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"DEVELOPMENT OF STAGE DISHARGE RELATIONSHIP AT BARMAN STATION ON NARMADA RIVER"

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Abstract- NARMADA is the largest west flowing peninsular river, ranks seventh in discharge. A number of dams have been constructed on the river and its tributaries. As such, a need arise to regulate the reservoir for releasing the adequate water in the river throughout the year. River discharge is an important hydrological parameter in any water resource management which requires collection of daily discharge data. This is mainly in the form of forecasting or estimating the magnitude of hydrological variable like rainfall or runoff. But, direct measurement of daily discharge in number of points in all the streams is not only prohibitive in cost, but also very much time consuming, which can be best achieved by developing stage discharge relationship. Prediction of stage discharge relation is of immense importance for reliable planning, design and management of most of the water resource project.

The present study was carried out to develop a river stage and discharge modeling using Artificial Neural Network (ANN) and Linear Regression. From the literature and the developed models, it is clear that ANN models for river stage discharge are more efficient than the other traditional methods. Ten ANN models were developed with two hidden layers and 10, 11, 12, 13, 14, 15, 16, 17, 18 and 19 numbers of neurons respectively. The developed models were trained, tested and validated on the data sets of Barman station on Narmada River in Madhya Pradesh. The value of Coefficient of Correlation and the value of Coefficient of Determination obtained from ANN were compared with those obtained by Linear Regression. Comparing observed data and the estimated data through developed ANN models, it has been proved that the developed ANN models show good results than the traditional models.

1. INTRODUCTION

General

Management of water resource requires input from hydrological studies. This is mainly in the form of estimation or forecasting of the magnitude of hydrological variable like rainfall and runoff using past experience. Such forecast provides a warning of the flood extremes or draught condition and help to optimize the operation of systems like reservoirs and power plants.

A large number of hydrological analyses require mapping and modeling of non-linear system data. Traditionally such mapping is performed with the help of conceptual models or statistical tools such as regression and curve fitting. However, when the underlying physical laws are unknown or not precisely known, it is rather difficult to model the phenomenon adequately. Attempts have been made to develop a technique that does not require algorithm or rule development and thus reduces the complexity of the software. One such technique is known as Neurocomputing and the networks laid out with many parallel processing elements to do this Neurocomputing are known as artificial neural network. Flood forecasting is vital for reducing the damage and loss of life caused by flooding.

Keeping the above scenario in mind, the present study was taken up in developing a neural network model for the river discharge using the past river stage and discharge as inputs. The model was trained using Feed Forward Back Propagation algorithm. ANN is the most widely accepted machine learning method and is widely used in areas of water related research such as rainfall-runoff modeling, prediction of discharge etc.

Stage Discharge

The parameters, stage and discharge, describe processes that develop in time and generally exhibit random fluctuations such that their values can be predicted only in a statistical sense. Historical data are used to determine the properties of the time series. For obvious reasons, the longer the time series, the better are the estimates of parameters describing the process.

Discharge cannot be measured directly. It is functionally dependent on the upon river geometry as well as on flow conditions prevailing at the desired time. However, water surface elevation, i.e., stage can be measured directly. When discrete or continuous recording of stage against time is plotted, a stage hydrograph is available. If functional relationship between stage and discharge at some location in a river can be established, then discharge can be estimated from it. The functional relationship or a plot between stage and discharge is expressed as a RATING CURVE or STAGE DISCHARGE RELATIONSHIP. In hydrology, a rating curve is a graph of discharge versus stage for a given point on the stream, usually at gauging station. The development of rating curve involves two steps. In the first step, a relationship between stage and discharge is established by measuring the stage and corresponding discharge in the river. And in the second part, stage of the river is measured and discharge is calculated using the relationship established in the first step. If the stage discharge relationship doesn't change with time, it is called permanent control. If the relationship does change, it is called shifting control. Shifting control is due to erosion or deposition of sediment at the stage measurement site.

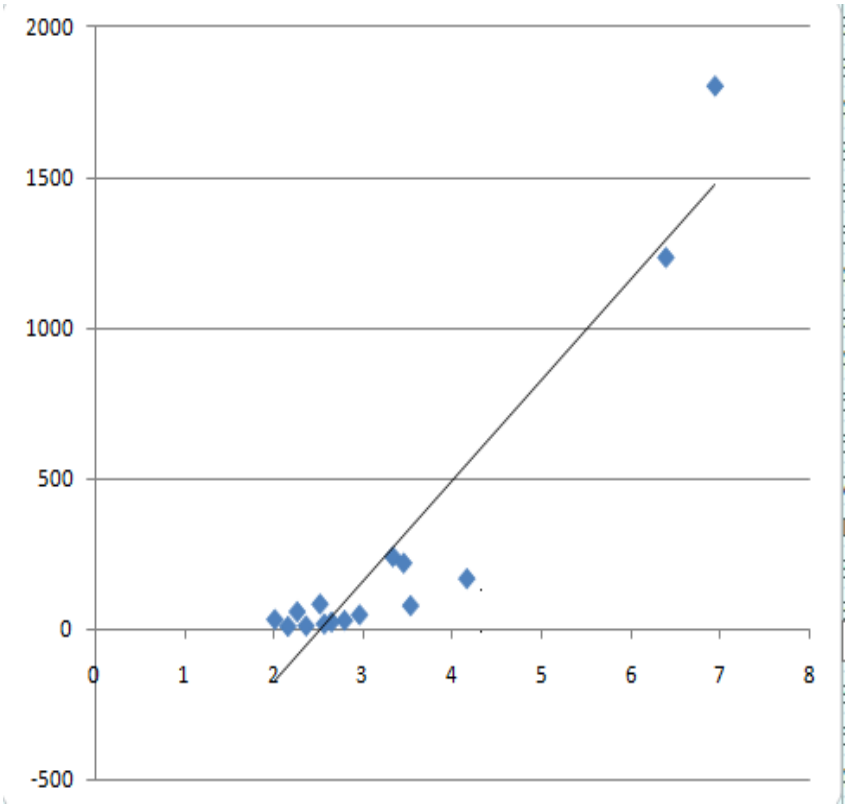

Fig.1: Rating Curve

Artificial Neural Network

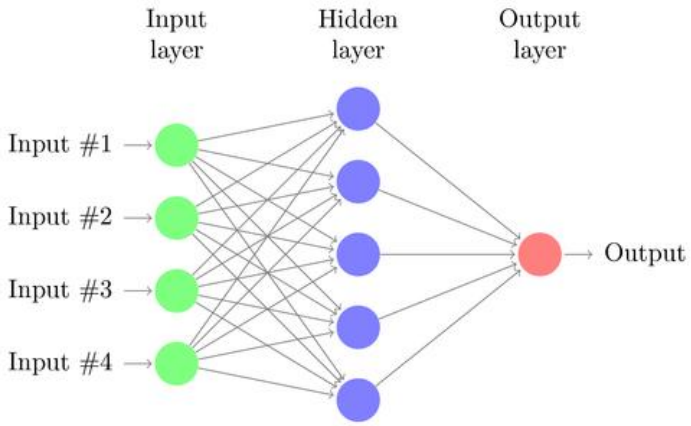

Fig.2: General Architecture of ARTIFICIAL NEURAL NETWORK

ANN models have been used successfully to model complex non linear input output relationships in an extremely interdisciplinary field. The natural behavior of hydrological processes is appropriate for the application of ANN method. Several studies indicate that ANN have proven to be potentially useful tool in hydrological modeling such as for modeling of rainfall-runoff processes, water quality prediction, operation of reservoir system etc.

