COMPARISON OF TREND AND PROBABILITY OF FLOOD AT THREE DIFFERENT GAUGING STATIONS OF AMBICA RIVER

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Abstract: Study of river is important in building resilient strategies to manage environmental changes. Trend analysis shows the behavioural changes taking place over a period of time in hydrological, environmental or any other system. Frequency analysis, are used to estimate the probability of the occurrence of a given flood event. The recurrence interval is based on the probability that the given event will be equaled or exceeded in any given year. Ambica River lies in the semi-arid to dry sub humid region of south Gujarat, India. The trend of daily discharge, monthly average discharge and suspended sediment concentration from year 2000-2015, flood recurrence interval and probability of flood of annual peak discharge of 37 years for Gadat gauging site are assessed and compared. The suspended sediment data and daily discharge data of Gadat, Unai and Waghai gauging sites of Ambica River has been collected from Central Water Commission, Tapi division, Surat and State Water Data Centre, Gandhinagar. The results of trend analysis showed decreasing trend at Waghai and Unai gauging station and increasing at Gadat for daily discharge data.

Keywords: Trend analysis, recurrence interval, flood probability, Mann-Kendall test.

1. INTRODUCTION

Sediments are alluvium (soil particles) carried, transported and deposited by the river. These are the results of disintegration of rocks by physical as well as chemical processes. The material thus brought to deposition stage in delta region of river finally ends up in sea. Sediment transport has led to many problems of reservoir silting, floods, meandering of rivers, velocity of flow, aggradation and degradation etc. To overcome this situation, large amount of expenditure is incurred in regulatory structure.

Trend analysis allows assessing the behaviour of hydrologic parameters with time. Discharge and transport of sediments are important hydraulic parameters of river hydraulics. Average discharge and suspended sediment concentration data have been used to find trend in the Ambica River. There are various parametric and non-parametric test for finding trends in the rivers. Parametric methods are well developed and documented (Box and Jenkins, 1970; Box and Tiao, 1975; D'Astous and Hipel, 1979). However, with some hydrologic data there may be compelling reasons for using a nonparametric approach to trend detection. Hirsch et al. (1982) and Lettenmaier et al. (1982) discuss the reasons for using non parametric procedures for water quality data. There are missing values in the data. The parametric procedures for trend detection is used when serial correlation exists (Box and Tiao, 1975; Hipel et al., 1975), depend on uniform sampling. Techniques exist to deal with a few isolated data gaps (Lettenmaier, 1976 ;D 'Astous and H ipel, 1979) by estimating values for the missing data. However, if there are a lot of missing values, or one or more long gaps exist, the effect of data fill in on the identification of the stochastic process and the ultimate trend testing becomes very problematic. Harned et al. (1981) have employed various methods of aggregating seasonal data into annual summary values. This has the advantage that such annual series typically have only minimal serial dependence and thus testing for trends can be carried out in straight forward fashion (either parametrically or non-parametrically).Non parametric approach has been used in the present analysis. Flooding is a natural event occurring in a stream. The annual disaster record reveals that flood occurrence has increased by 10 folds during the last 45 years, from 20 events in the year 1960 to 190 events in 2005(Scheuren et al.,2007). Impact of flood has become a great challenge for engineers to work on.

Thus, trend, flood recurrence interval and probability of flood analysis for study at this area would let to understand the behaviour of river and predict the future occurrence of flood in streams enabling early working on preventive measures against any negative effect.

2. STUDY AREA AND DATA COLLECTION

The study area encompasses gauging sites on Ambika River. It is a wadable stream having access from low height bridge from where measurements are observed. Gadat is the only gauging site under Central Water Commission (CWC) on the Ambika River. Unai and Waghai gauging stations are working under Narmada Water Resources, Water Supply and Kalpsar Department (NWRWSKD). Hydrological, meteorological, precipitation and sediment concentrations are observed at these sites. Figure 1 shows the location of gauging sites on Ambica River.

General Information about the basin

Ambica is one of the major west flowing rivers of Gujarat. It originates from Saputara Hill ranges close to village Kotambi of Surgana taluka in Nasik district, Maharashtra. It is located between 20°51’29” latitude to 72°59’06” longitude. It has two main tributaries Khapri and Walam. Table1 shows length, elevation range and drainage area of Ambica River. In this study, hydrological data (daily discharge and suspended sediment concentration) of 15 years has been considered for the three gauging sites. The availability of data at three gauging sites is shown in Table 2.

Table1: Spatial data of Ambica river

Parameters	Unit	Value
Maximum Elevation	m	1050
Minimum Elevation	m	100
Length of river	km	136
Drainage area	Km^2	2715

Table 2: Data availability at gauging sites

Sr.No.	Gauging site	Data period	Source of Data
1.	Gadat	1979-2015	C. W. C.
2.	Unai	1993-2015	S. W. D. C.
3.	Waghai	1998-2015	S. W. D. C.

