Effect Of Sedimentation On Reservoir Operation

[1]**Dr GKViswanadh,** [2]**M.visweswararao.**
[1]**Professor , JNTUH, Hyderabad** [2]**Professor Malla Reddy Institute of Technology**

ABSTRACT: Reservoirs are planned for various purposes like irrigation , drinking water,hydro power generation , industrial, flood control etc. When a demand is planned storage plays an important role as the demands of non monsoon have to be stored in the reservoir in monsoon and used in non monsoon. Sedimentation reduces the storage thereby the planned demands are not met fully. The downstream flows from reservoirin flood situation will also increase as they can not be stored in the reservoir. This aspect is considered in the planning and revised capacities after sedimentation of 50 years are considered. However it may happen that the sedimentation may increase more than planned and may cause problems in operation.Sometimesit may happen the sedimentation is less than planned and the planned benefits can be achieved with lesser FRL and the flows can be used in the downstream . Therefore in this study the effect of sedimentation on Almattireservoir operation is studied . The rate of siltation has reduced to 0.5 acre ft/ sq.mile/year from 1.2 acrefeet at planned stage.The reservoir is operated projected curves for 50 years with actual sedimentation based on hydrographic surveys and it is concluded that FRL of 518.80 m would be sufficient to meet the planned demands of 173 TMC at the required level of success of 75 % for irrigation, 100 % for drinking water requirements.
KEY WORDS : Sedimentation, Almatti reservoir,Area-capacity curves, planned demands

I.INTRODUCTION

The River Krishna rises in the Mahadev range of the Western Ghats near Mahabaleshwar at an altitude of 1337m above sea level and flows through Maharashtra, Karnataka and Andhra Pradesh gathering water on its way from innumerable rivers, streams or tributaries and drops into the Bay of Bengal. River Bhima and Tungabhara are major tributaries of river Krishna. Main Krishna, Bhima and Tungabhadra constitute the stems of the river Krishna. Jurala,Srisailam, Nagarjunasagar, Krishna delta are the major projects on main Krishna. Almatti reservoir was constructed across main Krishna in the state of Karnataka up stream of these reservoir s. This reservoir is very important as it has to cater to the needs of UKP project in addition to supply water to system down below.

Therefore the effect of sedimentation on the operation of this project is studied. The project is designed using the revised area capacity curves considering 50 year sedimentation assuming a rate of sedimentation of 1.2 acft/sq.mile/year as per CWC . However it is observed that this rate has reduced and is only 0.5 acft/sq.mile/year as per the latest hydrographic surveys in 2009. Hence the effect of this reduction in the operation of Almatti reservoir is proposed to be studied.

The salient features of Almatti reservoir are given below In Table 1.

Table 1 Salient Features of Almatti reservoir

SL.NO	Particulars	Details
1	Type of reservoir	Major
2	Purpose of reservoir	Irrigation and power
3	Year of impoundment to FRL	2003
4	Silt rate assumed for design	1.00 Acft/Sq. Mile/year
5	Catchment area	35926 Sq.Kms
6	Annual rain fall in mm	500
7	Lowest bed level	488.95 m
8	Crest level	509.016 m
9	Dead storage level(MDDL)	506.87 m
10	Sill of river sluice	495.306 m
11	FRL	519.6 m
12	MWL	519.80 m
13	Maximum water spread	181 Sq. Km
14	FRL for stage 3	524.256 m
15	Maximum water spread at 524.256	487.87 Sq. Km
16	Height of dam from lowest B.L	40.3 m
17	Design flood intensity	31007 Cumecs
18	Top width of dam	7.5 m
19	No. And size of spill way gates	26 nos of 15 *10.584 m(radial)
20	No. And size of gates in stage 3	26 no.s of 15*15.24 m(radial)

II. LITERATURE REVIEW

Loss of storage volumeof a reservoir was studied by Jose, Carlos et.al for semiarid areas of Brazil due to sedimentation of seven representative watersheds in the tate of Ceará, Brazil. Water yield is computed using stochastic modelling for several reliability levels and water yield reduction is quantified for the focus areas. The yield–volume elasticity concept, which indicates the relative yield reduction in terms of relative storage capacity of the reservoirs, is presented and applied. Results show that storage capacity was reduced by 0.2% year-1 due to silting, that the risk of water shortage almost doubled in less than 50 years for the most critical reservoir, and that reduction of storage capacity had three times more impact on yield reduction than the increase in evaporation. Average 90% reliable yield–volume elasticity was 0.8, which means that the global water yield (Q90) in Ceará is expected to diminish yearly by 388 L s-1 due to reservoir silting.