Artificial Neural Network (ANN) can be defined as a data processing system consisting of large number of simple, highly interconnected processing elements (artificial neurons) in an architecture inspired by the structure of the cerebral cortex of the brain. A Neural Network is an artificial intelligence technique that mimics the function of a human brain. The ANN tries to mimic the functioning of human brain, which contains billions of neurons and their interconnection. The architecture of ANN is designed by weights between neurons, a transfer function that generates the output in a neuron. The weights can be thought of as connection strength between neurons which are activated during training process. The objective of ANN is to process the information in a way that is previously trained, to generate satisfactory results. Neural Network can learn from experience, generalize from previous example to new ones and abstract essential characteristics from inputs containing irrelevant data. The main control parameter of ANN model is interneuron connection strength, also known as weights. In all cases, output layer had only one neuron that is discharge. The ANN technology is an alternate computational approach inspired by studies of the brain and nervous system. The main theme of ANN focuses on modeling of a brain as a parallel computational device for various tasks that were performed poorly by traditional serial computers. ANNs have number of interconnected processing elements that usually operate in parallel and are configured in regular architectures. The collective behavior of ANN, like a human brain, demonstrates the ability to learn, recall and generalize from training patterns or data, the advantage of neural networks is they are capable of modeling linear and non linear systems.

Network Function

The word “network” in the term Artificial Neural Network refers to the interconnection between the neurons in different layers in each system. An ANN is typically defined by three types of parameters:
1. The interconnection pattern between the different layers of neurons.
2. The learning process for updating the weights of the interconnection.
3. The activation function that converts a neuron’s weighted input to its output activation.

Mathematically, a neuron’s network function f(x) is defined as the composition of other functions $g_i(x)$, which can further be defined as a composition of other functions. This can be conveniently represented as a network structure, with arrows depicting the dependencies between variables.

Learning Paradigms

There are three major learning paradigms; these are Supervised Learning, Unsupervised Learning and Reinforcement Learning.

Supervised Learning:
In Supervised Learning, we are given a set of example pair (x, y), x € X, y € Y and the aim is to find a function F: X → Y that matches the example. In other words, we wish to infer the mapping implied by the data.
The supervised learning is applicable in Pattern Recognition (or classification) and Regression. It is also applied to Sequential Data (for speech and gesture recognition), which can be thought of as learning with a teacher.

Unsupervised Learning:
Unsupervised Learning is the machine learning task of inferring a function to describe hidden structure from unlabelled data. It is related to the problems of density estimation in statistics. More application includes Clustering, Estimation of Statistical Distribution, Compression and filtering.

Reinforcement Learning:
In reinforcement learning, data x are usually not given, but generated by an agent's interaction with the environment. At each point in time t, the agent performs an action y_{et}, and the environment generates an observation x_t, according to some dynamics which are usually unknown.
Reinforcement learning paradigm can be applied to Control Problems, Games and other Sequential decision making tasks.

Applications

The utility of Artificial Neural Network models lies in the fact that they can be used to develop a function from given observations. This is used in the application where the complexity of data makes the design of such function by hand impractical.

Real Life Applications:

- Function Approximation or Regression Analysis including time series prediction and Fitness Approximation.
- Classification including pattern and sequence recognition.
- Data Processing including filtering, clustering and blind source separation.
- Robotics
- Control including computer numerical control.

Application areas include the system identification and control (like natural resource

management), Game Playing (chess, poker), Pattern Recognition (face identification, radar system), Sequence Recognition (hand written text recognition), Medical Diagnosis, Financial Applications, Visualization and E-mail spam filtering.

An ANN based hybrid lung cancer detection system named HLND improves the accuracy of diagnosis and the speed of lung cancer radiology. The models do not depend on assumptions about correlation of different variables.

MATLAB

MATLAB is a high level language and interactive environment for numerical computation, visualization and programming. Using MATLAB, you can analyze data, develop algorithms, and create models and applications. The language tools and built in math functions enable you to explore multiple approaches and reach a solution faster than a spreadsheets or traditional programming languages such as C/C^{++} or java. You can use MATLAB for a range of applications including, signal processing and communication, image and video processing, control system, test and measurements, computational finance and computational biology. More than a millions engineers and scientists in industry and academia use MATLAB, the language of technical computing.

- Mathematics

Linear algebra, basic statistics, differentiation and integration, Fourier transforms and other mathematics.

- Graphics

Two and three dimensional plots, images, animation, visualization.

- Data import and export

Text files, spreadsheets and other file format, bi data, web access.

- Advanced software development

Object oriented programming, code performance, unit testing.

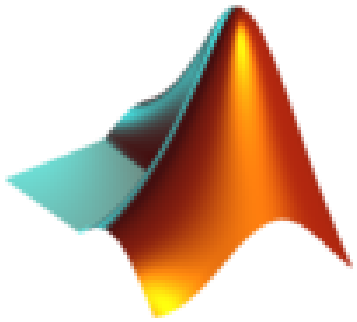

Fig.3: Mat lab Log

Linear Regression

Linear regression, in statistics, is an approach to model the relationship between a dependent variable and an independent variable. When only one independent variable is taken into account, it is called Simple Linear Regression, and if more than one independent variable is taken, it is called Multiple Linear Regression. Linear regression was the first type of regression analysis to be studied, and to be used in practical applications. Because, models which depends linearly on their unknown parameters to easier to fit than the models which are non-linearly dependent.

Linear regression models are often fitted using the least square approach, but they may also b fitted by other ways.

Linear Regression might be used to identify the strength of the effect that the independent variables have on dependent variable.

Also, Regression Analysis predicts trends and future values.

II STUDY AREA DATA COLLECTION

STUDY AREA

Fig. 4&5: Location of BARMAN in MADHYA PRADESH, INDIA

Barman is the town on the banks of NARMADA River in NARSINGHPUR district of MADHYA PRADESH in INDIA. BARMAN is the holy place where we will find many temples to visit. Near to BARMAN town is the RAGMARG national highway, where you can get transportation for big cities. It is the education centre for surrounding villages.

