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RAINFALL RUNOFF REGRESSION MODEL FOR GALWA CATCHMENT IN BANAS RIVER BASIN

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ABSTRACT

For proper planning designing and maintaining of a water resource project previous hydrological and meteorological data of the concerned area are required. Galwa dam is constructed across river Galwa, a tributary of river Banas which is situated in Rajasthan in India. The total monthly and monsoon rainfall over the catchment of the Galwa is taken as the rainfall measured at the Nainwa rain-gauge station which is influencing maximum to the catchment. Runoff generated from the catchment is measured at the Galwa dam site. Statistical analysis on the rainfall for different periods in the catchment & runoff data is carried out. Rainfall Runoff relations between the total rainfall and corresponding runoff for different months i.e. July, August & September and Monsoon period were developed. Three types of empirical relations i.e. linear, polynomial & logarithmic were developed and the corresponding correlation factors were also calculated. These relations can be used for the computation of inflow from catchment and further planning for new projects.

Index Terms*: *Rainfall, Runoff, Catchment, Total rainfall, Statistical Analysis, Coefficient of variation, Skewness, Regression Analysis, Correlation Coefficient, Determination Coefficient.

I INTRODUCTION

The rainfall which is clearly a natural hydrological phenomenon depends on various parameters. The knowledge of rainfall occurred and runoff generated from a specified area in a particular period is very important for planning designing and optimum utilization of water resources project. Local physiographic, climatic and biotic factors influence very much the rainfall and the corresponding surface runoff generated in a particular catchment. Developmental activities required for human development is increasing and changing with time which are ultimately changing the local physiographic biotic and abiotic factors. The local climate is changing due to change in the local physiographic and biotic factors and vice versa due to which the behavior of rainfall and corresponding runoff is also changing. There may be some empirical relations i.e. linear, polynomial, logarithmic and exponential between the rainfall and corresponding runoff, which can be used for computing water inflow generated from the catchment.

II LITERATURE REVIEW

M. Afzal Ali Baig and P Mallikarjuna (1) developed empirical relations between rainfall and runoff for the Bahuda river basin in Andra Pradesh by multiple correlation and regression analysis carried out for forecasting empirical relationships between the rainfall and corresponding runoff generated in particular period.

Gunwant Sharma et.al (2) have developed rainfall-runoff relation for Meja Catchment and also studied the trends in annual rainfall and runoff. It was found that the trend on occurrence of rainfall in the past thirty four years i.e. from 1979 to 2012 is roughly equal while the observed runoff is reducing in the previous thirty four years in the Meja Catchment.

John F. Joseph and Earnest Falcon (3) studied the hydrologic trends and correlations in South Texas River Basin and found the majority of trends and correlations were found to be statistically significant at the level 0.05 and all relationships were positive or increasing.

Hamed (4) reviewed trends in U.S. rivers and found three to have increasing trends, one to have a decreasing trend, and the remaining to not have a trend statistically significant at the level of 0.05.

The Intergovernmental Panel on Climate Change (5) indicates that extreme weather (including heavy rainfall and prolonged dry periods) is likely becoming more common in some regions of the world due to global warming.

Krishnegowda et al (6) have developed rainfall runoff relationship for Malathi river basin.

Mallikarjuna and Vishnu Vardhan (7) generated monthly rainfall sequences independently for the four raingauge stations of Kalangi basin located in Andhra Pradesh and concluded that the Thomas-Fiering model for the independent generation of synthetic sequences of rainfall may be used in the design of water resources system of Kalangi Basin.

Sudhisri et al. (8) developed the rainfall-runoff models for annual, pre-monsoon, monsoon and post-monsoon seasons and found to have high correlation coefficient.

Mallikarjuna and Prabhakara Rao (9) developed a relationship between rainfall and other meteorological parameters such as relative humidity, wind velocity; temperature and sunshine hours for the Tirupati area of the drought prone Rayalaseema region through multiple correlation and regression analysis.

Gorantiwar and Majumdar (10) analysed the streamflow sequences of some west Bengal streams and modeled the streamflow using autoregressive model of first order.

Mirza et al (11) have reported the trends and persistence in precipitation in Ganga, Bramhaputra and Meghna river basin.