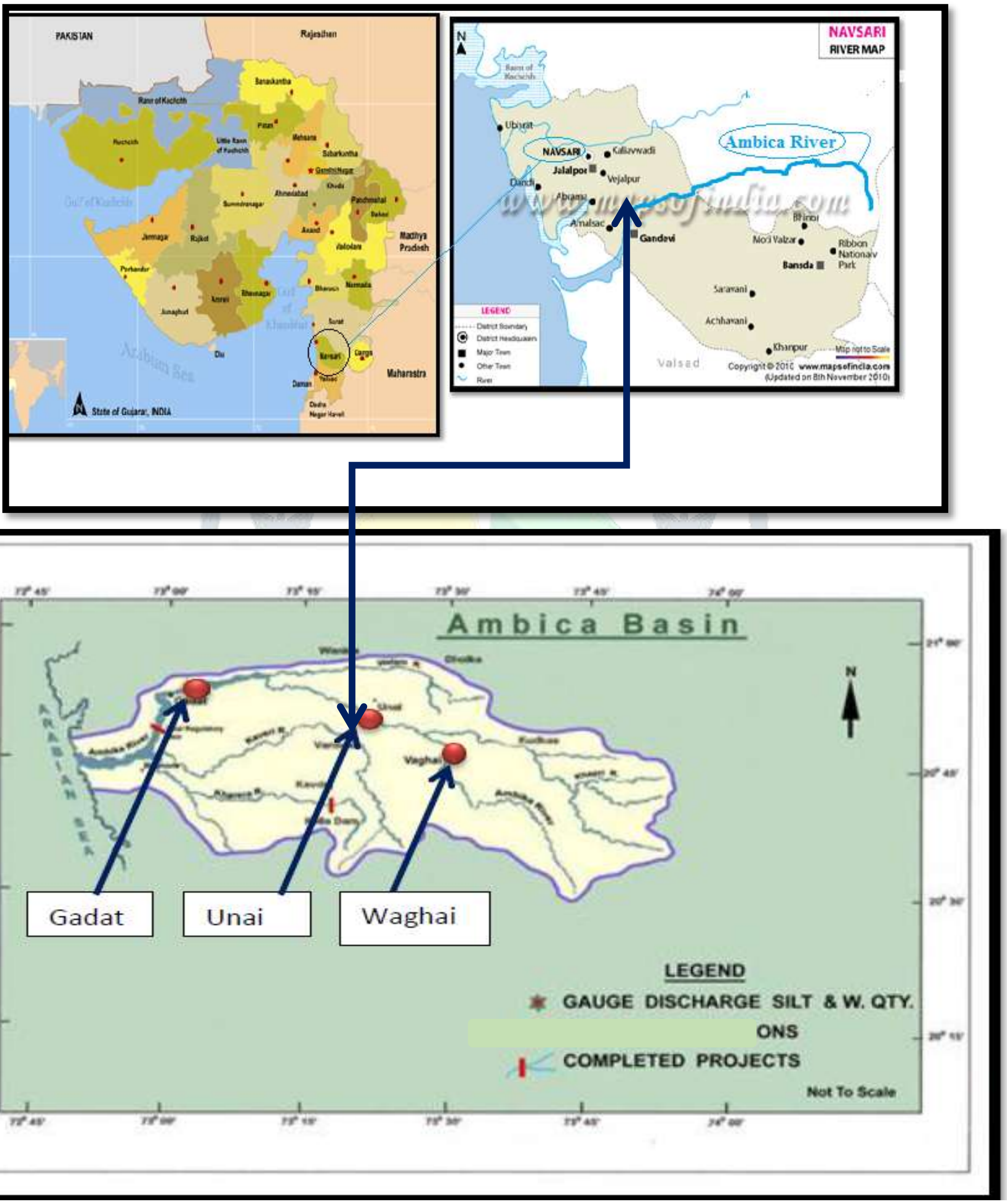


Figure 1: Location of gauging sites on Ambica river

3. METHODOLOGY

In this paper, flood recurrence interval and probability of flood for maximum yearly discharge for each gauging station is calculated in order to predict its occurrence time. Secondly, trend is calculated by performing Mann-Kendall's test on hydrological data (discharge and suspended sediment concentration).A sampled calculation is carried out to show z-statistics value.

