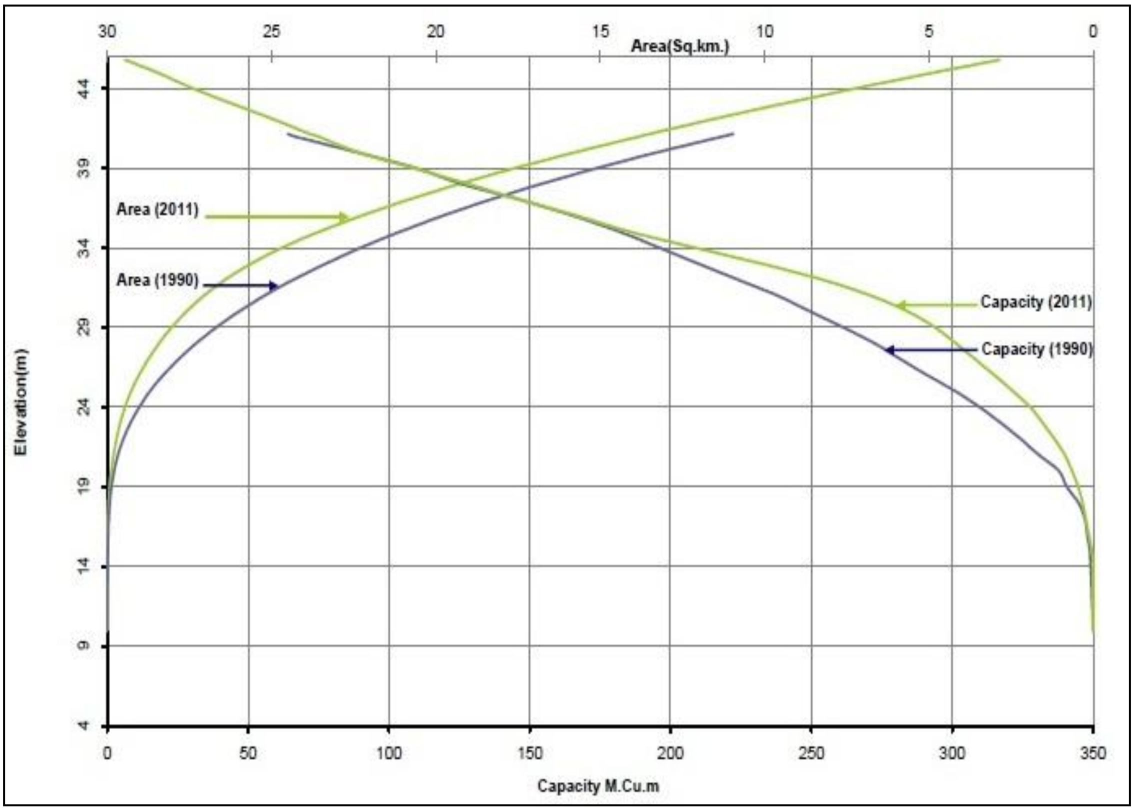


Fig. 5.1: Elevation-Area-Capacity Curve

Table - 5.3:Elevation-Area-Capacity Table(Salaulim Reservoir)

Elevation (m)	Pre-impoundment Table Supplied by Project		Corrected Pre-impoundment Table		2011 Survey	
	Area (Sq.km)	Capacity (M.Cu.m)	Area (Sq.km)	Capacity (M.Cu.m)	Area (Sq.km)	Capacity (M.Cu.m)
10.00		0.00	0.00	0.00	0.00	0.00
14.00		0.60	0.078	0.16	0.00	0.00
15.00	0.098	1.54	0.098	0.25	0.04	0.02
16.00		1.65	0.18	0.38	0.14	0.11
17.00	-	1.80	0.25	0.60	0.23	0.29
18.00		3.00	0.45	0.95	0.32	0.57
19.00	-	4.20	0.80	1.57	0.46	0.96
20.00	1.214	6.48	1.21	2.50	0.64	1.51
21.00	-	7.80	1.65	3.85	0.87	2.26
22.00		10.80	2.20	5.77	1.17	3.28
22.50	2.430	12.30	-	-	-	-
23.00	-	13.80	2.80	8.27	1.53	4.63
24.00		17.40	3.45	11.40	191	6.36
25.00	4.250	21.89	4.25	15.22	2.45	8.54
26.00		26.40	5.05	19.85	3.00	11.26
27.00	-	32.40	5.85	25.30	3.58	14.55
28.00		38.40	6.65	31.55	4.17	18.43
29.00	-	46.80	7.60	38.67	4.80	22.92
30.00		54.89	8.60	46.77	5.64	28.14
31.00	-	65.40	9.60	55.87	6.76	34.34
32.00		78.00	10.80	66.07	8.23	41.83
33.00	-	91.80	12.00	77.47	10.07	50.98
34.00		106.80	13.20	90.07	12.11	62.07
35.00	14.340	116.57	14.34	103.87	14.09	75.17
36.00		138.00	15.80	118.97	15.68	90.06
37.00	-	156.00	17.40	135.57	17.41	106.60
37.50	18.210	165.29	-	-	-	-
38.00		174.60	19.20	153.87	19.00	124.80
39.00	-	193.20	20.60	173.77	20.67	144.64
40.00	22.610	212.15	22.61	195.27	22.36	166.15
41.00	-	231.60	24.30	218.62	23.59	189.12
41.15		234.36	24.50	222.28	23.84	192.68

5.1.5 RATE OF SILTATION

Capacity at FRL as per pre impoundment survey 1990	=	222.28 M.Cu.m
Capacity at FRL as per 2011 survey	=	192.68 M.Cu.m
Silting in 21 years (1990-2011)	=	222.28 – 192.68
	=	29.6 M.Cu.m

Annual Siltation	=	29.6 / 21	=	1.41 M.Cu.m
Rate of siltation	=	1.41 x 1000 / 209		
	=	6.75 Th.cum/Sq.km/year		
	=	6.75 mm/year		
	=	67.50 ha.m/100Sq.km./year		

5.1.6 SILTATION IN DIFFERENT ZONES OF THE RESERVOIR

1. Loss of Gross Storage Capacity at FRL

Capacity at FRL as per pre-impoundment survey 1990	=	222.28 M.Cu.m
Capacity at FRL as per 2011 survey	=	192.68 M.Cu.m
Loss of storage in **21 years (1990-2011)**	=	222.28 – 192.68
	=	29.6 M.Cu.m
Percentage loss of Gross storage at FRL in 21 years	=	29.6 x 100 / 222.28
	=	13.32
Annual percentage loss	=	13.32 / 21
	=	0.63

2. Loss of Dead Storage Capacity

Capacity at MDDL (**20.42m**) as per pre-impoundment survey	=	3.066 M.Cu.m
Capacity at MDDL as per 2011 survey	=	1.822 M.Cu.m
Loss of storage upto MDDL	=	3.066 – 1.822
	=	1.244 M.Cu.m

Percentage loss of dead storage capacity in 21 years	=	1.244 x 100 / 3.066
	=	40.57
Annual percentage loss	=	40.57 / 21
	=	1.93

3. Loss of Live Storage Capacity

Live storage capacity as per pre-impoundment survey	= 219.214 M.Cu.m
Live storage capacity as per 2011 survey	= 190.858 M.Cu.m
Loss of live storage capacity	= 219.214-190.858
	= 28.356 M.Cu.m
Percentage loss of live storage capacity in 21 years	= 28.356 x 100 / 219.214
	= 12.94
Annual percentage loss	= 12.94 / 21
	= 0.62

5.2 RANAPRATAP SAGAR RESERVOIR

5.2.1 EARLIER CAPACITY SURVEY

The Elevation-Area-Capacity table of the pre-impoundment survey(1970) and salient data of the project have been furnished by the CWC.

5.2.2 RATE OF SILTATION-PLANNING STAGE

The practice in vogue before the eighties was to provide dead storage to accomomodate 100 years of sedimentation. Entire sediment was assumed to deposit at the lowest level. . The assumption that sediment would settle within dead storage only, was found to be not valid and the reservoir surveys indicated that the sedimentation took place throughout the reservoir with different rates in live and dead storages. The period required for complete sedimentation of the dead storage thus would be normally more than the “planned life” of the reservoirs planned prior to 1965. It is not appropriate to compare the assumed sedimentation rate at the planning stage of these old reservoirs with the average rate obtaining in the first 10 or 30 years after impoundment and conclude that the actual rate of sedimentation is “alarming” (Ref: CWC-Compendium on silting of Reservoirs in India, 2001). Comparison of the assumed rate at planning stage with the 100 - year average rate based on trend line obtaining during operation stage is appropriate; if at all a comparison is needed. Better alternative would be to compare the “assessed life” of reservoir based on reservoir sedimentation survey data with “planned life”.

5.2.3 ELEVATION-AREA-CAPACITY TABLE(1987)

Elevation-Area-Capacity tables have been generated using the grid generated from XYZ file. Geosoft utilities, GRIDVOL and GRIDSTAT have been used to compute capacities and areas at various levels from the lowest bed level at values of area and capacity as per 2011 –Survey corresponding to reservoir elevations at 0.1 m interval are given in **Tables 5.4 & 5.5(Data furnished by CWC)** for ready reference.

Table 5.4 :Elevation Area Table(2011) of Ranapratap Sagar Reservoir

Unit: Sq.km.

ELEVATION (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
319	0.00	0.058	0.116	0.174	0.232	0.290	0.348	0.406	0.464	0.522
320	0.058	0.648	0.716	0.784	0.852	0.920	0.988	1.056	1.124	1.192
321	1.260	1.327	1.394	1.461	1.528	1.595	1.662	1.729	1.796	1.863
322	1.930	2.017	2.104	2.191	2.278	2.365	2.452	2.539	2.626	2.713
323	2.800	2.899	2.998	3.097	3.196	3.295	3.394	3.493	3.592	3.691
324	3.790	3.948	4.106	4.264	4.442	4.580	4.738	4.896	5.054	5.212
325	5.370	5.557	5.744	5.931	6.118	6.305	6.492	6.679	6.866	7.053
326	7.240	7.496	7.752	8.008	8.264	8.520	8.776	9.032	9.228	9.544
327	9.800	10.114	10.428	10.742	11.056	11.370	11.684	11.998	12.312	12.626
328	12.940	13.490	14.040	14.590	15.140	15.690	16.240	16.790	17.340	17.890
329	18.440	19.030	19.620	20.210	20.800	21.390	21.980	22.570	23.160	23.750
330	24.340	25.148	25.956	26.764	27.572	28.380	29.188	29.996	30.804	31.612
331	32.420	33.268	34.116	34.964	35.812	36.660	37.508	38.356	39.204	40.052
332	40.900	41.803	42.706	43.609	44.512	45.415	46.318	47.221	48.124	49.027
333	49.930	51.113	52.296	53.479	54.662	55.845	57.028	58.211	59.394	60.577
334	61.760	62.692	63.624	64.556	65.488	66.420	67..352	68.284	69.216	70.148
335	71.080	72.119	73.158	74.197	75.236	76.275	77.314	78.353	79.392	80.431
336	81.470	82.383	83.296	84.209	85.122	86.035	86.948	87.861	88.774	89.687
337	90.600	91.618	92.636	93.654	94.672	95.690	96.708	97.726	98.744	99.762
338	100.780	101.558	102.336	103.114	103.892	104.670	105.448	106.226	107.004	107.782
339	108.560	109.478	110.396	111.314	112.232	113.150	114.068	114.986	115.904	116.822
340	117.740	118.493	119.246	119.999	120.752	121.505	122.258	123.011	123.764	124.517
341	125.270	126.096	126.922	127.748	128.574	129.400	130.226	131.052	131.878	132.704
342	133.530	134.432	135.334	136.237	137.139	138.041	138.943	139.846	140.748	141.650
343	142.100	143.028	143.956	144.884	145.812	146.740	147.668	148.596	149.748	141.650
344	151.380	152.148	152.916	153.684	154.452	155.220	155.988	156.756	157.524	158.292
345	159.060	159.626	160.192	160.758	161.324	161.890	162.456	163.022	163.588	164.154
346	164.720	165.286	165.852	166.418	166.984	167.550	168.116	168.682	169.248	169.814
347	170.380	171.147	171.914	172.681	173.448	174.215	174.982	175.749	176.516	177.283
348	178.050	178.521	178.992	179.463	179.934	180.405	180.876	181.347	181.818	182.289
349	182.760	183.231	183.702	184.173	184.644	185.115	185.586	186.057	186.528	186.999
350	187.470	187.973	188.476	188.979	189.482	189.985	190.488	190.991	191.494	191.997
351	192.500	192.984	193.468	193.952	194.436	194.920	195.404	195.888	196.372	196.856
352	197.340	197.910	198.480	199.050	199.620	200.190	200.760	201.330	201.900	204.670
353	206.870	208.257	209.644	211.031	212.418	213.805	215.192	216.579	217.966	219.353
354	220.740	222.140								
AREA AT MDDL OF 343.00m =142.100 Sq. km. **AREA AT FRL OF 352.80 m =201.900 Sq.km.**										

