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Study of Sediment Yield of Krishna River

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Abstract - *Sediment Yield directly or indirectly affects the various multipurpose projects on any river. Thus the efficient estimation of Sediment Yield plays a vital role in understanding the major issues concerning to sediments transport to reservoir sedimentation. The present Paper focusto study and develop mathematical model for deriving relationship between discharge and sediment yield of Krishna river. Various human activities within the watershed such as agriculture, urbanization and construction of dam has affected the sediment yield from the watershed. The monthly, seasonally and yearly field data of 41 years (1972-2012) of four station namely-Karad,Yadgir, Bavapuram and Wadenpalli, and one station named Cholachguda of 31 years (1982-2012) has been obtained from CWC, Krishna Division, Hyderabad. From the data so collected, field data of 29 years (1972-2000) for four station and 19 years (1982-2000) for one remaining station. Mathematical computation model is prepared using the non linear curve fitter of Origin –Pro 7.5 software. The results so obtained are compared with the remaining field data for the years 2000-2012. The evaluation of the model gives satisfactory results with the overall good R2 value. The mathematical analysis of the record give equation of the sediment rating curve in the power form Qs = a Qb , where Qs = Sediment Yield and Q = Water Discharge.,a and b are Mathematical constants.*

Key Words: Sediment yield, discharge, Specific sediment yield, Krishna river, Origin-pro 7.5 software

1.INTRODUCTION

The phenomenon of sediment transport is major issue for multi-purpose projects on the river. The study of such an issue is very necessary to understand the various major problems, related to river and multi-purpose projects like reduction of storage capacity of reservoir, reduction in carrying capacity of the river and channels, increase in probability of flooding during peak discharge, impact of change in watershed characteristics on the sediment yield.

The present study is proposed to study the sediment yield of Krishna Basin. Krishna River is selected as a representative hydrological regime for detailed studies of sediment yield into the river. In order to understand the sediment yield, five CWC sediment observation stations are studied.

The main objectives of the study is to analyse the seasonal and spatial variation in discharge and sediment yield for above listed station of Krishna river and to develop a mathematical model of sediment rating curve for Krishna basin.

2. DATA COLLECTION

The sample data was collected from Krishna and Godavari Basin Organization (KGBO), Hyderabad. The data was obtained for the CWC – Sediment Observations stations namely- Karad, Cholachguda, Yadgir, Bavapuram and Wadenpalli, for the period from 1972-2012. These data include the Daily discharge and the sediment concentration of coarse particles, medium particle and fine particles.

3. METHODOLOGY

Daily data of sediment yield in terms of concentration (g/l) and corresponding discharge (cumec) for 5 major sediment observation stations are obtained. Sediment concentration data (g/l) is converted to sediment yield (tonnes/day) by the following relation in order to understand the relation between the sediment yield and discharge.

$$Q_S = x * Q * C$$

Where;

Q_S = Sediment yield (Tonne/day)
Q = Water Discharge (cumec)
C = Sediment Concentration (grams/litre)
x = Unit conversion factor (0.0864 for S.I. unit)

Non-linear fitting is done using the Non-linear Curve fit option in Origin Pro-7.5 for developing best fitting curve for the relation between discharge and sediment yield. Mathematical relationship is developed between the discharge and the sediment yield for the seasonal data.

The data collection is divided into two different parts, as below:

The data used for the computation of model (1972-2000, except for Cholachguda:1982-2000)

The data used for the validation of model (2000-2012)

4. DATA ANALYSIS

The sediment rating curves is developed for monsoon season, to understand the relationship between discharge and sediment yield for observation stations of Krishna basin namely – Karad, Cholachguda, Yadgir, Bavapuram and Wadenpalli. A considerable quantity of sediment erosion

occurs for the monsoon period as compared to the non-monsoon period, which directly or indirectly affects various multipurpose project and its regulating policies. Thus the variation of sediment yield in terms of the corresponding discharge has been presented in order to understand the Krishna basin characteristics.

