Saltwater Intrusion and Hydraulic Conductivity Estimation in East Baton Rouge Parish, Louisiana

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ABSTRACT
This research developed a regional saltwater intrusion model to study the on-going saltwater intrusion problem in East Baton Rouge (EBR) Parish, Louisiana. The model was based on SEAWAT. We used multiple generalized parameterization (GP) methods and Bayesian model averaging (BMA) method to estimate spatially correlated hydraulic conductivity. The model was applied to saltwater intrusion simulation in the "1,500-foot" sand for 90 years. The simulation results indicated that major saltwater intrusion would bypass the current network of monitoring wells and reach the Lula Avenue pumping center within 75 years via the west side of the monitoring well, EB-807A. Additional observation wells would be needed to place at the west of EB-807A to monitor potential large saltwater intrusion.

INTRODUCTION
This research studied the saltwater intrusion problem in East Baton Rouge (EBR) Parish. In EBR, there are twelve freshwater aquifers. Ten of the aquifers were originally named according to their general depth in the Baton Rouge industrial district (Meyer and Turcan 1955). Most of the aquifers have been reported the saltwater intrusion problem for more than fifty years due to excessive groundwater withdrawal. In this study, we focused on the "1,500-foot" sand, which is one of the major sources of drinking water in EBR. Groundwater withdrawal from the "1,500-foot" sand began in 1927 (Torak and Whiteman 1982). From 1940 to 2001 water level has declined about 52.8 meters (160 ft) at the observation well EB-168. To better understand the on-going saltwater intrusion problem in the "1,500-foot" sand, this study adopted SEAWAT (Guo and Langevin 2002) to develop a saltwater intrusion model.

METHODS

Data collection and groundwater model calibration
The study area shown in Figure 1 extended about 300 km^2 and included major part of the Baton Rouge metropolitan area. Northern area of the Baton Rouge Fault was the "1,500-foot" sand and southern area of the fault was the "1,200-foot" sand. Through the USGS National Water Information System website, we collected 706 groundwater head data from 18 observation wells located at the "1,500-foot" sand (see Figure 1a). These head data were recorded between January 1990 and December 2004 and were used to calibrate the groundwater model. The groundwater data at well EB-780A at the "1,200-foot" sand determined the south boundary condition. The Louisiana Capital Area Ground Water Conservation Commission (CAGWCC) provided monthly pumping data of 16 production wells located in the study area (see Figure 1b). The specific storage was 0.0000221 $meter^{-1}$. We used the groundwater data at EB-917 and EB-780A to estimate hydraulic characteristic (HC) for the Baton Rouge fault. The identified HC value was 0.000155 day^{-1}. USGS Water Resources Division in Louisiana provided electrical resistivity data at 21 E-log sites (see Figure 1a). The resistivity data determined the thickness of the "1,500-foot" sand as well as the average formation resistivity. We used the Archie's law to interpret the formation factor into porosity and used the Kozeny-Carman equation to estimate hydraulic conductivity.

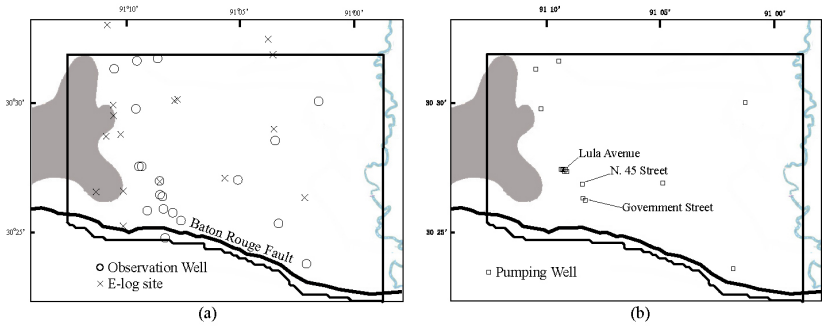

Figure 1. The study area.
(a) The location of groundwater head observation wells and E-log wells.
(b) The location of production wells.

We adopted the generalized parameterization (GP) method (Tsai 2006) and Bayesian model averaging (BMA) approach (Hoeting et al. 1999) to estimate the hydraulic conductivity distribution. Three GP methods were considered in the BMA including NN-VT (combination of natural neighbor interpolation and Voronoi tessellation methods), ID-VT (combination of inverse distance interpolation and Voronoi tessellation methods), and OK-VT (combination of ordinary kriging and Voronoi tessellation methods). The identified hydraulic conductivity distribution was shown in Figure 2a. Figure 2b showed the groundwater head distribution for April 2001.