Table 5.5 : Elevation Capacity Table(2011) of Ranapratap Sagar Reservoir

Unit: M.cu.m

ELEVATION (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
319	0.00	0.00	0.01	0.03	0.05	0.07	0.10	0.14	0.19	0.23
320	0.29	0.35	0.42	0.49	0.58	0.67	0.76	0.86	0.97	1.09
321	1.21	1.34	1.48	1.62	1.77	1.92	2.09	2.26	2.43	2.62
322	2.81	3.00	3.21	3.42	3.65	3.88	4.12	4.37	4.63	4.89
323	5.17	5.45	5.75	6.05	6.37	6.69	7.03	7.37	7.73	8.09
324	8.47	8.85	9.25	9.67	10.11	10.56	11.02	11.51	12.00	12.52
325	13.05	13.59	14.16	14.74	15.34	15.96	16.60	17.26	17.94	18.64
326	19.35	20.09	20.85	21.64	22.45	23.29	24.15	25.05	25.96	26.90
327	27.87	28.87	29.89	30.95	32.04	33.16	34.32	35.50	36.71	37.96
328	39.24	40.56	41.94	43.37	44.86	46.40	47.99	49.65	51.35	53.11
329	54.93	56.80	58.74	60.73	62.78	64.89	67.06	69.28	71.57	73.92
330	76.32	78.79	81.35	83.99	86.70	89.50	92.38	95.34	98.38	101.50
331	104.70	107.98	111.35	114.81	118.35	121.97	125.68	129.47	133.35	137.31
332	141.36	145.50	149.72	154.04	158.44	162.94	167.53	172.20	176.97	181.83
333	186.78	191.83	197.00	202.29	207.69	213.22	218.86	224.62	230.50	236.50
334	242.62	248.84	255.16	261.57	268.07	274.67	281.35	288.14	295.01	301.98
335	309.04	316.20	323.46	330.83	338.30	345.88	353.56	361.34	369.23	377.22
336	385.32	393.51	401.79	410.17	418.63	427.19	435.84	444.58	453.41	462.34
337	471.35	480.46	489.67	498.99	508.40	517.92	527.54	537.26	547.09	557.01
338	567.04	577.16	587.35	597.62	607.97	618.40	628.91	639.49	650.15	660.89
339	671.71	682.61	693.61	704.69	715.87	727.14	738.50	749.95	761.50	773.13
340	784.86	796.67	808.56	820.52	832.56	844.67	856.86	869.12	881.46	893.88
341	906.37	918.93	931.58	944.32	957.13	970.03	983.01	996.08	1009.22	1022.45
342	1035.77	1049.16	1062.65	1076.23	1089.90	1103.66	1117.51	1131.45	1145.48	1159.60
343	1173.78	1188.04	1202.39	1216.83	1231.37	1245.99	1260.71	1275.53	1290.43	1305.43
344	1320.52	1335.70	1350.95	1366.28	1381.69	1397.17	1412.73	1428.37	1444.09	1459.88
345	1475.74	1491.68	1507.67	1523.72	1539.82	1555.98	1572.20	1588.47	1604.80	1621.19
346	1637.63	1654.13	1670.69	1687.30	1703.97	1720.70	1737.48	1754.32	1771.22	1788.17
347	1805.18	1822.26	1839.41	1856.64	1873.95	1891.33	1908.79	1926.33	1943.94	1961.63
348	1979.40	199723	2015.10	2033.03	2051.00	2069.01	2087.08	2105.19	2123.35	2141.55
349	2159.80	2178.10	2196.45	2214.84	2233.28	2251.77	2270.31	2288.89	2307.52	2326.20
350	2344.92	2363.69	2382.51	2401.39	2420.32	2439.28	2458.31	2477.38	2496.50	2515.68
351	2534.90	2554.18	2573.50	2592.87	2612.29	2631.76	2651.27	2670.84	2690.45	2710.11
352	2729.82	2749.59	2769.41	2789.28	2809.22	2829.21	2849.25	2869.36	2889.52	2909.86
353	2930.44	2951.20	2972.09	2993.12	3014.30	3035.61	3057.06	3078.65	3100.37	3122.24
354	3144.24									
CAPACITY AT MDDL OF 343.00m =1173.78 M.cu.m										
CAPACITY AT FRL OF 352.80 m = 2889.52 M.cu.m										

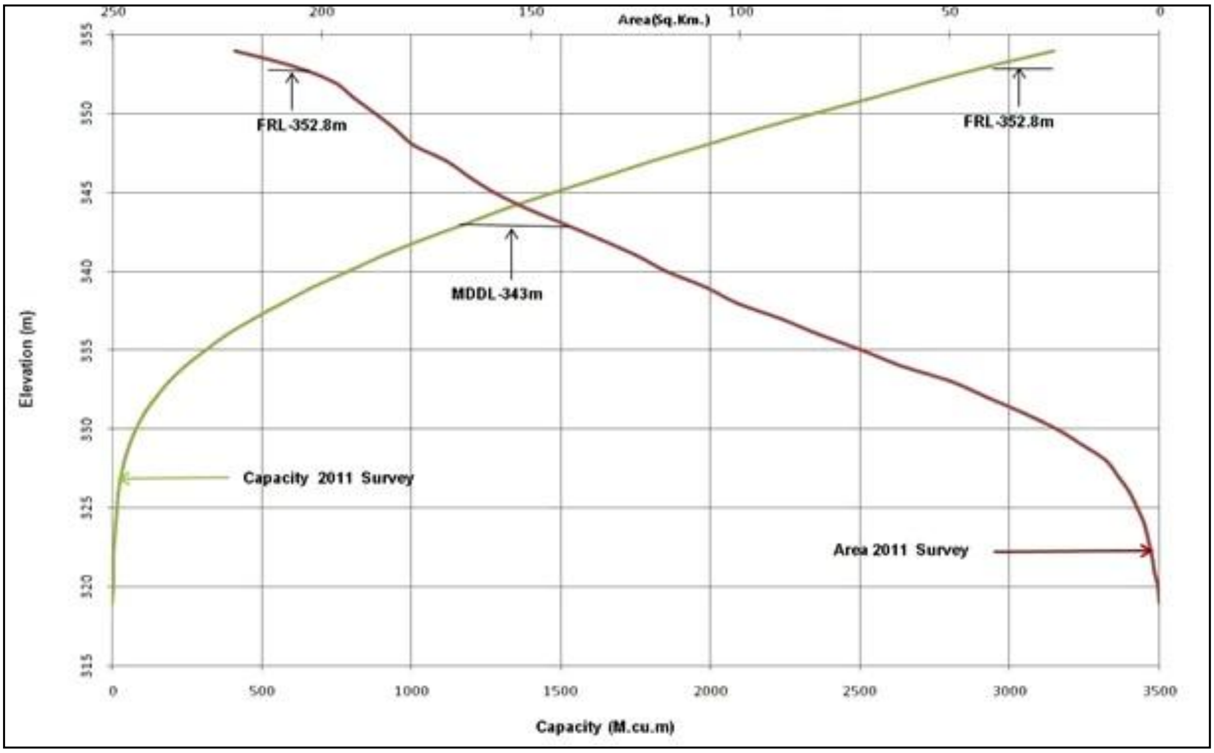


Fig.5.2: Elevation-Area-Capacity Curve

(Figure furnished by CWC)

5.2.4 LOSS OF STORAGE

Loss of storage is assessed from the reservoir capacities as per the current survey and the pre-impoundment survey. The Ranapratap sagar reservoir was impounded in the year 1970.On comparing the capacities as per pre-impoundment and 2011 survey ,it is observed that storage loss increases in the lower reaches ,while a decrease in the middle and upper reaches.For the purpose of conducting sedimentation studies,the pre-impoundment values have been adjusted ,adopting the principle that the cumulative loss below that level.It is observed that the cumulative loss at EL 337.56 m is 238.59 M.cu.m and thereafter the cumulative loss shows a decreasing trend.Hence the cumulative loss at all elevations above 337.56m is taken as 238.59 M.cu.m and the table has been recast.The adjusted table is given at **Table 5.6(Data furnished by CWC):**

Table 5.6: Adjusted pre-impoundment capacity Table(Ranapratap Sagar)

ELEVATION (m)	Preimpoundment Capacities (M.cu.m)	2011 capacity (M.cu.m)	Cumulative loss of storage (M.cu.m)	Adjusted preimpoundment capacities (M.cu.m)
317.75	0.00	0.00	0.00	0.00
319.27	4.62	0.02	4.60	4.62
320.80	14.18	0.97	13.21	14.18
322.32	22.69	3.47	19.22	22.69
323.84	31.21	7.87	23.34	31.21
323.84	31.21	7.87	23.34	31.21
326.89	119.28	26.81	92.47	119.28
328.42	167.50	45.17	122.33	167.50
329.94	224.24	74.88	149.36	224.24
331.46	298.50	120.52	177.98	298.50
332.99	388.91	186.29	202.62	388.91
334.51	496.47	275.34	221.13	496.47
334.51	496.47	275.34	221.13	496.47
337.56	762.28	523.69	238.59	762.28
339.08	917.69	680.43	237.26	919.02
340.61	1075.58	858.09	217.49	1096.68
342.13	1245.80	1053.20	192.60	1291.79
343.66	1418.48	1269.60	148.88	1508.19

345.18	1638.03	1504.47	133.56	1743.06
346.70	1860.06	1754.32	105.74	1992.91
348.23	2074.68	2020.48	54.20	2259.07
349.75	2331.24	2298.21	33.03	2536.80
351.28	2601.63	2589.00	12.63	2827.59
352.80	2904.80	2889.52	15.28	3128.11

5.2.5 RATE OF SILTATION

In a cascade system of reservoirs, a part of the sediment brought by the river gets deposited in the u/s reservoir. The trap efficiency of the reservoir depends on the capacity-inflow ratio, reservoir draw downs, location of the sluices, sediment sizes etc. In respect of Ranapratap Sagar reservoir the free catchment is only 2,280 sq.km and 23,025 sq.km catchment is intercepted by the Gandhi Sagar dam. However, the inflow into the reservoir constitutes 16.35% from the free catchment and 83.65% is the machine discharge from Gandhi Sagar dam. Since 16.35% inflow into the reservoir is from 2280 sq.km, 100% inflow corresponds to 13,945 sq.km say 14,000 sq.km, proportionately. Hence,for working out the rate of sedimentation, the effective catchment area is taken as 14000 sq. km.

Adjusted Capacity at FRL as per pre-impoundment survey 1970 = 3128.11M.Cu.m

Capacity at FRL as per 2011 survey = 2889.52 M. Cu.m

Silting in 41 years (1970-2011) = 3128.11-2889.52
= 238.59 M.Cu.m

Annual Siltation = 238.59/41 = 5.82 M.Cu.m

Rate of Siltation =5.82 x 1000/14000 =0.416Th.Cum/Sq.km/year
= 0.416 mm/year
=4.16 ha.m/100Sq.km/year

5.2.6 SILTATION IN DIFFERENT ZONES OF THE RESERVOIR

1. ***Loss of Gross Storage Capacity at FRL***

Adjusted Capacity at FRL as per pre-impoundment survey 1970 = 3128.11M.Cu.m

Capacity at FRL as per 2011 survey = 2889.52 M. Cu.m

Silting in 41 years (1970-2011)	= 3128.11-2889.52 = 238.59 M.Cu.m
Percentage loss of Gross Storage at FRL in 41 years	= 238.59x100/3128.11 = 7.63
Annual percentage loss	= 7.63/41 = 0.19

2. *Loss of Dead Storage Capacity*

Capacity at MDDL (343.00m) as per pre-impoundment survey	= 1412.37 M.Cu.m
Capacity at MDDL as per 2011 survey	= 1173.78 M.Cu.m
Loss of storage up to MDDL	= 1412.37-1173.78 = 238.59 M.Cu.m
Percentage loss of dead storage capacity in 41 years	= 238.59x100/1412.37 = 16.89
Annual percentage loss	= 16.89/41 = 0.41

3. *Loss of live Storage Capacity*

Live storage capacity as per pre-impoundment survey	= 3128.11-1412.37 = 1715.74 M.cum
Live storage capacity as per 2011 survey	= 2889.52-1173.78 = 1715.74 M.cum
Loss of live storage capacity	= 1715.74-1715.74 = 0.00 M.cum
Percentage loss of live storage capacity in 41 years	= 0.00
Annual percentage loss	= 0.00

5.3 BHIMA(UJJANI) RESERVOIR

5.3.1 EARLIER CAPACITY SURVEY

The Elevation–Area-Capacity table of the pre–impoundment survey has been furnished by the CWC.