4.1 Mean seasonal Discharge v/s Sediment Yield for the monsoon period

The graph of mean seasonal Discharge v/s Sediment Yield for the monsoon period for Karad using the statistical analysis software- Origin Pro 7.5 is given below:

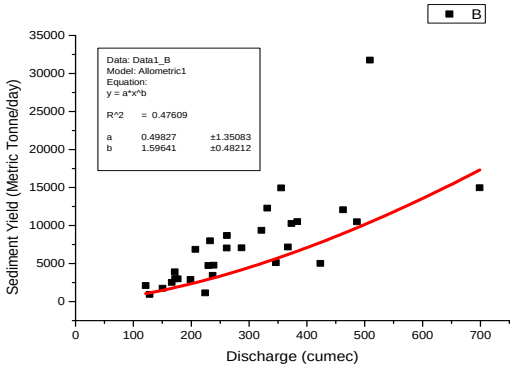

Fig –1: Sediment Discharge Rating Curve of Karad Station

Likewise graph of sediment rating curve for Cholachguda, Yadgir, Bavapuram and Wadenpalli for years 1972-2000 is developed. Details of rating curve parameter for monsson season are shown in table 1.

Table 1: Details of Rating Curve Parameters for Monsoon Season

Year	Station	Parameters		R2	Equation
		A	B		
1972-2000	Karad	0.4982	1.5964	0.4760	Qt = 0.4982 * (Q) 1.5964
1982-2000	Cholachguda	87.4509	1.3894	0.7805	Qt = 87.4509 * (Q) 1.3894
1972-2000	Yadgir	0.3061	1.8332	0.5581	Qt = 0.3061 * (Q) 1.8332
1972-2001	Bavapuram	13.221	1.1427	0.6483	Qt = 13.221 * (Q) 1.1427
1972-2002	Wadenpalli	0.38705	1.2834	0.7228	Qt = 0.3870 * (Q) 1.28343

The data are clustered into different months for understanding the relation between discharge and Sediment yield on the monthly basis. These data are clustered for the months of monsoon, i.e. June, July, August, September, and October. The graphs of mean monthly Discharge v/s Sediment Yield for the monsoon period of Karad station for the year from 1972 to 2000 are shown in the figures below.