Flood Recurrence Interval and Probability of Maximum Yearly Discharge At Each Gauging Stations

Method

The following procedure is followed:

1. Obtain a list of annual maximum flood flows for the site.
2. Rank them from largest to smallest
3. For each one, calculate the recurrence interval (T) by Geological Survey method.

$$\mathrm{RI} = \frac{\mathrm{N}+1}{\mathrm{m}}$$

; m = rank magnitude of flood

; N = number of years of flood

$$\text{Exceedence probability: } \mathrm{P} = \frac{1}{\mathrm{RI}} * 100$$

For each gauging station, the maximum discharge for each year has been selected. Rank was allotted from largest to smallest .For each rank, recurrence interval (RI) was calculated as

Trend Analysis and Sen Slope

a. Mann Kendall Test

It is non-parametric test and commonly employed to detect monotonic trends in series of environmental data, climate data or hydrological data. This test has been conducted on hydrological data available at three gauging sites. It has been performed using XLSTAT of MS Excel.

$$\mathrm{S} = \sum \sum_{j=i+1}^{n} \mathrm{sgn}(\mathrm{Xj} - \mathrm{Xi})$$

where N is number of data points. Assuming (xj-xi) = θ, the value of sgn(θ) is computed as follows:

$$\mathrm{sgn}(\mathrm{Xj} - \mathrm{Xi}) = \begin{cases} +1 & \text{if } (\mathrm{Xj} - \mathrm{Xi}) > 0 \\ 0 & \text{if } (\mathrm{Xj} - \mathrm{Xi}) = 0 \\ -1 & \text{if } (\mathrm{Xj} - \mathrm{Xi}) < 0 \end{cases}$$

This statistics represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples (N>10), the test is conducted using a normal distribution with the mean and the variance as follows:

$$\mathrm{Var(S)} = \frac{1}{18}\left[(\mathrm{n(n-1)(2n+5)}) - \sum_{p-1}^{q} (\mathrm{tp(tp-1)(2tp+5)})\right]$$

and for non- tied values, variance is calculated as

$$\mathrm{Var(S)} = \frac{1}{18}[(\mathrm{n(n-1)(2n+5)})]$$

Where n is the number of tied (zero difference between compared values) groups, and t_p is the number of data points in the k^{th} tied group. The standard normal deviate (Z-statistics) is then computed as

$$\mathrm{Zmk} = \begin{cases} \frac{\mathrm{S}-1}{\sqrt{\mathrm{Var(S)}}} \\ \frac{\mathrm{S}+1}{\sqrt{\mathrm{Var(S)}}} \end{cases} \begin{pmatrix} \text{if } \mathrm{S} > 0 \\ \text{if } \mathrm{S} = 0 \\ \text{if } \mathrm{S} < 0 \end{pmatrix}$$

where Xi and Xj are the sequential data values of the time series in the years i and j, n is the length of the time series, t_p is the number of ties for the p^{th} value, and q is the number of tied values. Positive values of Z_{MK} indicate increasing trends, while negative Z_{MK} values indicate decreasing trends in the time series.

When $|Z_{Mk}| > Z_{1-\alpha/2}$, the null hypothesis is rejected and a significant trend exists in the time series. $Z_{1-\alpha/2}$ is the critical value of Z from the standard normal table where the value of $Z_{1-\alpha/2}$ is 1.96 for 5% significance level.

b. Sen's Slope Method

If a linear trend is present in a time series, then the true slope (change per unit time) can be estimated by using a simple nonparametric procedure developed by Sen (1968). This means that linear model *f (t)* can be described as

$$f(t) = Q_t + B$$

To derive an estimate of the slope Q, the slopes of all data pairs are calculated

$Q_i = \frac{x_j - x_k}{j-k}$, *i= 1 , 2,…, N, j > k*

If there are *n* values of *xj* in the time series we get as many as *N = n(n-1)/2* slope estimates *Qi*.

The Sen's estimator of slope is the median of these *N* values of *Qi*. The *N* values of *Qi* are ranked from the smallest to the largest and the Sen's estimator is

$$Q = \begin{cases} Q_{\frac{N+1}{2}}, & if\ N\ is\ odd \\ \frac{1}{2}\left(Q_{\frac{N}{2}} + Q_{\frac{N+2}{2}}\right), & if\ N\ is\ even \end{cases}$$

A 100(1-α) % two-sided confidence interval about the slope estimate is obtained by the nonparametric technique based on the normal distribution. The method is valid for n as small as 10 unless there are many ties (Salmi et al. 2002).
At first we compute

$$C_a = Z_{1-\frac{\alpha}{2}} \sqrt{VAR(S)}$$

where $Z_{1-\alpha/2}$ is obtained from the standard normal distribution.

Next $M1 = (N - C\alpha)/2$ and $M2 = (N + C\alpha)/2$ are computed. The lower and upper limits of the confidence interval, *Q min* and *Q max*, are the $M1^{th}$ *largest* and the $(M2+1)^{th}$ largest of the N ordered slope estimates *Qi*. If *M1* and/or *M2* are not a whole numbers, the respective limits are interpolated.

