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GIS based Groundwater Modelling of Agricultural Canal Command Area

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ABSTRACT

Groundwater is major source of water requirements of various sectors like irrigation, domestic, and industries. Ground water is the major component of all the water resources of the basin, sub-basin and micro-basin of the same hydrological cycle. Majority of people depend upon it for fulfilling potable supply. The sustainable development of ground water resource requires precise quantitative assessment based on reasonably valid scientific principles.

Protection of ground water level by predicting the pre monsoon and post monsoon water level of the groundwater by using the artificial neural network and the spatial representation of the ANN predicted groundwater level using ArcGIS is prime objective of this work. This paper focuses on the quantification of groundwater level prediction for a canal command area using the geographical information system and artificial neural network. The area is part of Sai River basin in Raebareli District.

The results suggest that the model predictions are reasonably accurate as evaluated by various statistical indices. In this paper, the results suggest that the ANN models are able to predict the groundwater levels of pre monsoon and post monsoon up to two seasons in advance reasonably well. Such prediction of groundwater level may be useful in planning conjunctive use in irrigation as well as for domestic and industrial purpose. Results from study establish that low groundwater level is near the head reaches of canal which also indicate area of highest recharge.

KEYWORDS: Agricultural Canal Command Area, Artificial Neural Network (ANN), Matlab, Geographic Information System (GIS).

1. INTRODUCTION

A Geographic Information System (GIS) is an organized collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, manipulate, analyze and display many forms of geographically referenced information (ESRI, 1995). From many years, GIS had been build based on a centralized paradigm where the complete set of data is stored on single server. Much recent attention has focused on developing GIS functionality in the Internet/ World Wide Web and private intranets and is termed as Web GIS. [3]

Modern GIS technologies use digital information, for which various digitized data creation methods are used. The most common method of data creation is digitization, where a hard copy map or survey plan is transferred into a digital medium through the use of a computer program, and geo-referencing capabilities. With the wide availability of ortho rectified imagery (both from satellite and aerial sources), heads-up digitizing is becoming the main avenue through which geographic data is extracted. Heads-up digitizing involves the tracing of geographic data directly on top of the aerial imagery instead of by the traditional method of tracing the geographic form on a separate digitizing tablet .

2. GROUND WATER MODELLING

Groundwater is water located beneath the ground surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands.

The importance of groundwater for the existence of human society cannot be overemphasized. Groundwater makes up about twenty percent of the world's fresh water supply, which is about 0.61% of the entire world's water, including oceans and permanent ice. Groundwater is the major source of drinking water in both urban and rural India. [8]

2.1 Ground Water Flow Model

Groundwater flow models are used to calculate the rate and direction of movement of groundwater through aquifers and confining units in the subsurface. Fate and transport models estimate the concentration of a chemical in groundwater beginning at its point of introduction to the environment to locations down gradient of the source. Fate and transport models require the development of a calibrated groundwater flow model or an accurate determination of the velocity and direction of groundwater flow that has been based on field data.

There are two types of ground water flow model:

- **(I)** Conceptual model
- **(II)** Mathematical model

(I) Conceptual model

A conceptual model consists of the following items:

- The geometry of the boundaries of the investigated aquifer domain.
- The kind of solid matrix comprising the aquifer.
- The mode of flow in the aquifer. (e.g., one-dimensional, two-dimensional horizontal, or three-dimensional).
- The relevant state variables and the area or volume, over which the averages of such variables are taken.
- Initial conditions within the considered domain.

(II) Mathematical Model

A mathematical model consists of the following items:

- A definition of the geometry of the considered domain and its boundaries.
- An equation that expresses the balance of the considered extensive quantity.
- Constitutive equations that define the behavior of the fluids and solids involved.
- An equation that expresses initial conditions that describe the known state of the considered system at some initial time.
- An equation that defines boundary conditions that describe the interaction of the considered domain with its environment.[1]

3. CANAL COMMAND AREA

An artificial channel filled with water and designed for navigation, or for irrigating land, etc. Canals are man-made channels for water. Mainly canal is use for the irrigation purpose in India. In Indian a large number of industries depend on the water that water is supplies from canal channels. Canal water is also used for drinking, washing clothes, and irrigation. In canal irrigation systems in India, water supplies reach the fields through a network of main canals, branch canals (secondary canals) and distributaries (tertiary canals). The Distributary is the basic unit of irrigation management in large canal systems, as it is the last point of control in main irrigation systems operation. [6]

Water use for agriculture cannot be considered in isolation of other uses. This requires an integrated approach for sustainable water resources planning, management and operation under a river basin framework. Due to competition from increasing demands for agriculture, domestic, power, industrial, environmental and other uses, allocation of water to different stakeholders in appropriate quantity and quality has become increasingly difficult. In the recent time Uttar Pradesh state of India has developed one of the largest canal networks in the world to support predominantly for agriculture need. Most of the canals are run-of-river system supplemented occasionally by small reservoirs.

