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Extended Abstracts

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5.1
Modelling as a tool of groundwater assessment

title: **Modelling of water table fluctuations in the presence of canal seepage and pumping**

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Agriculture is the main source of income to the Indian rural population which comprises almost 80 percent of the total population. The water logging problem due to rise of water table near to the ground surface resulting from seepage of water through beds of unlined canals has been reported from many heavily irrigated areas since the onset of green revolution in late sixties. Pumping of ground water using bore wells located in the vicinity of canals has been suggested as one of the effective measures to minimize the effect of water logging problems. The present paper deals with the development of a mathematical model to predict the dynamic behaviour of the water table in the presence of seepage owing to intermittently applied canal irrigation and groundwater pumping from any number of wells. Figure 1 presents a schematic diagram of a homogeneous anisotropic aquifer system of length A and width B. The aquifer system is characterized with the zero flux condition at all four boundaries. The aquifer is receiving recharge from a canal which is being represented by three strip recharge basins namely B1, B2 and B3, joined together. This figure also shows a well adjacent to the B3 segment of canal which is being used for ground water pumping to lower the level of the water table. For demonstration purpose only one well is shown, but in principle the model is developed to consider any number of wells with different pumping rates.

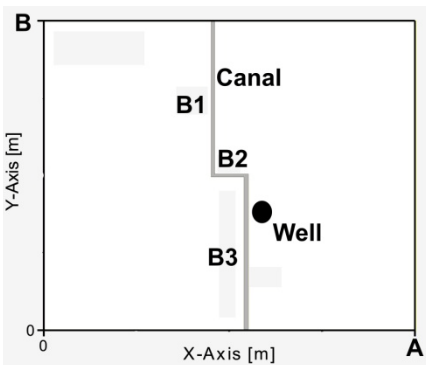

Figure1. Schematic diagram of aquifer with canal and well.

FORMULATION OF THE PROBLEM

Ground water flow in the aquifer system under consideration is represented by following 2-D linearized Boussinesq equation:

$$\frac{\partial^2 H}{\partial x^2} + \beta \frac{\partial^2 H}{\partial y^2} + \frac{2}{K_x} P(x,y,t) = \frac{1}{a}\frac{\partial H}{\partial t} \tag{1}$$

subject to the following initial and boundary conditions:

$$H(x,y,0) = 0 \tag{2}$$

$$\frac{\partial H}{\partial x}(0,y,t) = \frac{\partial H}{\partial x}(A,y,t) = 0, \qquad 0 \le y \le B$$

(3 & 4)

$$\frac{\partial H}{\partial y}(x,0,y) = \frac{\partial H}{\partial y}(x,B,t) = 0, \qquad 0 \le x \le A$$

in which $H = h^2 - h_0^2$, $a = K\bar{h} / S$, = Kx/Ky, and *P (x,y,t)* represent the sum of time varying recharge rate and pumping rates from multiple basins and wells. Intermittently applied time varying recharge and pumping rates have been approximated by using linear elements of different lengths and slopes depending on the nature of variation of recharge and pumping rates. *P (x,y,t)* is mathematically represented by

$$P(x,y,t) = \sum_{i=1}^{N} p_i(t)[H_a(x - x_{i1}) - H_a(x - x_{i2})].[H_a(y - y_{i1}) - H_a(y - y_{i2})] \quad (5)$$

$p_i(t)$ = recharge rate of ith basin, N = Total number of basins,

$H_a(x)$ = unit step function,

$p_i(t)$ is approximated by a series of line elements given by:

$$p_i(t) = \begin{cases} r_{ij}t + c_{ij}, & t_{ij} \le t \le t_{i,j+1} \\ r_{ik}t + c_{ik}, & t \ge t_k \end{cases} \quad (6)$$

r_{ij} and c_{ij} are the slope and intercept of the jth linear element of the ith basin.

