A Saltwater Upconing Model to Evaluate Wellfield Feasibility

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ABSTRACT
A SEAWAT modeling analysis was conducted to evaluate potential saltwater upconing at a proposed wellfield in northwest Florida, USA. A practical approach was developed for setting and adjusting the model-edge head and salinity boundary conditions in the three-dimensional model. Simulations of 1,000 yr duration provided appropriate equilibrium pre-pumping conditions. Simulations of well withdrawal resulted in upconing of the 250 mg/L chloride concentration surface by 35 m in 50 years, which is still below the production zone of the wells. The modeling results are being used to plan a future water-supply source and to develop a supplemental field study.

INTRODUCTION
The Northwest Florida Water Management District has identified an area in northeast Franklin County as a potential location for a new 7,600 m^3/d wellfield. The wellfield, located approximately 10 km inland (northwest) of the Gulf of Mexico, would help meet projected future water demand in this growing rural county. The wellfield area is largely covered by planted pines and by wetlands that have been altered by past silvicultural practices.

A field investigation program and groundwater modeling analysis were conducted to help assess the feasibility of this groundwater supply. Density-dependent groundwater modeling was used to estimate saltwater upconing that would potentially result from the groundwater withdrawal.

The general hydrogeology of the region consists of two aquifers – the Surficial Aquifer System (SAS) and the Floridan Aquifer System (FAS) – separated by an aquitard called the Intermediate System (Pratt et al. 1996). The proposed water supply wells would be screened in the FAS, which is a regional limestone aquifer with significant zones of secondary porosity formed by mineral dissolution.

METHODS
A SEAWAT (Langevin et al. 2003) model was constructed to assess potential effects of the proposed groundwater withdrawals. A three-dimensional model grid was designed with 328 rows, 263 columns, a minimum horizontal spacing of 30 m near the proposed wellfield, and a maximum horizontal spacing of 300 m. Vertically, the model consisted of 16 layers (Figure 1), with layers 1 and 2 representing the SAS and Intermediate System, respectively. Test simulations with different levels of discretization were used to assess appropriate domain size and grid spacing for this analysis.