Daniel Rohi et.al have studied the sedimentation and its effect on the productivity of hydropower. Sedimentation of reservoirs has become a serious threat to the operation of the reservoir and hydroelectric power in Indonesia. Reservoir sedimentation in Indonesia has reached 1.28% per year. Reservoirs with small capacities (less than 200 million m3) suffered a loss of storage capacity which is about 2.05%. Expected loss due to sedimentation in 284 large dams in Indonesia shrink water volume reached about 12.4 billion cubic meters. Economically it is converted to 84 million dollars per year. Based on the observation and analysis of historical data to reservoirs and Sutami hydropower it was found that the rate of sedimentation in the Sutami reservoir is 4.76 million m3 / year so that the reservoir capacity remain 54% in 2011. Nevertheless, the production capacity of Sutami hydropower is still very good, indicated by the capacity factor 34% -76% range, and the average 50.5%. High rate of sedimentation in the Sutami reservoir did not provide significant impact on the productivity of hydropower.This may be due to even sediment distribution pattern . For other small reservoirs the loss of hydropower production is significant.

VC Pande et.al have studied the loss of live storage capacity caused by high rate of sediment deposition behind the dam. There are several impacts of soil erosion and sedimentation on ‘production and consumption’ in the region affected by reservoir. This includes reservoir siltation leading to loss of hydropower generation capacity, reduction in irrigation water supply affecting agricultural production, and impact on drought or flood cycles. Sedimentation effects in most reservoirs worldwide, not just in India, are affecting their capacity. It is difficult to replace the lost capacity of a reservoir. Treatment of river catchment in terms of soil conservation could be an alternative to desiltation of reservoir. The present article estimates the marginal cost of siltation in the Sardar Sarovar Project (SSP) reservoir, which is being constructed on the Narmada river in Gujarat. Non-adoption of proper soil and water conservation measures, including forest plantation, in the catchment area of the Sardar Sarovar reservoir will result in annual loss of Rs 1105–1137 million by accounting for loss in power generation and reduction in irrigated area alone in the command area. However, these losses can be minimized by treating the catchment area with appropriate location-specific soil and water conservation measures.

G. Mathaias et.al have studied the sedimentation and its effects on the reservoir and on down streamreaches.Dams interrupt the continuity of sediment transport through rivers, resulting in loss of reservoir storage and reduced usable life, and depriving downstream reaches of sediments essential for channel form and aquatic habitats. With the acceleration of new dam construction globally, these impacts are increasingly widespread. The reservoirs in five continents are studied with respect to their ability to manage reservoir sediments and mitigating downstream sediment starvation. Where geometry is favorable it is often possible to bypass sediment around the reservoir, which avoids reservoir sedimentation and supplies sediment to downstream reaches with rates and timing similar to pre-dam conditions. Sluicing (or drawdown routing) permits sediment to be transported through the reservoir rapidly to avoid sedimentation during high flows; it requires relatively large capacity outlets. Turbidity currents can often be vented through the dam, with the advantage that the reservoir need not be drawn down to pass sediment. In planning dams, we recommend that these sediment management approaches be utilized where possible to sustain reservoir capacity and minimize environmental impacts of dams.

Pinston et.al have studied the sedimentation problem in the context of climate change.The US Army Corps of Engineers (USACE) is the largest operator of dams in the United States. Each USACE dam was planned, designed and built to provide specific benefits to the American public, including navigation, flood risk reduction, hydropower generation, recreation, and water supply. Most of the USACE dams have operated for more than 50 years, with some approaching 100 years of operation. Sedimentation impacts all of these dams to varying degrees by reducing reservoir volumes over time. Even though sedimentation was taken into account in design, there may be gradual loss of functionality with respect to a dam's authorized purpose(s) over time. There may be many factors for sedimentation among these is climate change, which has been identified as a major cause of future vulnerability to reservoirs due to its role in changing sedimentation patterns. Both observed and projected hydroclimate trends impact the rate of sediment delivery to reservoirs. Important drivers include increasing heat waves, changes in drought frequency and magnitude, altered freeze-thaw cycles, changes in snow volume and the onset of snowmelt, increased heavy precipitation, and changes in the frequency, magnitude, and duration of floods. Some reservoirs have experienced impacts from sedimentation, resulting in a loss of storage capacity for water supply, flood risk reduction, recreation and other authorized purposes. For the majority of reservoirs, repeated, accurate surveys are vital to determining current sedimentation status from which to estimate future decreases in reservoir storage due to sedimentation. Only by understanding the rate at which sedimentation is encroaching on the authorized reservoir purposes plans canbe developed to sustainably manage its reservoirs and maximize reservoir service life.