Srinivasan and Thandaveshwara (12) fitted lower order periodic autoregressive/ autoregressive moving average (PAR/PARMA) models to the monsoon-dependent river flows of Southern India measured at Chunchanakatte (Cavery river), Akkihebbal (Hemavathy river) and Unduwadi (Lakshmanathirtha river) and showed that the above models do not seem to perform satisfactorily in modeling highly variable monsoon dependent river flows.

Verma and Haque (13) developed a stochastic model for generation of daily rainfall sequences by analyzing rainfall data at Mokhada rain guage station.

Reddy and Vedula (14) compared the applicability of different streamflow generating models using the same historic data of monthly streamflows into upper Cauvery river basin and found that the Thomas- Fiering model was found best to preserve the mean, standard deviation and lag one correlation of historic streamflows.

Koteshwaram and Alva (15) and Bhargava and Bansal (16) studied the secular trends and periodicities in the monsoon and annual rainfall of selected stations in India.

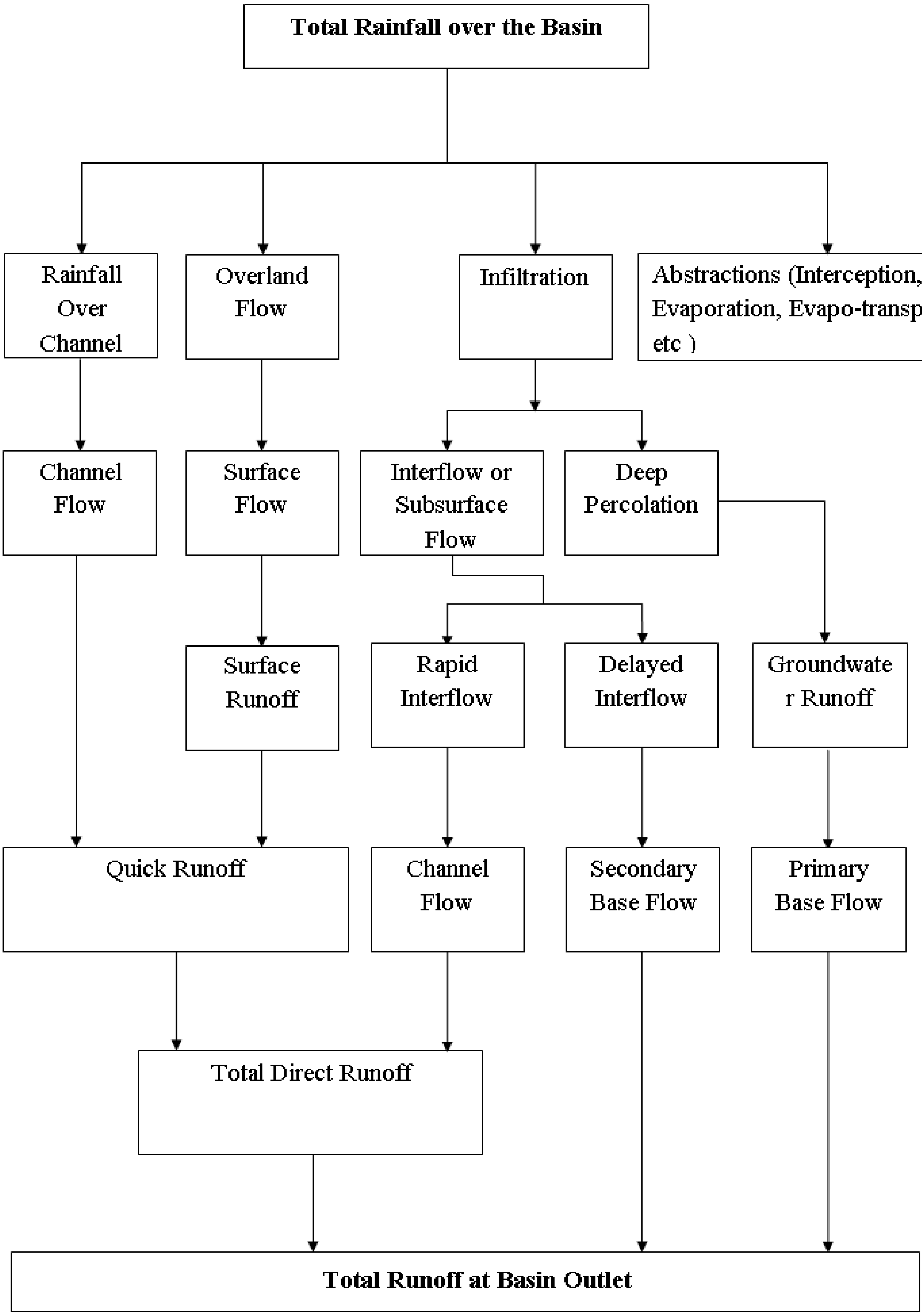


Figure-1 Flow Chart for generated runoff in a basin

III. STUDY AREA

The Galwa catchment area is up to the Galwa Dam. The dam site is located 7 Km. from Uniara town in Tonk district in Rajasthan in India at latitude 25°53' N and longitude 76°02' E. Galwa dam is constructed across river Galwa, a tributary of river Banas for providing irrigation facilities in 43 villages in Uniara and Sawai Madhopur tehsils. The total catchment area is 405.1 Square Km. The rain gauge station influencing the maximum is Nainwa. This dam was constructed in 1960 as an earth cum masonry type with spillway of length 244m; gross storage is 48.7 MCM, live storage 47.22 MCM.

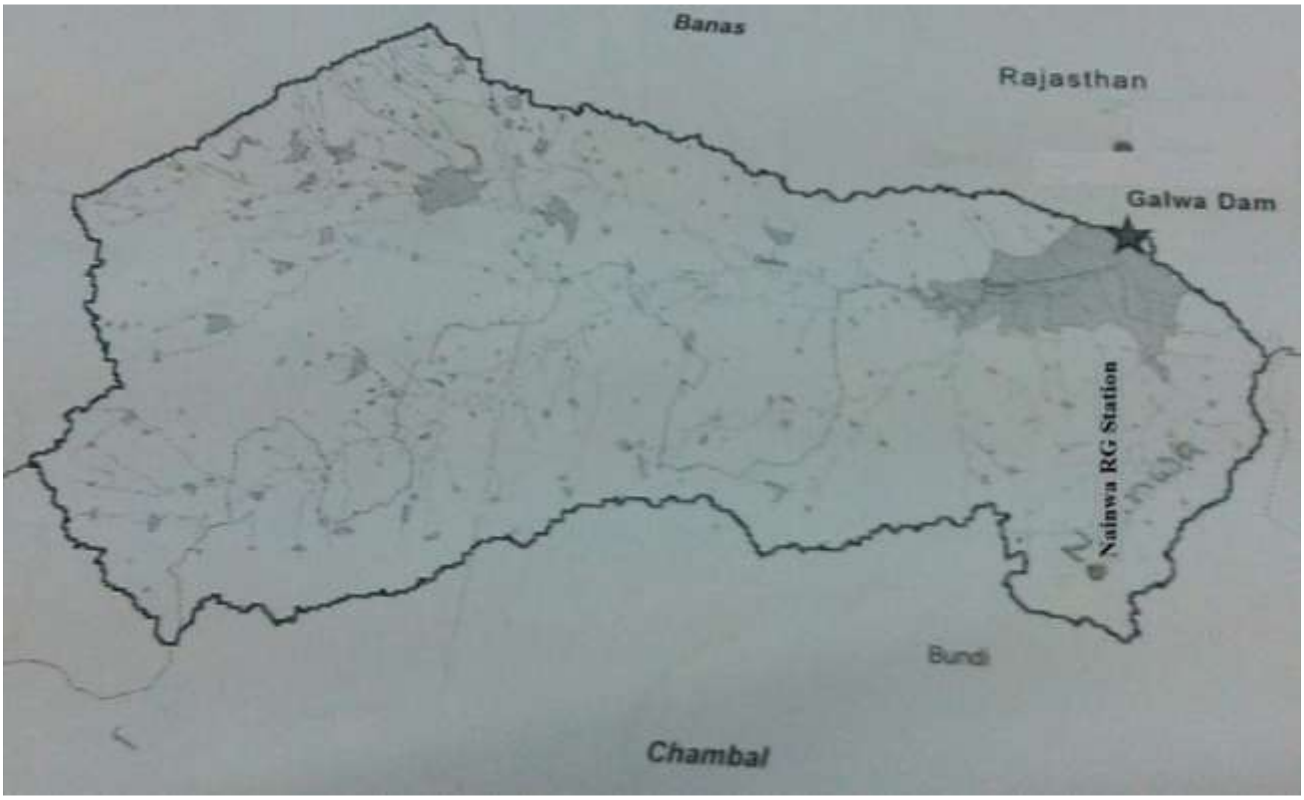


Figure-2 Catchment area plan with the location of raingauge station and dam site for Galwa Catchment