5.3.2 RATE OF SILTATION- PLANNING STAGE

The practice in vogue before the eighties was to provide dead storage to accommodate 100 years of sedimentation. Entire sediment was assumed to deposit at the lowest level. The assumption that sediment would settle within dead storage only, was found to be not valid and the reservoir surveys indicated that the sedimentation took place throughout the reservoir with different rates in live and dead storages. The period required for complete sedimentation of the dead storage thus would be normally more than the "planned life" of the reservoirs built prior to 1965.It is not appropriate to compare the assumed sedimentation rate at the planning stage of these old reservoirs with the average rate obtaining in the first 10 or 30 years after impoundment and conclude that the actual rate of sedimentation is "alarming" (Ref: CWC-Compendium on silting of Reservoirs in India, 2001). Comparison of the assumed rate at planning stage with the 100 - year average rate based on trend line obtaining during operation stage is appropriate; if at all a comparison is needed. Better alternative would be to compare the "assessed life" of reservoir based on reservoir sedimentation survey data with "planned life".

5.3.3 ELEVATION-AREA-CAPACITY TABLE

Elevation-Area-Capacity tables have been developed using the grid generated from XYZ file. Geosoft utilities, GRIDVOL and GRIDSTAT have been used to compute capacities and areas at various levels from the lowest bed level. Values of areas and values as per 2011 – survey corresponding to reservoir elevations at 0.1 m interval are given in **Tables 5.7 & 5.8(Data furnished by CWC)**.

Table 5.7: Elevation Area Table(2011) of Bhima(Ujjani) Reservoir

Unit:Sq.km.

Elevation (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
460	0.000	0.025	0.040	0.055	0.070	0.085	0.100	0.115	0.130	0.145
461	0.160	0.183	0.206	0.229	0.252	0.275	0.298	0.321	0.344	0.367
462	0.390	0.416	0.442	0.468	0.494	0.520	0.546	0.572	0.598	0.624
463	0.650	0.706	0.762	0.818	0.874	0.930	0.986	1.042	1.098	1.154
464	1.210	1.286	1.362	1.438	1.514	1.590	1.666	1.742	1.818	1.894
465	1.970	2.041	2.112	2.183	2.254	2.325	2.396	2.467	2.538	2.609
466	2.680	2.783	2.886	2.989	3.092	3.195	3.298	3.401	3.504	3.607
467	3.710	3.853	3.996	4.139	4.282	4.425	4.568	4.711	4.854	4.997
468	5.140	5.298	5.456	5.614	5.772	5.930	6.088	6.246	6.404	6.562
469	6.720	6.901	7.082	7.263	7.444	7.625	7.806	7.987	8.168	8.349
470	8.530	8.722	8.914	9.106	9.298	9.490	9.682	9.874	10.066	10.258
471	10.450	10.698	10.946	11.194	11.442	11.690	11.938	12.186	12.434	12.682
472	12.930	13.199	13.468	13.737	14.006	14.275	14.544	14.813	15.082	15.351
473	15.620	15.953	16.286	16.619	16.952	17.285	17.618	17.951	18.284	18.617
474	18.950	19.291	19.632	19.973	20.314	20.655	20.996	21.337	21.678	22.019
475	22.360	22.805	23.250	23.695	24.140	24.585	25.030	25.475	25.920	26.365
476	26.810	27.339	27.868	28.397	28.926	29.455	29.984	30.513	31.042	31.571
477	32.100	32.716	33.332	33.948	34.564	35.180	35.796	36.412	37.028	37.644
478	38.260	38.959	39.658	40.357	41.056	41.755	42.454	43.153	43.852	44.551
479	45.250	46.005	46.760	47.515	48.270	49.025	49.780	50.535	51.290	52.045
480	52.800	53.607	54.414	55.221	56.028	56.835	57.642	58.449	59.256	60.063
481	60.870	61.713	62.556	63.399	64.242	65.085	65.928	66.771	67.614	68.457
482	69.300	70.194	71.088	71.982	72.876	73.770	74.664	75.558	76.452	77.346
483	78.240	79.256	80.272	81.288	82.304	83.320	84.336	85.352	86.368	87.384
484	88.400	89.447	90.494	91.541	92.588	93.635	94.682	95.729	96.776	97.823
485	98.870	100.011	101.152	102.293	103.434	104.575	105.716	106.857	107.998	109.139
486	110.280	111.555	112.830	114.105	115.380	116.655	117.930	119.205	120.480	121.755
487	123.030	124.331	125.632	126.933	128.234	129.535	130.836	132.137	133.438	134.739
488	136.040	137.545	139.050	140.555	142.060	143.565	145.070	146.575	148.080	149.585
489	151.090	152.671	154.252	155.833	157.414	158.995	160.576	162.157	163.738	165.319
490	166.900	168.564	170.228	171.892	173.556	175.220	176.884	178.548	180.212	181.876
491	183.540	185.399	187.258	189.117	190.976	192.835	194.694	196.553	198.412	200.271
492	202.130	204.414	206.698	208.982	211.266	213.550	215.834	218.118	220.402	222.686
493	224.970	227.001	229.032	231.063	233.094	235.125	237.156	239.187	241.218	243.249
494	245.280	247.258	249.236	251.214	253.192	255.170	257.148	259.126	261.104	263.082
495	265.060	266.972	268.884	270.796	272.708	274.620	276.532	278.444	280.356	282.268
496	284.180	286.338	288.496	290.654	292.812	294.970	297.128	299.286	301.444	303.602
497	305.760	310.815	315.870	320.925	325.980	331.035	336.090	341.145	346.200	351.255

AREA AT MDDL OF 491.03m =184.098 Sq. km.

AREA AT FRL OF 496.83m = 302.091 Sq. km.

Table 5.8:Elevation Capacity Table(2011) of Bhima(Ujjani) Reservoir

Unit:M.cu.m

Elevation (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
460	0.000	0.007	0.010	0.015	0.021	0.029	0.038	0.049	0.061	0.075
461	0.090	0.107	0.127	0.148	0.172	0.199	0.227	0.258	0.292	0.327
462	0.365	0.405	0.448	0.494	0.542	0.593	0.646	0.702	0.760	0.821
463	0.885	0.953	1.026	1.105	1.190	1.280	1.376	1.477	1.584	1.697
464	1.815	1.940	2.072	2.212	2.360	2.515	2.678	2.848	3.026	3.212
465	3.405	3.606	3.813	4.028	4.250	4.479	4.715	4.958	5.208	5.466
466	5.730	6.003	6.287	6.580	6.884	7.199	7.523	7.858	8.204	8.559
467	8.925	9.303	9.696	10.102	10.523	10.959	11.408	11.872	12.351	12.843
468	13.350	13.872	14.410	14.963	15.532	16.118	16.718	17.335	17.968	18.616
469	19.280	19.961	20.660	21.377	22.113	22.866	23.638	24.427	25.235	26.061
470	26.905	27.768	28.649	29.550	30.471	31.410	32.369	33.346	34.343	35.360
471	36.395	37.452	38.535	39.642	40.773	41.930	43.111	44.318	45.549	46.804
472	48.085	49.391	50.725	52.085	53.472	54.886	56.327	57.795	59.290	60.811
473	62.360	63.939	65.551	67.196	68.874	70.586	72.331	74.110	75.922	77.767
474	79.645	81.557	83.503	85.483	87.498	89.546	91.629	93.745	95.896	98.081
475	100.300	102.558	104.861	107.208	109.600	112.036	114.517	117.042	119.612	122.226
476	124.885	127.592	130.353	133.166	136.032	138.951	141.923	144.948	148.026	151.156
477	154.340	157.581	160.883	164.247	167.673	171.160	174.709	178.319	181.991	185.725
478	189.520	193.381	197.312	201.313	205.383	209.524	213.734	218.015	222.365	226.785
479	231.275	235.838	240.476	245.190	249.979	254.844	259.784	264.800	269.891	275.058
480	280.300	285.620	291.021	296.503	302.066	307.709	313.433	319.237	325.122	331.088
481	337.135	343.264	349.478	355.775	362.157	368.624	375.174	381.809	388.529	395.332
482	402.220	409.195	416.259	423.412	430.655	437.988	445.409	452.920	460.521	468.211
483	475.990	483.865	491.841	499.919	508.099	516.380	524.763	533.247	541.833	550.521
484	559.310	568.202	577.199	586.301	595.508	604.819	614.235	623.755	633.380	643.110
485	652.945	662.889	672.947	683.119	693.406	703.806	714.321	724.949	735.692	746.549
486	757.520	768.612	779.831	791.178	802.652	814.254	825.983	837.840	849.824	861.936
487	874.175	886.543	899.041	911.669	924.428	937.316	950.335	963.483	976.762	990.171
488	1003.710	1017.389	1031.219	1045.199	1059.330	1073.611	1088.043	1102.625	1117.358	1132.241
489	1147.275	1162.463	1177.809	1193.313	1208.976	1224.796	1240.775	1256.911	1273.206	1289.659
490	1306.270	1323.043	1339.983	1357.089	1374.361	1391.800	1409.405	1427.177	1445.115	1463.219
491	1481.490	1499.937	1518.570	1537.389	1556.393	1575.584	1594.960	1614.523	1634.271	1654.205
492	1674.325	1694.652	1715.208	1735.992	1757.004	1778.245	1799.714	1821.412	1843.338	1865.492
493	1887.875	1910.474	1933.275	1956.280	1979.488	2002.899	2026.513	2050.330	2074.350	2098.574
494	2123.000	2147.627	2172.452	2197.474	2222.694	2248.113	2273.728	2299.542	2325.554	2351.763
495	2378.170	2404.772	2431.564	2458.548	2485.724	2513.090	2540.648	2568.396	2596.336	2624.468
496	2652.790	2681.316	2710.058	2739.015	2768.188	2797.578	2827.182	2857.003	2887.040	2917.292
497	2947.760	2978.589	3009.923	3041.763	3074.108	3106.959	3140.315	3174.177	3208.544	3243.417
CAPACITY AT MDDL OF 491.03 m =1487.005 M.cu.m										
CAPACITY AT FRL OF 496.83m = 2896.093 M.cu.m										

5.3.4 LOSS OF STORAGE

Loss of storage is to be assessed based on elevation – area – capacity values of 2011 survey and the pre-impoundment survey 1977. 2011 survey is the first survey after impoundment. **Table 5.9(Data furnished by CWC)** gives the area/capacity of the reservoir as per pre-impoundment survey 1977 and hydrographic survey 2011. The elevation-area-capacity curve 2011, superimposed on the curve of pre-impoundment survey is at **Figure 5.3(Figure furnished by CWC).**

Table – 5.9: Elevation-Area-Capacity Table 1977 and 2011(Bhima Reservoir)

Elevation (m)	Pre-impoundment survey-1977		Hydrographic survey 2011	
	Area (Sq. km.)	Capacity (M.cu.m)	Area (Sq. km.)	Capacity (M.cu.m)
458	0.00	0.00	0.00	0.00
459	0.84	0.28	0.00	0.00
460	1.27	1.328	0.00	0.000
461	1.42	2.672	0.160	0.090
462	2.12	4.430	0.390	0.365
463	2.54	6.757	0.650	0.885
464	3.54	9.783	1.210	1.815
465	4.24	13.668	1.970	3.405
466	5.31	18.433	2.680	5.730
467	7.08	24.607	3.710	8.925
468	8.49	32.381	5.140	13.350
469	11.56	42.367	6.720	19.280
470	20.20	58.047	8.530	26.905
471	22.80	79.534	10.450	36.395
472	25.40	103.622	12.930	48.085
473	28.80	130.705	15.620	62.360