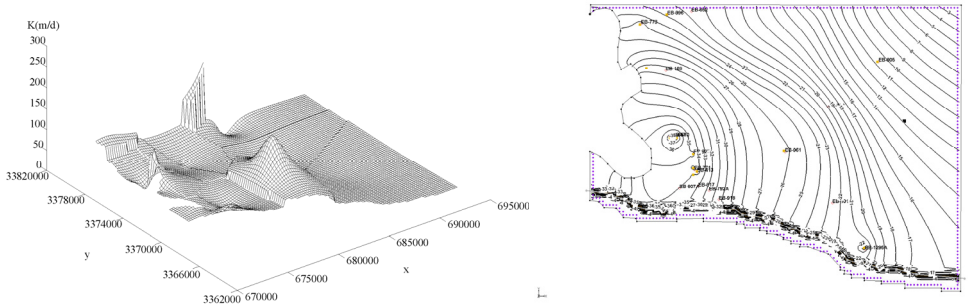

Figure 2. (a) The hydraulic conductivity distribution using BMA.
(b) The groundwater head distribution for April 2001.

The groundwater model also incorporated the connector well, EB-1293, which connects the "800-foot" and "1,500-foot" sands. The CAGWCC installed EB-1293 between the municipal supply wells on Government Street and the freshwater-saltwater interface in the "1,500-foot" sand. The connector well started to operate in 1998 as an initial test of a recharge barrier to mitigate saltwater encroachment in the “1,500-foot” sand. The recharge rate from the "800-foot" sand was estimated around 500 gallons per minute (gpm) (CAGWCC Newsletter, January 2002). The groundwater model considered the connector well as a recharge well with a rate of 500 gpm.

RESULTS

Using individual zonation and interpolation methods, the NN method gave better model goodness of fit to the groundwater head observations than the ID and OK methods. Nevertheless, three GP methods significantly reduced the fitting residuals and performed better than the zonation and interpolation methods. The fitting residual could not be reduced much because large model error came from model structure error. The identified hydraulic conductivity distribution using BMA with three GPs was obtained. Using BMA, we found that the within-GP

variances were much higher than the between-GP variances. This was because the GP methods resulted in similar hydraulic conductivity distributions.

The saltwater intrusion simulation results showed the following observations:

(1) Saltwater had strong lateral transport along the Baton Rouge Fault once it crossed the fault. The cause of saltwater intrusion is due to the huge cone of depression formed by the production wells at Lula Avenue. The salt dispersion width at the region east of EB-918 was around 850 meters from the fault and was almost unchanged after 30 years simulation.

(2) Saltwater accumulated at two spots. One spot was at 600 meters southeast of EB-807A. Higher salt concentrations migrated clockwise across EB-807A toward the Lula Avenue pumping center. The other spot was at 2200 meters southwest of EB-807A.

(3) The 100 ppm isochlor (the front line) migrated to the production well adjacent to the observation well, EB-1295A, before year 2035.

(4) The 100 ppm isochlor first touched down the observation well, EB-918, and few years later it touched EB-807A. Due to the clockwise movement of saltwater along the fault from the east, the salt concentrations in EB-807A and EB-918 were similar.

(5) The 100 ppm isochlor touched EB-917 and EB-792A almost at the same time. The simulation results showed similar salt concentrations in EB-917 and EB-792A due to the clockwise movement of saltwater along the fault.

(6) Before year 2080, the 100 ppm isochlor reached the Lula Avenue pumping center.

(7) Saltwater began to move eastward approaching the Government Street pumping center after year 2035.

(8) The connector well demonstrated halting the saltwater intrusion northward approaching the Government Street pumping center.

(9) Although the saltwater was close to the Government Street pumping center, the simulation results showed that saltwater would reach the Lula Avenue pumping center before it reached the Government Street pumping center.

CONCLUSIONS

Using multiple generalized parameterization (GP) methods with Bayesian model averaging (BMA) was able to consider non-uniqueness in parameterization methods for groundwater inverse modeling. According to the simulation results major saltwater intrusion would bypass the current network of monitoring wells and reach the Lula Avenue pumping center within 75 years via the west side of EB-807A. An array of additional monitoring wells is suggested at the west of EB-807A to monitor potential large saltwater intrusion.

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