IV. DATA USED

Monthly rainfall data for the month July, August and September in the period 1996 to 2010 at Nainwa raingauge station which is in the Galwa catchment and the water inflow in the dam measured in the months July, August and September coming from the Galwa catchment observed by IMD and Water Resources Department Rajasthan are used in the study. The analysis is done on monthly and monsoon period basis. Since only one rain-gauge station is influencing the catchment, so the necessity of Thiessen polygon is not required. The inflow coming in the Galwa dam in the different months or monsoon period is used as runoff is computed in the depth form by dividing the total inflow in the particular period by the catchment area. The total weighted average monthly and monsoon rainfall and runoff depths in mm are shown in Table-1.

V METHODOLOGY

Location of raingauge stations are marked on the catchment area. Thiessen polygon is drawn and the influence area with the influence factors of the various raingauge stations are determined by measuring the individual effected area. Total weighted rainfall in mm occurring in the catchment is computed using the influence factors. Here only one rain-gauge station at Nainwa is available so the Thiessen polygon is not required. The inflow coming from the catchment up to the Galwa dam in the month is determined, than the runoff in mm in the depth form is computed by dividing the volume of water inflow with the catchment area. Graphs between the rainfall in mm taking on X axis and corresponding runoff in mm on Y axis are plotted. Regression equations /graphs in various forms i.e. linear, polynomial, exponential and logarithmic assuming the rainfall as independent variable and the runoff as dependent variable can be plotted. The reliability/ performance of the relation/ graph can be checked by computing the various statistical parameters i.e. Correlation Coeff. (R), Determination Coeff. (R^2). Statistical parameter R represents about the strength of the relationship between observed rainfall and the runoff. R value between 0.6 to 1.0 indicates that there is a good relation and parameter R^2 provides information about the percentage of variation of runoff on rainfall.

VI. STATISTICAL AND REGRESSION ANALYSIS

The computed monthly and monsoon rainfall in mm and the corresponding water inflow depth computed in mm are statistically analyzed. Various statistical parameters are obtained which are shown in the Table-2. Parabolic, Linear and Logarithmic relation with their correlation and determination coefficients between the rainfall in mm and corresponding runoff in mm are obtained by the regression analysis.

Table 1:- Computed Total Rainfall and Corresponding Runoff Generated

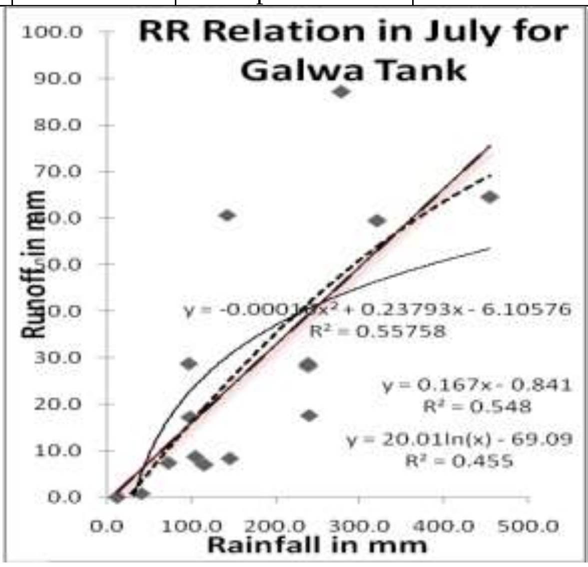
	Total Rainfall (in mm)				Corresponding Runoff Generated (in mm)			
Year	July	Aug	Sept.	Monsoon	July	August	Sept.	Monsoon
1996	145.90	217.00	100.40	463.30	8.29	82.25	26.64	117.18
1997	238.80	151.60	65.00	455.40	28.68	19.65	1.83	50.16
1998	143.00	61.00	76.00	280.00	60.60	8.00	0.00	68.60
1999	278.80	152.20	59.20	490.20	87.16	48.95	0.00	136.11
2000	455.60	124.60	28.40	608.60	64.48	29.65	0.00	94.12
2001	321.10	141.10	0.00	462.20	59.39	8.74	0.00	68.13
2002	12.00	94.80	61.00	167.80	0.00	7.23	0.00	7.23
2003	97.20	141.40	80.00	318.60	28.68	10.17	13.70	52.55
2004	41.00	419.00	18.00	478.00	0.79	92.00	0.00	92.79
2005	239.00	18.00	153.00	410.00	28.17	0.00	0.00	28.17
2006	240.00	136.00	10.50	386.50	17.63	14.24	0.00	31.87
2007	99.00	176.00	91.00	366.00	17.18	0.00	0.99	18.17
2008	105.00	88.00	114.00	307.00	8.64	1.04	6.22	15.90
2009	73.00	102.00	19.00	194.00	7.36	1.38	0.00	8.74
2010	116.00	271.00	95.00	482.00	6.99	47.86	16.07	70.92