Country	INDIA
State	MADHYA PRADESH
District	NARSINGHPUR
Population	7000
Language	Hindi
Pin code	487330
Vehicle registration number	MP49
Telephone code	07793
Nearest city	NARSINGHPUR
Literacy	60%
Climate	Normal as per season

Table No.1: General Characteristics of BARMAN

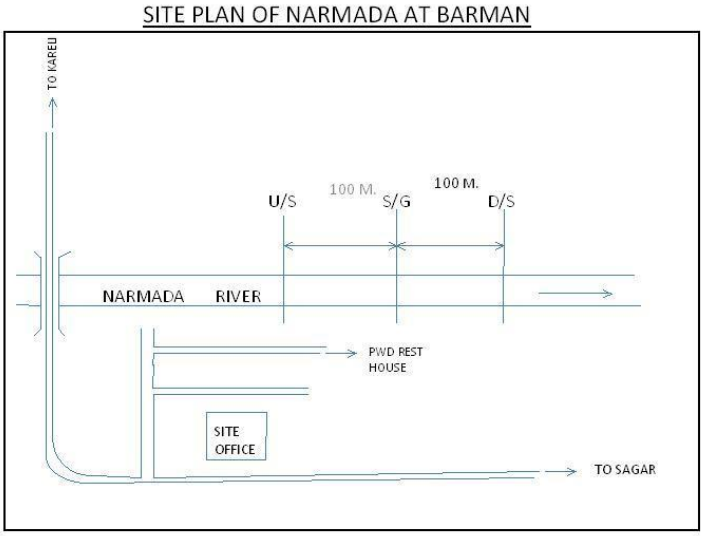

Fig.6: Site Plan at BARMAN

DATA COLLECTION

The daily stage-discharge data for barman station located on NARMADA River was collected from CENTRAL WATER COMMISSION department in GANDHINAGAR ranging from 20/11/1971 to 31/05/2013.

III METHODOLOGY

General

Stage and Discharge data of the section at Barman station is available since October 1971, up to May 2013. Hence, we have daily stage discharge data or roughly 42 years. Monthly average stage discharge was calculated, out of which, 70% of the data is used for developing the model and rest 30% of data is used for validating the model. The model is then trained using Levenberg Marquardt back propagation. By training, we can get the Mean Square Error values and Regression values for training, validation and testing.

Mean Square Error is the average squared difference between outputs and targets. Lower values are best. Zero means no error.

Regression values measure the correlation between outputs and targets. An R value of 1 means close relationship and R value of 0 means random relationship.

Linear Regression Analysis was then carried out using the average monthly river stage discharge data. Finally, the mean square error value and the regression values obtained from both ANN and Linear Regression was compared.

4.2 Procedure for developing Stage Discharge relation by Artificial Neural Network in MATLAB:

1. Import the data from excel sheet in the workspace window of data.
2. Give command “nftool” in the command window of MATLAB.
3. This command opens the Neural Network Fitting Tool window, which gives introduction about the fitting problems and a general architect of a Neural Network. Click next.
4. Window for selecting the data appears on the screen, where we have to get the Input Data as well as Target Data from the workspace. Click next.
5. Validation and Test data window appears on screen. Here we have to divide the data as 70% for training and rest 30% for testing and validating. Click next.

6. Network architecture window appears which shows the architecture of the network. Also here we can set the number of neurons so that the network can perform well.

7. Next, train the network to fit the inputs and targets using Levenberg-Marquardt Back propagation.

8. Once the training is completed, regression plots are generated which shows the nature of working of that particular network mode