In hydro-coop builtenaug 2013It was concluded that the siltation is a rather minor problem for many dams but may reduce by decades the possible long life of 50 % of them and may be a key problem within few years or few decades for over 10% of large or small dams.The key problems are the loss of storage especially for irrigation or drinkable water, the damages to turbines of hydropower plants and the impacts to the river, especially downstream of the dam.The overall cost of world reservoirs siltation has been evaluated between 15 and 20 Billion U.S. $ per year, i.e. 30% of the overall annual expenses of 60 Billion for dams or 10% of the 200 Billion $ annual dam benefits. But the siltation ratios are much higher for 10 or 20 % of dams which are most prone to siltation . It was indicated that the siltation problem would impact their overall design including the choice of the dam site, the reservoir volume and all spilling facilities. With reasonable levels of maintenance, the structural life of dams is virtually unlimited, and most reservoirs are designed and operated on the concept of a finite life which will ultimately be terminated by sediment accumulation rather than structural obsolescence.Design life is the planning period used for designing the reservoir project. Planning and economic studies are typically based on a period not exceeding 50 years, whereas engineering studies often incorporate a 100-year sediment storage pool in the design.The sediment in dams is critical. Leaving sediment management as it is may lead to not only reduction but full loss of reservoir functions. With proper treatment of sediment, it is possible to maintain its function economically along centuries.

III.METHODOLOGY

While planning a multipurpose project the area capacity curves after 50 years are developed. The silt rate is determined or assumed based on previous experience and total silt in 50 years is worked out. This is distributed adoting standard procedures like modified area rduction method.Almatti reservoir is operated with area capacity curves developed with the assumed design silt rate of 1.2 acft/sq,mile/year for 50 years sedimentation for a period of 47 years and the success rates of planned demands with proposed FRL of +519.6 m is studied. IN 2009 actual hydrgraphic surveys are conducted and the assumed silt rate is proved to be on the higher side. Therefore the revised area capacity curves with actual observed rate of siltation for 50 years from year of impoundment are developed by adopting the same pattern observed during the 2009 hydrographic survey of Almatti conducted by the state of Karnataka through Ms. TojoVikasLimited.Then different FRLs are tried to achieve the success of all demands at Almatti and Narayanapur complex and suitable FRL to get the required success is obtained. It will be less than planned FRL of 519.6 m as the siltation rate has decreased considerably. This involves integrated operation of UKP complex of Almatti and Narayanapur for different secnarios namely with planned sediment and actual observed sediment rates. In the second scenario different FRLs are tried by reducing FRL of 519.6 m to meet the planned demands of 173 TMC. The monthly planned demands are shown in Table 2.

The area capacity curves after accounting for 50 year sedimentation based on design silt rate and based on observed sedimentation rate are given in Table 3& Table 4 respectively.

A comparison of Table 3 and 4 show that while the capacity at FRL as per planning after 50 years sedimentation is around 100 TMC where as the same is 108.30 TMC indicating that there will be an additional storage of 8 TMC available for use as per actual observed sedimentation.

Integrated working tables are prepared with the above area capacity curves for 50 year sedimentation for both cases i.e designed, and observed rates of sedimentation. In the first case a FRL of 519.6 m is adopted to utilise 173 TMC at Almatti and N'pur reservoirs with the above demands. In the second case the FRl is reduced in steps of 0.1 m from 519.6 m and around the same success is achieved. From the studies it is observed that the FRL of +518.80 m is sufficient to maintain the success of the project to the required levels

TABLE 2

Planned Demand pattern of UKP project(Almatti and Narayapur

Month	Demand under Almatti			demand under Narayanapur	grand total			
	drinking	Irrigation	total	drinking	irrigation	RTPS	total	
July	0.29	1.2	1.49	0.4	7.9	0.4	8.7	10.19
Aug	0.29	2.5	2.79	0.4	20.3	0.4	21.1	23.89
Sep	0.29	1.5	1.79	0.4	14.8	0.4	15.6	17.39
Oct	0.29	1	1.29	0.4	9.6	0.4	10.4	11.69
Nov	0.29	1.9	2.19	0.4	17.4	0.4	18.2	20.39
Dec	0.29	2.2	2.49	0.4	20.5	0.4	21.3	23.79
Jan	0.29	2.4	2.69	0.4	20	0.4	20.8	23.49
Feb	0.29	1.4	1.69	0.4	9.1	0.4	9.9	11.59
Mar	0.29	0.1	0.39	0.4	0.6	0.4	1.4	1.79
Apr	0.29	0	0.29	0.4	0	0.4	0.8	1.09
May	0.29	0	0.29	0.4	0	0.4	0.8	1.09
Total	3.48	14.6	18.1	4.8	124.2	4.8	134	151.9
		Evaporation in Almatti and Narayanapur			21.12			
							TOTAL USE	173

