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Groundwater Modelling in Bina River Basin, India using Visual Modflow

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Abstract— The study focused on groundwater recourse assessment through steady-state flow modelling in Bina River basin. Bina River is a tributary of Betwa River and is the main source of water for domestic water supply and irrigation supply. Despite its importance for the people in the region, the hydrogeological system of the Bina River basin is not well understood. This study reports a simulation study for better understanding of the groundwater balance at Bina River Basin using Visual MODFLOW. The model involved a steady-state hydrogeological simulation of the two-layered aquifer. The groundwater modelling approach was found to be efficient in identifying the dominant hydrological processes in Bina River basin including evapotranspiration and recharge. The aquifer system was modelled numerically by Visual MODFLOW (flex). The model domain was delineated based on field traverses, topographic maps and digital elevation model extracted from Survey of India toposheet contour lines in ILWIS platform. Aquifer parameters were assigned based on given data by CGWB and WRD, which were then adjusted during the model calibration. The main recharge mechanism considered was direct recharge from rainfall. The model was calibrated to static water levels during 2009 pre- monsoon in each block of Bina River Basin. The overall model results are comparable with the observation well data. The sensitivity of the calibrated model was tested by systematically changing one parameter or input variable at a time and it was found that the model is highly sensitive to changes in ET and recharge rate.
Key words: AET, CGWB, ET, ILWIS, WRD

I. INTRODUCTION

Groundwater is vital source of water across the Globe because of its availability and general good quality. Earlier groundwater was considered safe for domestic use, but recent circumstances has indicated that groundwater is vulnerable to depletion in many countries. Because of this danger, it is now became our need to understand the processes by which groundwater is made available to us. Groundwater investigation's has led to development of comprehensive conceptual models and to analytical solutions or numerical methods of groundwater modelling. Modelling and simulation are popular instruments to manage groundwater resources now. Groundwater Modelling of Bina River basin, Madhya Pradesh, India is presented in this paper after a detail study and assessment of the area. As a result of the study groundwater declination is found in several places and hence remedial measures must be taken into account.

II. SITE DESCRIPTION

The area selected for present study is Bina River basin of Madhya Pradesh, India. Bina River is a tributary of Betwa River in Bundelkhand region of Madhya Pradesh. Study area is bounded by Latitude 23'18''N to 24'15'' N and Longitudes 78'02''E to 78'32''E. Bina River originates from Begamganj Block of Raisen District and enters Sagar district at Rahatgarh block and It transverses Kurwai block of Vidisha district and Bina Tehsil before confluence with river Betwa near Basoda town in Vidisha. Presently, domestic water supplies to Rahatgarh, Khurai and Bina town. The study area is located partly in Sagar, Vidisha and Raisen districts of Madhya Pradesh. Bina river basin is situated at 24° 10' N to 24° 42' N latitudes and 78° 09' E to 78° 23' E longitudes. The study area is located in survey of India toposheet Nos. 55I/2, 3, 6, 7 and 11 on 1:50,000 scale.

The upper part of the study area is highly undulating and covered by forests, barren lands and localized rain-fed agriculture. The drainage density is more in the upper catchment as compared to the lower part of the Bina river basin, later is mostly gently sloping to plain topography largely covered with agricultural fields. The streams are dry after the monsoon months despite enough rainfall; the average annual rainfall in recent years over the basin is 1049 mm and during monsoon months, i.e. June to October the rainfall is 980.35 mm. Therefore groundwater is exploited for domestic and agricultural uses during Rabi season causing depletion of the water table in most of the area.

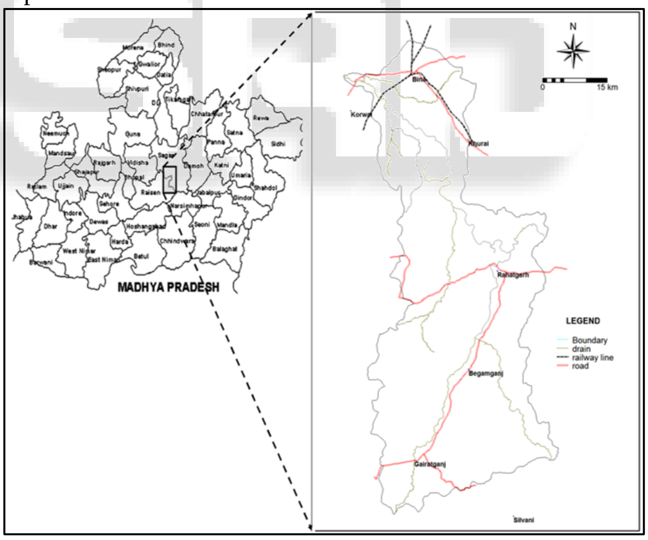

Fig. 1: The area selected for present study is Bina River basin of Madhya Pradesh