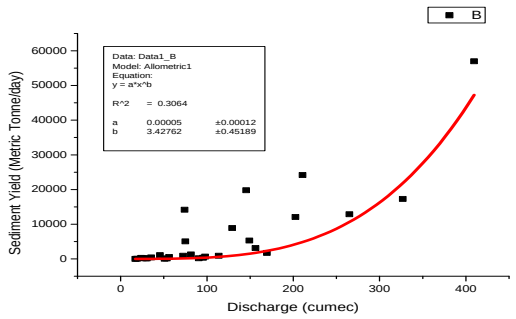

Fig –2: Sediment Discharge Rating Curve of Karad Station-June Month

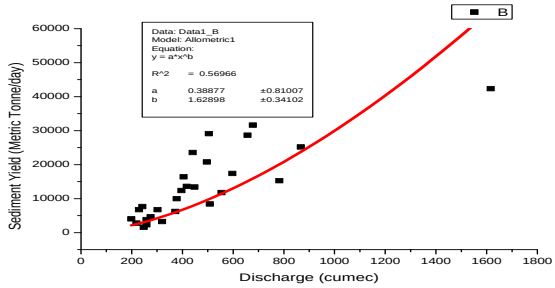

Fig -3: Sediment Discharge Rating Curve of Karad Station-July Month

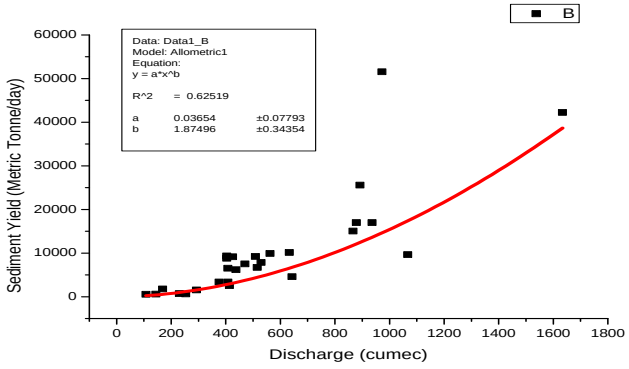

Fig –4: Sediment Discharge Rating Curve of Karad Station-August Month

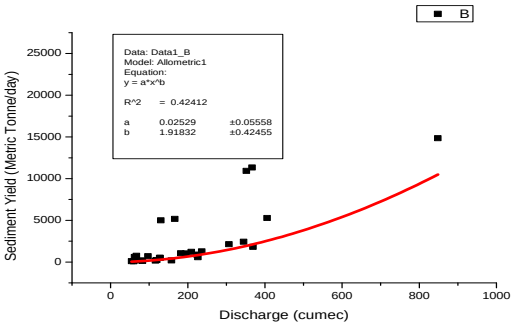

Fig -5: Sediment Discharge Rating Curve of Karad Station- September Month

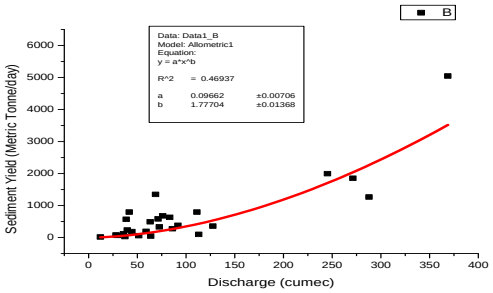

Fig -6: Sediment Discharge Rating Curve of Karad Station- October Month

The details of the values obtained for the sediment rating curve parameters for Cholachguda, Yadgir, Bavapuram and Wadenpalli are tabulated as below:

Table: 2 Details of Rating Curve Parameters for Different Months

Year	Station	Month	Parameters		R^2	Equation
			A	b		
1972-2000	Karad	June	0.0005	3.427	0.306	Qt = 0.0005 * (Q) 3.42762
		July	0.3887	1.628	0.569	Qt =0.3887 * (Q) 1.6289
		August	0.0365	1.874	0.625	Qt = 0.03654 * (Q) 1.87496
		September	0.0252	1.918	0.424	Qt = 0.02529 * (Q) 1.9183
		October	0.0966	1.777	0.469	Qt = 0.09662 * (Q) 1.77704
1982-2000	Cholachguda	June	4.0336	2.071	0.5329	Qt = 4.0336 * (Q) 2.0713
		July	12.824	1.677	0.3989	Qt = 12.8243 * (Q) 1.5964
		August	2.8992	2.047	0.4889	Qt = 2.8992 * (Q) 2.0475
		September	0.2486	2.63	0.6383	Qt = 0.2486 * (Q) 2.63
		October	83.85	1.379	0.8511	Qt = 83.85 * (Q) 1.3797
1972-2000	Yadgir	June	0.0749	2.215	0.4708	Qt = 0.0749 * (Q) 2.2156
		July	0.0423	2.082	0.5330	Qt = 0.04235 * (Q) 2.0821
		August	6.2201	1.325	0.4408	Qt = 6.2201 * (Q) 1.3253
		September	0.5227	1.598	0.6160	Qt = 0.52275 * (Q) 1.59874
		October	5.2979	1.370	0.5730	Qt = 5.2979 * (Q) 1.3705
1972-2001	Bavapuram	June	1.8836	1.159	0.9795	Qt = 1.8836 * (Q) 1.1594
		July	3.6389	1.350	0.6050	Qt = 3.63898 * (Q) 1.35039
		August	77.296	0.820	0.4976	Qt = 77.29621 * (Q) 0.82043
		September	0.0451	1.952	0.3586	Qt = 0.0451 * (Q) 1.95229
		October	0.0569	1.989	0.5299	Qt = 0.05697 * (Q) 1.98953
1972-2002	Wadenpalli	June	0.477	1.163	0.4012	Qt = 0.477 * (Q) 1.1637
		July	0.045	1.606	0.7929	Qt = 0.045 * (Q) 1.6067
		August	0.0216	1.598	0.6350	Qt = 0.02165 * (Q) 1.59814
		September	0.3009	1.296	0.5931	Qt = 0.3009 * (Q) 1.2968
		October	0.0012	1.926	0.4232	Qt = 0.00127 * (Q) 1.92685

4.2 Validation of the Model:

By analysing the data and finding out the equation of Sediment rating curve for the years 1972-2000, the mathematical model for the prediction of sediment yield is validated for the period of 2001-2012.

Figure 7. shows the variation of the sediment yield at Karad station for the year 2001-2012,

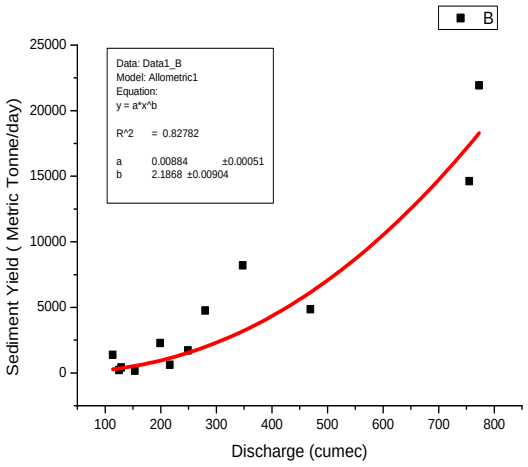

Fig -7: Sediment Rating curve for Karad station for 2001-2012

Co-efficient of determination:

In statistic, the coefficient of determination, denoted R2 or r2 and pronounced R squared, is a number that indicates how well data fit a statistical model.

