Study of Well Abstraction Effect on Groundwater Table Using Micro-Fem: A Case Study of Vadodara District

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***Abstract-*— The Groundwater is the water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations. The objectives of the present study are, to study the well abstraction effect on the head of ground water, compare the well abstraction effect for the different discharges of the well, to draw flow lines using finite element method and to delineate the area contributing to the well, using finite element method. In this study, finite element method is used to carry out the analysis as a numerical method. Micro-FEM is a tool which used finite element method for groundwater modeling purpose. In this study various NHS located in Savli, Waghodia, Vadodara, Karjan, Padra, Sinor and Dabhoi taluka of Vadodara district are considered. Well abstraction effect on ground water head is studied for NHS in Vadodara district. From this study, it is concluded that for Vadodara district in basalt aquifer system, ground water head for 30lps discharge may vary from 3.415 to 24.808 mbgl, for 35lps discharge, it may vary from 3.687 to 25.057 mbgl, for 40lps discharge, it may vary from 4.051 to 25.417 mbgl and in older alluvium aquifer system, ground water head for 30lps discharge may vary from 7.498 to 28.957 mbgl, for 35lps discharge, it may vary from 7.512 to 29.41 mbgl, for 40lps discharge, it may vary from 7.641 to 29.516 mbgl. In younger alluvium aquifer system, ground water head for 30lps discharge, it may vary from 7.398 to 47.889 mbgl, for 35lps discharge, it may vary from 7.638 to 48.138 mbgl, for 40lps discharge, it may vary from 8.046 to 48.569 mbgl and in coastal alluvium aquifer system, the ground water head for 30lps discharge, it may vary from 13.418 to 35.054 mbgl, for 35lps discharge, it may vary from 13.526 to 35.303 mbgl, for 40lps discharge, it may vary from 14.019 to 35.418 mbgl. But area contributing to the well remains independent from the well abstraction effect. From the above study, the flow lines are drawn using finite element method and then the same are used to delineate the distance of the area contributing to the well. It is observed that the distance of the flow line from the well location remains independent of discharge of that respective well.**

Keywords— Well abstraction effect, groundwater table, Finite element method, MICRO-FEM

I. INTRODUCTION

Groundwater is the water present beneath Earth's 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. Groundwater is also often withdrawn for agricultural, municipal, and industrial use by constructing and operating extraction wells. For groundwater flow systems and management of groundwater resources, groundwater model is required. Applying a model is an exercise in thinking about the way a system works. For this reason, mathematical modeling should be performed at the beginning of every hydrogeological study that addresses nontrivial questions. Mathematical models can be solved analytically or numerically. Numerical models use an approximate form of the governing equation to calculate head at selected locations. In contrast to analytical solutions and the AEM, a numerical solution is not continuous in space or time; the head is calculated at discrete points (nodes) in space and for specified values of time. The numerical methods most commonly used in groundwater modeling are the finite-difference (FD) method and the Finite-element (FE) method. The objectives of the present study are, to study the well abstraction effect on the head of ground water, compare the well abstraction effect for the different discharges of the well, to draw flow lines using finite element method and to delineate the area contributing to the well, using finite element method.

II. STUDY AREA AND DATA COLLECTION

In this study Vadodara district is selected to carry out the ground water modeling work. Vadodara district with 7548.50 Sq km area, is located central part of mainland Gujarat, lies between 21°49'19" and 22°48'37" north latitude and 72°51'05"and 74°16'55" east longitude. Location of Vadodara district is shown in Fig. 1.

Fig. 1. Location of Vadodara district& Vadodara district map and NHS and Aquifer system in Vadodara District

Ground water regime monitoring is the basic component of groundwater management, and it is carried out in parts of Vadodara district through National Hydrograph Network Stations (NHNS or NHS). NHS are observation wells, consisting of dug wells and purpose built bore wells shown in Fig. 1. For the NHS covered in this taluka of Vadodara district, groundwater analyses were carried out for the discharge of 30lps, 35lps, and 40lps, based on the data collected from the various well locations. In Vadodara, there are different types of principle aquifer systems, namely, alluvium, basalt, granite, gneiss, shale, and quartzite.

