

Prediction of Groundwater Levels Using Artificial Neural Network: A Case Study of Gandhinagar and Kalol Taluka

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ABSTRACT: Groundwater is the most reliable and valuable resource of water. Groundwater is an important water resource for domestic, industrial, and agricultural activities. During the last decades, due to the increasing demand for water in all sector, it is observed that ground water level are depleting in some areas. Ground water level prediction is very useful in planning and management of water resources. In this research an artificial neural network has been used for groundwater prediction. Model considers rainfall, rainfall- runoff and Aquifer characteristics as input parameters and Static Groundwater level as output parameter. The dataset was divided into different combinations of testing and validation ratio and the models were developed for Gandhinagar and Kalol Talukas with the selected combinations. The predicted outputs are compared with the observed outputs with different combinations of testing and validation dataset by means of the model evaluation parameters like coefficient of correlation (r), Coefficient of Determination (r^2) and Discrepancy ratio (D.R.). The study reveals that the Artificial Neural Network tool can be used for the ground water level prediction.

KEYWORDS: ARTIFICIAL NEURAL NETWORK, RAINFALL, STATIC GROUNDWATER LEVEL.

I. INTRODUCTION

Regarding the limitation of water reservoirs, it is important to manage the use of water favorably for sustainable development. Therefore, in order to effective management of groundwater, it is important to model and predict the fluctuations in groundwater level so that the authorities can plan prerequisites for reduction of unforeseeable variations. Studies on groundwater levels reveal spatial and temporal information on aquifers and help us to take appropriate measures. For management of groundwater resources, traditional numerical methods, with specific boundary conditions, are able to depict the complex structures of aquifers including complicated prediction of groundwater levels. However, the vast and accurate data required to run a numerical model are difficult to obtain owing to spatial variations, and the unavailability of previous hydro geologic surveys. As a result, numerical methods have been restricted in their use in remote, sparsely monitored areas.

Groundwater systems possess features of complexity, nonlinearity and multi-scale, and randomness-all governed by natural and/or anthropogenic factors, which complicate the dynamic predictions. If sufficient data are not available, and accurate predictions are more important than understanding the actual physics of the situation, empirical models remain a good alternative method and can provide useful predictions without the costly calibration time. In view of these factors, a stochastic model based on hydro-meteorological data requires no special experiments and brings enormous convenience to the prediction of regional-scale groundwater dynamics.

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Drinking water in any developed area is majorly governed by ground water. The incorporation of water everyday with the growth in population. The ground water level is going depressed day by day. To reserve ground water level rainfall plays dynamic role. But due to development complete consumption of rainfall is almost difficult in any developed city. Groundwater is one of the most valuable natural resources for many developing countries, as it is reliable in dry seasons or droughts, cheaper to extract, requires little treatment and is less affected by catastrophic events. In the more arid or medium rainfall areas, where rainfall is low or medium, groundwater may be the major source of supply for domestic, agricultural and industrial purposes. Sujatha and Kumar concluded Performance of four types of functionally different artificial neural network (ANN) models. Tirupati, located in Chittoor district of the drought-prone Rayalaseema region in India, having resident population of over 3.0 lakhs and pilgrims of over 50,000 per day was chosen as the study area. As its groundwater levels showed a rapid decline in the last decade due to the overexploitation for the domestic, agricultural and industrial needs, accurate prediction is very essential to plan better conservation of groundwater resources. Results showed that Feed forward neural network trained with training algorithm Levenberg-Marquardt is suitable for accurate prediction of groundwater levels.

[1] Kumar developed a neural network model for ground water level prediction. Various models developed before for ground water level prediction with artificial neural network methodology. Most of these models consider rainfall and current ground water level as input parameter. This model considers rainfall-runoff as an important factor which represents the performance of rain water harvesting techniques in urban area. So this model predicts the ground water level with the effect of rain water harvesting techniques. [2] Sujatha and Kumar used four types of functionally different artificial neural network (ANN) models. Tirupati, located in Chittoor district of the drought-prone Rayalaseema region was chosen as the study area. As its groundwater levels showed a rapid decline in the last decade due to the overexploitation for the domestic, agricultural and industrial needs, accurate prediction is very essential to plan better conservation of groundwater resources. Results showed that Feed forward neural network trained with training algorithm Levenberg-Marquardt is suitable for accurate prediction of groundwater levels. [6] Mayilvaganan and Naidu applied neural network and fuzzy logic techniques as modelling tools. In their study, they used artificial neural network (ANN), Mamdani fuzzy inference systems (MFIS) and Adaptive Neuro Fuzzy (ANFIS) to predict the groundwater levels of Thuringapuram watershed, Tamilnadu. Antecedent rainfall and water levels are taken as inputs, and the future water level is an output. In this study, 25 years of water level data were analysed. The analysis of the three models is performed by using the same input and output variables. The models are evaluated using three statistical performance criteria namely Mean Absolute Percentage Error, Root Mean Squared Error and Regression coefficient. For performance evaluation, the model predicted output was compared with the actual water level data. Simulation results reveal that ANFIS is an efficient and promising tool.