9. Similarly, the steps are repeated for different models till we obtain the least mean error for the network.

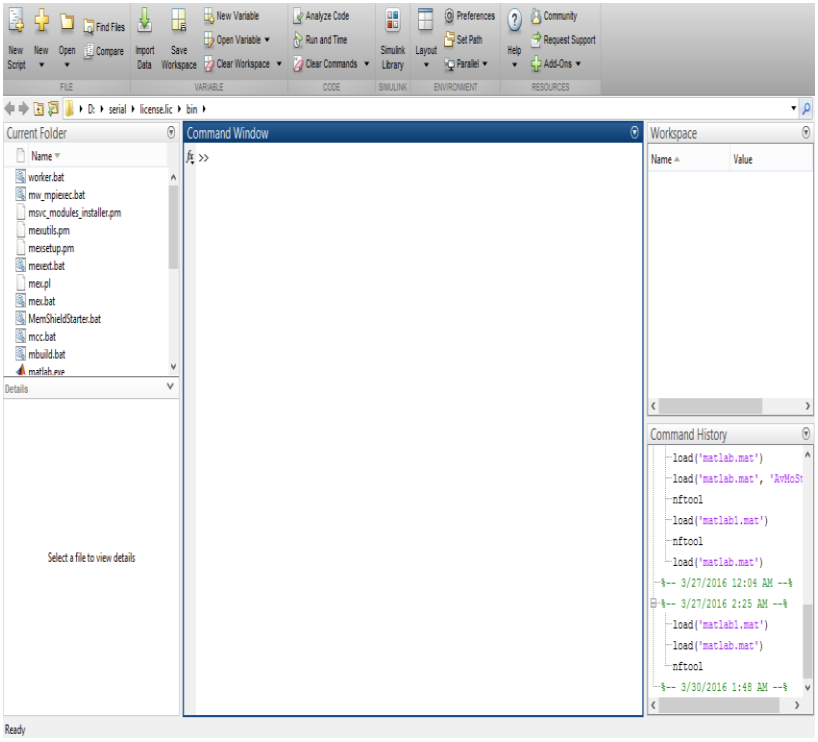

Fig. 7 Main window of Matlab

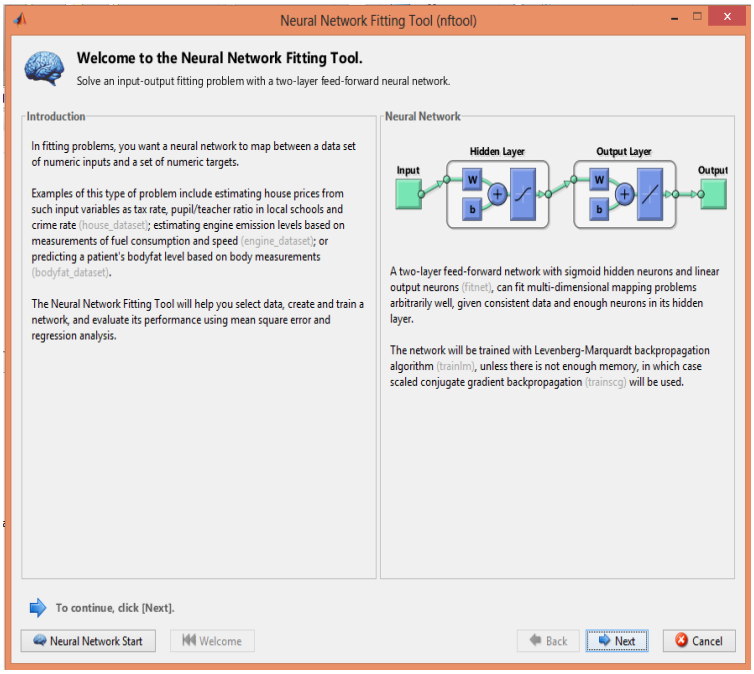

Fig.8: Neural Network Fitting Tool Window

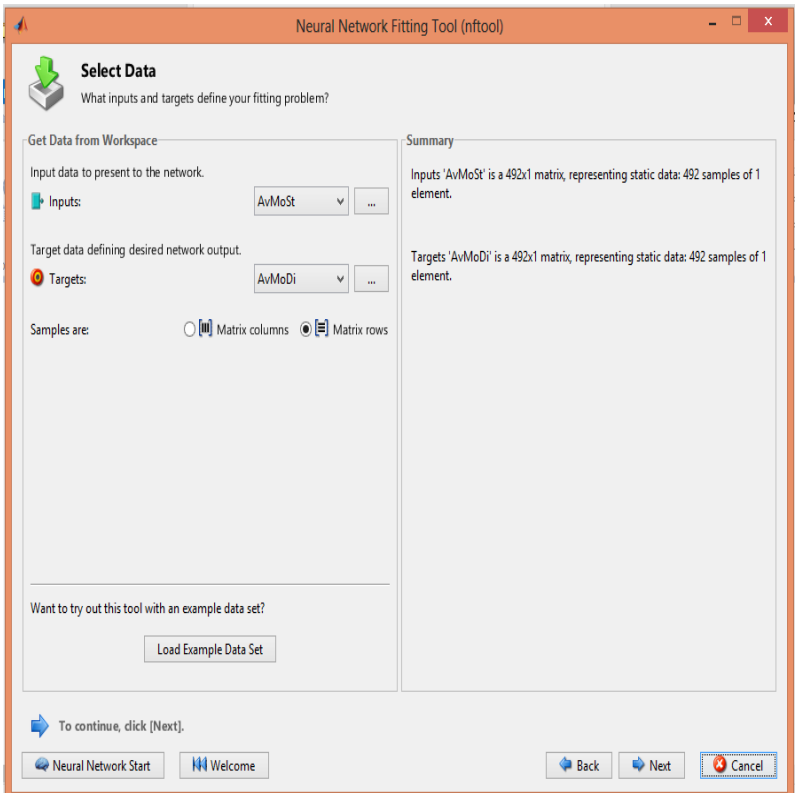

Fig.9: Window for selecting Input and Target Data

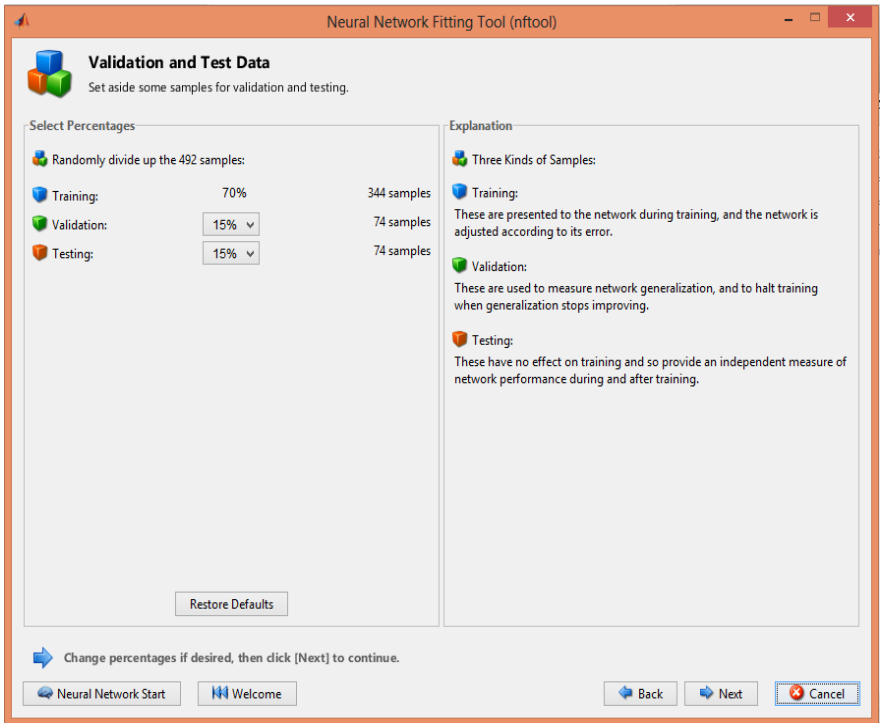

Fig.10: Validation and Test data window

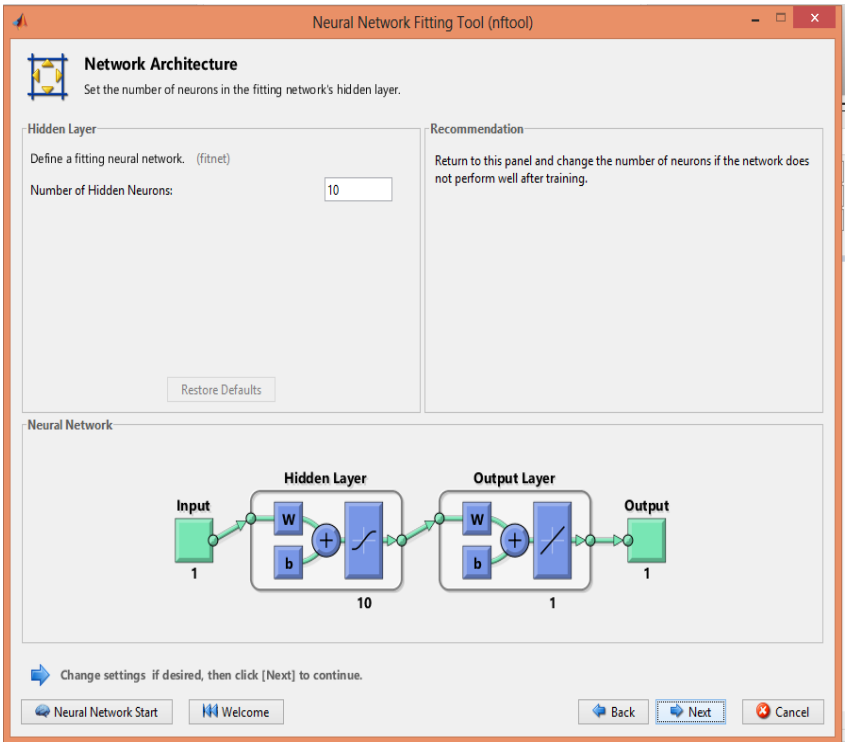

Fig.11: Network Architecture Window

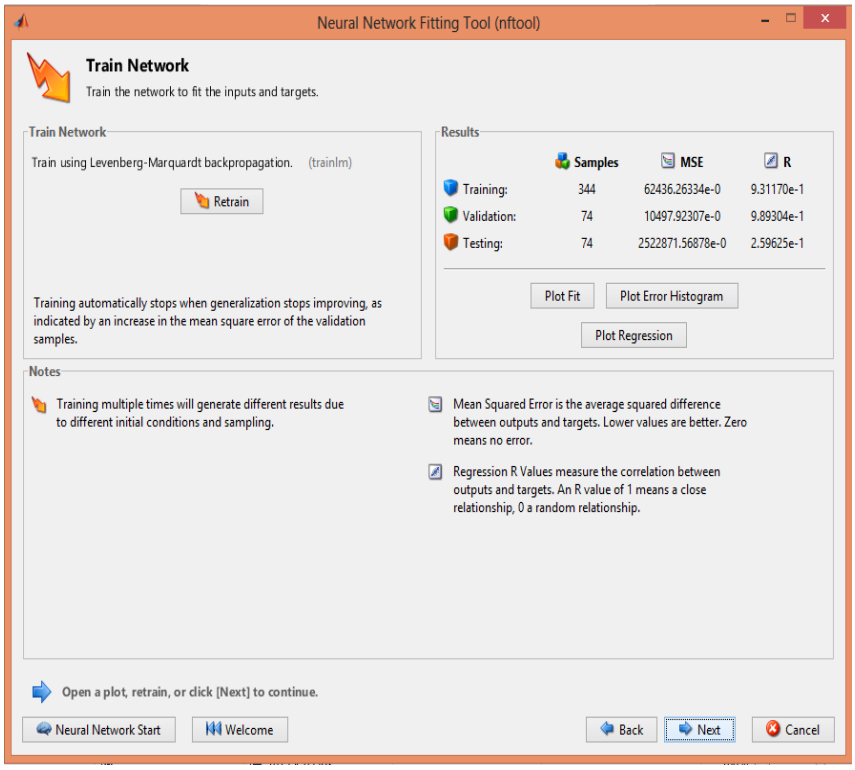

Fig.12: Window for Training the Network

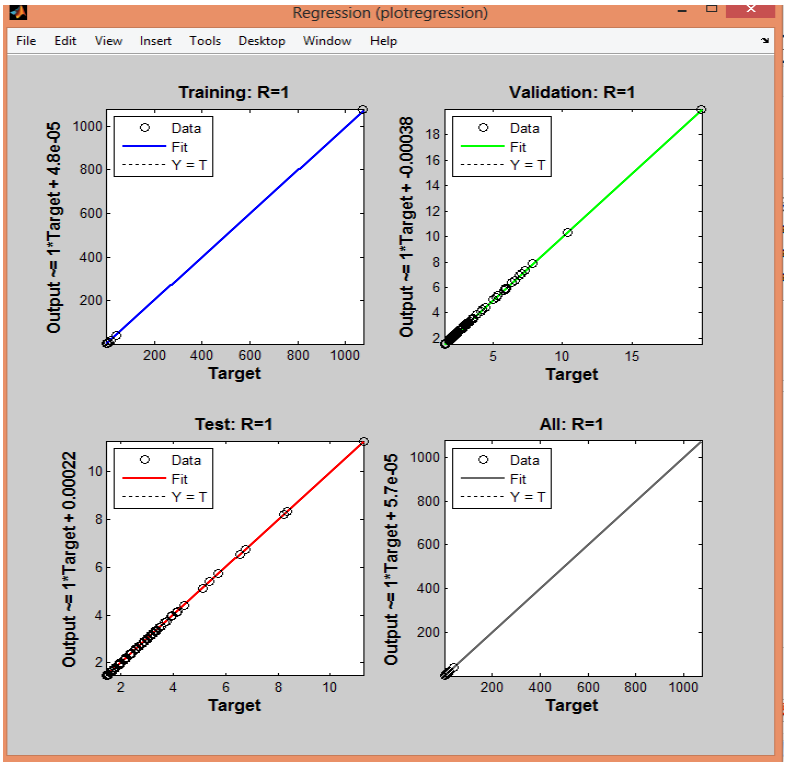

Fig.13: Window showing Regression Plot for the Network