Note: All figures in TMC

TABLE 3

Almatti level area capacity curves after 50 years sedimentation (with designed sedimentation rate)

Slno	level in mts	Area in TMSFT	capacity in TMC
1	502.90	0.05	0.1
2	506.10	0.41	1.9
3	507.32	0.65	4
4	508.54	0.89	7
5	509.46	1.08	10
6	510.68	1.35	14.8
7	511.59	1.58	19.2
8	512.51	1.80	24.3
9	513.41	2.01	30
10	514.33	2.38	36.64
11	515.25	2.76	44.1
12	516.16	3.23	53.1
13	517.08	3.73	63.6
14	518.29	4.45	79.8
15	519.21	5.02	94.1
16	520.12	5.57	109.8
17	521.04	6.03	127.3
18	521.95	6.54	146.1
19	522.87	7.08	166.6
20	524.39	8.12	204.5

TABLE 4
Revised capacities after 50 year sedimentation based on 2009 survey

sl.no	Level in meters	Revised as per survey 2009 areain km^2	capacity in MM^3	Capacity after 50 years sedimentation MM^3	TMC
1	503.5	40.31	203.03	44.42	1.57
2	506.1	75.15	356.34	155.96	5.51
3	507.3	91.67	455.68	253.71	8.96
4	508.5	108.4	575.44	367.35	12.97
5	509.7	128.14	717.34	493.95	17.44
6	510.9	147.25	882.69	653.18	23.07
7	511.5	159.64	974.63	738.99	26.10
8	512.7	186.31	1182.19	936.46	33.07
9	513.6	204.86	1358.58	1102.35	38.93
10	514.5	233.89	1554.32	1294.20	45.70
11	515.4	275.32	1783.51	1508.09	53.26
12	516.3	314.86	2049	1768.99	62.47
13	517.2	355.56	2349.92	2065.93	72.96
14	518.4	421.8	2815.51	2529.38	89.32
15	519	454.93	3078.41	2786.16	98.39
16	519.6	488.26	3361.28	3066.58	108.30
17	520.8	546.86	3983.54	3685.17	130.14
18	521.95	607.798	4647.73	4346.30	153.49
19	522.87	658.242	5226.756	4922.27	173.83
20	524.256	754.255	6203.23	5897.21	208.26

IV.RESULTS AND CONCLUSIONS

From the above study of Almatti complex consisting of Almatti and n'pur it can be concluded that an FRl of +518.80 m is sufficient to meet the planned demand of 173 TMC. Similarly if the demand is increased to 303 TMC as proposed by Karnataka and as considered by the KWDT 2 the FRL proposed as +524.256 will also reduce in view of the reduction of sediment rate compared to the designed rate. It is recommended that any approval for this project for 303 TMC by the sanctioning agencies may consider this aspect also.

REFERENCES

[1] Jose, Carlos, Dearujo et. Al -Loss of reservoir volume by sediment deposition and its impact on water availability in semi arid Brazil- Hydrological sciencies-51(1)-Feb 2006

[2] Daniel Rohi et. Al- The impact of sedimentation in reservoirs on performance operation of hydropower a case study -Sutami Hydro power Indonesia

[3] VC Pande et.al-cost of siltation in Sardar Sarover reservoir- inplications for catchment treatment-current science vol 106, no. 1 Jan 2014

[4] G. Mathias et.al- sustainable sediment management in reservoirs and regulated rivers-Experiences from five catchments-Earth future vol.2 issue 5 May 2014, p.256-280

[5] Pinson,AbbaKer et.al-US Army corps of engineers reservoir sedimentation in the context of climate change civil works technical report 5/2016- Us army corp of engineers Washington DC

[6] HydrocoopBuilliten Aug 2013 - dams with significant siltation problems

[7] Project reports and other records of Almatti

[8] Sediment survey of Almatti by Tozovikas ltd. Karnataka

[9] KWDT 2 reports