II. ARTIFICIAL NEURAL NETWORK

An artificial neural network is a type of biologically inspired computational model, which is based loosely on the functioning of the human brain. It is more useful to think of a neural network as performing an input-output mapping via a series of simple processing nodes or neurons.

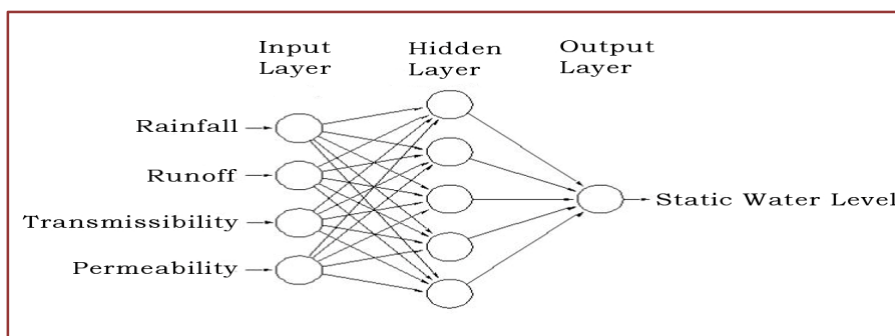


Figure 1 Typical artificial neural network structure with three layers

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The design of the multilayer neural network can have many layers where a layer represents a set of parallel processing units (or nodes). The three-layer ANN used in this study holds only one hidden (intermediate) layer as shown in Fig. 1. A multilayer ANN can have more than one hidden layer but a single hidden layer is enough for forecasting the problems. It is the hidden layer nodes that permit the network to identify and capture the appropriate patterns in the data, and to perform complex non-linear mapping between the input and the output variables. The input layer of nodes has to important role which is to transmit the external inputs to the neurons of the hidden layer. Hence the number of input nodes corresponds to the number of input variables. The outputs of the hidden layer are passed to the last (or output) layer, which provides the final output of the network.

III. STUDY AREA AND DATA COLLECTION

The Gandhinagar district is located between 23.22° N Latitude and 72.68° E Longitude. Gandhinagar and Kalol Taluka falls in Sabarmati basin with average per capita water availability of 307 and 318 cum respectively which is much less than the bench mark value of 1000 cum signifying “water starved” condition. Further, from point of view of ground water development the taluka falls under over exploited category. Gandhinagar Taluka in Gandhinagar District of Gujarat state has 74 villages and 5 urban areas. The total area of Gandhinagar Taluka is 685.8 Sq.Km. also Kalol Taluka has 69 villages and 3 nos. of urban areas. The total area of Kalol Taluka is 482.23 Sq.Km.

The following data are used for Groundwater level Prediction using ANN.

- Rainfall
- Aquifer characteristics (Transmissibility, T and Permeability, K)
- Static Groundwater Table Pre monsoon and Post monsoon

IV. METHODOLOGY

In this research work input parameters for neural network model are selected on the basis of their usefulness. Rainfall is the first parameter which plays an significant role in conserving the ground water level. Static ground water level is on 2nd number on the basis of that forecast has been done. The next parameter is rainfall-runoff. It represents the utilization of rainfall. So it becomes an important consideration. Next Aquifer characteristics selected on the basis of fluctuations of groundwater.

The steps involved in the identification of a nonlinear model of a system are selection of input-output data suitable for Testing and Validation i.e. 80-20%, 70-30 % and 60-40%; selection of a model structure and estimation of its parameters; and validation of the identified models. Method Adapted for groundwater level prediction: Artificial Neural Network(ANN).

To find the best method for the prediction of Groundwater level by evaluating the models with the performance indices such as Coefficient of Correlation (r), Coefficient of Determination (r^2) and Discrepancy Ratio (D.R.).

V. RESULT AND DISCUSSION

For The prediction of groundwater levels of Gandhinagar and Kalol taluka, the models were developed using all possible training algorithms using ANN.

A. Groundwater level prediction for Gandhinagar Taluka

Table 1 show that while using ANN for Gandhinagar Taluka the best model comes out is 60-40% model with Cascade Forward Back propagation algorithm which having Coefficient of Correlation (r) 0.999, Coefficient of Determination (r^2) 0.999 and Discrepancy ratio (D) 0.995 for Testing and Coefficient of Correlation (r) 0.999, Coefficient of Determination (r^2) 0.998 and Discrepancy ratio (D) 1.003 for validation.