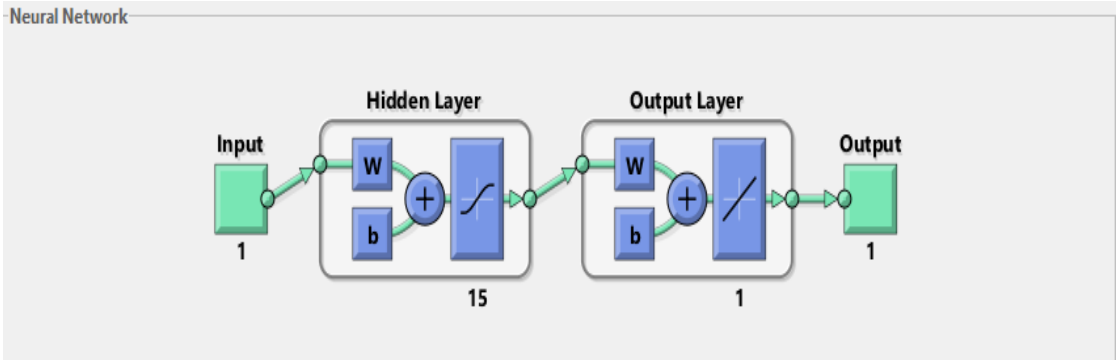

Fig.14: ANN Architecture

LINEAR REGRESSION ANALYSIS:

Steps to be followed or carrying out Linear Regression:

1. Open the excel program. Copy and paste the monthly average river stage and discharge data in two different columns in a blank worksheet.

2. Create a scatter chart with stage on x-axis and discharge on y-axis. Obtain the value of R^2 and the equation on chart area by adding trendlines.

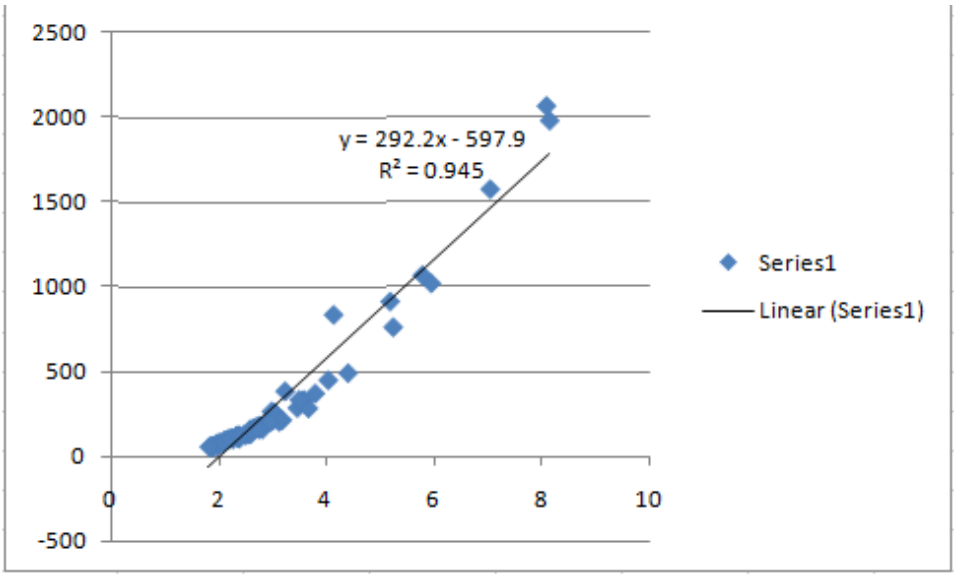

Fig.15: Scatter Plot of Stage and Discharge

3. Now, select the Data menu, select the Data Analysis command on the Analysis tab. A popup box will appear. Scroll down and select the Regression. Click Ok.