III. DATA AND INPUTS

A. Evapotranspiration

The evapotranspiration at actual field condition is less than Potential Evapotranspiration and it is the actual evaporation occurring in the basin, direct measurement of the AET is difficult, hence it is usually estimated from the PET. The average evapotranspiration value of AET was 703 mm/year which is typical a semi-arid climate.

B. *Rainfall Data*

The annual average rainfall was taken 1049 mm in Bina River basin, Rainfall Data has been taken from State Data Centre, WRD, Bhopal (Madhya Pradesh).

C. *Pumping Well*

The pumping well are assigned to each block as per the amount of draft in the area due to data unavailability of pumping wells. The abstraction rate of the well for the water supply of Bina town indicates that most of the wells are continuously functional throughout the year. For this study, the average abstraction rate from the Bina River basin is 800 m^3/day. The abstraction rate of the well is considered in the total average of the abstraction rate. Based on the abstraction records from the CGWB and WRD, Bhopal (Madhya Pradesh).

D. *Observation Well Data*

The groundwater level data from 26 observation wells, recorded by using a water level using these data, hydraulic gradient and direction of flow are also determined. These wells influence GWLs and quantity of withdrawal of groundwater in the villages.

E. *Pumping Test*

The pumping test has been conducted CGWB for year 2008, 2010 in the Report Dynamic Ground Water Resources of Madhya Pradesh, 2009 and 2011. As part of the present work, the collected pumping test data were analysed to understand the aquifer system behaviour of the area.

F. *Groundwater Level Analysis*

Ten year of groundwater level monitoring data were collected from the CGWB and WRD. A trend of groundwater level in selected boreholes which have continuous records for about ten years and the average groundwater level from all observation wells are considered. As it can be observed there is a general groundwater level decline in response to the ongoing groundwater abstractions. There is a groundwater level rise in response to the direct recharge from rainfall during the monsoon period. Based on the groundwater level monitoring data Initial Water Table is estimated by Pre-Monsoon level (May of year 2008) in every block of Bina River basin.

G. *Geophysics*

For the present study, geophysical survey results data were collected from previous studies mainly conducted by Central Ground Water Board. The resulting analysis of these surveys is used as supportive data for the lithologic log and geological cross-section for identifying the hydro stratigraphic units. The interpretation results of the geophysical survey results are calibrated by comparing with the lithologic log and the resistivity value of the subsurface material at the same location in order to have an idea of the resistivity values of geologic formation where there is no well log data.

H. *Hydraulic Conductivity*

It consist of defining the Hydraulic Conductivity to the Aquifer Zone. The conductivity was determined by dividing the transmissivity with the saturated thickness, thus it could be claimed that the conductivity obtained in this way represents an average conductivity for the whole saturated strata. The mean was determined K_x and $K_y = 8.09X10^{-05}$ m/s $K_z=1x10^{-05}$ m/s and Second Aquifer has average Hydraulic Conductivity K_x and $K_y = 4.04X10^{-05}$ m/s $K_z=5x10^{-06}$ m/s. By taking the average of hydraulic conductivity from well data. (Annexure 4).

The hydraulic property data for the Bina River basin aquifer system is derived from aquifer pumping tests carried out in the previous studies. The pumping test results have been documented on a number of published and unpublished reports.

IV. DEFINING PROPERTY ZONE

Zonation for the input parameters was carried out based on geological information, point hydraulic conductivity and transmissivity data of the pumping tests. Initially, the hydraulic parameters estimated from pumping test results of previous studies were applied, later the parameters were adjusted during the calibration process.