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Table 1 Performance Evaluation Parameters for different training algorithms of Gandhinagar Taluka – Testing and Validation

Ratio %	Network type	Testing			Validation		
		r	r ²	D.R.	r	r ²	D.R.
80-20	Radial Basis Exact Fit	0.998	0.996	1.024	1.000	1.000	1.000
70-30	Feed Forward Back propagation	0.997	0.993	1.001	0.998	0.996	1.003
60-40	Cascade Forward Back propagation	0.999	0.999	0.995	0.999	0.998	1.003

Fig.2 and 3 shows Comparison of observed SWL and predicted SWL of model 60-40% during testing and validation respectively for Gandhinagar. From figures it is observed that for Gandhinagar for training and validation predicted static water level by ANN is very- very closed to the observed Static water level.

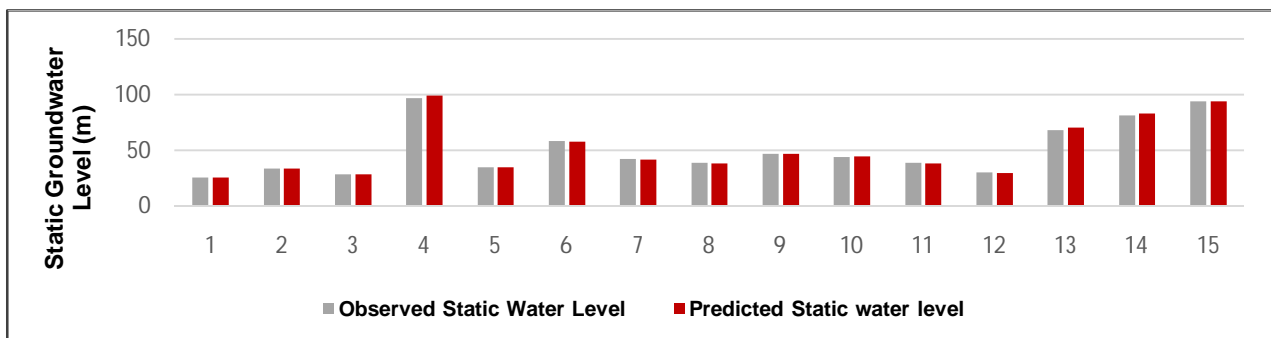


Figure 2 Comparison of observed SWL and predicted SWL of model 60-40% during testing (For Gandhinagar)

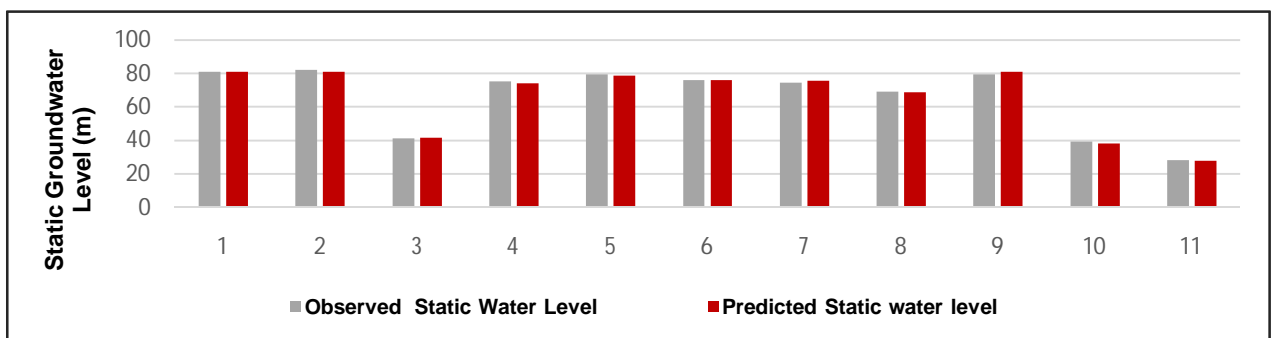


Figure 3 Comparison of observed SWL & predicted SWL of model 60-40% during Validation (For Gandhinagar)

B. Groundwater level prediction for Kalol Taluka

Table 2 shows Performance Evaluation Parameters for different training algorithms for testing and validation of Kalol Taluka.

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Table 2 Performance Evaluation Parameters for different training algorithms of Kalol Taluka – Testing 60% and Validation 40%

Ratio %	Network type	Testing			Validation		
		r	r ²	D.R.	r	r ²	D.R.
80-20	Layer recurrent	0.987	0.974	1.010	1.000	1.000	1.002
70-30	Linear layer (design)	0.999	0.998	0.999	1.000	1.000	1.000
60-40	Linear layer (design)	0.998	0.997	1.001	1.000	1.000	1.001

The results shows in table, that while using ANN for Kalol taluka, the best model comes out is 60-40% model with Linear layer (design) algorithm which having Coefficient of Correlation (r) 0.998, Coefficient of Determination (r²) 0.997 and Discrepancy ratio (D.R) 1.00 during training and Coefficient of Correlation (r) 1.00, Coefficient of Determination (r²) 1.00 and Discrepancy ratio (D.R) 1.001 during validation.