474	33.40	161.776	18.950	79.645
475	38.80	197.843	22.360	100.300
476	44.00	239.215	26.810	124.885
477	49.40	285.889	32.100	154.340
478	55.20	338.162	38.260	189.520
479	61.60	396.533	45.250	231.275
480	68.00	461.307	52.800	280.300
481	74.20	532.384	60.870	337.135
482	82.80	610.845	69.300	402.220
483	91.40	697.910	78.240	475.990
484	100.00	793.577	88.400	559.310
485	110.20	898.636	98.870	652.945
486	120.80	1014.096	110.280	757.520
487	134.00	1141.438	123.030	874.175
488	148.00	1282.381	136.040	1003.710
489	163.40	1438.017	151.090	1147.275
490	178.80	1609.059	166.900	1306.270
491	197.00	1796.886	183.540	1481.490
492	216.00	2003.313	202.130	1674.325
493	236.00	2229.239	224.970	1887.875
494	261.20	2477.738	245.280	2123.00
495	286.80	2751.633	265.060	2378.170
496	312.00	3050.944	284.180	2652.790
496.83	336.50	3320.000	302.090	2896.09

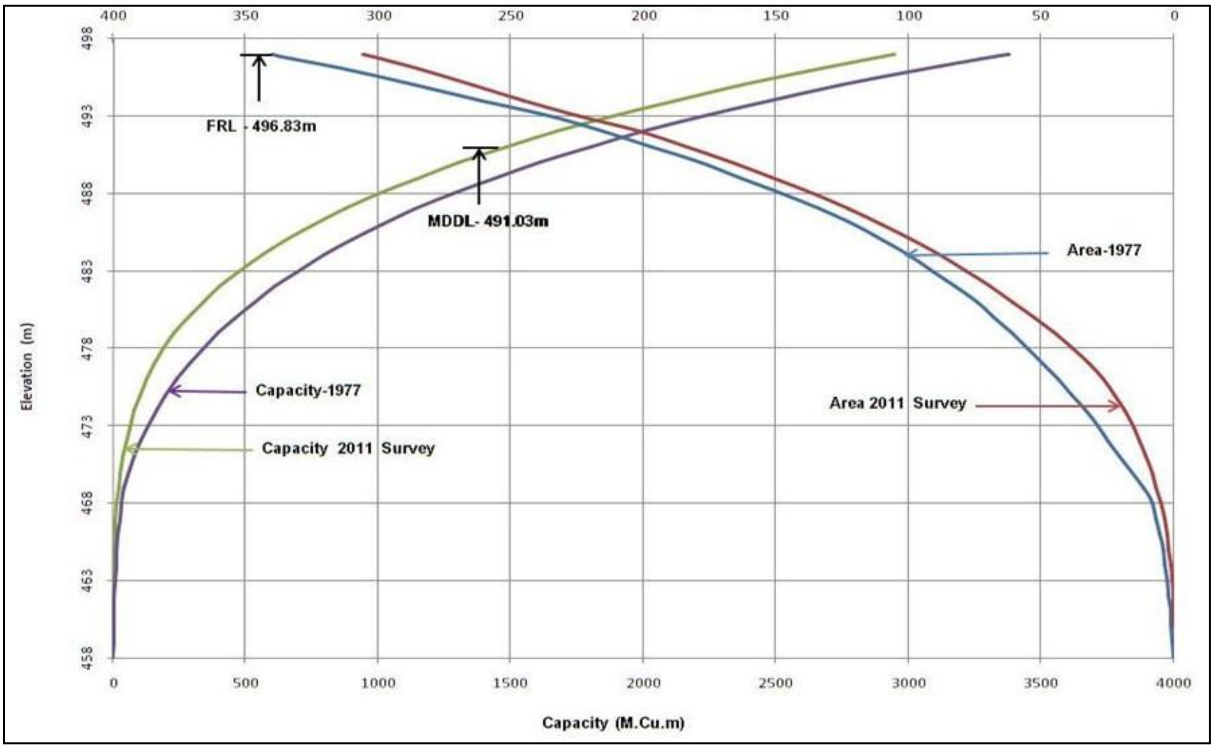


Fig.5.3: Elevation-Area-Capacity Curve

5.3.5 RATE OF SILTATION

In a cascade system of reservoirs a part of the sediment brought by the stream get trapped in the u/s reservoirs.The sediment passing through these reservoirs depends upon their trap efficiencies. The Bhima (Ujjani) valley with its tributaries and streams has 22 dams built on it and Bhima (Ujjani) dam is the terminal dam on the river and is the largest in the valley. The total catchment area of the reservoir is 14858 Sq.km, out of which 5092 sq.km is intercepted by u/s reservoirs. For working out the rate of sedimentation, it may not be appropriate either to include or exclude the whole intercepted catchment. Since a large number of reservoirs exist in the u/s, a rational approach as made in some other cascade system of reservoirs is not feasible here. Hence, the rate of sedimentation of the reservoir has been worked out by considering only 50% of the catchment intercepted by the u/s reservoirs. Thus the effective catchment for working out the rate of sedimentation would be 9766 (free catchment) + 2546 (50% of the intercepted catchment) = 12312 sq.km.

Capacity at FRL as per pre impoundment survey 1977			=	3320.00 M.Cu.m
Capacity at FRL as per 2011 survey			=	2896.09 M.Cu.m
Silting in 34 years (1977-2011)			=	3320.00–2896.09
			=	423.91 M.Cu.m
Annual Siltation	=	423.91/34	=	12.47 M.Cu.m/yr
Rate of Siltation	=	12.47 x 1000/12312		
	=	1.013Th.Cu.m/sq.km/year		
	=	1.013 mm/year		
	=	10.13 Ha.m/100sq.km./year		

5.3.6 SILTATION IN DIFFERENT ZONES OF THE RESERVOIR

1. ***Loss of Gross Storage Capacity at FRL***

Capacity at FRL as per pre-impoundment survey 1977	=	3320.00 M.Cu.m
Capacity at FRL as per 2011 survey	=	2896.09 M.Cu.m
Loss of storage in 34 years (1977-2011)	=	3320.00 – 2896.09
	=	423.91 M.Cu.m

Percentage loss of Gross storage at FRL in 34 years	=	423.91x100 / 3320.00
	=	12.77%
Annual percentage loss	=	12.77/34
	=	0.38%

2. ***Loss of Dead Storage Capacity***

Capacity at MDDL (491.03) as per pre-impoundment survey	=	1802.80 M.Cu.m
Capacity at MDDL as per 2011 survey	=	1487.28 M.Cu.m
Loss of storage up to MDDL	=	1802.80-1487.28
	=	315.52
Percentage loss of dead storage capacity in 34 years	=	(315.52/1802.80) x 100
	=	17.50%
Annual percentage loss	=	17.50/34
	=	0.51%

3. ***Loss of Live Storage Capacity***

Live storage capacity as per pre-impoundment survey	=	3320.00–1802.80
	=	1517.20 M.Cu.m
Live storage capacity as per 2011 survey	=	2896.09–1487.28
	=	1408.81 M.Cu.m
Loss of live storage capacity	=	1517.20-1408.81
	=	108.39 M.Cu.m
Percentage loss of live storage capacity	=	(108.39/1517.20)x100
	=	7.14%
Annual percentage loss	=	7.14/34
	=	0.21%

5.4 TRAP EFFICIENCY OF RESERVOIRS

Brown developed a formula that relates TE to a capacity-watershed area ratio(C/W) based on data from various reservoirs.

$$TE = 100 \left(1 - \frac{1}{1 + D\,\frac{C}{W}} \right)$$

Where C is the reservoir storage capacity expressed in acres/feet and W the catchment area expressed in miles^2 or

$$TE = 100 \left(1 - \frac{1}{1 + 0.0021\,D\frac{C}{W}} \right)$$

Where C is the reservoir storage capacity expressed in m^3 and W is the catchment area expressed in km^2.Values of D range from 0.046 to 1 ,with a mean value of 0.1 and they are dependent on the characteristics of a reservoir.

1. SALAULIM RESERVOIR

By using a value Of W(catchment area) as 209 sq. km , D as mean value i.e. 0.1 and using the values of reservoir storage capacity from **Table 5.2** corresponding to different elevations in above discussed formula given by Brown,we obtain a trap efficieny of a reservoir corresponding to different elevation as given in **Table 5.10.**

2. RANAPRATAP SAGAR RESERVOIR

By using a value of W (catchment area) as 14000 sq.km. ,D as mean value i.e. 0.1 and using the values of reservoir storage capacity from **Table 5.5** corresponding to different elevations in above discussed formula given by Brown,we obtain a trap efficiency of a reservoir corresponding to different elevations as given in **Table 5.11.**

3. BHIMA(UJJANI) RESERVOIR

By using a value of W(catchment area) as 12312 sq.km. . D as mean value i.e. 0.1 and using the values of reservoir storage capacity from **Table 5.8** Corresponding to different elevations in above discussed formula given by Brown,we obtain a trap efficiency of reservoir corresponding to different elevations as given in **Table 5.12**.

Table 5.10: Trap Efficiency table of Salaulim Reservoir

ELEVATI0N (m)	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900
14	0.000	0.000	0.1004	0.2005	0.3005	0.4998	0.6984	0.9947	1.2894	1.6794
15	1.9699	2.4504	2.9261	3.5844	4.2338	5.0561	5.8643	6.7463	7.6977	8.7136
16	9.7893	10.9197	12.0999	13.3247	14.5159	15.8174	17.1489	18.4390	19.8189	21.1529
17	22.5639	23.9253	25.2957	26.6718	28.1021	29.4776	30.8496	32.2154	33.5284	34.8767
18	36.2124	37.5336	38.8388	40.1626	41.4647	42.7444	44.0323	45.2936	46.5281	47.7630
19	48.9683	50.1443	51.3387	52.5000	53.6503	54.7873	55.9090	57.0135	58.0994	59.1486
20	60.1942	61.2029	62.2047	63.1698	64.1257	65.0700	65.9775	66.8722	67.7419	68.5969
21	69.4172	70.2313	71.0201	71.7922	72.5545	73.2911	74.0162	74.7160	75.4034	76.0716
22	76.7154	77.3461	77.9631	78.5612	79.1452	79.7148	80.2659	80.8026	81.3214	81.8262
23	82.3170	82.7909	83.2514	83.6986	84.1326	84.5513	84.9599	85.3538	85.7359	86.1044
24	86.4634	86.8114	87.1503	87.4816	87.8038	88.1169	88.4224	88.7189	89.0068	89.2872
25	89.5592	89.8239	90.0805	90.3302	90.5720	90.8063	91.0340	91.2554	91.4698	91.6780
26	91.8797	92.0756	92.2653	92.4501	92.6290	92.8028	92.9716	93.1354	93.2945	93.4486
27	93.5982	93.7434	93.8849	94.0219	94.1546	94.2839	94.4094	94.5311	94.6496	94.7644
28	94.8760	94.9847	95.0915	95.1928	95.2928	95.3899	95.4844	95.5765	95.6659	95.7530
29	95.8377	95.9205	96.0013	96.0802	96.1574	96.2327	96.3063	96.3782	96.4484	96.5170
30	96.5839	96.6494	96.7137	96.7766	96.8384	96.8990	96.9582	97.0163	97.0732	97.1288
31	97.1832	97.2367	97.2892	97.3408	97.3915	97.4412	97.4900	97.5379	97.5849	97.6309
32	97.6760	97.7203	97.7639	97.8067	97.8488	97.8901	97.9306	97.9704	98.0094	98.0476
33	98.0852	98.1219	98.1579	98.1934	98.2280	98.2620	98.2954	98.3280	98.3600	98.3913
34	98.4219	98.4519	98.4812	98.5099	98.5379	98.5653	98.5921	98.6183	98.6438	98.6689
35	98.6933	98.7172	98.7404	98.7631	98.7852	98.8068	98.8278	98.8483	98.8683	98.8878
36	98.9069	98.9255	98.9437	98.9615	98.9788	98.9958	99.0124	99.0285	99.0444	99.0598
37	99.0750	99.0898	99.1043	99.1184	99.1322	99.1457	99.1589	99.1718	99.1844	99.1967
38	99.2088	99.2206	99.2322	99.2435	99.2547	99.2655	99.2761	99.2866	99.2968	99.3068
39	99.3166	99.3262	99.3356	99.3448	99.3538	99.3627	99.3714	99.3799	99.3883	99.3965
40	99.4045	99.4124	99.4201	99.4277	99.4351	99.4424	99.4495	99.4564	99.4632	99.4699
41	99.4765	99.4829	99.4892	99.4954	99.5016	99.5075	99.5134	99.5191	99.5248	99.5303
42	99.5358	99.5411	99.5463	99.5515	99.5565	99.5615	99.5664	99.5712	99.5759	99.5805
43	99.5851	99.5896	99.5940	99.5983	99.6026	99.6068	99.6109	99.6149	99.6189	99.6228
44	99.6267	99.6305	99.6343	99.6379	99.6416	99.6451	99.6486	99.6521	99.6555	99.6588
45	99.6621	99.6653	99.6686	99.6717	99.6748	99.6778	99.6808	99.6838	99.6867	