3.1 Types of Canal Command

- Distributaries Canal Commands
- Minor Canal Command

3.2 Role of GIS in Groundwater Modelling of Agricultural Canal Command Area

Geographic information system can be very useful in Groundwater Modelling of Agricultural Canal Command Area. Geography matters a lot when the decision to be taken or the problems to be tackled are spatial in nature. GIS is emerging as a very effective tool in the industries that involve logistics or use the transportation services [5]. GIS is most important for agriculture purpose in India and for whole world. GIS gives the spatial representation of the tackled area. To provide a conjunctive use of groundwater and surface water resources for both irrigated agricultural land and urban water supply in the developing world and the great potential that planned conjunctive use has as an adaptation strategy to accelerated climate change. It is primarily of relevance to larger alluvial plains, which often possess major rivers and important aquifers with large storage reserves in close juxtaposition. GIS provide that location of rivers and aquifers with large reservoirs and to produce the spatial representation of that river or canal command area. [4]

In large canal irrigation project areas, integrated management of surface and groundwater resources can improve water use efficiencies and agricultural productivity and also control water logging. Such integrated management requires an estimation of spatial distribution of recharge and groundwater flow in the underlying aquifer. Recharge occurs both as percolation losses from fields and seepage losses from the water distribution network. Percolation losses are influenced by weather, soil properties, land use, and canal water and groundwater use. Seepage losses depend on the conditions of flow in the water distribution system. In large irrigation project areas all the factors influencing the recharge of groundwater vary spatially. In this study, a geographical information system (GIS) is used to map the spatial distribution of recharge which then serves as input to a regional groundwater flow model for simulating the behavior of the underlying aquifer. The basis is that the project area can be divided into a set of basic simulation units (BSUs) that are homogenous with respect to the conditions that influence the recharge processes. A daily field soil water balance model and a simple canal flow model are used to estimate the percolation and seepage losses, respectively. The combination of models and GIS can be used as an integrated decision support system to assess the groundwater resources and derive strategies for integrated management of canal and groundwater resources in the project area. [2]

GIS and Remote sensing data based performance indices namely adequacy, equity and water use efficiency for the distributaries of the Mahi Right Bank Canal command in Gujarat, India. The analysis showed that performance indicators could identify the problem distributaries, an intensively managed and studied irrigation system. The integration of Remote Sensing data and GIS tools to regularly compute performance indices could provide irrigation managers with the means for efficiently managing the irrigation system [7]. The use of geographical information system (GIS) in development of conceptual groundwater model. Various layers of information such as canal network recharge zones, subsurface geology and digital terrain model (DTM) of Hanumangarh and Sriganganagar districts were developed in GIS and were then transferred to finite difference grid for developing mathematical groundwater flow model of the area. From that ground water model we can measure the depth of water. And then we will know how that water is use for irrigation, domestics and industrial purpose. Also water is most important for environmental area.

4. OBEJECTIVE OF THE PRESENT WORK AND STUDY AREA

The main objective of the work is to predict groundwater level in a canal command area. The study area is Deeh Distributary part of Jaunpur branch of Sharda Shayak canal system. The topographical information of Deeh Distributary canal system is $(25^0 55' N - 26^0 30' N)$ latitude and $(81^0 15' E - 81^0 45' E)$ longitude and covering an area of 682111.00 ha fall in district of Raebareli. The latitude and longitude of Raibareli District is (26° 13' 0" N, 81° 14' 0" E). Sai River is effluents throughout its reach. Deeh Distributary system is in fluent in character and contributes to the groundwater body.

