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# CHANGE IN FRESHWATER－SALTWATER INTERFACE IN COASTAL AQUIFERS

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## 1. INTRODUCTION

The use of coastal aquifers as operational reservoirs in water resources systems requires the development of tools that make it possible to predict the behavior of the aquifer under different conditions. Since many groundwater systems in coastal areas are in contact with saline water, one of the major problems is the prediction of the motion of the saltwater body in the aquifer. The quantitative understanding of the movement patterns and mixing between fresh and saltwater, and the factors that influence these processes, are necessary to manage and protect the coastal groundwater resources.

The movement will be advancing or retreating depending on whether the freshwater discharge through the aquifer is decreased or increased. Reduction in freshwater flow towards the sea causes intrusion of saltwater into the aquifer as the interface moves inland. Under such circumstances, it is important to study the movement rate of the interface and predict the shape of the interface profile due to changes in recharge or discharge of groundwater and related activities.

This study is assessing the quantitatively impact of changes in groundwater recharge and withdrawal pattern on the movement of the freshwater-saltwater interface in the Walawe river basin, Sri Lanka.

## 2. METHODOLOGY

When the width of the transition zone between freshwater and saltwater is small relative to the thickness of the aquifer, it can be assumed, for the purpose of analysis, that the two fluids are separated by a sharp interface. In this approach, together with Dupuit approximation, for each flow domain the equation of continuity may be integrated over vertical direction. *(Bear, 1979)*

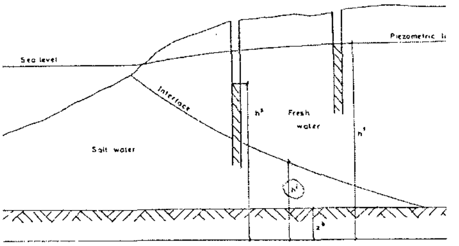


Fig. 1. Location of the interface, describing variables

The vertically integrated equations of freshwater and saltwater flow,

$$\nabla . q_f + S_f \frac{\partial \phi_f}{\partial t} = 0 \qquad and \qquad \nabla . q_s + S_s \frac{\partial \phi_s}{\partial t} = 0 \qquad (1)$$

where $q = -K . \nabla \phi$

By integrating along the vertical, for seawater region, finally the two regions can be simplified to the following system of differential equations. The variables are as shown in Fig. 1.

$$\frac{\partial}{\partial x}\left[K_{fx}\left(h^f - h^i\right)\frac{\partial h^f}{\partial x}\right] + \frac{\partial}{\partial y}\left[K_{fy}\left(h^f - h^i\right)\frac{\partial h^f}{\partial y}\right] + q_f = S_f \frac{\partial h^f}{\partial t} - \theta\left[\left(1+\delta\right)\frac{\partial h^s}{\partial t} - \delta \frac{\partial h^f}{\partial t}\right] \qquad (2)$$

$$\frac{\partial}{\partial x}\left[K_{sx}\left(h^i - z^b\right)\frac{\partial h^s}{\partial x}\right] + \frac{\partial}{\partial y}\left[K_{sy}\left(h^i - z^b\right)\frac{\partial h^s}{\partial y}\right] + q_s = S_s \frac{\partial h^s}{\partial t} - \theta\left[\left(1+\delta\right)\frac{\partial h^s}{\partial t} - \delta \frac{\partial h^f}{\partial t}\right] \qquad (3)$$

where the location of the interface

$$h^i = \frac{\rho_s}{\rho_s - \rho_f} h^s - \frac{\rho_f}{\rho_s - \rho_f} h^f \qquad \Rightarrow \qquad h^i = \left(1+\delta\right)h^s - \delta\, h^f \qquad (4)$$

| | |
|---|---|
| $h^f$, $h^s$ | piezometric heads of fresh and saltwater |
| $q_f$, $q_s$ | flow rate in fresh and salt water |
| $K_f$, $K_s$ | hydraulic conductivity in fresh and salt water |
| $S_f$ , $S_s$ | storage coefficient in fresh and salt water regions |
| $\theta$ | porosity of the aquifer media |
| $\rho_f$ , $\rho_s$ | density of freshwater and saltwater |

A numerical model, based on an implicit finite difference discretization scheme was developed for the solution of equations (2) and (3). The space derivative by a central difference scheme and the time derivative by a backward difference scheme were used.