Modeling software selection

After hydrogeological characterization of the site has been completed and the conceptual model developed, computer model software is selected. The selected model should be capable of simulating conditions encountered at a site. Similarly, one-dimensional/ two- dimensional/ three-dimensional groundwater flow and transport models should be selected based upon the hydrogeological characterization and model conceptualization. In the present study, Micro-FEM is used. The Windows version of Micro-FEM is a new program, based on the DOS package Micro-Fem. It takes the user through the whole process of groundwater modeling, from the generation of a finite-element grid through the stages of preprocessing, calculation, post processing, graphical interpretation, and plotting.

III. METHODOLOGY

*Step1. Grid Generation in Micro-FEM.*After fixing the node of a corner of the images and the well location on the image next step is to divide the whole area into the triangular element.

*Step-2. To mark river node & well node.*After generating the grid for entire area next step is to mark the river node and well node located in the area. In this step, river node is marked using line marker and the well node is marked using point marker. Next step is assigning a head value to the river head and well head.

*Step-3 To assign hydraulic parameter value to each node.*After making the river node and well node, next step is to assign a hydraulic parameter value such as transmissivity, vertical resistance, the thickness of the aquifer, precipitation in the area, etc. Assigned hydraulic parameter convert network into the model.

Step-4 To calculate head at all node of model. In Micro-FEM, after assigning a boundary condition and all hydraulic parameter value, the network is converted into the model. In this model calculation of head is necessary.

Step-5. To calculate the well abstraction effect in the area. In step-4, the head at the different nodes in the area in steady state condition are calculated. Next step is to calculate the head with well abstraction.

IV. RESULTS AND ANALYSIS

A. Results for Savli taluka

Using the properties of these aquifer systems for Savli, the analysis were made for the discharge rate of 30lps, 35lps and 40lps. Amongst the 8 observation wells considered in Savli taluka, 5 have an older alluvium as the principle aquifer system and 3 have basalt as the principle aquifer system, analysis of these wells are shown in Fig. 2 and 3(a to d are in clockwise from top left corner) respectively and are also given in Table I.

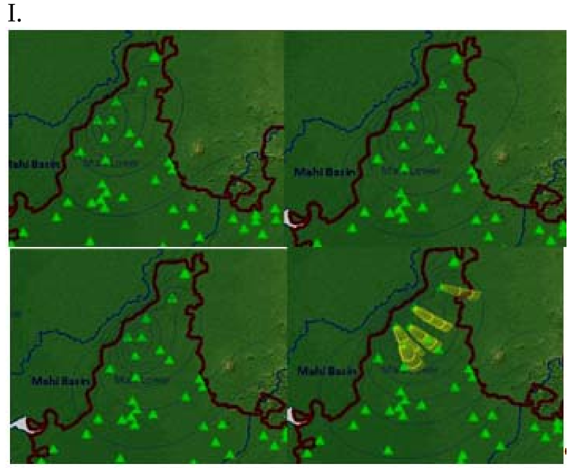

Fig. 2. Effect of well abstraction on ground water head in older alluvium system for NHS in Savli for (a) 30lps (b) 35lps (c) 40lps (d) maximum area contributing to well

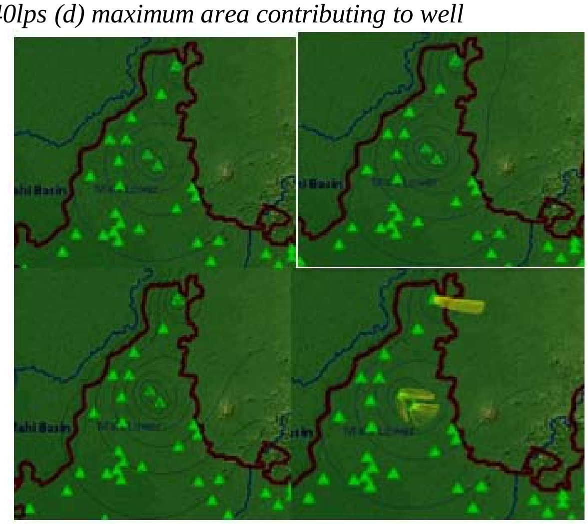

Fig. 3. Effect of well abstraction on ground water head in basalt system for NHS in Savli for (a) 30lps (b) 35lps (c) 40lps (d) maximum area contributing to well