4. RESULTS

Rank, recurrence interval and probability of flood have been calculated from year 1979 to 2015 for a period of 37 years for Gadat Gauging site. Table 3 shows flood frequency analysis where annual maximum discharge has been taken. Flood frequency curve for Gadat is shown in Figure 2.

Table 3: Flood frequency analysis of annual maximum discharge at Gadat

Rank	Year	Maximum Discharge (m3/s)	Recurrence Interval	Exceeding Probability %
1	1999	2989.10	38.000	2.63
2	2005	2894	19.000	5.26
:	:	:	:	:
:	:	:	:	:
16	1984	1551.20	2.375	42.11
17	1982	1537.10	2.235	44.74
:	:	:	:	:
:	:	:	:	:
36	2015	490.50	1.056	94.74
37	1991	450.70	1.027	97.37

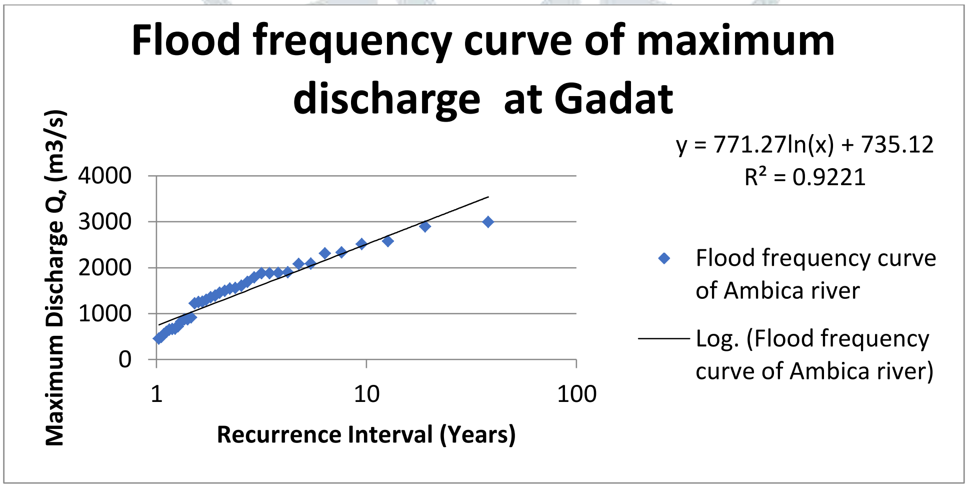


Figure 2 Flood frequency curve of maximum discharge at Gadat

Figure 2 shows flood frequency curve with $R^2 = 0.9221$ for logarithmic plot .This graph gives straight line showing linear relationship of Discharge with years. . Table 3 gives the probability of occurrence of flood event in future.

Mann-Kendall Trend Test and Sen's slope Result

Data from the year 2000 to 2015 has been considered for uniformity and comparison. Mann- Kendall test is performed on daily discharge and sediment data for Gadat, Unai and Waghai site as shown in Table 4. Table 5 shows the result of Mann-Kendall test of average monthly maximum discharge for the months from June to September at Gadat, Unai and Waghai. Ho and Ha are hypothesis. Null Hypothesis Ho= There is no trend and Ha= There is a trend.

From Table 4 and Table 5, it can be said that positive value of Kendall's tau shows increasing trend and negative value of Kendall's tau gives decreasing trend for daily discharge, monthly maximum discharge and suspended sediment concentration.

Table 4: Mann-Kendall's Test results and Sen Slope for discharge and sediment data at Gadat, Unai and Waghai site

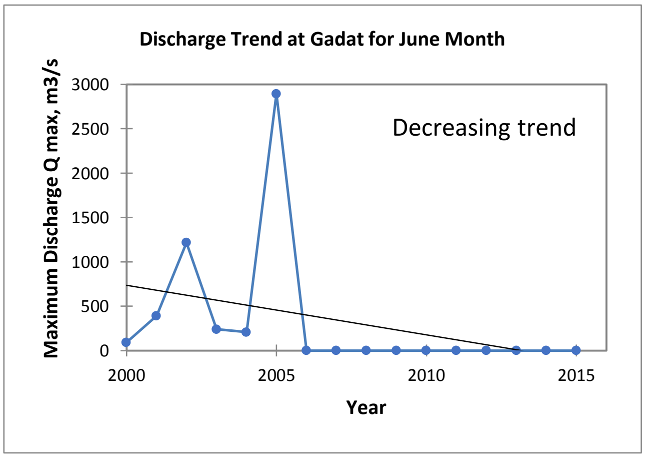
Gauging site	Year	Data set	Kendall's Tau	Sen slope	Trend
Gadat	2000-2015	Discharge	0.239	0.064	Increasing
Gadat	2000-2015	Sediment	0.166	2.604E-5	Increasing
Unai	2000-2015	Discharge	-0.122	-0.042	Decreasing
Unai	2000-2015	Sediment	-0.153	-0.00017	Decreasing
Waghai	2000-2015	Discharge	-0.101	0.014	Decreasing
Waghai	2000-2015	Sediment	0.038	0.000	Increasing

