"Development of Stage Discharge 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) . 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.

Key words: Narmada River, ANN

I. INTRODUCTION

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 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 back propagation algorithm.

II. 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 estimate 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. With the help of rating curve, a discharge hydrograph can be developed.

III. ARTIFICIAL NEURAL NETWORK

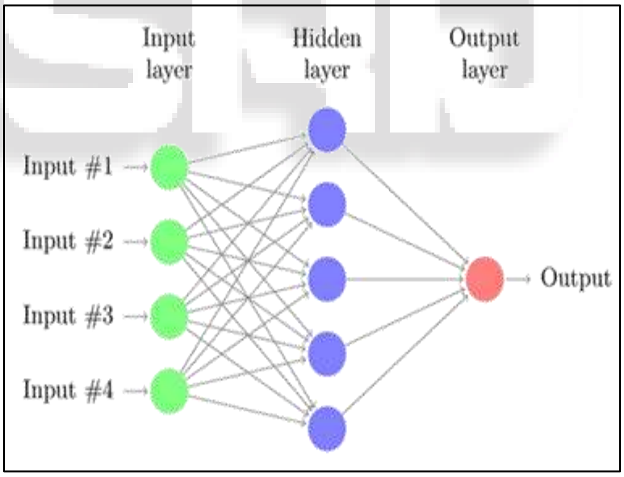

Fig. 1: General Architecture of ARTIFICIAL NEURAL NETWORK

The relationship of stage and discharge is highly complex and non-linear. It is one of the highly complex hydrological phenomena due to tremendous variability of watershed characteristics, precipitation patterns and the number of variables involved in the physical process. Hydrologists are often confronted with problems of prediction and estimation of discharge, runoff, precipitation, water stages and so on. Although many watersheds have been gauged to provide continuous records of stream flow, hydrologists are often faced with the situation where little or no information is available. In such instances, simulation models are often used to generate synthetic flows. These models are useful for the hydrologic and hydraulic planning and design as well as water resource management e.g.

hydropower generation, flood protection and irrigation. The existing popular models are considered as not flexible and they require many parameters. Obviously the models have their own weaknesses. Therefore, in the view of the importance of the relationship between stage-discharge, the present study was undertaken in order to develop the models which can be used to provide reliable and accurate estimates of discharge. 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, and learning laws, that define the relative importance of weights for input to a neuron. 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.

IV. STUDY AREA DATA COLLECTION

Fig. 2: 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 1: General Characteristics of Barman

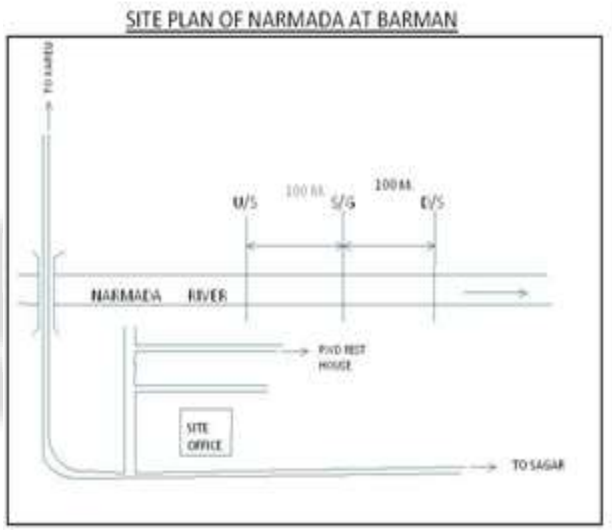

Fig. 3: Site Plan at BARMAN

V. 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.

VI. METHODOLOGY

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 were 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.

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.

