Accurate Estimation of Initial Saltwater-freshwater Interface for Simulating Saltwater Intrusion using numerical methods

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Abstract

Coastal aquifers are prone to saltwater intrusion as increased demand for freshwater leads to heavy, unregulated pumping from these coastal aquifers. Under sustainable pumping conditions, the saltwater-freshwater interface is stable but rarely monitored. When saltwater intrusion is first detected, saltwater-freshwater interface is already disturbed and starts moving inland. Any numerical simulation-based methodology to manage saltwater intrusion requires the initial saltwater-freshwater interface to be known. Numerical models need to satisfy the boundary conditions and the initial conditions (Cauchy–Riemann equation) for the solution to exist. However, in the absence of any monitoring, the initial position of the saltwater-freshwater interface is unknown, which forms the initial condition for numerical models and thus fall in the category of initial value problem. Pool and Carrera's correction factor for the sharp interface approach is used to estimate the initial saltwater-freshwater interface. Generally, groundwater head information is readily available, which can be used to locate the saltwater-freshwater interface. Ghyben-Herzberg relation is used for estimating the initial position of the interface, but the level of accuracy of the information derived from Ghyben-Herzberg relation is low. Hence, in this study Pool and Carrera's correction factor for density ratio is used in Ghyben-Herzberg relation for accurate estimation initial interface location. The developed method is applied to a real coastal site in Puri, India, where the aquifer is encroached by saltwater intrusion. The performance evaluation results show the applicability of this methodology.

Introduction

Source: The National Environmental Education Foundation (NEEF)

Development state
- Property development
- Increase freshwater demand
- Excess pumping

Detection State
- Decrease in water table below MSL
- Movement of saltwater towards pumping well
- Saltwater intrusion

Rectification state
- Identification of extent of saltwater intrusion
- Development of saltwater intrusion mathematical model

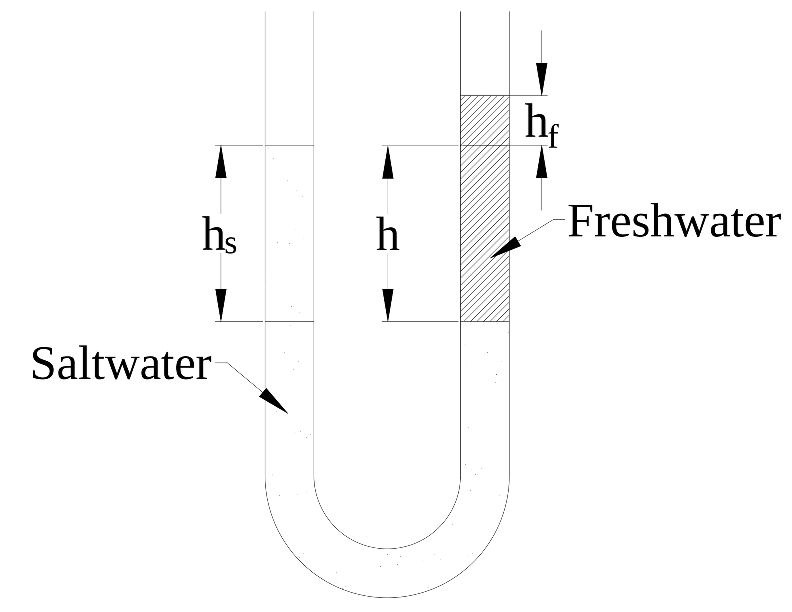
Aquifer parameters + Recharge parameters + Water table + Boundary conditions + Location of saltwater interface + Pumping = Simulated saltwater interface