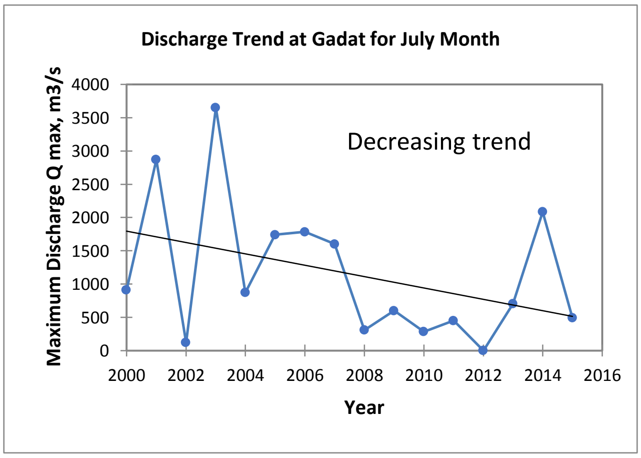
Table 5: Man-Kendall's test results and Sen's Slope for Monthly and seasonal average discharge at Gadat, Unai and Waghai site

Gauging site	Year	Month	Kendall's Tau	Sen slope	Trend
Trend Analysis for monthly maximum Discharge					
Gadat	2000-2015	June	-0.580	-8.852	Decreasing
		July	-0.250	-71.761	Decreasing
		August	-0.050	-14.220	Decreasing
		September	0.383	42.692	Increasing
Seasonal Average discharge			-0.217	-35.580	Decreasing
Unai	2000-2015	June	-0.505	-2.578	Decreasing
		July	-0.364	-52.107	Decreasing
		August	-0.524	-70.271	Decreasing
		September	-0.230	-15.100	Decreasing
Seasonal Average discharge			-0.467	-65.830	Decreasing
Waghai	2000-2015	June	-0.411	0.000	Decreasing
		July	-0.039	-1.123	Decreasing
		August	-0.162	-23.106	Decreasing
		September	0.124	5.249	Increasing
Seasonal Average discharge			-0.181	-16.808	Decreasing

Analysis of Trend of Maximum Monthly Discharge and Seasonal Average Discharge

Trend values are also called fits. The trend analysis plot displays the parameter values versus time. The plot includes the fits that are calculated from the fitted trend equation, the forecasts and the accuracy measures.