T.E at MDDL 0f 20.42m =64.67327%

T.E. at FRL 0f 41.15m =99.4861%

Table 5.11: Trap Efficiency table of Ranapratap Sagar Reservoir

Elevation (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
319	0.00	0.00	0.015	0.045	0.075	0.105	0.15	0.209	0.284	0.34
320	0.43	0.52	0.63	0.73	0.86	0.99	1.13	1.27	1.434	1.608
321	1.78	1.97	2.17	2.37	2.58	2.79	3.04	3.27	3.52	3.78
322	4.04	4.30	4.59	4.88	5.19	5.49	5.82	6.15	6.49	6.83
323	7.19	7.56	7.94	8.32	8.72	9.12	9.54	9.95	10.39	10.82
324	11.27	11.72	12.18	12.66	13.17	13.67	14.18	14.72	15.25	15.81
325	16.37	16.93	17.52	18.10	18.71	19.31	19.93	20.56	21.20	21.85
326	22.49	23.15	23.82	24.51	25.19	25.89	26.59	27.31	28.03	28.75
327	29.48	30.22	30.95	31.70	32.46	33.22	33.98	34.75	35.51	36.28
328	37.05	37.83	38.62	39.41	40.22	41.04	41.85	42.68	43.51	44.34
329	45.17	46.00	46.84	47.67	48.49	49.32	50.15	50.96	51.77	52.58
330	53.37	54.17	54.96	55.75	56.53	57.31	58.08	58.85	59.61	60.35
331	61.09	61.83	62.55	63.26	63.97	64.66	65.34	66.01	66.67	67.32
332	67.95	68.57	69.19	69.79	70.38	70.96	71.53	72.09	72.64	73.17
333	73.69	74.21	74.72	75.21	75.70	76.18	76.65	77.11	77.56	78.00
334	78.44	78.87	79.28	79.68	80.08	80.46	80.84	81.21	81.57	81.91
335	82.25	82.59	82.91	83.22	83.54	83.84	84.13	84.42	84.71	84.98
336	85.25	85.51	85.77	86.02	86.26	86.50	86.73	86.96	87.18	87.39
337	87.60	87.82	88.02	88.21	88.41	88.59	88.78	88.96	89.14	89.31
338	89.48	89.64	89.81	89.96	90.12	90.27	90.41	90.56	90.69	90.84
339	90.97	91.10	91.23	91.36	91.48	91.60	91.72	91.84	91.95	92.06
340	92.17	92.28	92.38	92.48	92.58	92.68	92.78	92.87	92.96	93.06
341	93.15	93.24	93.32	93.40	93.48	93.57	93.65	93.72	93.80	93.87
342	93.95	94.02	94.09	94.16	94.23	94.30	94.37	94.43	94.50	94.56
343	94.62	94.68	94.75	94.80	94.86	94.92	94.97	95.03	95.08	95.14
344	95.19	95.24	95.29	95.35	95.39	95.44	95.49	95.54	95.59	95.63
345	95.67	95.72	95.76	95.81	95.85	95.89	95.93	95.97	96.01	96.05
346	96.08	96.12	96.16	96.19	96.23	96.27	96.30	96.33	96.37	96.40

347	96.44	96.47	96.50	96.53	96.56	96.59	96.62	96.65	96.68	96.71
348	96.74	96.77	96.79	96.82	96.85	96.87	96.90	96.93	96.96	96.98
349	97.00	97.03	97.05	97.08	97.10	97.12	97.14	97.16	97.19	97.21
350	97.23	97.26	97.28	97.29	97.32	97.34	97.36	97.38	97.40	97.42
351	97.44	97.46	97.47	97.49	97.51	97.53	97.55	97.56	97.58	97.60
352	97.61	97.63	97.65	97.66	97.68	97.69	97.71	97.73	97.74	97.76
353	97.77	97.79	97.80	97.82	97.84	97.85	97.87	97.88	97.89	97.90
354	97.92	97.94								
T.E. at MDDL of 343.00 m = 94.63% **T.E. at FRL of 352.80 m = 97.74%**										

Table 5.12:Trap Efficiency table of Bhima(ujjani) Reservoir

ELEVATION (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
460	0.0	0.012	0.017	0.025	0.036	0.050	0.065	0.083	0.104	0.13
461	0.153	0.182	0.216	0.252	0.292	0.338	0.386	0.438	0.495	0.554
462	0.619	0.686	0.758	0.835	0.916	1.00	1.09	1.18	1.28	1.38
463	1.49	1.60	1.72	1.85	1.99	2.14	2.29	2.46	2.63	2.81
464	3.00	3.20	3.41	3.63	3.87	4.11	4.36	4.63	4.91	5.19
465	5.48	5.79	6.10	6.43	6.76	7.09	7.44	7.79	8.16	8.53
466	8.90	9.28	9.68	10.09	10.51	10.93	11.37	11.82	12.27	12.74
467	13.21	13.69	14.19	14.69	15.22	15.74	16.28	16.84	17.40	17.97
468	18.55	19.13	19.73	20.33	20.94	21.56	22.18	22.82	23.46	24.10
469	24.74	25.40	26.05	26.72	27.38	28.05	28.73	29.41	30.09	30.77
470	31.45	32.14	32.83	33.51	34.19	34.88	35.57	36.25	36.94	37.62
471	38.30	38.98	39.66	40.34	41.02	41.69	42.37	43.05	43.72	44.39
472	45.06	45.72	46.38	47.04	47.70	48.35	48.99	49.64	50.28	50.91
473	51.54	52.16	52.78	53.40	54.02	54.63	55.23	55.83	56.43	57.02
474	57.59	58.18	58.75	59.32	59.88	60.43	60.98	61.52	62.06	62.59
475	63.11	63.62	64.14	64.64	65.15	65.64	66.14	66.62	67.11	67.58
476	68.05	68.52	68.97	69.43	69.88	70.32	70.76	71.20	71.63	72.05
477	72.47	72.88	73.29	73.69	74.09	74.48	74.87	75.25	75.63	76.00
478	76.37	76.73	77.09	77.44	77.79	78.13	78.47	78.81	79.14	79.46
479	79.77	80.09	80.39	80.70	81.00	81.29	81.59	81.87	82.15	82.43
480	82.70	82.97	83.23	83.49	83.74	83.99	84.24	84.48	84.72	84.95
481	85.18	85.41	85.63	85.85	86.06	86.27	86.48	86.68	86.88	87.08
482	87.27	87.47	87.65	87.84	88.02	88.19	88.36	88.54	88.71	88.87
483	89.03	89.19	89.35	89.50	89.65	89.80	89.95	90.09	90.23	90.27
484	90.51	90.65	90.78	90.91	91.04	91.16	91.28	91.41	91.53	91.64
485	91.76	91.87	91.98	92.09	92.20	92.31	92.41	92.52	92.62	92.72
486	92.82	92.91	93.00	93.10	93.19	93.28	93.37	93.46	93.54	93.63
487	93.71	93.79	93.87	93.96	94.03	94.11	94.19	94.26	94.33	94.41

488	94.48	94.55	94.62	94.68	94.75	94.82	94.88	94.95	95.01	95.07
489	95.14	95.19	95.25	95.32	95.37	95.43	95.48	95.54	95.60	95.66
490	95.70	95.75	95.80	95.86	95.90	95.96	96.00	96.05	96.10	96.15
491	96.19	96.65	96.28	96.32	96.37	96.41	96.45	96.49	96.54	96.58
492	96.62	97.02	96.69	96.73	96.77	96.80	96.84	96.88	96.92	96.95
493	96.98	97.34	97.05	97.09	97.12	97.15	97.18	97.22	97.25	97.28
494	97.31	97.34	97.37	97.40	97.43	97.46	97.48	97.51	97.54	97.57
495	97.59	97.62	97.64	97.67	97.69	97.72	97.74	97.77	97.79	97.81
496	97.84	97.86	97.88	97.90	97.92	97.95	97.96	97.99	98.01	98.03
497	98.05	98.07	98.09	98.11	98.13	98.15	98.17	98.18	98.20	98.22

T.E. at MDDL of 491.03 m = 96.21%

T.E. at FRL of 496.83 m = 98.02%

5.5 COMPARISON

Table 5.13: Comparison of Reservoir Parameters

S.No.	Parameters	Salaulim Reservoir	Ranapratap Sagar Reservoir	Bhima(Ujjani) Reservoir
1.	**Catchment Area**	209 Sq.km.	14000Sq.km.	12312 Sq.km.
2.	**Rate of Siltation**	67.50 ha.m/100 Sq.km./year	4.16 ha.m/100 Sq.km./year	10.13 ha.m/100 Sq.km./year
3.	**Loss of Gross Storage Capacity at FRL (Annual percentage loss)**	0.63%	0.19%	0.38%
4.	**Loss of Dead Storage Capacity (Annual percentage loss)**	1.93%	0.41%	0.51%
5.	**Loss of Live Storage Capacity(Annual percentage loss)**	0.62%	0.0%	0.21%
6.	**TE at FRL**	99.486%	97.74%	98.02%
7.	**TE at MDDL**	64.67%	94.63%	96.21%

5.6 VERTICAL SEDIMENT DISTRIBUTION

Vertical sediment distribution tables and curve have drawn on comparing the capacities at the time of impoundment and 2011 survey.

1. SALAULIM RESERVOIR

The vertical sediment distribution table is at **Table 5.14(a) & 5.14(b)(Data furnished by CWC)** and the sediment distribution curve is at **Figure 5.4**.

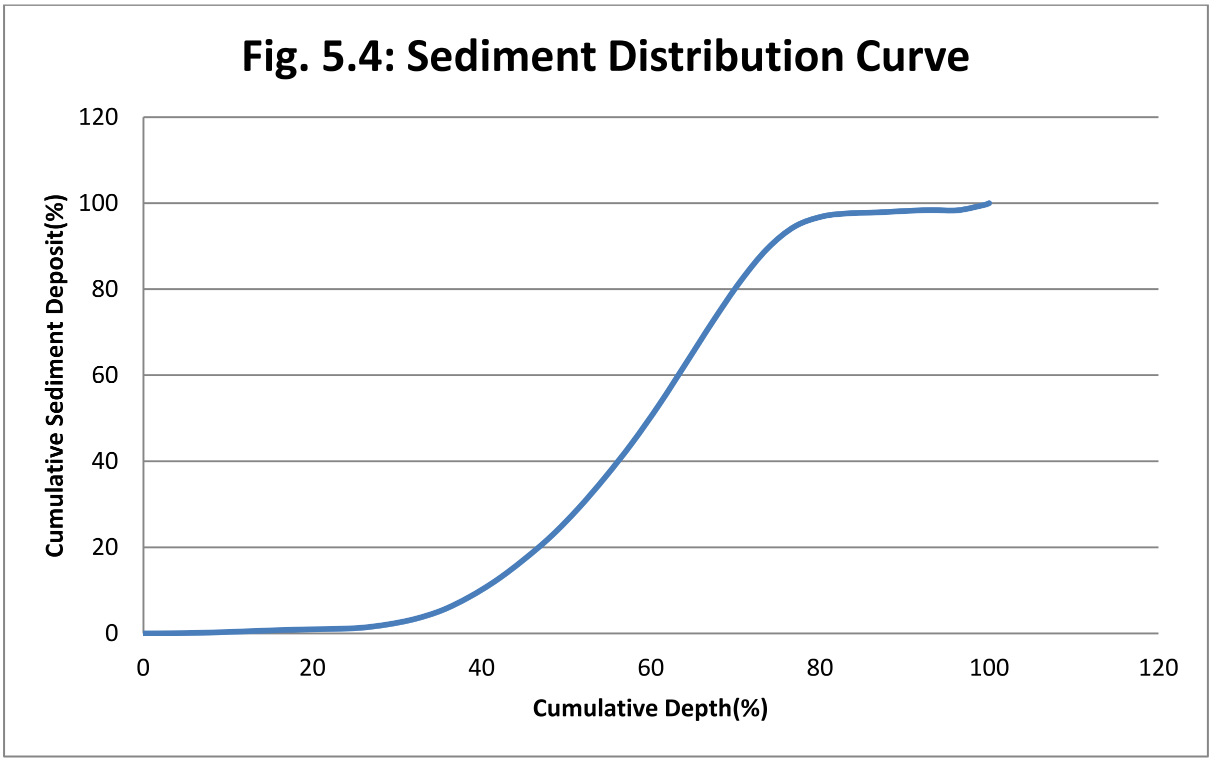
Table5.14(a): Vertical Sediment Distribution