Table 2:- Statistical Parameters for Total Rainfall and Corresponding Runoff Generated

Sr. No.	Statistical Parameter	Total Rainfall (in mm)				Runoff Generated (in mm)			
		July	August	September	Monsoon	July	August	September	Monsoon
1	Max	455.6	419.0	153.0	608.6	87.2	92.0	26.6	136.1
2	Min	12.0	18.0	0.0	167.8	0.0	0.0	0.0	7.2
3	Range	443.6	401.0	153.0	440.8	87.2	92.0	26.6	128.9
4	Average	173.7	152.9	64.7	391.3	28.3	24.7	4.4	57.4
5	Median	143.0	141.1	65.0	410.0	17.6	10.2	0.0	52.6
6	Variance	14302.2	9113.0	1873.4	14409.7	732.8	892.8	65.2	1608.8
7	St. Dev.	119.6	95.5	43.3	120.0	27.1	29.9	8.1	40.1
8	Var. Coeff.	0.7	0.6	0.7	0.3	1.0	1.2	1.9	0.7
9	Skewness	0.9	1.6	0.2	-0.4	1.0	1.4	2.0	0.5

Table 3:- Various Empirical Relations between Rainfall and Runoff

Sr. No.	Month	Type of Relation	Relationship	Correlation Coeff.	Determination Coeff.
1	July	Parabolic	Y= -0.00016 (x2) + 0.23793 (x) - 6.105	0.747	0.558
		Linear	Y= 0.1676 (x) - 0.8413	0.740	0.548
		Logarithmic	Y= 20.02 log (x) - 69.098	0.677	0.458
2	August	Parabolic	Y= 0.00007 (x2) + 0.2276 (x) - 12.17696	0.820	0.673
		Linear	Y= 0.2567 (x) - 14.507	0.820	0.673
		Logarithmic	Y= 28.07 log (x) - 111.01	0.669	0.448
3	September	Parabolic	Y= -0.00109 (x2) + 0.2258 (x) - 3.79	0.490	0.24
		Linear	Y= 0.0755 (x) - 0.5231	0.405	0.164
4	Monsoon	Parabolic	Y= 0.00012 (x2) + 0.1551 (x) - 22.554	0.723	0.523
		Linear	Y= 0.2411 (x) - 36.98	0.721	0.52
		Logarithmic	Y= 78.071 log (x) - 404.5	0.697	0.486
		Exponential	Y= 3.644 $e^{0.006 x}$	0.807	0.652