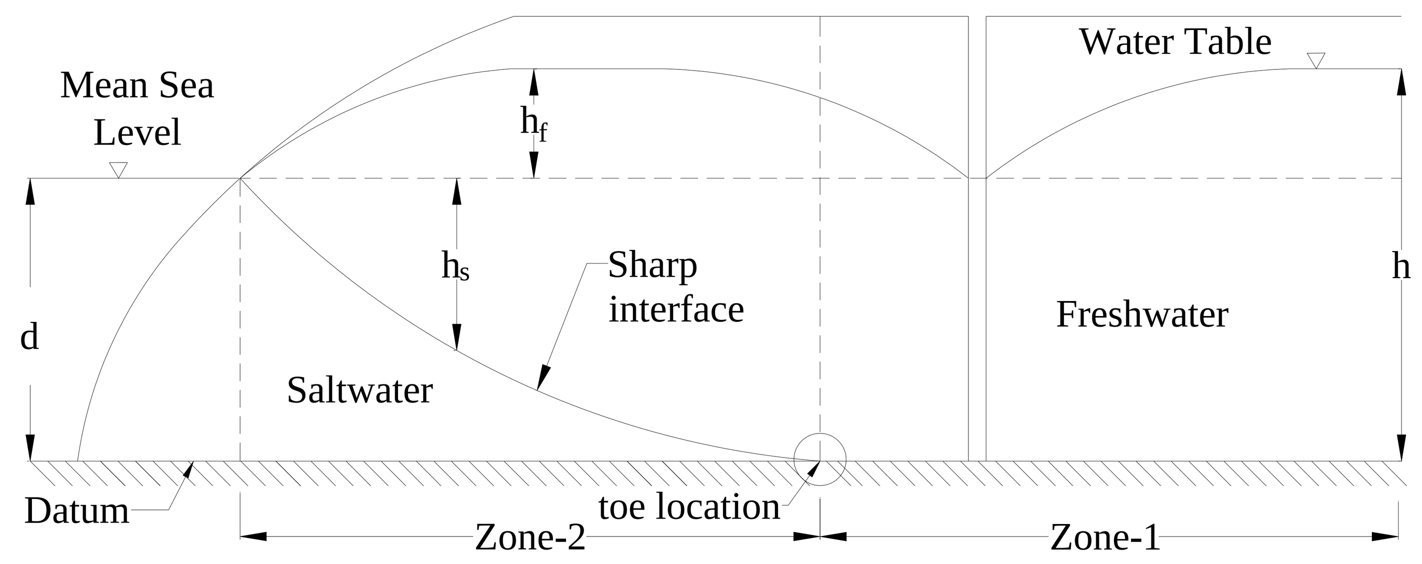
Methodology

Ghyben Herzberg principle

$$h_s = \varepsilon\, h_f$$

$$\varepsilon = \frac{\rho_f}{(\rho_s - \rho_f)}$$





Disadvantage of using Ghyben Herzberg principle

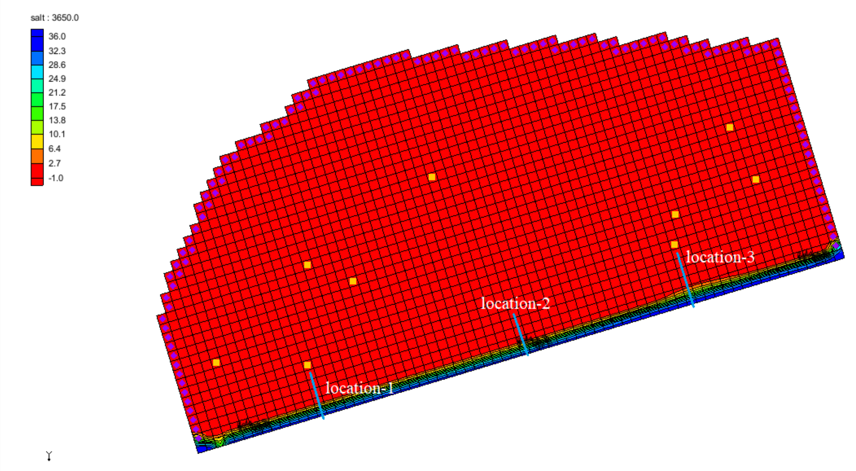
1. It does not considers effects of dispersion while determining the saltwater intrusion.
2. It over estimates the location of the saltwater interface.

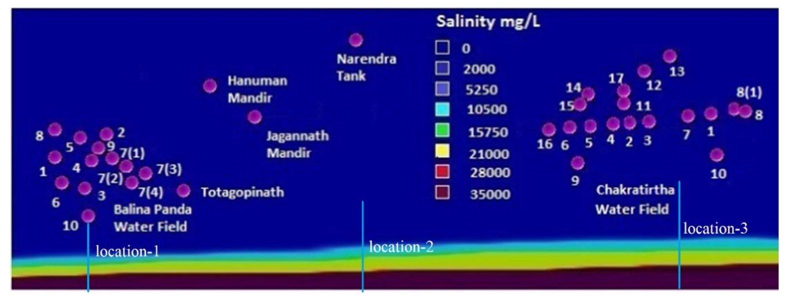
Pool and Carrera's correction factor

$$\varepsilon^* = \varepsilon\left[1 - \left(\frac{\alpha_t}{d}\right)^{\frac{1}{6}}\right]$$

Results

1. **Name of the study area**
   - Puri city. East coast of India
2. **Location**
   - $19^\circ 47'$ to $19^\circ 50'$ north latitude and $85^\circ 48'$ to $85^\circ 52'$ east longitudes
3. **Population**
   - 200 thousand (2011 census)
4. **Amount of water supply**
   - 20×10^3 m^3/day from 36 production wells





Compare the toe location location of the isosalinity contour (5 kg/m^3)

Scenario	Location-1	Location-2	Location-3
Actual scenario (Vijay & Mohapatra, 2016)	155.4 m	182.6	209.1
Developed model	157.6 m	181.3 m	210.8

Conclusion

1. The developed methodology is able to simulate location of the interface with less than 5% accuracy
2. The developed method is viable option for limited data availability conditions
3. This method can be further refined by applying numerical techniques.

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