Elevation (m)	Depth (m)	Depth (%)	Original Capacity (M.Cu.m)	Capacity-2011 (M.Cu.m)	Sediment Deposit	Sediment Deposit (%)
41.15	31.15	100.0	222.284	192.679	29.61	100.00
41	31	99.5	218.624	189.122	29.50	99.64
40	30	96.3	195.274	166.149	29.13	98.36
39	29	93.1	173.774	144.636	29.14	98.41
38	28	89.9	153.874	124.804	29.07	98.18
37	27	86.7	135.574	106.601	28.97	97.85
36	26	83.5	118.974	90.056	28.92	97.66
35	25	80.3	103.874	75.172	28.70	96.93
34	24	77.0	90.074	62.073	28.00	94.57
33	23	73.8	77.474	50.980	26.49	89.48
32	22	70.6	66.074	41.830	24.24	81.88
31	21	67.4	55.874	34.338	21.54	72.73
30	20	64.2	46.774	28.139	18.64	62.94
29	19	61.0	38.674	22.916	15.76	53.22
28	18	57.8	31.549	18.428	13.12	44.31
27	17	54.6	25.299	14.551	10.75	36.30
26	16	51.4	19.849	11.261	8.59	29.00
25	15	48.2	15.224	8.537	6.69	22.58
24	14	44.9	11.399	6.357	5.04	17.03
23	13	41.7	8.274	4.633	3.64	12.30
22	12	38.5	5.774	3.279	2.49	8.43
21	11	35.3	3.849	2.259	1.59	5.37
20	10	32.1	2.499	1.505	0.99	3.36
19	9	28.9	1.574	0.955	0.62	2.09
18	8	25.7	0.949	0.565	0.38	1.30
17	7	22.5	0.599	0.290	0.31	1.04
16	6	19.3	0.384	0.108	0.28	0.93
15	5	16.1	0.245	0.020	0.22	0.76

14	4	12.8	0.157	0.000	0.16	0.53
13	3	9.6	0.088	0.000	0.09	0.30
12	2	6.4	0.039	0.000	0.04	0.13
11	1	3.2	0.010	0.000	0.01	0.03
10	0	0.0	0.000	0.000	0.00	0.00

Table 5.14(b):Vertical Distribution of Sediment Deposit

Percentage Depth	Percentage Sediment Deposit
Top 10% of the Reservoir Depth	1.0
10-20%	2.0
20-30%	9.0
30-40%	23.0
40-50%	27.0
50-60%	20.0
60-70%	11.5
70-80%	4.0
80-90%	1.5
Bottom 10% of the Reservoir Depth	1.0



2. RANAPRATAP SAGAR RESERVOIR

The vertical sediment distribution table is at **Table 5.15 (a) & 5.15 (b)(Data furnished by CWC).** The sediment distribution curve is at **Figure 5.5**.

Table 5.15(a): Vertical Sediment Distribution

Elevation (m)	Depth (m)	Depth %	Capacity-1970 (M.Cu.m)	Capacity-2011 (M.Cu.m)	Sediment Deposit M.Cu.m)	Sediment Deposit %
317.75	0.00	0.00	0.00	0.00	0.00	0.00
319.27	1.52	4.34	4.62	0.02	4.60	1.93
320.80	3.05	8.70	14.18	0.97	13.21	5.54
322.32	4.57	13.04	22.69	3.47	19.22	8.06
323.84	6.09	17.38	31.21	7.87	23.34	9.78
325.37	7.62	21.74	73.76	15.16	58.60	24.56
326.89	9.14	26.08	119.28	26.81	92.47	38.76
328.42	10.67	30.44	167.50	45.17	122.33	51.27
329.94	12.19	34.78	224.24	74.88	149.36	62.60
331.46	13.71	39.12	298.50	120.52	177.98	74.60
332.99	15.24	43.48	388.91	186.29	202.62	84.92
334.51	16.76	47.82	496.47	275.34	221.13	92.68
336.04	18.29	52.18	621.66	388.60	233.06	97.68
337.56	19.81	56.52	762.28	523.69	238.59	100.00
339.08	21.33	60.86	919.02	680.43	238.59	100.00
240.61	22.86	65.22	1096.68	858.09	238.59	100.00
342.13	24.38	69.56	1291.79	1053.20	238.59	100.00
343.66	25.91	73.92	1508.19	1269.60	238.59	100.00
345.18	27.43	78.26	1743.06	1504.47	238.59	100.00
346.70	28.95	82.60	1992.91	1754.32	238.59	100.00
348.23	30.48	86.96	2259.07	2020.48	238.59	100.00
349.75	32.00	91.30	2536.80	2298.21	238.59	100.00
351.28	33.53	95.66	2827.59	2589.00	238.59	100.00
352.80	35.05	100.00	3128.11	2889.52	238.59	100.00

Table 5.15(b): Vertical Distribution of Sediment Deposit

Depth(%)	Sediment Deposit(%)
Top 10 % of the reservoir depth	1.0
10-20%	1.5
20-30%	2.5
30-40%	3.0
40-50%	6.5
50-60%	10.5
60-70%	25.0
70-80%	35.5
80-90%	10.0
Bottom 10% of the reservoir depth	4.5

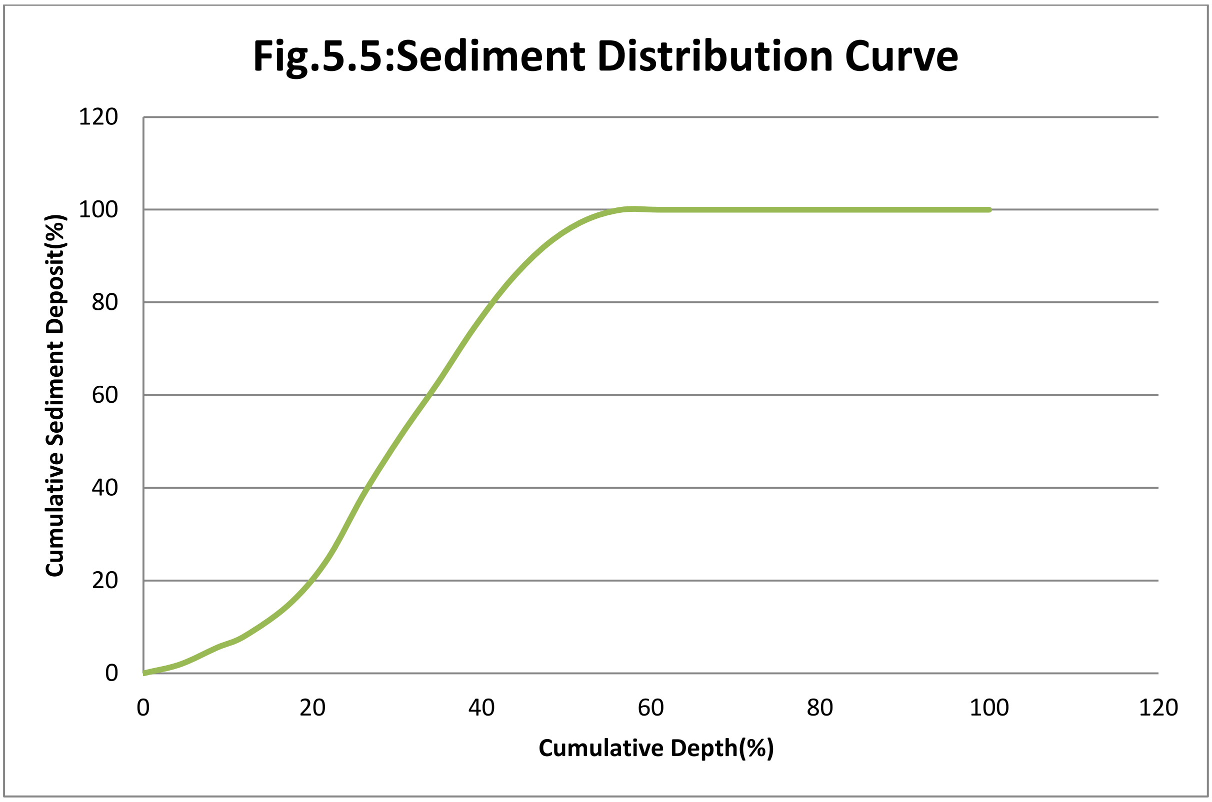


Fig.5.5:Sediment Distribution Curve
Cumulative Sediment Deposit(%)
Cumulative Depth(%)
0
20
40
60
80
100
120

3. BHIMA(UJJANI) RESERVOIR

The vertical sediment distribution table is at **Table 5.16 (a) & 5.16 (b) (Data furnished by CWC).** The sediment distribution curve is at **Figure 5.6**.

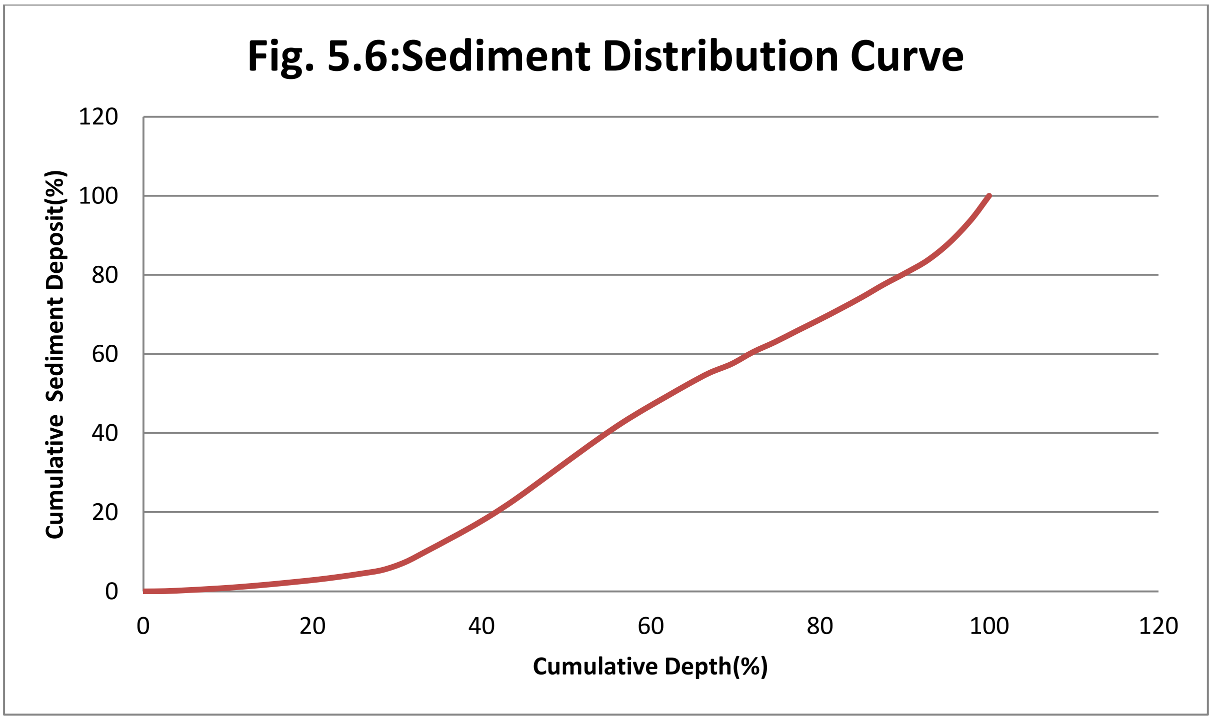
Table 5.16(a): Vertical Sediment Distribution