TABLE I. COMPARISON OF HEAD FOR NHS STATION IN SAVLI TALUKA (MBGL)

NHS Station	Type of Aquifer system	Discharge		
		30lps	*35lps*	*40lps*
Vejpur-2	Basalt	4.7	4.9	5.2
Chhaliyar	Older Alluvium	22.3	22.4	22.9
Dakor		7.4	7.5	7.6
Sankheda		22.6	22.9	23.1
Gothada		10.9	11.1	11.4
Tundav		14.7	15.1	15.3
Junasamalya	Basalt	12.0	12.4	12.6
Vadala		12.5	12.8	12.9

B Results for Vadodara taluka

Using the properties of these aquifer systems for Vadodara taluka, the analysis were made for the discharge rate of 30lps, 35lps and 40lps. Amongst the 6 observation wells considered in Vadodara taluka, 4 have an older alluvium as the principle aquifer system and 2 have a basalt as the principle aquifer system, analyses of these wells are shown in Fig. 4 and 5 (a to d are in clockwise from top left corner) respectively and are also given in Table II.

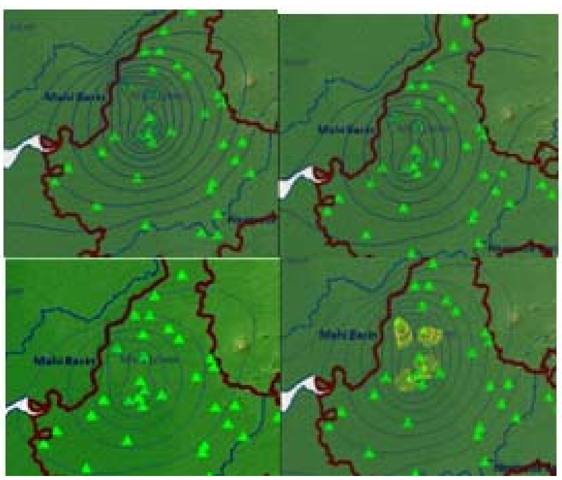

Fig. 4. Effect of well abstraction on ground water head in older alluvium system for NHS in Vadodara for (a) 30lps (b) 35lps (c) 40lps (d) maximum area contributing to well

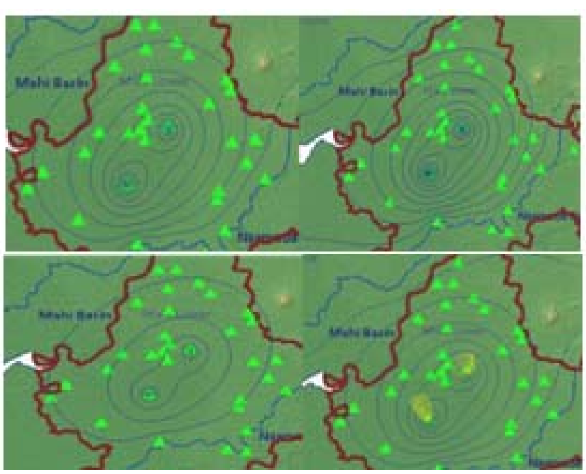

Fig. 5 Effect of well abstraction on ground water head in basalt aquifer system for NHS in Vadodara for (a) 30lps (b) 35lps (c) 40lps (d) maximum area contributing to well

TABLE II. COMPARISON OF HEAD FOR NHS STATION IN VADODARA TALUKA (MBGL)

NHS Station	Type of Aquifer system	Discharge		
		30lps	*35lps*	*40lps*
Sankarda	Older Alluvium	28.9	29.4	29.5
Asoj		27.2	27.4	27.6
Baroda-2		20.2	20.5	20.6
Baroda-1		15.9	16.0	16.2
Vadodara-1	Basalt	24.8	25.0	25.4
VadshalaPzi		17.9	18.0	18.1