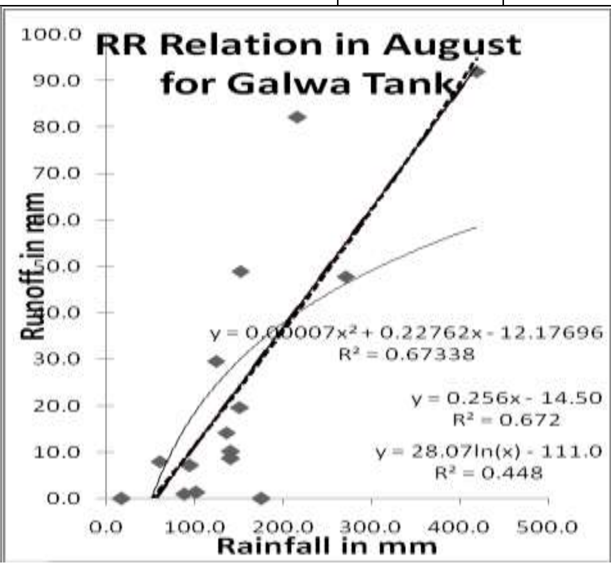
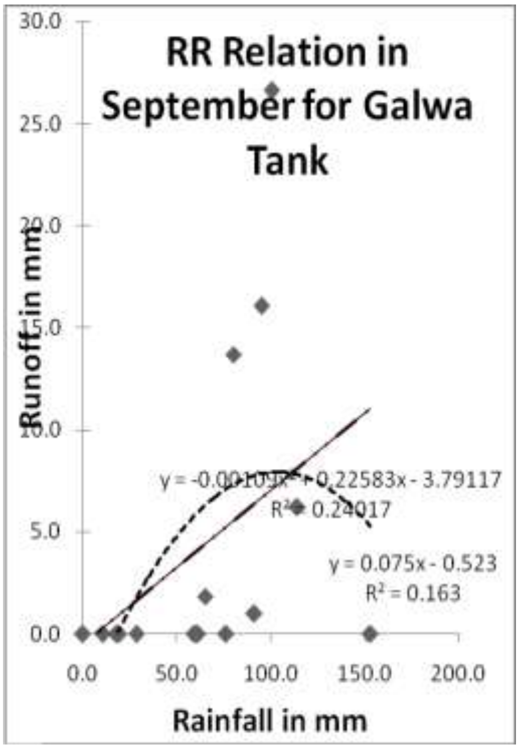


Figure-3 Rainfall Runoff Relation for July **Figure-4 Rainfall Runoff Relation for August**



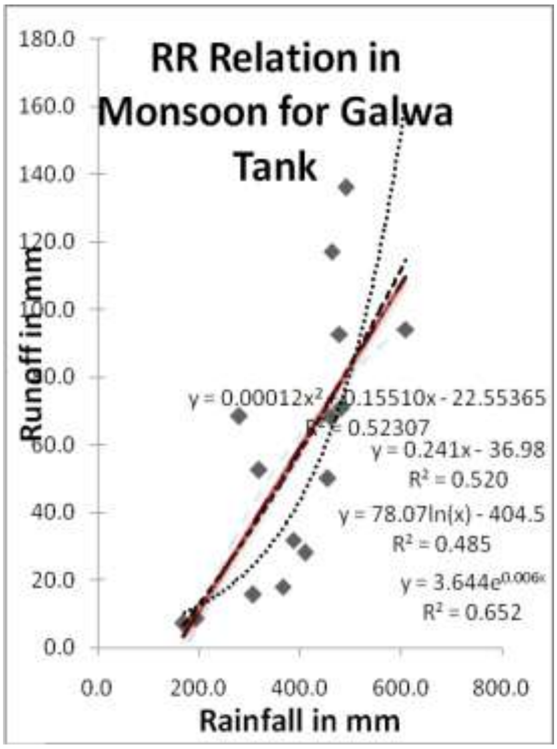


Figure-5 Rainfall Runoff Relation for September Figure-6 Rainfall Runoff Relation for Monsoon

VII. RESULTS AND DISCUSSIONS

Rainfall Contribution in the Galwa Catchment is maximum from Nainwa rain-gauge station. Variation of the total rainfall from the mean rainfall is minimum in September and maximum in July. The variation in total runoff is minimum in September and maximum in August. Rainfall and corresponding Runoff generated from the catchment are positively skewed in each month while the monsoon rainfall is skewed negatively. The parabolic, linear and logarithmic correlations between the rainfall and corresponding runoff with their correlation coefficients has been developed using regression analysis, results are shown in the Figure-3 to Figure-6.

Parabolic rainfall-runoff empirical relation gives highest coefficient of correlation and determination in each time period, secondly linear and then logarithmic as tabulated in Table-3.

Exponential rainfall-runoff empirical relation could not be achieved in the catchment except for monsoon period.

VIII CONCLUSION

Only three types of regressions i.e. Parabolic, Linear or Logarithmic can be developed in Galwa Catchment. Parabolic Rainfall-Runoff Regression Model is most suitable in the Galwa Catchment for different time periods, which can be used for computing runoff generated from the catchment or its part in the rainy days.

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