5. SYSTEM ARCHITECTURE (WORK DIAGRAM OR FLOW CHART)

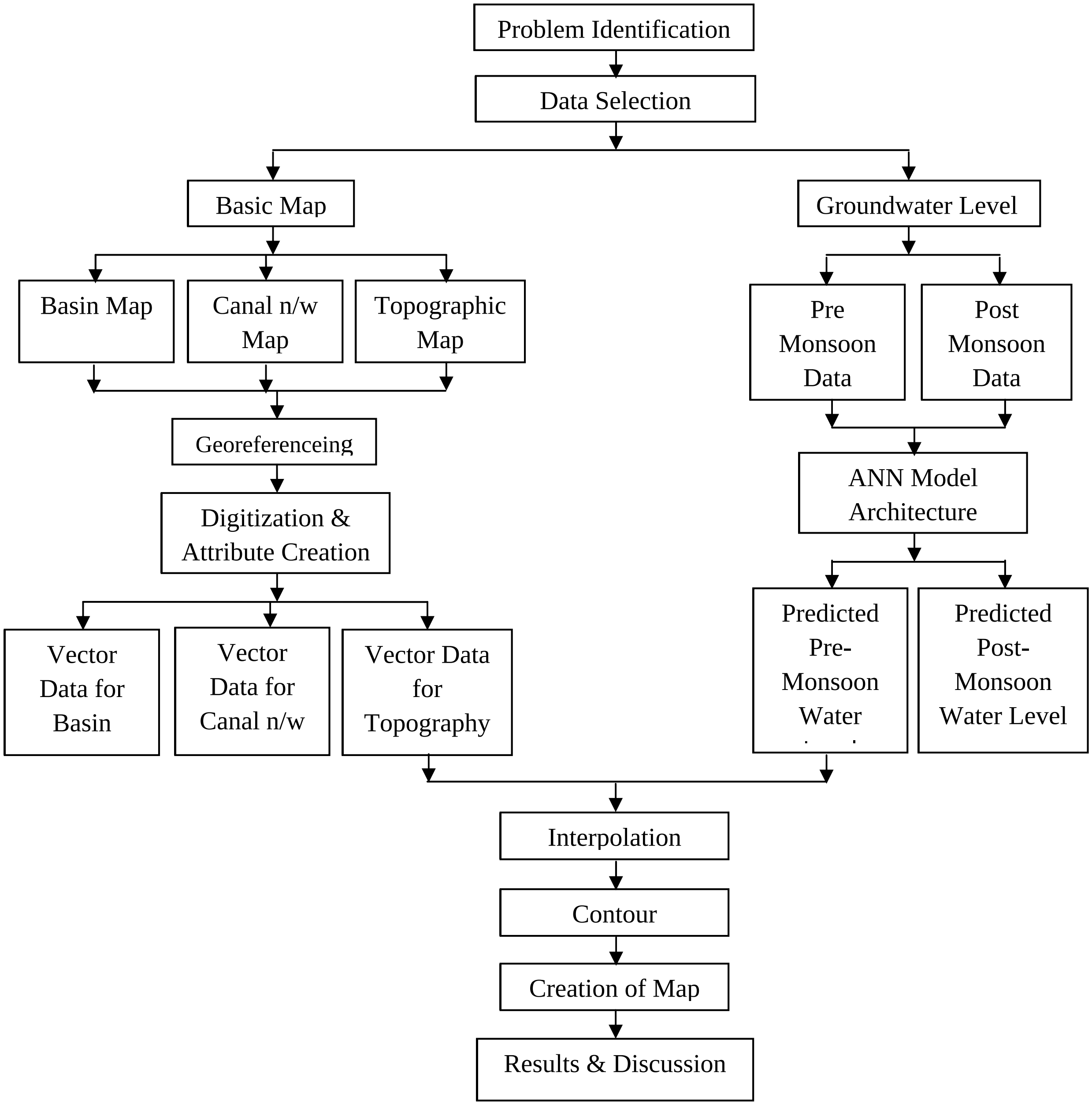


Figure 1: Flow Chart of Methodology

5.1 Methodology

In this work the methodology adopted to complete this work and capabilities of the system developed ground water modelling using artificial neural network and geographical information system (GIS). This work will explain basic ground water modelling from artificial neural network and to predict the depth of water (water level) for two years for pre Monsoon and post Monsoon data. The difference between pre Monsoon and post Monsoon water level indicates storage or recharge in the groundwater reservoir.

5.2 Overall Methodology

Overall methodology adopted in this work to accomplish the objectives may be listed as:

- Identification of parameters of problem basin boundary of the problem domain.