Elevation (m)	Depth (m)	Depth %	Capacity-1977 (M.cu.m)	Capacity-2011 (M.cu.m)	Sediment Deposit M.Cu.m)	Sediment Deposit %
458	0.00	0.00	0.00	0.00	0.00	0.00
459	1.00	2.58	0.28	0.00	0.280	0.07
460	2.00	5.15	1.328	0.000	1.328	0.31
461	3.00	7.73	2.672	0.090	2.582	0.61
462	4.00	10.30	4.430	0.365	4.065	0.96
463	5.00	12.88	6.757	0.885	5.872	1.39
464	6.00	15.45	9.783	1.815	7.968	1.88
465	7.00	18.02	13.668	3.405	10.263	2.42
466	8.00	20.60	18.433	5.730	12.703	3.00
467	9.00	23.18	24.607	8.925	15.682	3.70
468	10.00	25.75	32.381	13.350	19.031	4.50
469	11.00	28.33	42.367	19.280	23.087	5.45
470	12.00	30.90	58.047	26.905	31.142	7.35
471	13.00	33.48	79.534	36.395	43.138	10.18
472	14.00	36.05	103.622	48.085	55.537	13.10
473	15.00	38.63	130.705	62.360	68.345	16.12
474	16.00	41.20	161.776	79.645	82.131	19.38
475	17.00	43.78	197.843	100.300	97.543	23.00
476	18.00	46.36	239.215	124.885	114.330	26.97
477	19.00	48.94	285.889	154.340	131.549	31.03
478	20.00	51.52	338.162	189.520	148.642	35.06
479	21.00	54.08	396.533	231.275	165.258	38.98
480	22.00	56.66	461.307	280.300	181.007	42.70
481	23.00	59.23	532.384	337.135	195.249	46.06
482	24.00	61.80	610.845	402.220	208.625	49.21
483	25.00	64.38	697.910	475.990	221.920	52.35
484	26.00	66.96	793.577	559.310	234.267	55.26
485	27.00	69.54	896.636	652.945	243.691	57.49
486	28.00	72.10	1014.096	757.520	256.576	60.52
487	29.00	74.68	1141.438	874.175	267.263	63.04
488	30.00	77.26	1282.820	1003.710	279.110	65.84
489	31.00	79.84	1438.017	1147.275	290.742	68.58
490	32.00	82.41	1609.059	1306.270	302.789	71.43
491	33.00	84.98	1796.890	1481.490	315.400	74.40
492	34.00	87.56	2003.310	1674.325	328.985	77.60
493	35.00	90.14	2229.240	1887.875	341.365	80.52

494	36.00	92.71	2477.740	2123.00	354.740	83.68
495	37.00	95.28	2751.630	2378.170	373.460	88.10
496	38.00	97.86	3050.940	2652.790	398.150	93.92
496.83	38.63	100.00	3320.000	2896.090	423.920	100.00

Table 5.16(b): Vertical Distribution of Sediment Deposit

Depth (%)	Sediment Deposit (%)
Top 10%	20.00%
10-20%	11.00%
20-30%	11%
30-40%	11%
40-50%	14.50%
50-60%	14.50%
60-70%	11%
70-80%	4%
80-90%	2%
Bottom 10% of reservoir depth	1%



5.7 ESTIMATION OF SEDIMENT DEPOSIT

1. SALAULIM RESERVOIR

In view of the fact that rate of sedimentation reduces with passage of time, it is necessary to obtain the trend in sedimentation and sediment yield. It is, generally, possible to arrive at a relationship, S Vs T (S-Sediment deposit in M.Cu.m and T - period in years).Sediment volume prediction equation or trend line may be represented by: Vs = k T^m (furnished by CWC)where k and m are reservoir sedimentation parameters. From the studies carried out for the reservoirs, where large number of repeat surveys have been carried out, value of 'm' may be taken as 2/3(provided by CWC) and 'k' can be estimated from the survey data of the reservoir under consideration. The value of 'k' using the equation Vs = k $T^{*\,0.66}$ (where Vs = 29.61 i.e. gross sediment deposit in 21 years) works out to be 3.97.Estimated sediment deposit is given in **Table 5.17** and the corresponding graph of the same is given in **Figure 5.7**.

Table 5.17: Estimated Sediment Deposit

Year	T(years)	Estimated Sediment Deposit Vs=3.97 *T $^{0.66}$ (M.cum)
1990	0	0.00
2011	21	29.61
2020	30	37.47
2030	40	45.31
2040	50	52.49
2050	60	59.20
2060	70	65.50
2070	80	71.60
2080	90	77.40
2090	100	82.95
2100	110	88.33
2110	120	93.55

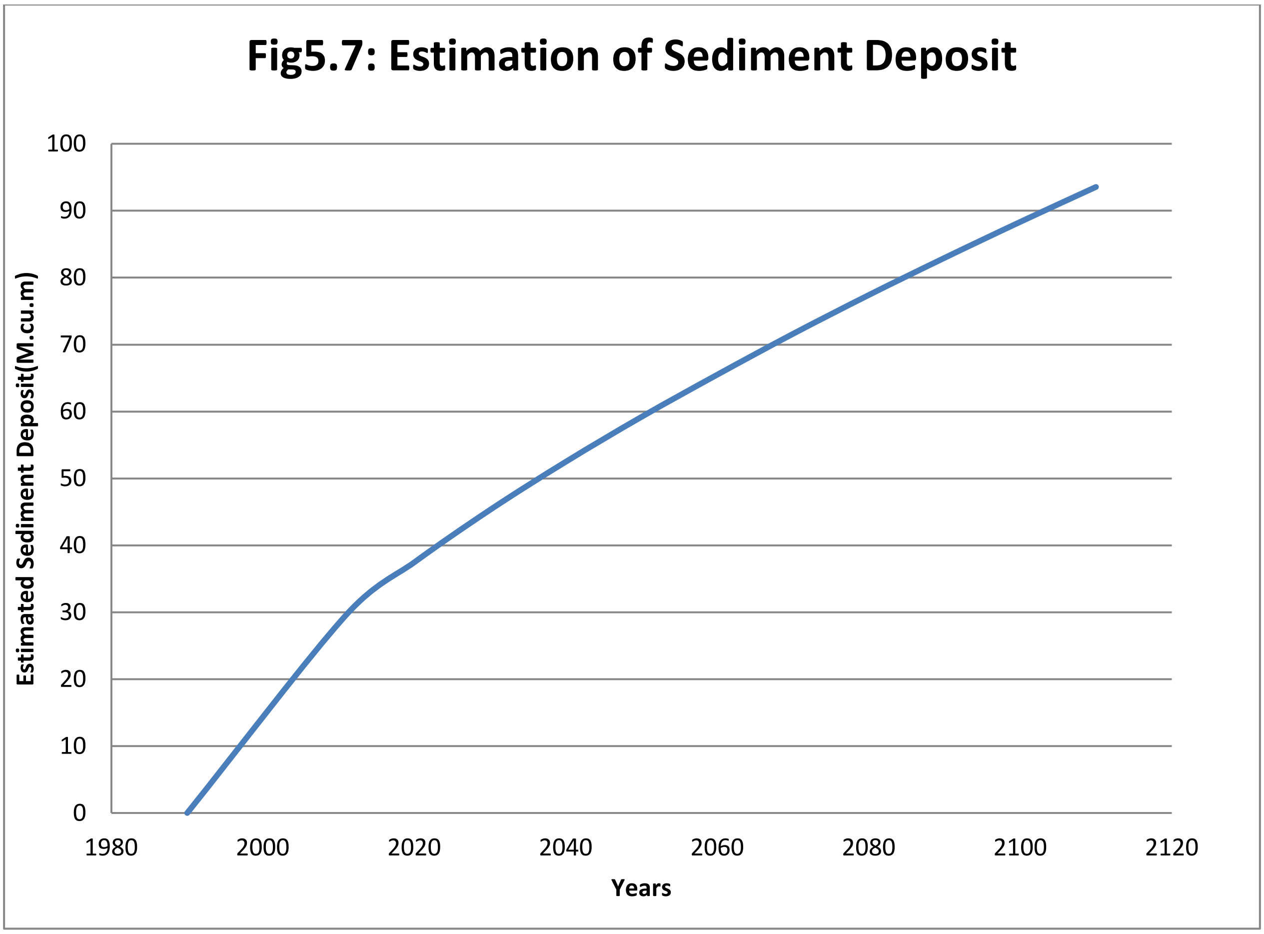


Fig5.7: Estimation of Sediment Deposit
100
90
80
70
60
50
40
30
20
10
0
Estimated Sediment Deposit(M.cu.m)
1980
2000
2020
2040
2060
2080
2100
2120
Years

2. RANAPRATAP SAGAR RESERVOIR

In view of the fact that rate of sedimentation reduces with passage of time, it is necessary to obtain the trend in sedimentation and sediment yield. It is, generally, possible to arrive at a relationship, S Vs T (S-Sediment deposit in M cum and T - period in years). Sediment volume prediction equation or trend line may be represented by: $Vs=kT^m$ (furnished by CWC) where k and m are reservoir sedimentation parameters. From the studies carried out for the reservoirs, where large number of repeat surveys have been carried out, value of 'm' may be taken as 2/3(furnished by CWC) and 'k' can be estimated from the survey data of the reservoir under consideration._The value of 'k' using the equation $Vs = k\ T^{0.66}$ (where Vs = 238.59, ie the gross sediment deposit in 41 (T) years)), works out to be 20.50.Estimated sediment deposit is given in **Table 5.18** and the corresponding graph of the same is given in **Figure 5.8**.

Table 5.18:Estimated Sediment Deposit

Year	T(years)	Estimated sediment deposit $Vs=20.50*T^{0.66}$ (M.cu.m)
1970	0	0
2011	41	239
2020	50	271
2030	60	306
2040	70	338
2050	80	370
2060	90	400
2070	100	428
2080	110	456
2090	120	483
2100	130	509
2110	140	535

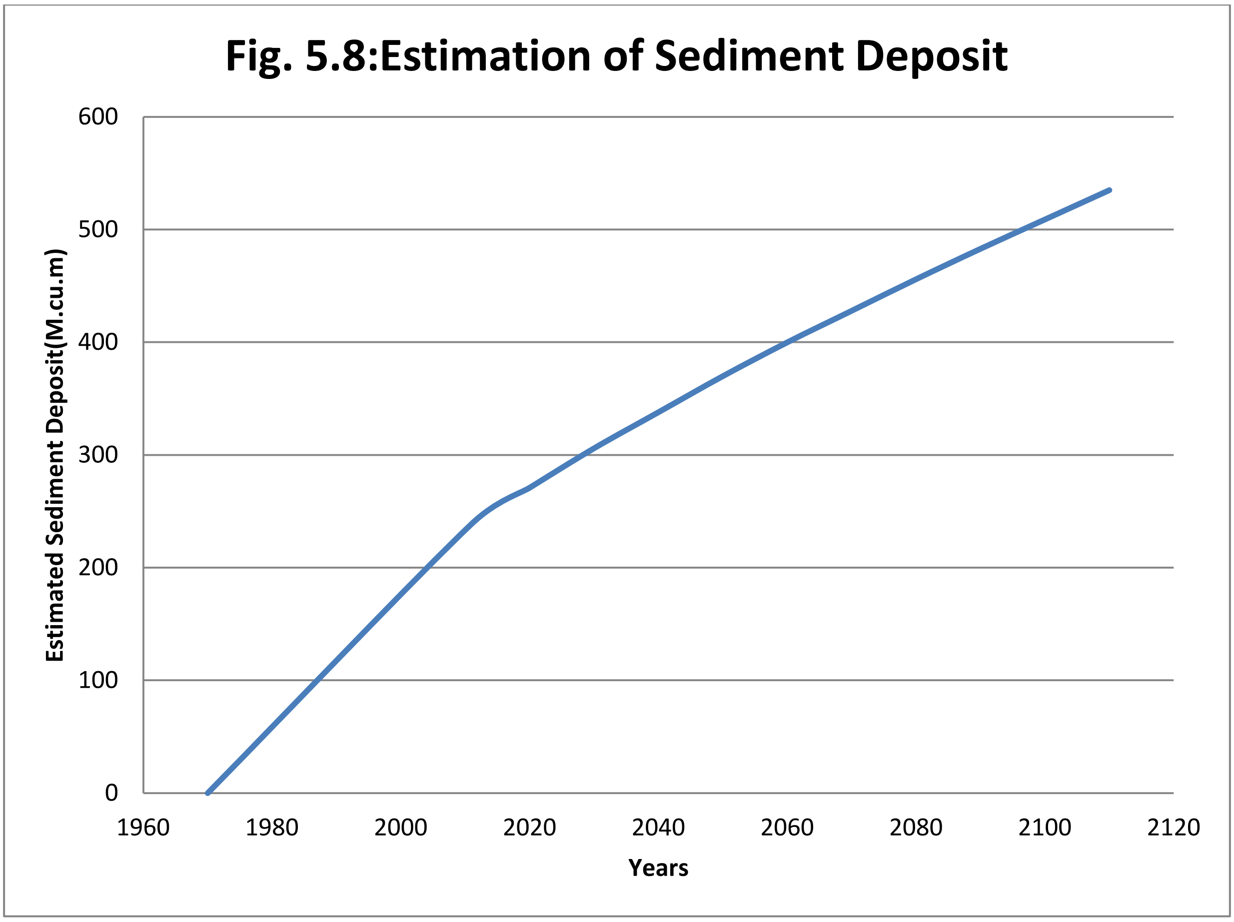


Fig. 5.8:Estimation of Sediment Deposit
600
500
400
300
200
100
0
Estimated Sediment Deposit(M.cu.m)
1960
1980
2000
2020
2040
2060
2080
2100
2120
Years