Field examples of artificial recharge from basin suggest that the rate of recharge initially increases with time and after attaining a maximum value, it decreases due to clogging of pores canal's bed. When recharge operation is discontinued, the recharge rate tends to approach zero value (Zomorodi, 1991; Detay, 1995; Mousavi and Rezai, 199). Taking into account of such pattern of recharge variation, an example of the time varying recharge due to canal seepage resulting from one cycle of irrigation, as shown in Figure 2 is considered for demonstration purpose. In this case, with the onset of canal irrigation, rate of recharge increases from initial zero value to a maximum value of 0.7m/d at 5th day. Thereafter, irrigation is discontinued. As a result, the recharge rate decreases to 0.2 m/d at a faster rate till 15th day and thereafter with a relatively slow rate, it decreases to zero at 30th day. This time varying recharge rate is approximated by using linear elements of different length and slope. (Manglik et al., 1997, Manglik et al 2006, Rai et al. 2006).

SOLUTION

The above discussed initial and boundary value problem is solved by using Finite Fourier cosine transform. The solution is given as:

$$H(x,y,t) = \frac{1}{AB}\bar{H}(0,0,t) + \frac{2}{AB}\sum_{m=1}^{\infty}\bar{H}(m,0,t)\cos\left(\frac{m\pi x}{A}\right) + \frac{2}{AB}\sum_{n=1}^{\infty}\bar{H}(0,n,t)\cos\left(\frac{n\pi y}{B}\right) + \frac{4}{AB}\sum_{m=1}^{\infty}\sum_{n=1}^{\infty}\bar{H}(m,n,t)\cos\left(\frac{m\pi x}{A}\right)\cos\left(\frac{n\pi y}{B}\right) \quad (7)$$

where:

$$\overline{H}(m,n,t)=\frac{2a}{K}\left[\sum_{i=1}^{N}g_i(m,n)\left\{\sum_{j=1}^{k-1}S_{ij}-S_{ik}\right\}\right]$$

$$g_i(m,n)=\left[x_{i2}\text{sinc}\left(\frac{m\pi x_{i2}}{A}\right)-x_{i1}\text{sinc}\left(\frac{\text{m}\pi x_{i1}}{A}\right)\right].\left[y_{i2}\text{sinc}\left(\frac{\text{n}\pi \text{y}_{\text{i2}}}{\text{B}}\right)-y_{i1}\text{sinc}\left(\frac{n\pi y_{i1}}{B}\right)\right]$$

$$\text{sinc}(x)=\sin(x)/x$$

$$S_{ij}=\frac{r_{ij}}{\alpha}\left[t_{i,j+1}\exp\{-\alpha(t-t_{i,j+1})\}-t_{ij}\exp\{-\alpha(t-t_{ij})\}\right]$$
$$-\left(\frac{r_{ij}}{\alpha^2}-\frac{c_{ij}}{\alpha}\right)\left[\exp\{-\alpha(t-t_{i,j+1})\}-\exp\{-\alpha(t-t_{ij})\}\right]$$

$$S_{ik}=\frac{r_{ik}}{\alpha}\left[t-t_{ik}\exp\{-\alpha(t-t_{ik})\}\right]-\left(\frac{r_{ik}}{\alpha^2}-\frac{c_{ik}}{\alpha}\right)\left[1-\exp\{-\alpha(t-t_{ik})\}\right]$$

$$\alpha=a\pi^2\left[\left(\frac{m}{A}\right)^2+\beta\left(\frac{n}{B}\right)^2\right]$$

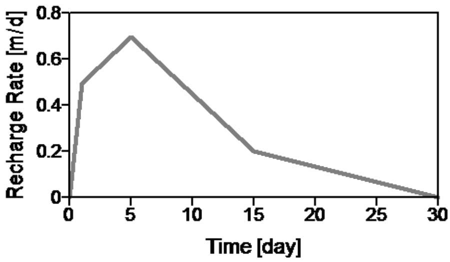

Figure2. The pattern of time varying recharge rate.

Application of this model (eq. 7) in the prediction of spatio-temporal variation of water table in the presence of seepage from canal and pumping would be demonstrated with the help of a synthetic numerical example with the time varying recharge rate shown in Figure 2. The model may be useful for appropriate planning of irrigation and pumping in order to prevent or at least minimize the effect of water logging and soil salinity. It can be also used to verify the results of a numerical model under developing stage.

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