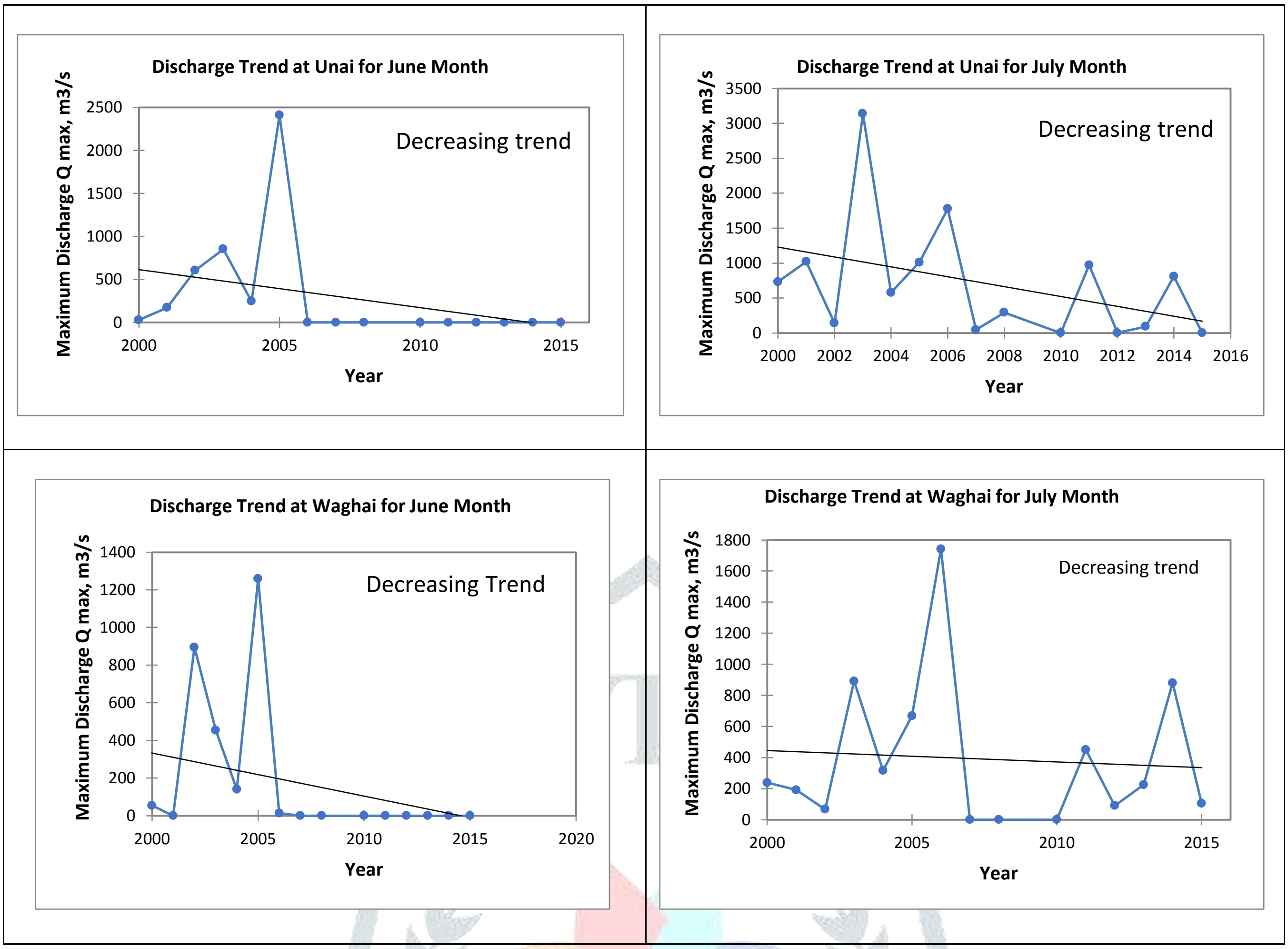
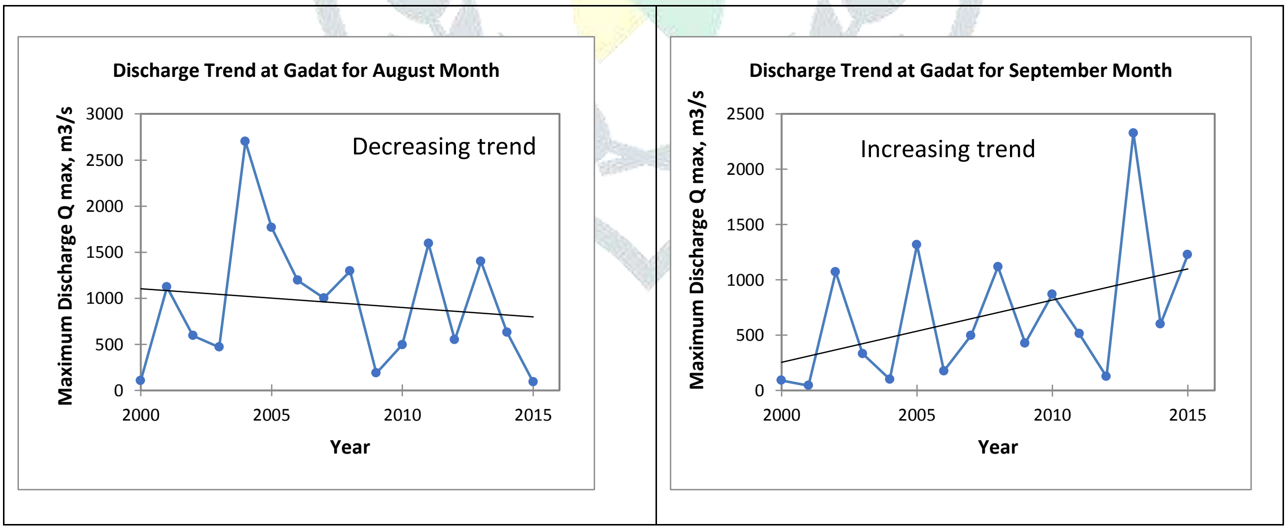


Figure 3 Time series of monthly maximum discharge for month of June and July of Gadat, Unai and Waghai gauging site

Figure 3 shows plot of monthly maximum discharge versus time for the month of June and July. There is a steep decreasing trend at Gadat, Unai and Waghai for June month. There is decreasing trend at Gadat, Unai and Waghai for the month of July.