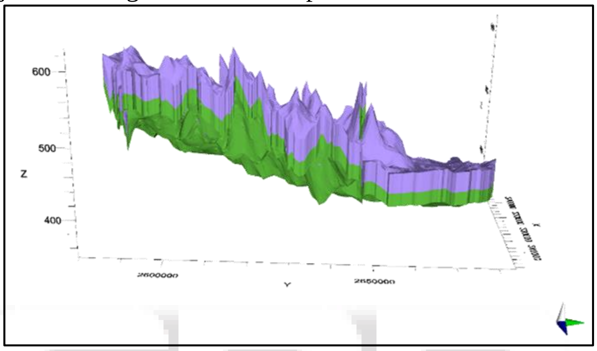

Fig. 2: Zone map of Bina River Watershed

A. *Specific Yield (Sy)*

It can be defined as volume of water that an unconfined aquifer releases from storage per unit surface area per unit decline in the water table. This parameter is unit less and varies with the grain size distribution of the aquifer material and the height of the water table, the capillary fringe above water table. *Sy* varies based on hydraulic conductivity and hydrogeological situation and in this study two *Sy* zones were utilized. Specific yield of aquifer is found out to be 0.11 according to CGWB, Bhopal

B. *Specific Storage (S_s)*

Specific storage is calculated by dividing Storage coefficient by the thickness of aquifer layer and average value of S_s in all the wells and it is found out to be $6.46x10^{-05}$ (1/m). Value of S_s .

C. *Initial Head*

For the present case, the static water level records of the wells are obtain from CGWB and WRD ,the initial hydraulic heads for the different blocks of Bina River basin ranges from 7 to 26 meters below ground surface level.

V. GRID SETTINGS

Finite difference grid of 100 x 80 numbers of Rows and columns are taken into consideration. These Row and columns have width and height value of 1044.8 and 622.5 m respectively. The grid size in the horizontal plane was prescribed by trial and error and was a compromise between model accuracy and computational time. Layer refinement is taken as 1 in each layer.

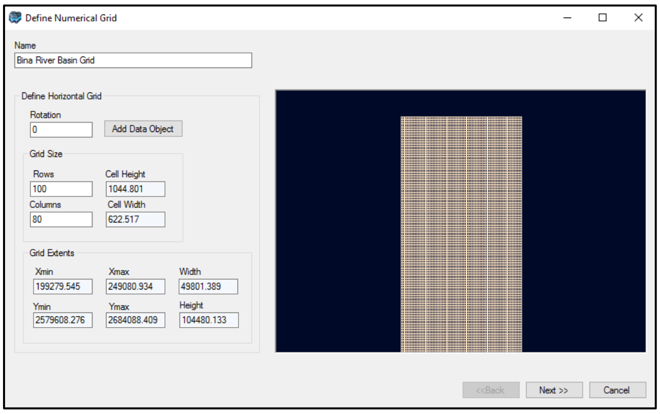

Fig. 3: Grid settings

VI. Results

Water table is obtained as result of the modelling software after calibrating the model to meet field values as given by CGWB and WRD. Figure 6.1. Show the water table for Bina river basin

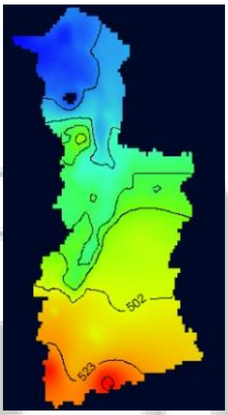

Fig. 4: Water Table in Bina River Basin

VII. Model Calibration

The model calibration was carried out for the scenarios with and without abstraction. The first step towards model calibration is to check the model reliability in generating field condition, when it is subjected only to the natural regime. The static water levels records before time of pumping were used in calibrating the natural regime of the groundwater flow system. Average groundwater levels of ten years monitoring data were used to calibrate a steady-state model.

The process of model calibration was done by hit and trial method to calibrate the model which was basically based on a visual judgment.

VIII. Conclusions

Finally it is advised to consider the following points in relation to groundwater resources development in the Bina River basin.

– Future groundwater resource development plans in the Bina River basin must be taken into account of balance between the groundwater recharge and the intended abstraction rates to ensure the sustainability of the resource in the catchment.
– It is advisable to redistribute the pumping wells from the narrow right upper bank of the catchment to the upper catchment to reduce the groundwater stress resulting from localised pumping.
– The pumping rate should not be kept high so that the groundwater levels in the Bina town becomes lower than the actual level at the outlet.

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