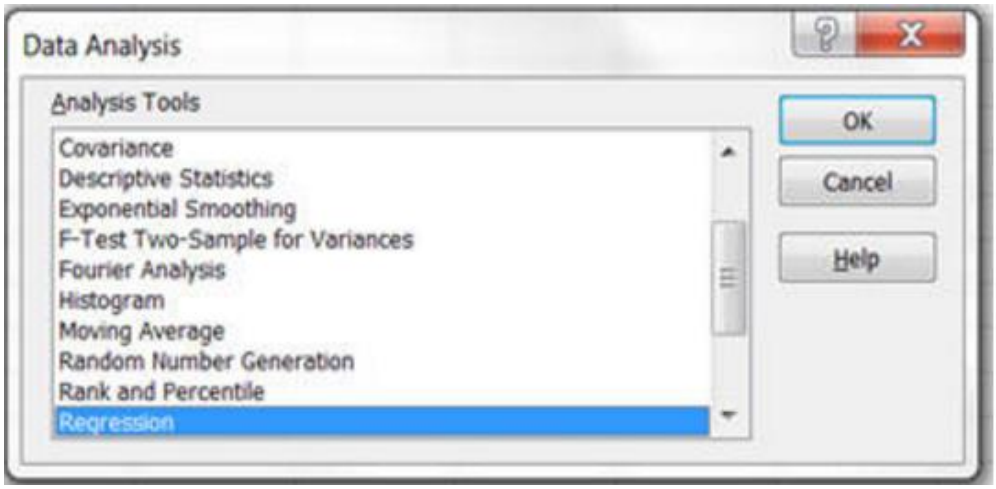

Fig.16: Regression Analysis Toolbox

4. The Regression wizard will be displayed. In the Input Y range, select all the values of Discharge. In the input X range, select all the values of stage.

5. Now, in the output range, select a cell from which you want to begin regression output. Verify you have checks in the remaining boxes.

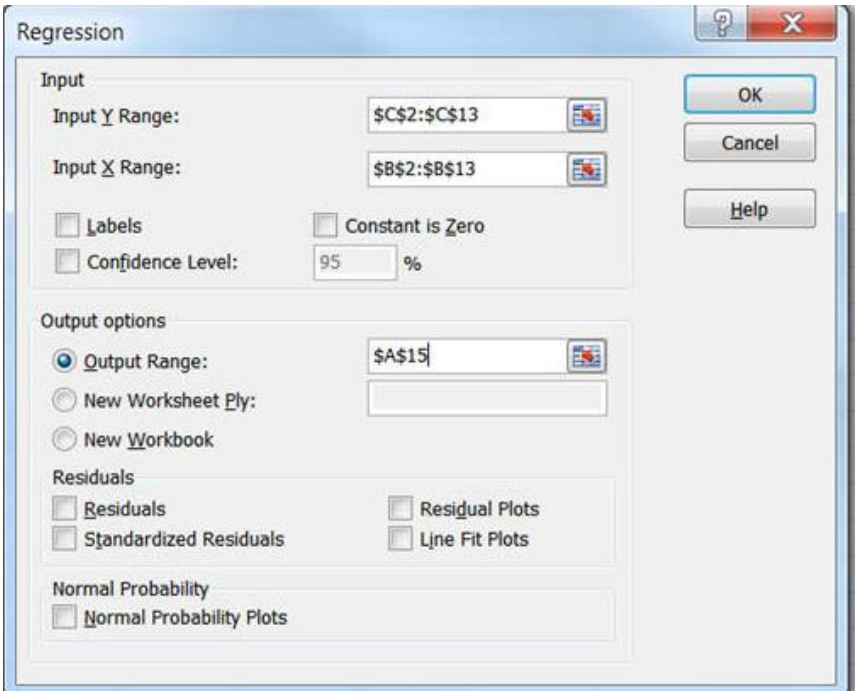

Fig.17: Window of selecting input range of variables

6. Click OK to run the regression. Verify your outputs that appear.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.97219296
R Square	0.94515915
Adjusted R Square	0.94435267
Standard Error	94.7242903
Observations	70

	df	*SS*	*MS*	*F*	*gnificance F*
Regression	1	10515559.9	10515560	1171.952	1.34E-44
Residual	68	610143.0002	8972.691		
Total	69	11125702.9			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	-597.97323	28.62325492	-20.8912	2.66E-31	-655.09	-540.856	-655.09	-540.856
X Variable 1	292.220035	8.536014585	34.23378	1.34E-44	275.1867	309.2534	275.1867	309.2534

Fig.18: Summary Output of Regression Analysis

A scatter chart was prepared prior to running the regression in order to pre- access the relationship between two variables. The value of R^2 from the scatter chart should match with that obtained from regression analysis. Also, the value of X variable and the intercept should match.

IV RESULTS AND DISCUSSION

The database compiled represents average monthly discharge data of roughly 40 years of the present study area. In this seminar report, 70% of data is used for training the model and rest 30% is used for testing the model. The goal of the training phase is to reach an optimal solution based on some performance measurements such as coefficient of determination and Mean Square Error values. Training automatically stops when generalization stops improving. Therefore, required model was developed in three phases: training phase (calibration phase), validation phase and testing phase. In the training phase, larger part of database was used to train the network, and rest of the data was used for validation and testing phase.

Sr. No.	Model	Train function	Input	No. of Hidden Layers	Output	Archi.	No. of Neurons	R Value
1	ANN1	Trainlm	1	2	1	FFBP	10	0.6615
2	ANN2	Trainlm	1	2	1	FFBP	11	0.9539
3	AAN3	Trainlm	1	2	1	FFBP	12	0.9784
4	ANN4	Trainlm	1	2	1	FFBP	13	1
5	ANN5	Trainlm	1	2	1	FFBP	14	0.8357
6	ANN6	Trainlm	1	2	1	FFBP	15	0.9348
7	ANN7	Trainlm	1	2	1	FFBP	16	0.5313
8	ANN8	Trainlm	1	2	1	FFBP	17	0.9901
9	ANN9	Trainlm	1	2	1	FFBP	18	0.9863
10	ANN10	Trainlm	1	2	1	FFBP	19	0.9443

TABLE 3: Details of ANN models

Regression values for ANA4, ANN8 and ANN9 are good enough, as it is closer to 1. Hence, this model is to be considered for further study.