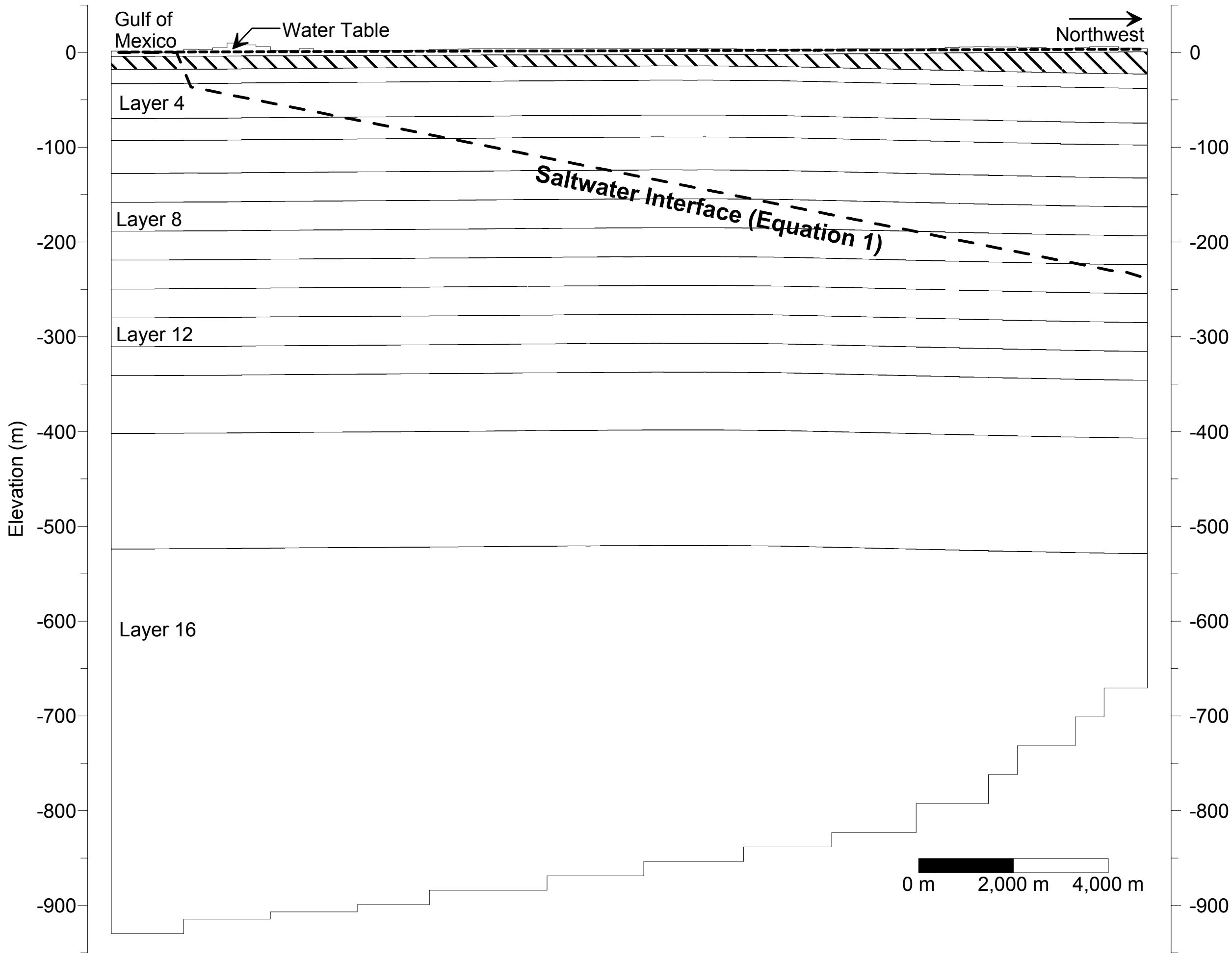

Figure 1. Model layers and specification of boundary conditions along the southwestern model edge (column 1).

Along the lateral model edges, head and salinity were specified using a sharp saltwater interface assumption (Figure 1). However, the interface was not assumed to be sharp in the model interior, but rather a brackish zone was allowed to develop through dispersion. The freshwater head (h_f) on the boundary above the interface was defined based on interpretation of regional monitoring data. Subsequently, the elevation of the saltwater interface (z_s, relative to mean sea level) was specified according to:

$$z_s = -\alpha h_f \tag{1}$$

The parameter α was used to adjust the interface location to approximately match field conditions. For ideal steady conditions, the Ghyben-Herzberg relationship would apply and α would be 40. However, based on interpretation of borehole geophysical logs and depth-discrete concentration data, a value of 70 appeared to be a more reasonable estimate of α for this study. Boundary nodes below the assumed saltwater interface were assigned a salinity of 35 g/L, corresponding to a specific gravity of 1.025. The head below the interface (h_s) was specified such that no vertical flow occurred across the interface on the boundary.

A 1,000-year pre-pumping equilibrium simulation was used to set initial conditions for predictive simulations. The 1,000 year time frame was shown to be appropriate based on stability of solute mass in the model and stability of the simulated salinity field. Each time boundary conditions or hydrogeologic properties were modified (e.g., during sensitivity simulations), a new pre-pumping equilibrium simulation was conducted to set initial conditions.

Model parameter values and reasonable ranges were initially estimated from analytical analyses of FAS aquifer performance tests (APTs) and SAS slug tests. Parameters were subsequently adjusted to optimize the fit between model-simulated and measured drawdown data for one of the APTs. Additionally, the boundary conditions in the model were adjusted so that the pre-pumping simulation reasonably matched observed heads at wells within the study area. A calibration sensitivity analysis was conducted to refine the reasonable ranges of model parameters.

A 1,000-year base-case predictive simulation was executed with two wells withdrawing 3,800 m^3/d each and with best-estimate values for model parameters and boundary conditions based on the calibration analysis. Subsequently, a predictive sensitivity analysis was conducted wherein model parameters were adjusted within their reasonable ranges to examine the effect of such changes on model results. Alternative withdrawal scenarios were also simulated by assuming different well locations and/or withdrawal rates.

RESULTS AND CONCLUSIONS

Figure 2 shows the simulated upconing of the 250 mg/L chloride concentration (0.46 g/L salinity) surface for the base case. This concentration represents the Secondary Maximum Contaminant Level (SMCL). The maximum amount of upconing is 35 m after 50 years of pumping, and 85 m after 1,000 years of pumping (steady-state). Figure 2 also shows that the pumping has minimal effect on the deeper saline water, represented by the 15,000 mg/L chloride (28 g/L salinity) surface.

