Development and Simulation of Groundwater Resources in Coastal Aquifer

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INTRODUCTION

One of the most difficult problem that encountered in groundwater resources development in coastal aquifer or on some islands is sea water intrusion. Especially when the groundwater extraction rate is larger than natural recharge to the coastal aquifer system. In this case study, a two dimensional numerical model is employed which describes regional groundwater flow and the movement of the sharp interface separating by sea water and fresh water. These result are then compared with the observed groundwater table, and the development groundwater quantity is discussed.

MATHEMATICAL MODEL

In the studied aquifer system, a wedge of intruding saltwater is supported by the freshwater discharge toward the sea. So the two-dimension partial differential equation for simulating equilibrium state between sea water level and ground water table in the aquifer system can be described by follow continuity equations (1) and (2), respectively, which must be solved simultaneously.

$$\frac{n_e}{k}\frac{\partial h_s}{\partial t}=\frac{\rho_f}{\rho_s}\left\{\frac{\partial h_s}{\partial x}\frac{\partial h_f}{\partial x}+h_s\frac{\partial^2 h_f}{\partial x^2}\right\}+\frac{\Delta\rho}{\rho_s}\left\{\left(\frac{\partial h_s}{\partial x}\right)^2+h_s\frac{\partial^2 h_s}{\partial x^2}\right\}+\frac{\rho_f}{\rho_s}\left\{\frac{\partial h_s}{\partial y}\frac{\partial h_f}{\partial y}+h_s\frac{\partial^2 h_f}{\partial y^2}\right\}+\frac{\Delta\rho}{\rho_s}\left\{\left(\frac{\partial h_s}{\partial y}\right)^2+h_s\frac{\partial^2 h_s}{\partial y^2}\right\} \quad (1)$$

$$\frac{n_e}{k}\frac{\partial h_f}{\partial t}=\frac{n_e}{k}\frac{\partial h_s}{\partial t}+\frac{\partial h_f}{\partial x}\left\{\frac{\partial h_f}{\partial x}-\frac{\partial h_s}{\partial x}\right\}+\left(h_f-h_s\right)\frac{\partial^2 h_f}{\partial x^2}+\frac{\partial h_f}{\partial y}\left\{\frac{\partial h_f}{\partial y}-\frac{\partial h_s}{\partial y}\right\}+\left(h_f-h_s\right)\frac{\partial^2 h_f}{\partial y^2}+\varepsilon \quad (2)$$

where n_e is effective porosity; k is hydraulic permeability; h_f is height of the freshwater above the reference point; h_s is height of the sea water above the reference point; $\Delta\rho$ is density difference equal ρ_s-ρ_f ; ε is the volumetric flow rate of sources or sinks per unit area {included precipitation, pumping and evapotranspiration and $\varepsilon = R_{ain} - E_v - Q_{pum}\ \delta(x-x_0)(y-y_0)$ }, δ is Dirac function. Equation (1) is used to describe saltwater flow, and (2) is used to describe freshwater flow. The accuracy and stability of various time difference schemes have been investigated by *Ueda and Jinno et al* [1981].

In the present analysis, the simulation procedure is based on finite-difference approximation. This means that a grid of node points Δx and Δy along the x and y directions must be set up and the time variable also be separated into discrete time steps of length Δt.

MODEL APPLICATION AND CALIBRATION

As the case study area is located in Subtropical zone, the precipitation and evapotranspiration are the most important control variables on groundwater fluctuation under natural conditions, therefor, the study of the vertical recharge and discharge to the groundwater aquifer system will affect the accuracy of the simulated groundwater heads distribution. The precipitation as the only sources of recharge to groundwater aquifer system was given by *K. Jinno et al.*(1996), and the evaluation of the evapotranspiration given by *Ying Ru et al.*(1996) have been utilized at the present paper.

Ground water table are simulated at each node of the finite-difference mesh, and the period from March 1991 to February 1992 was selected as the period of study on the basis of the data which were available. Evapotranspiration and precipitation were calculated for each element of the mesh using above mentioned method in the corresponding duration, and the withdraw at the pumping node was set at actually pumping quantity of the well at that node. In order to achieve a close agreement between simulated and observed groundwater table, different hydraulic permeability value $\{12.8\times10^{-4}$(m/s) and 2.10×10^{-4}(m/s)$\}$ were used in different calculated sub-areas. Figure 1 shows simulated and observed groundwater table fluctuations during the calculation period at four monitor wells.

To determine the amount of groundwater that can be extracted in the future without causing sea water intrusion, the natural freshwater flow through the groundwater system to the sea need first to be understood. We adopt the following equation to estimate the amount of groundwater outflow through the site of planned subsurface dam.

$$Q_f(t) = \left\{ \sum_{i=1}^{N} \int_0^T h_{fi}(t)\cdot v_i(t)\cdot \cos\alpha \, dt \right\} \cdot \Delta l \qquad (3)$$

where Δl is the grid length along the dam axis, h_{fi} is the fresh water level at i node, $v_i(t)$ is the flow velocity perpendicular direction to the dam axis, T is the calculation time, N is the number of the grids, and α is the angle between groundwater flow direction and x coordinate axis.

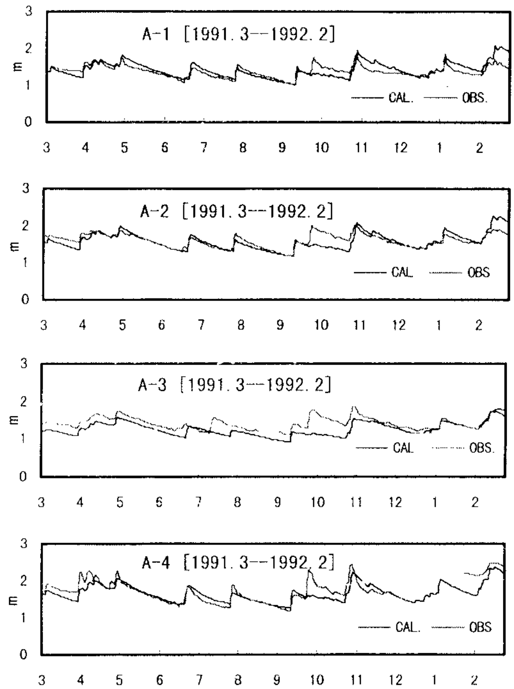

Fig.1 Simulated fresh water level and Observed level in 1991

CONCLUSION

The above mentioned models applied on the study area are considered useful to determine the groundwater table distribution and interface motion between freshwater and salt water. It also indicated that any change of freshwater flow will induce the movement of the interface, especially, the change of groundwater recharge and discharge. Increasing groundwater pumping to meet the demand of drinking and irrigation will reduce fresh water flow toward the sea and causes intrusion of sea water into the aquifer as the interface moves inland.

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