C Results for Padra taluka

Principle aquifer system of Padra taluka made up of coastal alluvium. Using the properties of this aquifer system for Padra taluka, the analysis was made for the discharge rate of 30lps, 35lps and 40lps. Amongst the 3 observation wells considered in Padra taluka,all of them are in coastal alluvium type soil, analyses of these wells are shown in Fig. 6. (a to d are in clockwise from top left corner) and are also given in Table III.

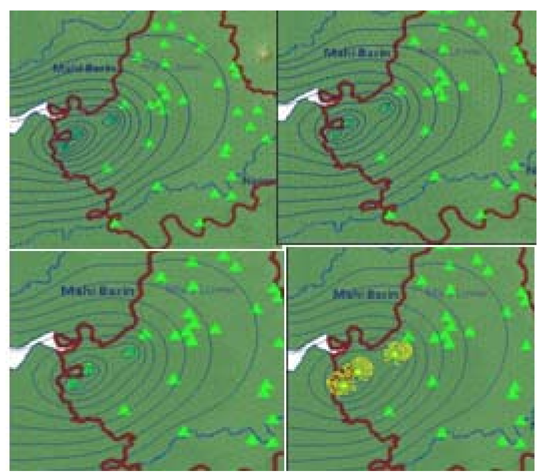

Fig. 6. Effect of well abstraction on ground water head in coastal alluvium for NHS in Padra for (a) 30lps (b) 35lps (c) 40lps (d) maximum area contributing to well

TABLE III. COMPARISON OF HEAD FOR NHS STATION IN PADRA TALUKA (MBGL)

NHS Station	Type of Aquifer system	Discharge		
		30lp	*35lp*	*40lp*
	Coastal alluviu	35.	35.	35.
Chitral		29.	29.	29.
Masor		13.	13.	14.

D Results for karjan taluka

Using the properties of this aquifer system for Karjan taluka, the analysis was made for the discharge rate of 30lps, 35lps and 40lps. Amongst the 3 observation wells considered in Karjan taluka, all of them are in younger alluvium type soil, analyses of these wells are shown in Fig. 7 (a to d are in clockwise from top left corner) and are also given in Table IV.

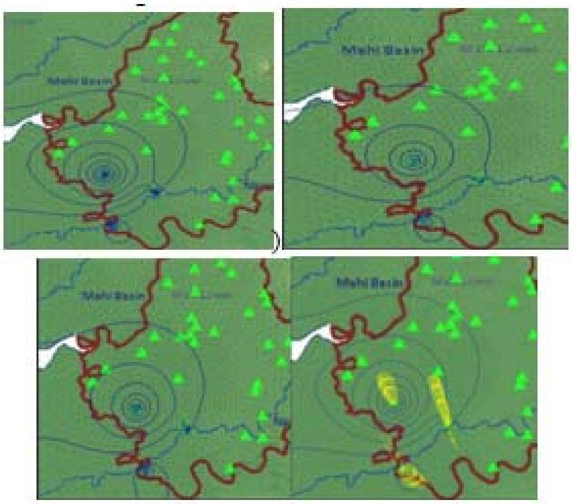

Fig. 7. Effect of well abstraction on ground water head in coastal alluvium for NHS in karjan for (a) 30lps (b) 35lps (c) 40lps (d) maximum area contributing to well

TABLE IV. COMPARISON OF HEAD FOR NHS STATION IN KARJAN TALUKA (MBGL)

NHS Station	Type of Aquifer system	Discharge		
		30lps	***35lps***	***40lps***
Haldarva I	Younger alluvium	35.9	36.0	36.2
Handod		31.0	31.4	31.8
Kurali i		47.8	48.1	48.5

E Results for Sinor taluka

Using the properties of this aquifer system for Sinor taluka, the analysis was made for the discharge rate of 30lps, 35lps and 40lps. Amongst the 3 observation wells considered in Sinor taluka, all of them are in younger alluvium type soil, analyses of these wells are shown in Fig. 8 (a to d are in clockwise from top left corner) and are also given in Table V.