## 3. STUDY AREA

The Walawe river basin is located in the southern part of Sri Lanka. The catchments area of the basin is 2442 $km^2$. Walawe river flows from north to south with the total river length of 105 km. The northern watershed boundary of the Walawe river lies along the crest of the high escarpment and marks the southern edge of the hill country of Sri Lanka. The western part of the basin includes the eastern ends of the Sabaragamuwa ridge systems. The eastern boundary of the basin is the watershed between the Walawe river and Kirindi Oya basin in the center, and the course of Malala Oya in south. The lower part of the basin is located in the dry zone, which has an annual rainfall less than 1500mm. This area consists of dune sand and alluvium with permeable sandy aquifer and it provides a thin lens of fresh groundwater along the coastal area.

## 4. RESULTS AND DISCUSSION

The case used as a reference was an unconfined aquifer in the lower part of the Walawe basin. The hydraulic conductivity and the storage coefficient were estimated approximately 7m/day and 0.002 using the pump test data of the groundwater monitoring wells in the area. Hydraulic conductivity data is matched with the values representative of the permeable sand/basalt aquifer (Freeze and Cherry, 1979). However there is not much field data available describing the actual position of the interface and its responses.

Considering constant head boundary condition for the seaward boundary, freshwater and saltwater heads were fixed at sea level. This allowed water to move in and out of the seaward boundary of the aquifer and a detailed analysis of the seepage face was not carried out. Neglecting any lateral flow from adjacent aquifers, it is assumed that the recharge to the aquifer is mainly from rainfall. The mean annual average recharge to the basin was calculated using a water balance approach. Those values were used to find the average annual groundwater flow to the coastal aquifer. The variation of the steady position of the interface with groundwater recharge is shown in Fig. 2. The increments in the groundwater recharge lead to change the time required to reach the steady state position. The simulated result of the location of the interface for the average groundwater flow in year 2000 was compared with the analytical solution for steady condition using the method developed by Van Der Veer (1977). The numerical model was not tracked the interface tip and toe and it leads to a deviation between numerical and analytical results (Fig.3).

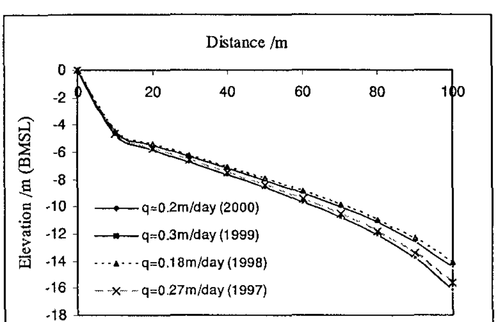


Fig. 2. Change in freshwater-saltwater interface with groundwater recharge

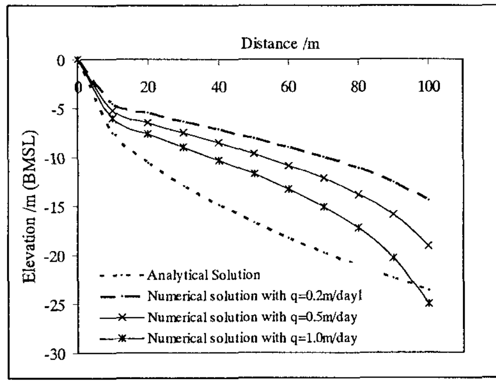


Fig. 3. Comparison between analytical and numerical solutions.

## 5. SUMMERY

Depending on aquifer characteristics and boundary conditions, the behavior of the adjustment of freshwater saltwater interface can be significantly influenced by the freshwater flow dynamics.

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