Fig.4 and 5 shows Comparison of observed SWL and predicted SWL of model 60-40% during testing and validation respectively for Kalol.From figures it is observed that for Kalol for training and validation predicted static water level by ANN is very- very closed to the observed Static water level.

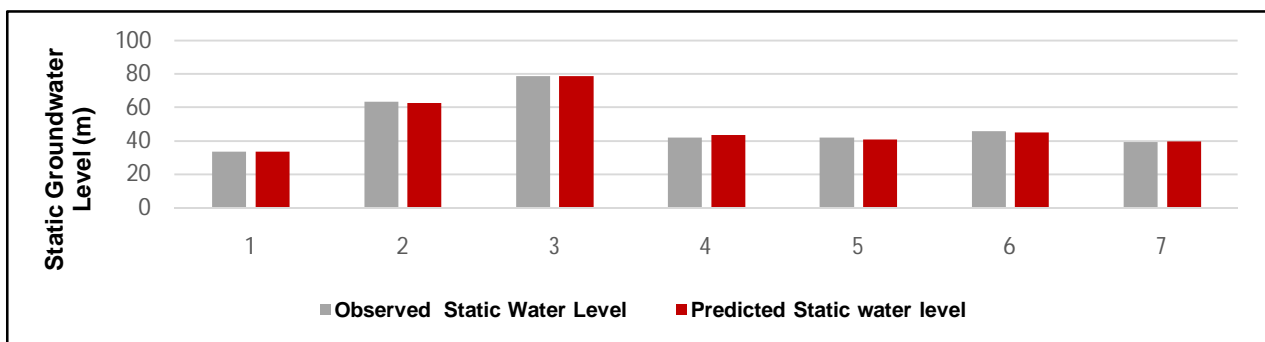


Figure 4 Comparison of observed SWL and predicted SWL of model 60-40% during testing (For Kalol)

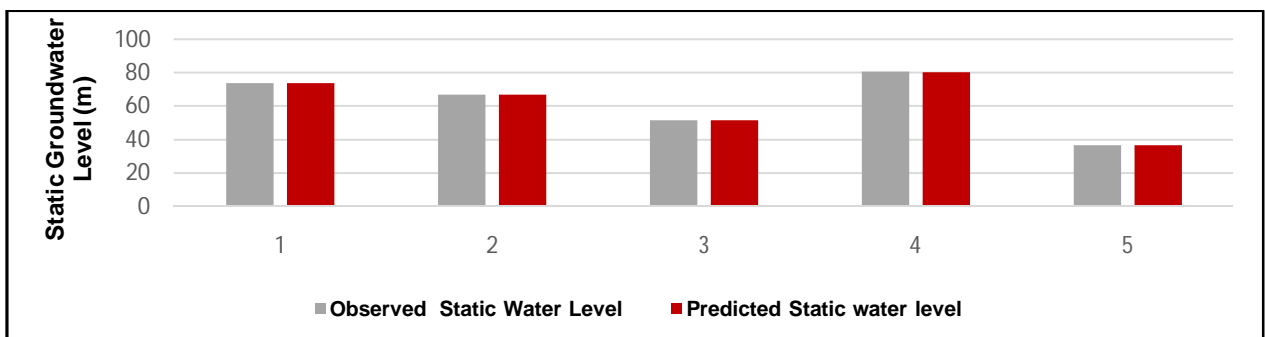


Figure 5 Comparison of observed SWL and predicted SWL of model 60-40% during testing (For Kalol)

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VI. CONCLUSION

As seen from the results of the different combinations of Testing and Validation data, From Artificial Neural Network, the results shows that the groundwater level prediction models are developed with ratio of 60-40% testing and validation datasets with Cascade forward back propagation algorithm gives the best results as Coefficient of correlation (r) value of 1.00 and 1.00, Coefficient of Determination (r^2) values of 0.998 and 0.998, and Discrepancy ratio (D.R.) values. 0.995 And 1.003 for Gandhinagar Taluka.

And For Kalol Taluka the groundwater level prediction models are developed with ratio of 60-40% testing and validation datasets linear layer (design) algorithm gives the best results as Coefficient of correlation (r) value of 0.998 and 0.999, Coefficient of determination (r^2) values of 0.997 and 1.00, and Discrepancy ratio (D.R.) values. 1.00 and 1.00.

Looking to the results of ANN technique it can be concluded that the ratio 60-40% Testing and validation of dataset provides the best results for Gandhinagar and Kalol Talukas for this study. Hence, the best model by ANN technique is model 60-40% for Gandhinagar and Kalol talukas.

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