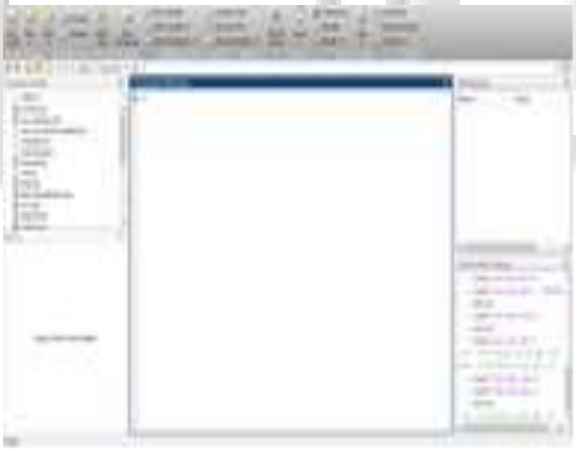

Fig. 4: Main window of Matlab

Fig. 5: Neural Network Fitting Tool Window

Fig. 6: Window for selecting Input and Target Data

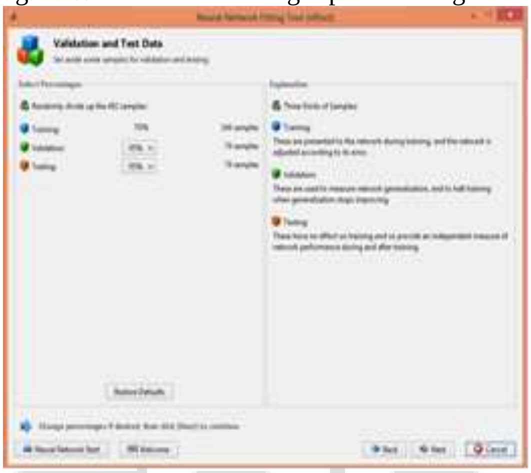

Fig. 7: Validation and Test data window

Fig. 8: Network Architecture Window

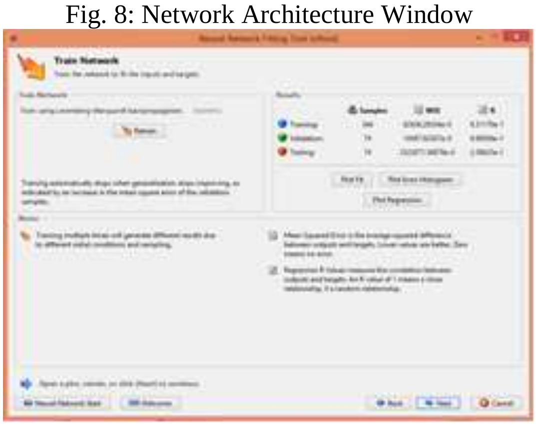

Fig. 9: Window for Training the Network

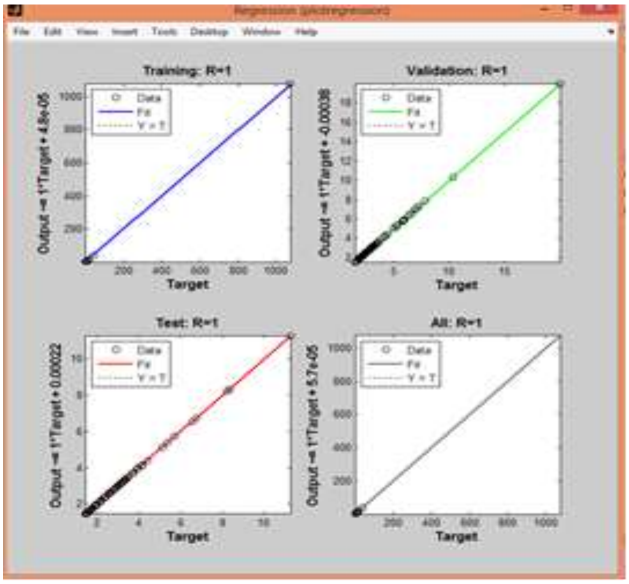

Fig. 10: Window showing Regression Plot for the Network

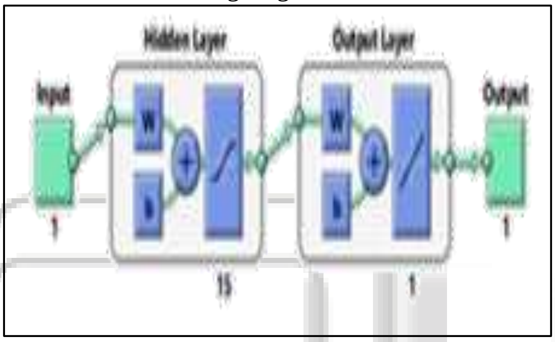

Fig. 11: ANN Architecture

VII. 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	No. of Neurons	R Value
1.	ANN1	10	0.6615
2.	ANN2	11	0.9539
3.	ANN3	12	0.9784
4.	ANN4	13	1
5.	ANN5	14	0.8357
6.	ANN6	15	0.9348
7.	ANN7	16	0.5313
8.	ANN8	17	0.9901
9.	ANN9	18	0.9863
10.	ANN10	19	0.9443

Table 2: Details of ANN Model

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.