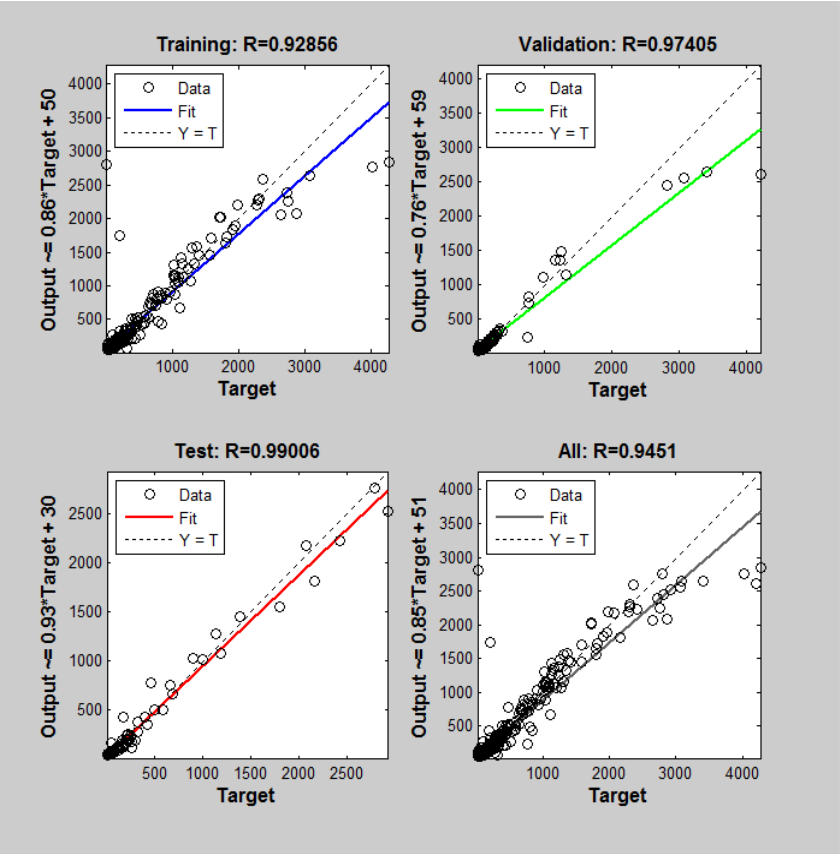

Fig.19: Regression plot for ANN8

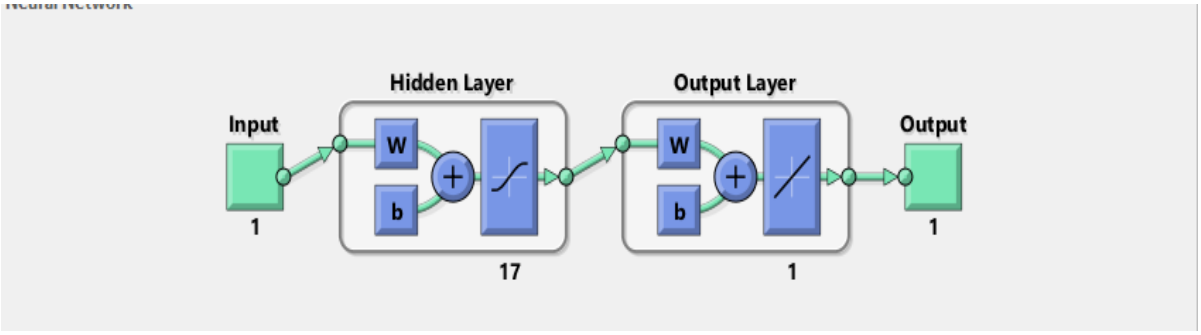

Fig.20: Neural Architect of ANN8

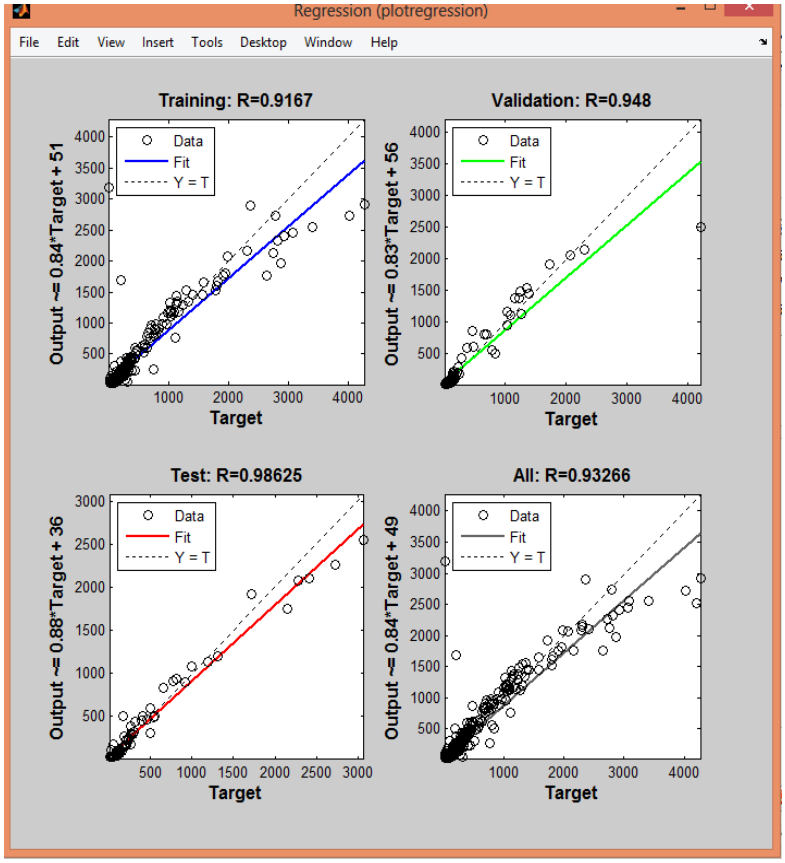

Fig.21: Regression Plot for ANN9

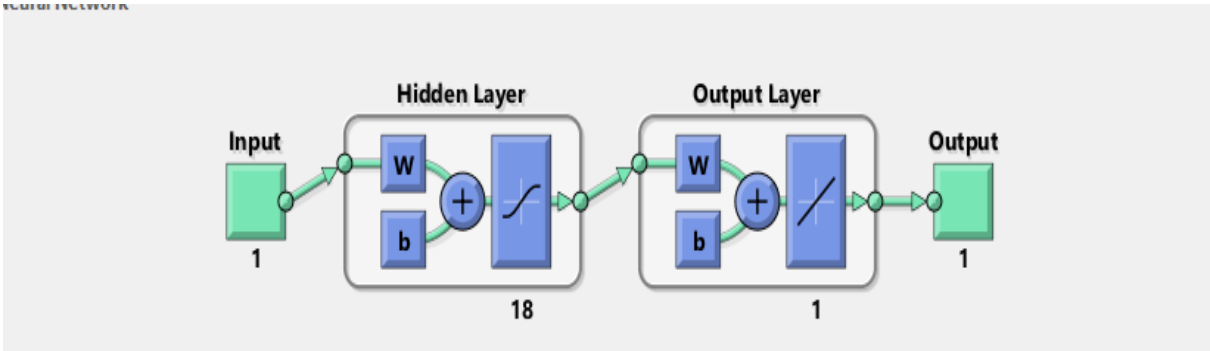

Fig.22: Neural Architect of ANN9

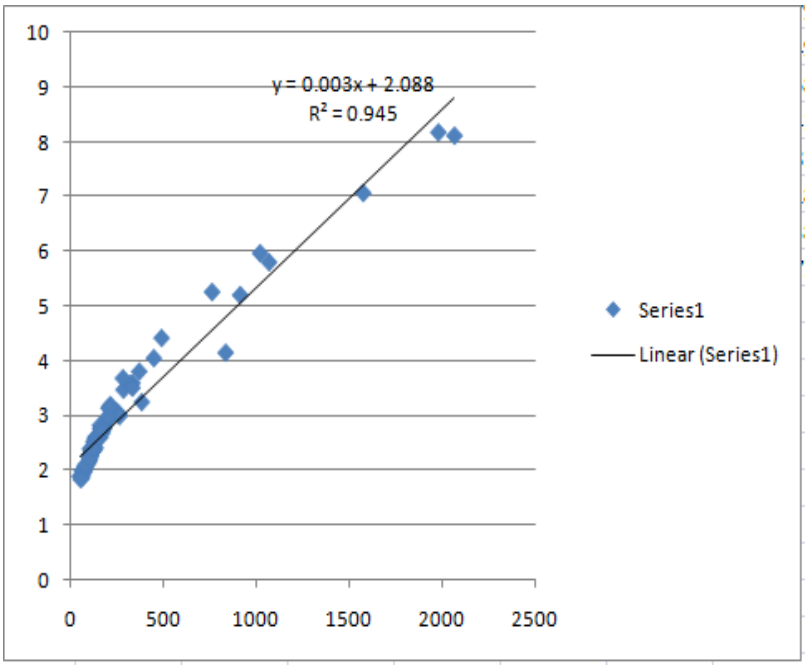

Fig.23: Comparison of Observed and Predicted Discharge for ANN4

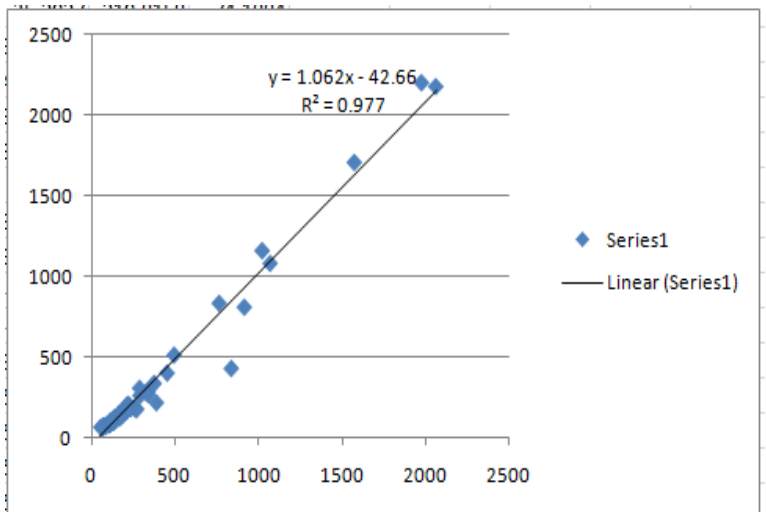

Fig.24: Comparison of Observed and Predicted Discharge of ANN8

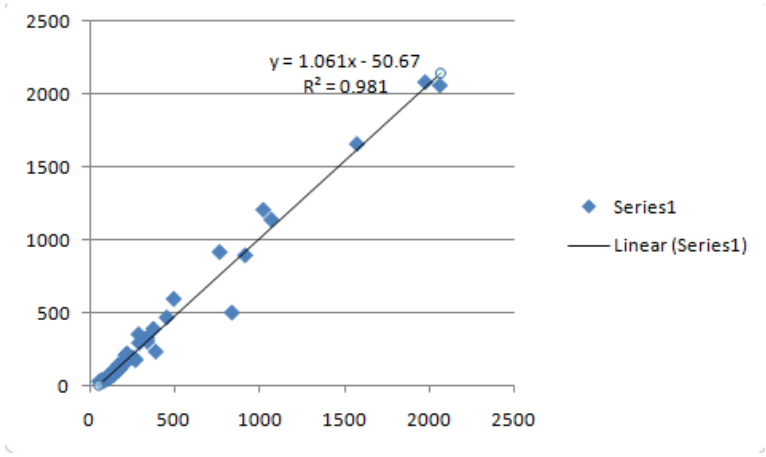

Fig.25: Comparison of Observed and Predicted Discharge of ANN9

Model	Coefficient of Correlation (R)	Coefficient of Determination (R^2)
ANN4	1	0.945
ANN8	0.9901	0.977
ANN9	0.9863	0.981
Linear Regression Model	0.972	0.9452

TABLE 4: Comparison Result of Ann models and Linear Regression

From the graphs obtained from the data analysis of ANN, it can be seen that the values of ANN4 are falling closer to actual values. In the ANN, the number of iteration makes the model to become more accurate due to the more number of data. As ANN4 gives better result than other two models, it can be used as a model for this study.

V CONCLUSION

THE Artificial Neural Network (ANN) shows good capability to model hydrological process. For this study, ANN4 is the best model. They are useful and powerful tools to handle complex problems. In this study, the result obtained shows clearly that the artificial neural networks are capable of modeling stage discharge relationship in the region where gauge level is irregular, thus confirming the general enhancement achieved by using artificial neural network in many other hydrological fields. The results indicate that artificial neural network is more suitable to predict stage discharge relationship than any other conventional methods. The ANN approach can provide a very useful and accurate tool to solve problem in water resource studies and management.