- Specification of groundwater recharge well and point (altitude) in the basin boundary of the canal command.
- Preparation of geo spatial groundwater and topography data base using ArcGIS.
- Development of ANN based groundwater time series prediction model using groundwater well data (pre Monsoon and post Monsoon data).
- Prediction of groundwater level using ANN model.
- Spatial representation of ANN predicted groundwater levels using ArcGIS.

6. RESULTS AND DISCUSSIONS

In this work to predict the groundwater level, data for pre and post monsoon is used. The eight pre monsoon and post monsoon groundwater level wells data location was used to predict water level. To develop the artificial neural network (ANN) model architecture data of eight locations were utilized and experimentations were performed with different iterations and different hidden layers using the MATLAB software. The best performing ANN architecture is finally selected based on their performance on training and testing data. After predication of water level, the spatial representation of the predicted groundwater level is done using ArcGIS.

As mentioned, the study area is Deeh Distributary part of Jaunpur branch of Sharda Shayak canal system. The study area is district of Raebareli of Uttar Pradesh which is in central Uttar Pradesh. Sai River is effluents throughout its reach. Deeh Distributary system is in fluent in character and contributes to the groundwater body. Such prediction of groundwater level may be useful in planning conjunctive use in irrigation as well as for domestic and industrial purpose.

6.1 ANN Model Architecture

The ANN model architecture for different iterations with different hidden layers of artificial neural network is experimented using MATLAB. The best performing ANN architecture is selected on the basis of least normalized error of training and testing for all taken eight locations. After the testing and training data we find the normalized error of all eight locations. After that we predict the groundwater level of pre monsoon and post monsoon value from selected eight normalized value.

6.2 ANN Predicted Groundwater Level

First of all, collect the data of pre monsoon and post monsoon of the eight locations from the given original data. Then prepare the ANN model architecture of the eight locations with different iterations and different hidden layers using the matlab software for prediction of groundwater level. And then select best of one of the best iteration, hidden node, input and output for training and testing data. After training and testing data find out the normalized error of the selected location. From selected data prepared the ANN model architecture for two seasons (pre monsoon and post monsoon). After the prediction of groundwater level shows the spatial representation of prediction data using ArcGIS. In the ArcGIS prepared the interpolation and contour map of the predicted pre monsoon and post monsoon data. The spatial map of predicted data using GIS is given below in the form of snap sort. Such prediction of groundwater level may be useful in planning conjunctive use in irrigation as well as for domestic and industrial purpose.

The table shows the predicted data which is given below:

Table 1: Predicted value of Post Monsoon and Pre Monsoon

SN	LOCATION	PR_96	PT_96	PR_97	PT_97	PR_98	PT_98	PR_99	PT_99	PR_2K	PT_2K	PR_01	PT_01	PR_02	Predicted Value PT_02	Predicted Value PR_03
1	Sichauna	7.9	3.75	8.21	5.06	6.6	2.85	6.2	4	6.6	5.05	7	4.1	6.2	3.91	6.89
2	Daudnagar	6.43	5.29	6.59	5.35	6.2	3.2	5.2	3.05	5.05	3.1	5	3.9	5.4	4.43	5.09
3	Nigoha	4.1	1.4	4.2	1.9	3.75	1.95	3.8	1.6	3.08	1.43	2.9	1.15	3.32	1.64	3.7
4	Mozamganj	7	3.37	6.75	4.62	6.97	3.34	6.87	3.62	3.93	3.45	5.5	3.2	8.74	3.73	3.75
5	Kundra	7.66	5.21	7.76	7.63	8.45	3.23	6.85	6.21	6.61	6.35	7.85	6.55	7.41	6.97	6.97
6	Bamhanpur	10.98	9.24	10.9	10.1	11.04	8.38	9.64	8.07	9.72	8.17	9.19	7.51	8.84	9.71	9.71
7	Jagatpur	6.2	3.34	5.92	2.76	5.56	2.12	4.56	2.12	3.31	1.65	3.42	1.22	4.62	3.77	3.78
8	Parshadepur	11.4	10.97	11.41	10.71	11.58	9.57	9.7	8.62	9.75	8.11	9.75	6.7	8.85	7.55	9.68

Figure 2, 3, 4, 5, 6, and 7 shows the illustrations for the GIS based Groundwater Modelling of Agricultural Canal Command Area. This is given below