The most general definition of the coefficient of determination is

$$R^2 \equiv 1 - \frac{SS_{\text{res}}}{SS_{\text{tot}}}.$$

Likewise sediment rating curve and coefficient of determination is determined for Cholachguda, Yadgir, Bavapuram and Wadenpalli. Details of validated rating curve parameter and R2 value for different month is tabulated below:

Table: 3 Details of validated Rating Curve Parameters and R^2 value for Different Months

Station	Particular	Parameters		R^2	Equation
		A	B		
Cholachguda Station	Mean Seasonal	87.45	1.389	0.855	Qt = 87.4509 * (Q) 1.3894
	Mean Monthly				
	June	4.033	2.071	0.77	Qt = 4.0336 * (Q) 2.0713
	July	12.82	1.677	0.796	Qt = 12.8243 * (Q) 1.5964
	August	2.899	2.047	0.495	Qt = 2.8992 * (Q) 2.0475
	September	0.248	2.63	0.834	Qt = 0.2486 * (Q) 2.63
	October	83.85	1.379	0.690	Qt = 83.85 * (Q) 1.3797
Karad Station	Mean Seasonal	0.498	1.596	0.875	Qt = 0.4982 * (Q) 1.5964
	Mean Monthly				
	June	0.0005	3.427	0.418	Qt = 0.0005 * (Q) 3.42762
	July	0.388	1.628	0.519	Qt =0.3887 * (Q) 1.6289
	August	0.036	1.874	0.895	Qt = 0.03654 * (Q) 1.87496
	September	0.025	1.918	0.675	Qt = 0.02529 * (Q) 1.9183
	October	0.096	1.777	0.315	Qt = 0.09662 * (Q) 1.77704
Yadgir Station	Mean Seasonal	0.306	1.833	0.466	Qt = 0.3061 * (Q) 1.8332
	Mean Monthly				
	June	0.074	2.215	0.826	Qt = 0.0749 * (Q) 2.2156
	July	0.042	2.082	0.841	Qt = 0.04235 * (Q) 2.0821
	August	6.220	1.325	0.556	Qt = 6.2201 * (Q) 1.3253
	September	0.52275	1.59874	0.53354	Qt = 0.52275 * (Q) 1.59874
	October	5.297	1.370	0.544	Qt = 5.2979 * (Q) 1.3705
Bavapuram Station	Mean Seasonal	13.22	1.142	0.521	Qt = 13.221 * (Q) 1.1427
	Mean Monthly				
	June	1.883	1.159	0.824	Qt = 1.8836 * (Q) 1.1594
	July	3.638	1.350	0.301	Qt = 3.63898 * (Q) 1.35039
	August	77.29	0.820	0.302	Qt = 77.29621 * (Q) 0.82043
	September	0.045	1.952	0.339	Qt = 0.0451 * (Q) 1.95229
	October	0.056	1.989	0.801	Qt = 0.05697 * (Q) 1.98953
Wadenpalli Station	Mean Seasonal	0.387	1.283	0.448	Qt = 0.38705 * (Q) 1.28343
	Mean Monthly				
	June	0.477	1.163	0.980	Qt = 0.477 * (Q) 1.1637
	July	0.045	1.606	0.693	Qt = 0.045 * (Q) 1.6067
	August	0.021	1.598	0.927	Qt = 0.02165 * (Q) 1.59814

	September	0.300	1.296	0.595	Qt = 0.3009 * (Q) 1.2968
	October	0.001	1.926	0.520	Qt = 0.00127 * (Q) 1.92685

The values of "a" and "b" of the above results show a huge variation in the relationship between discharge and sediment yield. The values of "a" is a measure of erosion severity. The higher values of "b" indicate the steepness of the curve. The Stations with high values of "a" and low "b" value, indicates a flat rating rating curve, which indicates that the loose sediment can be transported easily at almost all the discharges. The higher value of b indicate that rivers transport little sediment yield at low discharges.

For individual month, the pattern of variation for the sediment yield follows the order from low to high sediment yield – Karad, Cholachguda, Yadgir, Bavapuram and Wadenpalli. Except for the month of July where 174009.71 sediment yield (Metric Tonne) at 535.07 discharge (cumec) is observed.