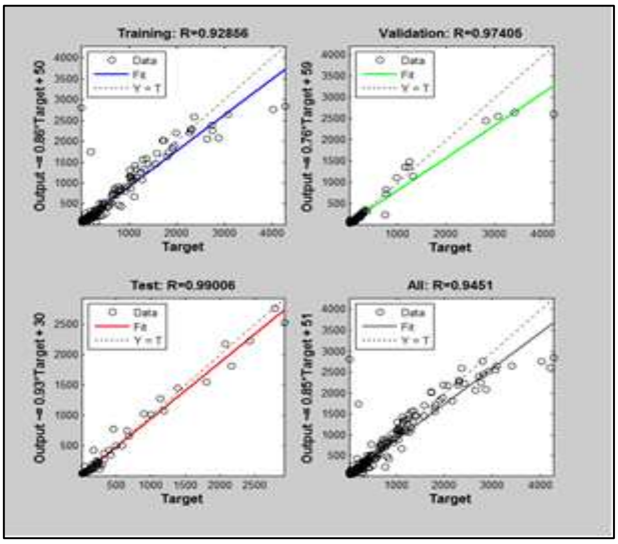

Fig. 12: Regression plot for ANN8

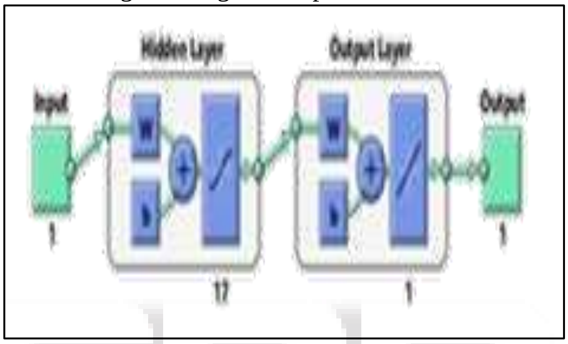

Fig. 13: Neural Architect of ANN8

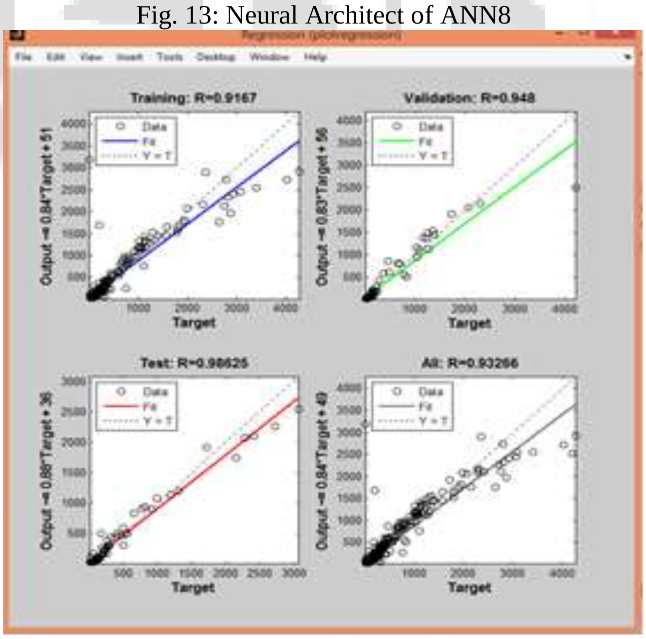

Fig. 14: Regression Plot for ANN9

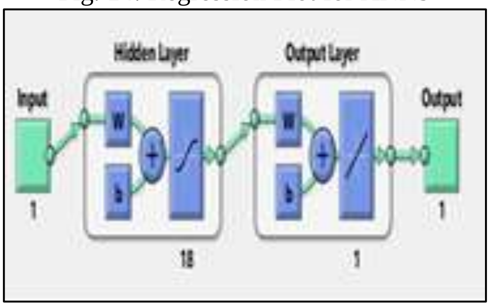

Fig. 15: Neural Architect of ANN9

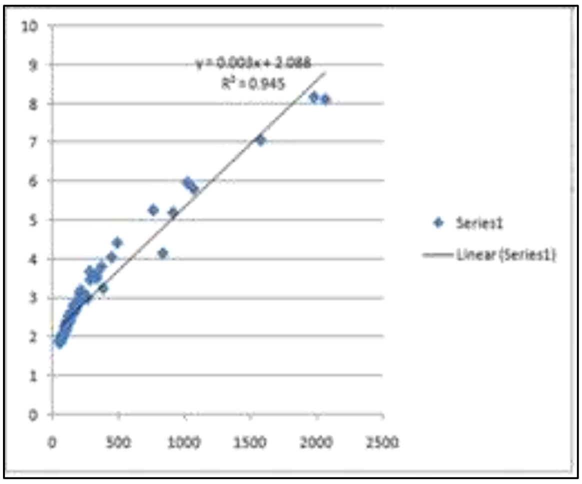

Fig. 16: Comparison of Observed and Predicted Discharge for ANN4

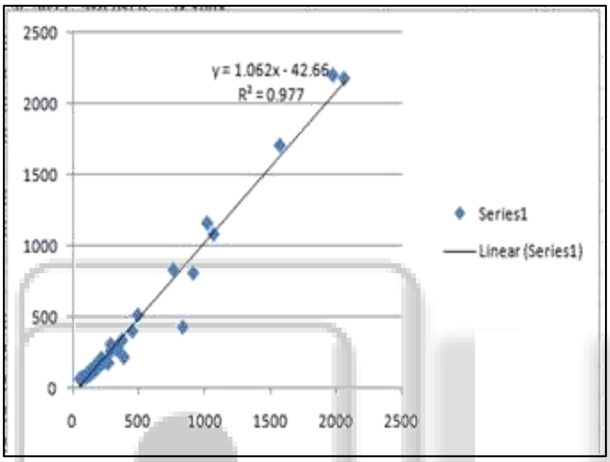

Fig. 17: Comparison of Observed and Predicted Discharge of ANN8

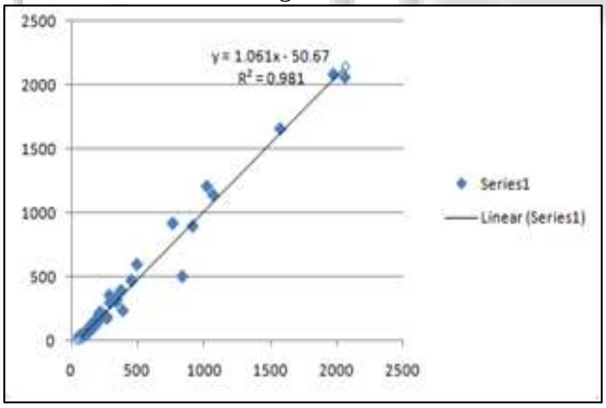

Fig. 18: Comparison of Observed and Predicted Discharge of ANN9

Model	R Value	R^2 Value
ANN4	1	0.945
ANN8	0.9901	0.977
ANN9	0.9863	0.981

Table 3: Details of ANN4, ANN8 and ANN9

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,

VIII. 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.

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