3. BHIMA(UJJANI) RESERVOIR

In view of the fact that rate of sedimentation reduces with passage of time, it is necessary to obtain the trend in sedimentation and sediment yield.It is, generally, possible to arrive at a relationship, S Vs T (S-Sediment deposit in M cum and T - period in years). Sediment volume prediction equation or trend line may be represented by: $Vs = k\ T^m$ (furnished by CWC) where k and m are reservoir sedimentation parameters. From the studies carried out for the reservoirs, where large number of repeat surveys have been carried out, value of 'm' may be taken as 2/3(furnished by CWC) and 'k' can be estimated from the survey data of the reservoir under consideration. The value of 'k' using the equation $Vs = k\ T^{0.66}$ (Vs = 423.91 and T = 34), works out to be 41.36. Estimated sediment deposit is given in **Table 5.19** and the corresponding graph of the same is given in **Figure 5.9.**

Table 5.19 :Estimated Sediment Deposit

Year	T (years)	Estimated Sediment Deposit $Vs = 41.36\ T^{(0.66)}$ (M.Cu.m)
1977	0	0
2011	34	423.91
2020	43	495
2030	53	568
2040	63	637
2050	73	702
2060	83	764
2070	93	824
2080	103	881
2090	113	937
2100	123	991
2110	133	1043

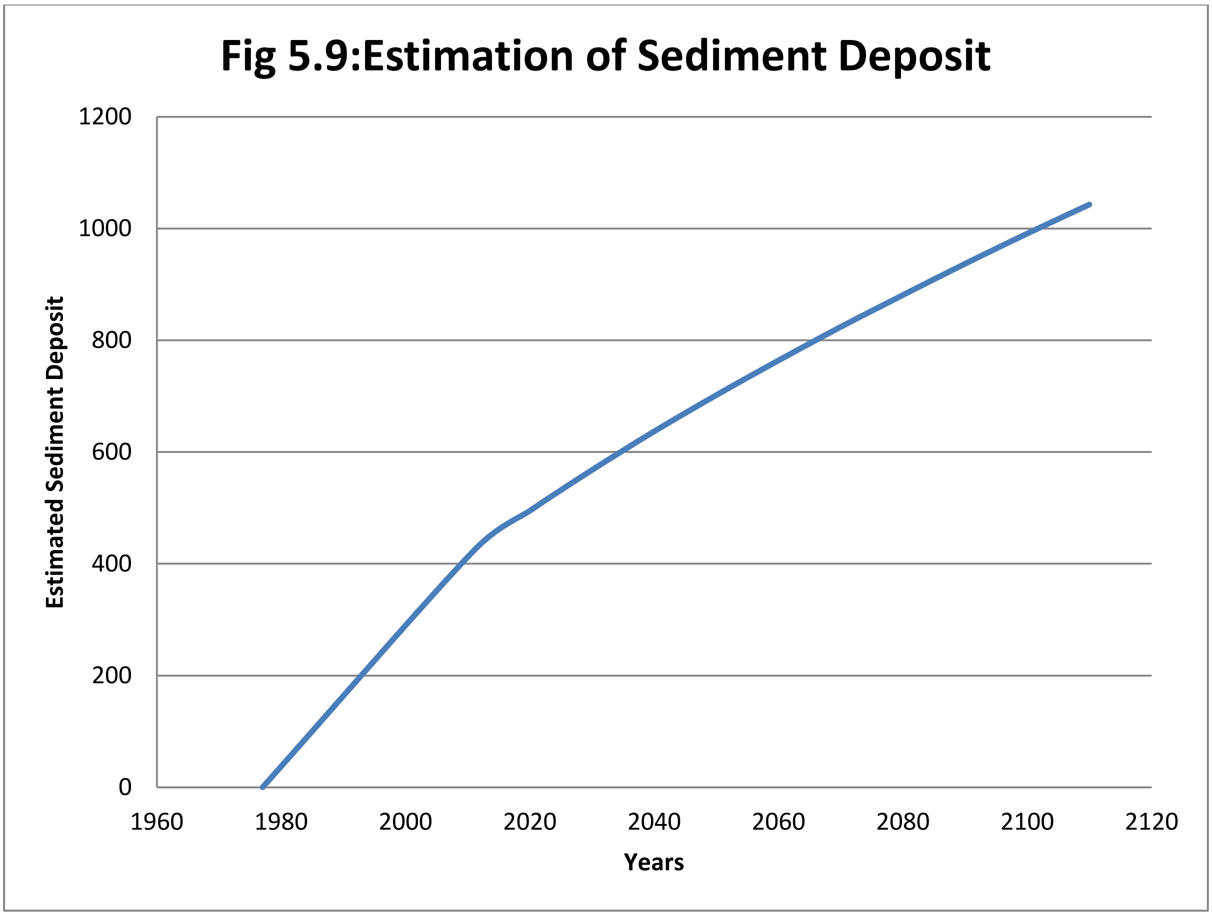


Fig 5.9:Estimation of Sediment Deposit
Estimated Sediment Deposit
1200
1000
800
600
400
200
0
1960
1980
2000
2020
2040
2060
2080
2100
2120
Years

CHAPTER - 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

1. SALAULIM RESERVOIR

- The surveys and studies carried out for the Salaulim reservoir by CWC presented in this report cover areas surveyed upto MWL EL 45.8m.
- The catchment of the Salaulim Dam drains an area of 209 sq.km. The height of the dam from deepest river bed level is 42.50 m.
- The gross storage capacity of the reservoir at FRL 41.15m was assessed as 234.36M cum at the first impoundment of reservoir in the year 1990.
- It is seen that the volume of sediment trapped during the past 21 years (1990-2011) works out to 29.6 M.Cu.m or 67.5 Ha m/100 Sq.km/year. The rate of sedimentation is not alarming there are many reservoir in western regions where silt rate more than the observed rate in salaulim reservoir viz Anayirunkal (71.1), Kuttyadi (167.7), Mangalam (63.3), Peechi (75.7).
- The reservoir is losing Gross storage capacity at the rate of 0.63% per annum and Dead Storage Capacity at the rate of 1.93%. The reservoir favours sedimentation in the lower and middle reaches simultaneously affecting both the dead and live storages. The annual loss of live storage is 0.62%. The percentage losses in various zones are more than the national average of 0.44% (in gross storage), 1.4% (in dead storage) and 0.31% (in live storage). As per the 'Compendium on Silting of Reservoirs in India' the observed rate of sedimentation in the reservoir having catchment area in the western ghat is much higher than the national average. Accordingly, the observed rate of sedimentation in the reservoir is not alarming.
- The Trap Efficiency of a Salaulim Reservoir at FRL works out to be 99.4861%.
- Project authorities may adopt the revised elevation capacity table as obtained from 2011 survey (Table 5.2) for operation of the reservoir and for effective assessment of inflow and outflow discharges.

2. RANAPRATAP SAGAR RESERVOIR

- The Ranapratap Sagar reservoir has a catchment area of 25,305 Sq. km out of which 23,025 Sq.km is intercepted by the Gandhi Sagar. The free catchment is 2280 Sq.km
- The inflow into the reservoir constitutes 16.35% from the free catchment and 83.65% is the machine discharge from Gandhi Sagar dam. Since 16.35% inflow into the reservoir is from 2280 sq.km, 100% inflow corresponds to 13,945 sq.km say 14,000 sq.km, proportionately. Hence, for working out the rate of sedimentation, the effective catchment area is taken as 14,000 sq.km..
- The gross storage capacity of the reservoir at FRL 352.80 m was 2904.80 M.Cu.m at the first impoundment of reservoir in the year 1970.
- It is seen that the volume of sediment trapped during the past 41 years works out to 5.77 M.Cu.m/year or 4.16 Ha.m/100 Sq.km/year. .
- The Trap Efficiency of a Ranapratap Sagar Reservoir at FRL works out to be 97.74%.
- The reservoir is losing Gross capacity at the rate of 0.18% per annum and Dead Storage Capacity at the rate of 0.41% per annum. No storage loss is observed in the live storage capacity. This may be either due to errors in the pre-impoundment capacity table, which may have been drawn through toposheet studies or degradation of the reservoir bed in the upper elevations due to the releases from Gandhi Sagar Dam. Gandhi Sagar Dam releases water directly into the Ranapratap Sagar reservoir.
- Project authorities may adopt the revised elevation capacity table as obtained from 2011 survey (Table 5.5) for operation of the reservoir and for effective assessment of inflow and outflow discharges.

3. BHIMA(UJJANI) RESERVOIR

- The catchment of the Bhima (Ujjani) in Maharashtra drains an area of 14,858 Sq.km out of which 5092 sq.km is intercepted by u/s reservoirs.
- For working out the rate of sedimentation, it may not be appropriate either to include or exclude the whole intercepted catchment. Since a large number of reservoirs exist in the u/s, a rational approach as made in some other cascade system of reservoirs is not feasible here. Hence, the rate of sedimentation of the reservoir has been worked out by considering only 50% of the catchment intercepted by the u/s reservoirs. Thus the effective catchment for working out the rate of sedimentation would be 9766 (free catchment) + 2546 (50% of the intercepted catchment) = 12312 sq.km.
- The gross storage capacity of the reservoir at FRL 496.83 m was assessed as 3320 M.Cu.m at the first impoundment of reservoir in the year 1977.
- The construction of the project was completed in the year 1980. But the first impounding of water took place in the year 1977.
- It is seen that the volume of sediment trapped during the past 34 years (1977-2011) works out to 12.47 M.Cu.m/year or 10.13 Ha.m/100sq.km./year.
- The reservoir is losing Gross capacity at the rate of 0.38% per annum and Dead Storage and Live Storage Capacity at the rate of 0.51% and 0.21% respectively.
- The Trap Efficiency of a Bhima(Ujjani) Reservoir at FRL works out to be 98.02%.
- Project authorities may adopt the revised elevation capacity table as obtained from 2011 survey (Table 5.8) for operation of the reservoir and for effective assessment of inflow and outflow discharges.

REFERENCES

M.A. Eizel-Din, M.D. Bui & P. Rutschmann, E. Failer, C. Grass & K. Kramer, A.S. Hussein, A. Saghayroon-Elzein "Trap efficiency of reservoirs on the Nile River" River Flow 2010 - Dittrich, Koll, Aberle & Geisenhainer (eds) - © 2010 Bundesanstalt für Wasserbau ISBN 978-3-939230-00-7.

N.M.T.K. Revel, L.P.G.R. Ranasiri, R.M.C.R.K. Rathnayake and K.P.P. Pathirana "Estimation of Sediment Trap Efficiency in Reservoirs" ENGINEER - Vol. XLVIII, No. 02, pp. [43-49], 2015.

Gert Verstraeten and Jean Poesen "Estimating trap efficiency of small reservoirs and ponds: methods and implications for the assessment of sediment yield" Progress in Physical Geography 24,2 (2000) pp. 219–251.

M. M. A. shahs "An overview of reservoir sedimentation in some African river basins" Sediment Problems: Strategies for Monitoring, Prediction and Control (Proceedings of the Yokohama Symposium, July 1993). LAHS Publ. no. 217, 1993.