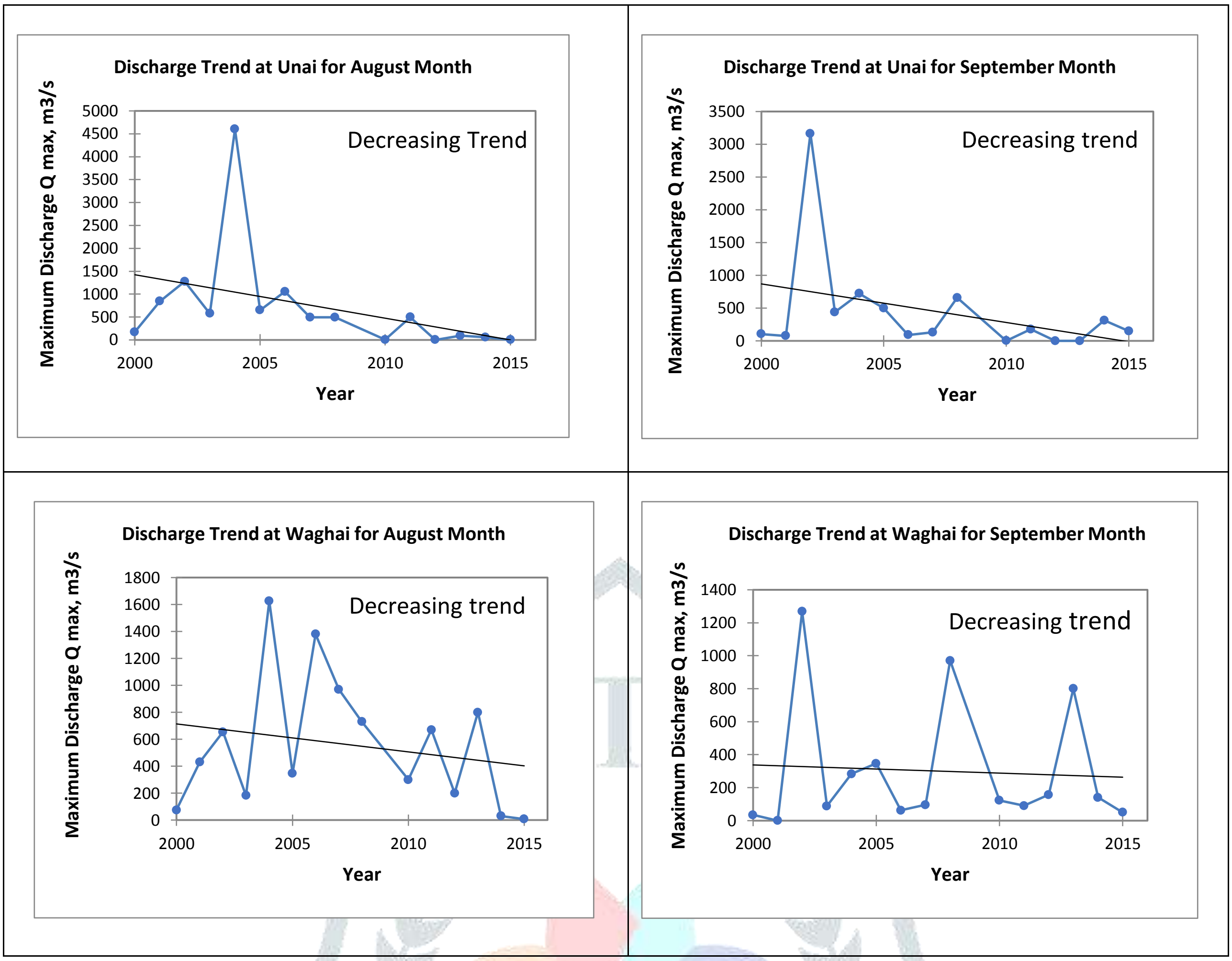
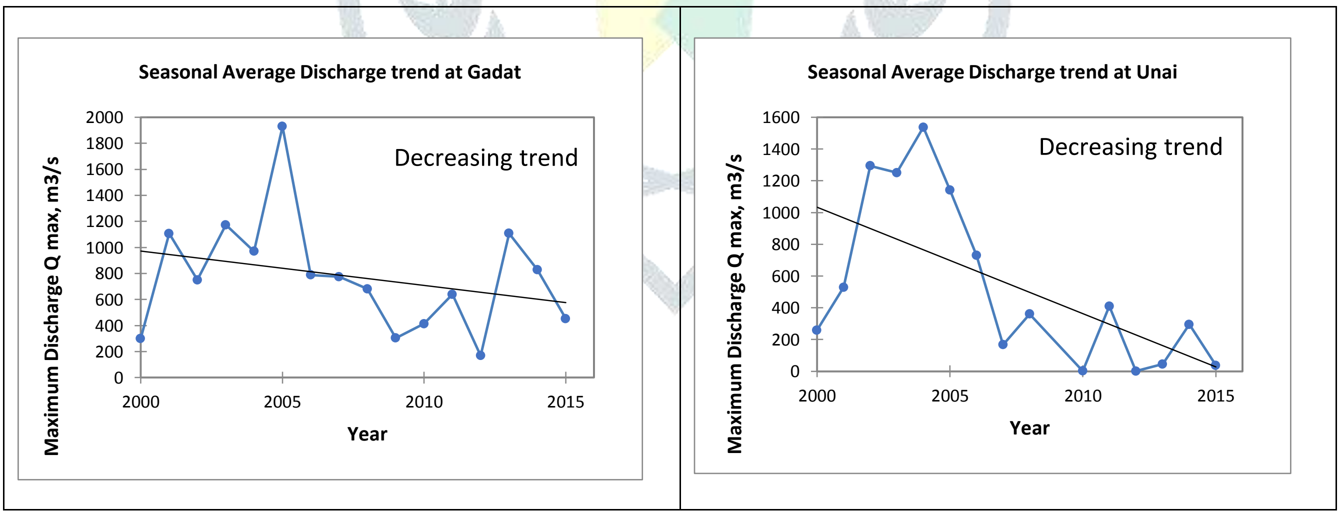