Results from sensitivity simulations indicated that the degree of upconing was insensitive to most model parameters; a notable exception was that higher vertical conductivity of the FAS resulted in greater upconing and vice versa. Importantly, some reasonable parameter changes (e.g., lower values of α, higher dispersivity) resulted in a higher initial elevation of the SMCL surface which then allowed withdrawals to pull this surface further into the production zone.

The feasibility of the proposed wellfield can be judged partially on these model results. The amount of upconing would not likely result in withdrawal of water exceeding the chloride SMCL within 50 years. A field program is currently being planned that will better define the current (pre-pumping) elevation of this surface. The model will be updated based on data from the additional field investigation and then used for a revised assessment of withdrawal effects.

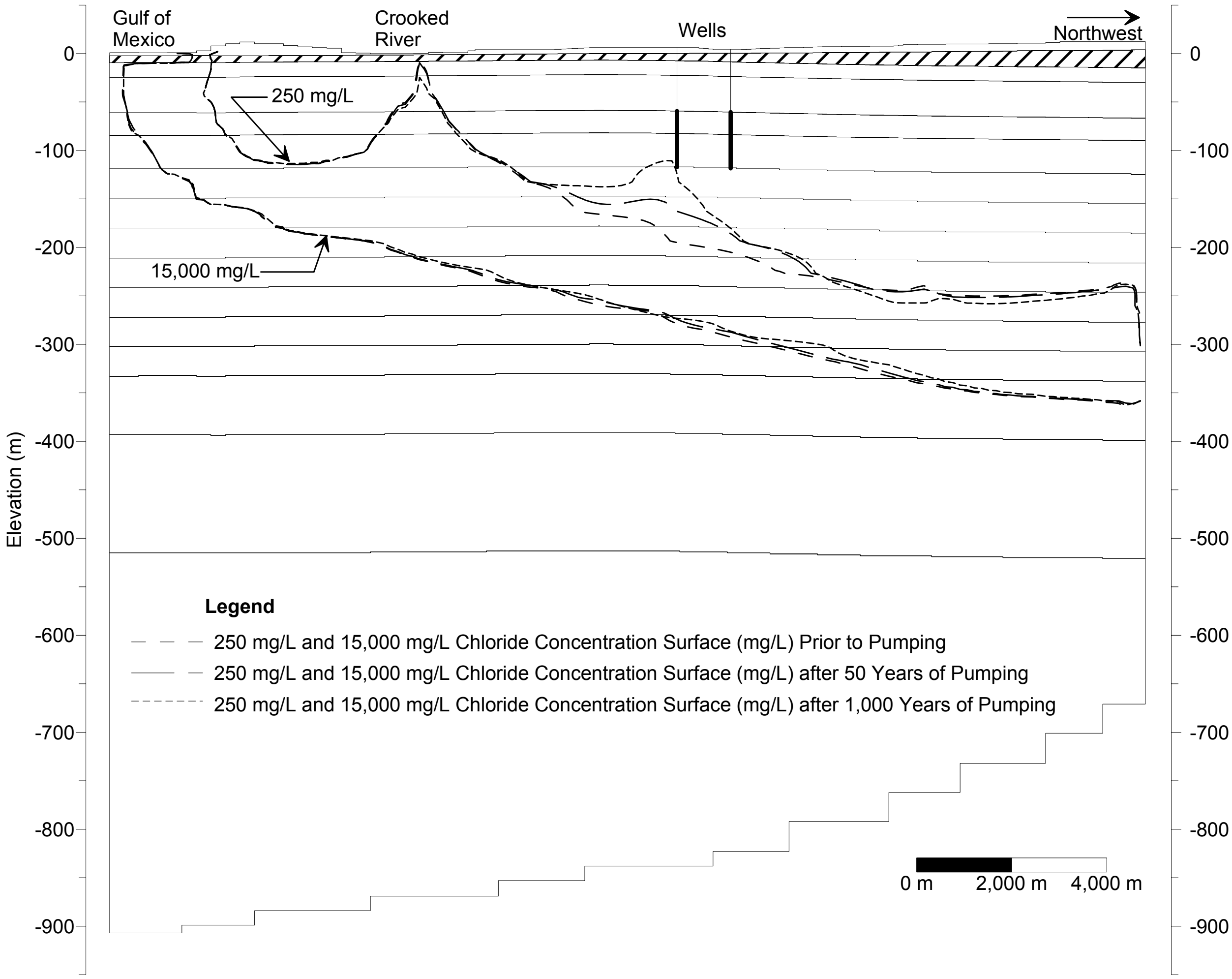

Figure 2. Simulated upconing for the base case predictive simulation (column 153).

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