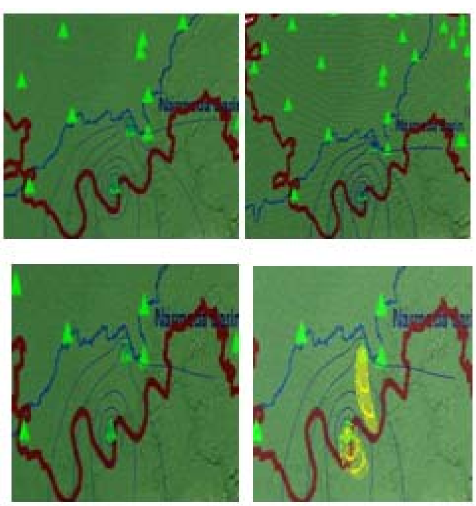

Fig. 8. Effect of well abstraction on ground water head in Younger Alluvium for NHS in Sinor for (a) 30lps (b) 35lps (c) 40lps (d) maximum area contributing to well

TABLE V. COMPARISON OF HEAD FOR NHS STATION IN SINOR TALUKA (MBGL)

NHS Station	Type of Aquifer system	Discharge		
		30lps	***35lps***	***40lps***
Segwachouki ii	Younger alluvium	33.7	33.8	34.0
Sinor		23.5	23.6	24.0

F Results for Waghodia taluka

Using the properties of this aquifer system for Waghodia taluka, the analysis was made for the discharge rate of 30lps, 35lps and 40lps. Amongst the 5 observation wells considered in Waghodia taluka, all of them are in Basalt type soil, analyses of these wells are shown in Fig. 9 (a to d are in clockwise from top left corner) and are also given in Table VI.

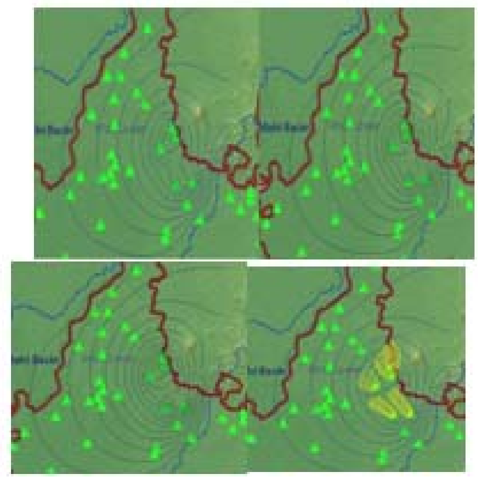

Fig. 9. Effect of well abstraction on ground water head in Basalt for NHS in Waghodia for (a) 30lps (b) 35lps (c) 40lps (d) maximum area contributing to well

TABLE VI. COMPARISON OF HEAD FOR NHS STATION IN WAGHODIA TALUKA (MBGL)

NHS Station	Type of Aquifer system	Discharge		
		30lps	***35lps***	***40lps***
Waghodia Pz	Basalt	7.1	7.27	7.64
Karamasiya		10.9	11.5	12.0
ChellaKaramsiya Pz		3.4	3.68	4.05
Patiyapura		10.5	10.9	11.0
Saidal		4.8	5.13	5.51

G Results for Dabhoi taluka

Using the properties of these aquifer systems for Dabhoi the analysis were made for the discharge rate of 30lps, 35lps and 40lps. Amongst the 5 observation wells considered in Dabhoi taluka, 3 have basalt as the principle aquifer system and another 2 have younger alluvium as the principle aquifer system, analyses of these wells are shown in Fig. 10 and 11 (a to d are in clockwise from top left corner) respectively and are also given in Table VII.