Analysing the sediment yield at different station on seasonal basis exhibits different contribution in different seasons. Table below shows the contribution of sediment yield for monsoon period at different stations.

Table- 4: Contribution of Sediment yield for monsoon period at different stations:

Monsoon period			
Station	Discharge (m3/sec)	Sediment Yield (Million Metric Tonne)	Contribution of yield in %
Karad	46032.551	1.034112	5.226342
Cholachguda	7419.4998	3.707541	18.7377
Yadgir	87086.003	11.31716	57.19629
Bavapuram	54019.139	2.649631	13.39108
Wadenpalli	230186.36	1.078088	5.448593

Table- 5: Contribution of Sediment yield for non monsoon period at different stations:

Non-monsoon period			
Station	Discharge (m3/sec)	Sediment Yield (Million Metric Tonne)	Contribution of yield in %
Karad	6167.4790	0.0102	1.795926
Cholachguda	3711.5455	0.1726	30.48723
Yadgir	7471.6182	0.2363	41.73914
Bavapuram	6537.4152	0.0811	14.32603
Wadenpalli	59491.4198	0.0660	11.65167

From the above tables it can be observed that the Yadgir Station contributes maximum sediment yield with 56.766%. Least sediment yield is observed at the Karad station, since it is the first observations station near the origin of Krishna river. Bavapuram and Cholachguda station shows 13.41% and 19.06 % respectively. Wadenpalli station observes vey less 5% of sediment yield to the total yield.

Yadgir station is near the confluence of Tributary Bhima and Krishna river. It accounts for the yield from the Bhima watershed. a huge yearly discharge of 94557 cusec has resulted in higher yield. It has no major projects on the river

Bavapuram station accounts for the sediment yield from the Tungabhadra tributary. Also the yearly discharge observed for the Bavapuram observation station is high as 60556.5 cusec, but yet contributes only 2.7307 Million metric tonne. The presence of Tungabhadra dam, which is just on the upstream part of station may have resulted in the reduction of the sediment yield at Bavapuram station.

Wadenpalli station observes a lesser yield of 5.62 % , little more than that observed at Karad – 5.13%, since it has the large watershed area(235544 sq.km) and being the last station on Krishna river. Instead of resulting a large sediment yield at Wadenpalli station, it observes only 5.62% of yield because of the Muli-purpose projects on the river namely- P.D.Jurla Project, Srisailam dam and Nagarjunsagar Dam.

Cholachguda station is near the confluence of tributary Malaprabha and Krishna River. Hence it accounts for the sediment yield from the Malaprabha river. The yearly discharge observed is 11131.05 cusec yet shows a high sediment yield of 3.88 million metric tonne, contributing almost 19.06 % of sediment yield. Since it has no Multi-purpose project on the river Malaprabha, it could be one of the reason for higher sediment yield.

During Monsoon period, period the trend of sediment contribution is same as that for the annual period for all the stations. for the non monsoon period the discharge observed at Cholachguda station is least as compared to the other stations, yet it shows the sediment yield of 0.1726 (30.48%) Million metric tonne. Highest sediment yield at Yadgir station is high , and low at Karad station during non-monsoon period. For non-monsoon period Bavapuram station observed only 14.32 % of sediment yield. The water stored at Tungabhadra dam, would have been utilised for different purposes such as power generation and irrigation demands. As a result the water released during the non-monsoon period would have been low, finally resulting in the low sediment yield.

5. CONCLUSION

The validation of the model holds good for Karad and Cholachguda station on the mean seasonal basis, but Karad station shows a lower R2 value for the month of June, july and October depicting the variance in the relationship between sediment yield and discharge for these month. October month of Cholachguda station shows bas relationship between sediment yield and discharge. Due to the decrease in the

sediment yield at Yadgir and and Bavapuram station it show a low value of R^2. June and July month of Yadgir station show comparatively good results. July, August and September of the Bavapuram station shows low value, while for June and October month a sufficiently good results are obtained. For Wadenpalli station, the clustering of the data on monthly basis results in the better relation between the sediment yield and discharge

It can be concluded from the station that the construction of the dam on the river helps in reducing the impact of sediment yield on the river. Considerable quantity of sediment yield is lowered because of the presence of the dam on the river. Moreover Sediment reducing technique must be practised at the watershed for reducing the sediment yield.

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