ANN PREDICTED GROUNDWATER LEVELUSINING ArcGIS

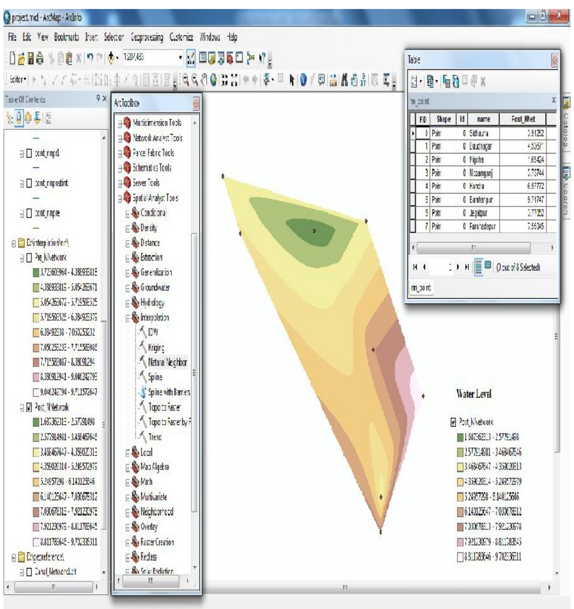


Figure 2: Interpolation of Predicted Post Monsoon Groundwater level

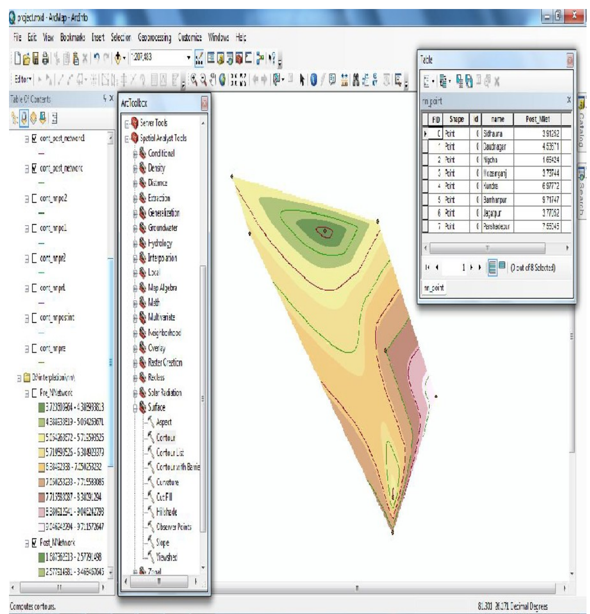
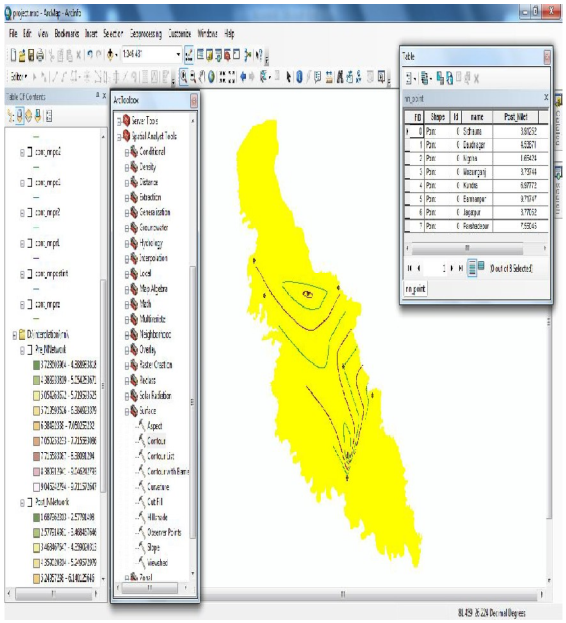