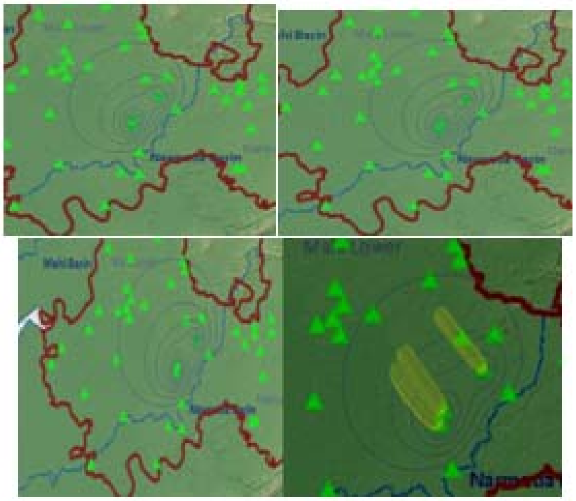

Fig. 10. Effect of well abstraction on ground water head in basalt aquifer system for NHS in Dabhoi for (a) 30lps (b) 35lps (c) 40lps (d) maximum area contributing to well

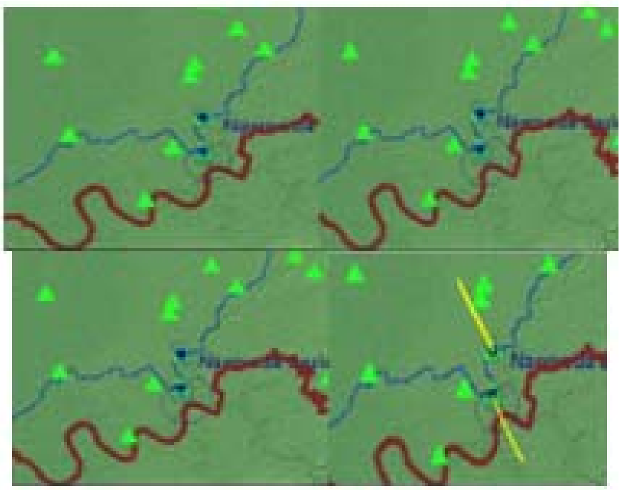

Fig. 11. Effect of well abstraction on ground water head in younger alluvium aquifer system for NHS in Dabhoi for (a) 30lps (b) 35lps (c) 40lps (d) maximum area contributing to well

TABLE VII. COMPARISON OF HEAD FOR NHS STATION IN DABHOI TALUKA (MBGL)

NHS Station	Type of Aquifer system	Discharge		
		30lps	*35lps*	*40lps*
Amreshwar		8.8	9.0	9.4
Vega	Basalt	7.9	8.0	8.6
Dabhoi		6.0	6.2	6.4
Vadaj	Younger	7.3	7.6	8.0
Gamod	Alluvium	22.2	22.6	23.0

V. CONCLUSIONS

From this study, it is concluded that for Vadodara district in basalt aquifer system, ground water head for 30lps discharge may vary from 3.415 to 24.808 mbgl, for 35lps discharge, it may vary from 3.687 to 25.057 mbgl, for 40lps discharge, it may vary from 4.051 to 25.417 mbgl and in older alluvium aquifer system, ground water head for 30lps discharge may vary from 7.498 to 28.957 mbgl, for 35lps discharge, it may vary from 7.512 to 29.41 mbgl, for 40lps discharge, it may vary from 7.641 to 29.516 mbgl. In younger alluvium aquifer system, ground water head for 30lps discharge, it may vary from 7.398 to 47.889 mbgl, for 35lps discharge, it may vary from 7.638 to 48.138 mbgl, for 40lps discharge, it may vary from 8.046 to 48.569 mbgl and in coastal alluvium aquifer system, the ground water head for 30lps discharge, it may vary from 13.418 to 35.054 mbgl, for 35lps discharge, it may vary from 13.526 to 35.303 mbgl, for 40lps discharge, it may vary from 14.019 to 35.418 mbgl. But area contributing to the well remains independent from the well abstraction effect. From the above study, the flow lines are drawn using finite element method and then the same are used to delineate the distance of the area contributing to the well. It is observed that the distance of the flow line from the well location remains independent of discharge of that respective well.

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