Figure 4 Time series of monthly maximum discharge for month of August and September of Gadat, Unai and Waghai gauging site

Figure 4 shows plot of monthly maximum discharge versus time for the month of August and September. There is a steep decreasing trend at Gadat, Unai and Waghai for August month. There is increasing trend at Gadat and Waghai while decreasing at Unai for the month of July.



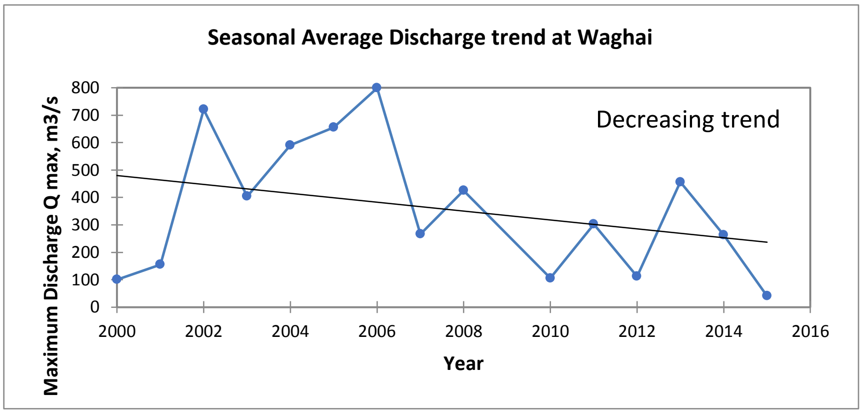


Figure 5 Time series of maximum discharge for monsoon period at Gadat, Unai and Waghai site

Figure 5 shows the relation of seasonal maximum discharge with time. It show decreasing trend for Gadat, Unai and Waghai site. For the year 2005, the maximum discharge was observed for Gadat, Unai and Waghai site.

7. CONCLUSION

- The lowest discharge value with last rank has the highest probability 97.37% of occurrence. The highest discharge value with first rank has least probability of occurrence 2.63 %.
- There is increasing trend at Gadat site and decreasing trend at Unai and Waghai site for discharge data from year 2000 to 2015 may be because of a tributary joining Ambica River between Unai and Gadat gauging station.
- Trend is increasing at Gadat and Waghai site while trend is decreasing at Unai site for suspended sediment concentration data from year 2000 to 2015 may be because of a tributary joining Ambica River between Unai and Gadat gauging station.
- Trend is significantly decreasing at Gadat, Unai and Waghai site for the month of June, July and August for monthly maximum discharge and seasonal average discharge.

REFERENCES

[1] Bussi, G., Dadson, S.J., Bowes, M.J. and Whitehead, P.G., “Seasonal and Inter-annular changes in sediment transport identified through sediment rating curves”, Journal of Hydrologic Engineering, © ASCE Publication, September 2016.

[2] Ma, Y., Huang, H. Q., Xu, J., Brierley, G. J. and Yao, Z., “ Variability of effective discharge for suspended sediment transport in a large semi-arid river basin”, Journal of Hydrology, © Elsevier Publication, May 2010, pp.357-369.

[3] Ulke, A., Tayfur, G. and Ozkul, S., “Predicting suspended sediment loads and missing data for Gediz river, Turkey”, Journal of Hydrologic Engineering, © ASCE Publication, Vol. 14, September 2009.

[4] Burn DH, Hesch NM (2007) Trends in evaporation for the Canadian Prairies. J Hydrol 336:61–73

[5] Burn DH, Cunderlik DH, Pietroniro A (2004) Hydrological trends and variability in the Liard River Basin. Hydrolog Sci J 49(1):53–67

[6] Gellens D (2000) Trend and correlation analysis of k-day extreme precipitation over Belgium. Theor Appl Climatol 66:117–129

[7] Hamed KH, Rao AR (1998) A modified Mann-Kendall trend test for auto correlated data. J Hydrol 204:182– 196

[8] Box, G. E. P., and G. M. Jenkins, Time Series Analysis: Forecasting and Control, Holden-Day, San Francisco1, 970.