Figure 3: Contour of Predicted Post Monsoon Groundwater level



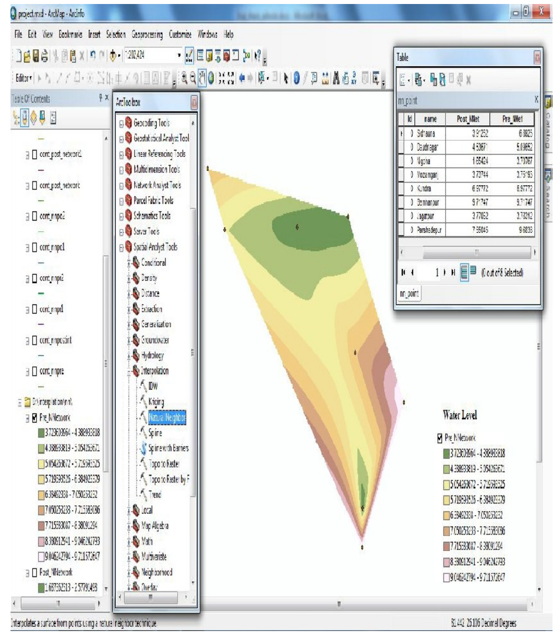
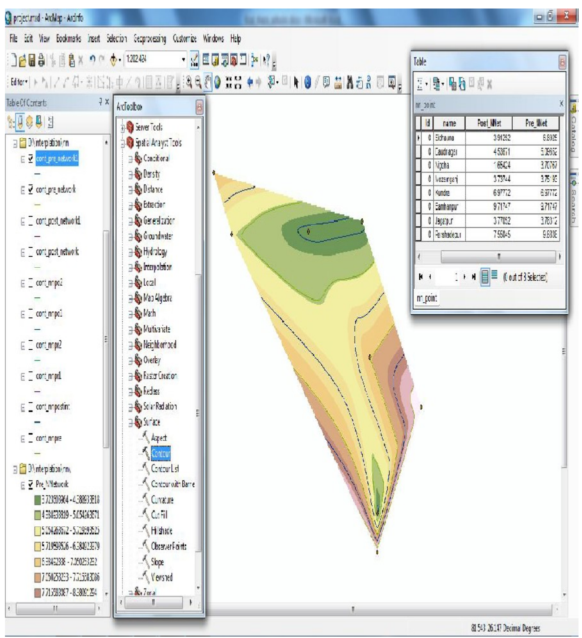


Figure 4: Contour of Predicted Post Monsoon Groundwater level basin

Figure 5: Interpolation of Predicted Pre Monsoon Groundwater level



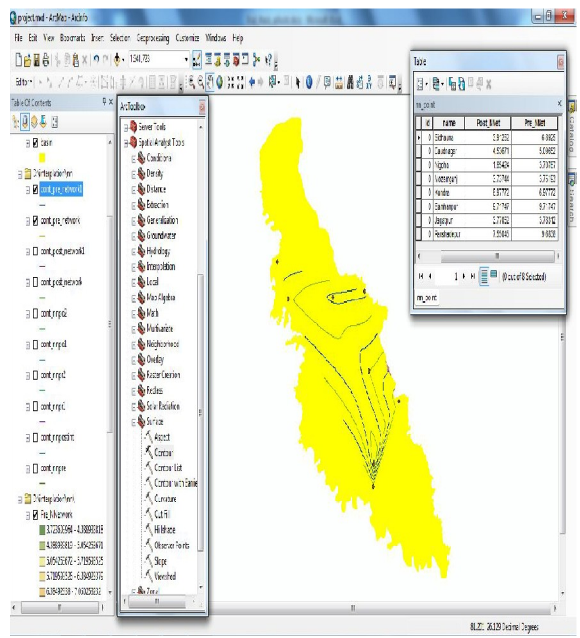


Figure 6: Contour of Predicted Pre Monsoon Groundwater level

Figure 7: Contour of Predicted Pre Monsoon Groundwater level with basin

7. CONCLUSION AND FUTURE RECOMMENDATIONS

Present study, present the GIS based Groundwater modelling for a canal command area and demonstrate methodology for groundwater level prediction in the canal command area. The present status of groundwater level in the canal command area is shown by interpolation of the groundwater well information in the study area using ArcGIS. Topographic variation is also shown using ArcGIS. Groundwater level data from these model are utilized to develop an ANN based time series prediction model. Developed ANN model perform reasonably well as evident by performance statistics. Trained ANN model is further employed to predict groundwater level for two next steps. The predicted water level in spatial variation is again shown using ArcGIS.

Following conclusion may be specified:

1. GIS is an effective tool for presenting the spatial variability of groundwater levels in canal command area.
2. The post monsoon groundwater level in general is close to ground surface compared to pre monsoon.
3. The low groundwater level is near the head reaches of canal which also indicate area of highest recharge.

However, it is recommended that conjunctive use study considering both groundwater and surface water may further be developed.

Many recommendations can be drawn out of this work. The recommendations listed here in address future studies that can consider the followings issues:

1. A conjunctive use study considering both groundwater and surface water may further be developed.
2. Scenario analysis is required to predict the corresponding recharge behavior.
3. It is important to consider different methods in order to carry out a cross comparison analysis.

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