VI REFERENCES

- D. C. S. Bisht1, M. M. Raju2, M. C. Joshi3 (2010). "ANN based River Stage Discharge Modeling or Godavari River in India." Vol.14, No.3, 48–62

- A. Joorabchi†, H. Zhang† and M. Blumenstein‡ "Application of Artificial Neural Network in Flow Discharge Prediction for the Fitzroy River, Australia." Journal of Coastal Research, SI 50 (Proceedings of the 9th International Coastal Symposium), 287 – 291. Gold Coast, Australia, ISSN 0749.0208.

- Jinet Das1, Akshay Chaudhary2, "Analysis of River Flow Data to Develop Stage Discharge Relationship." IJRET: International Journal of Research in Engineering and Technology.

- ARUN GOEL "ANN Based Approach for Predicting Rating Curve of an Indian River." International Scholarly Research Network ISRN Civil Engineering Volume 2011, Article ID 291370, 4 pages doi:10.5402/2011/291370

- B. Bhattacharya, D.P Solomatine "Application of Artificial Neural Network in Stage Discharge Relationship." Proc. 4-th International Conference on Hydroinformatics, Iowa City, USA, July 2000.

- Mohammed Lateef Ahmed, Mohammed Sharif, and Mohammad Shakeel "Analysis of Discharge and Gauge Level Data at Old Railway Bridge, Delhi." Int'l Conference on Artificial Intelligence, Energy and Manufacturing Engineering (ICAEME'2014), June 9-10, 2014 Kuala Lumpur (Malaysia).

- S. RAID and J. MANIA "Rainfall Runoff Model Using An Artificial Neural Network Approach" Mathematical and Computer Modeling 40 (2004) 839-846, France.
- A. A. Adegbola, O. S. Olaniyan, "Computation Of River Discharge From A Formulated Rating Equation in Hydrological Catchments With Inadequate Data" Civil and Environmental Research, ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online) Vol.3, No.7, 2013.

- The ASCE Task Committee on Application of Artificial Neural Networks in Hydrology, Journal of Hydrologic Engineering, Vol.5, No.2, April, 2000.ASCE