

## **Development of Salinity Concentration Maps using Geochemical, Geophysical, and Geostatistical Methods in the Cretaceous Aquifer System**

Primary Contact: Jonathan A. Gillip, Hydrologist, Arkansas Water Science Center, 401 Hardin Rd., Little Rock, AR 72211, (501) 228-3646, [jgillip@usgs.gov](mailto:jgillip@usgs.gov)

### **BACKGROUND**

The Mississippi Embayment and underlying Cretaceous groundwater systems are rich in water resources. However, large areas of aquifers are largely unusable due to elevated total dissolved-solids concentrations. Cretaceous aquifers are known to have high salinity in certain areas. The Tokio Formation is largely undeveloped as a source of groundwater and may be viable in southwestern Arkansas; however the total dissolved-solids concentration may be as high as 2,500 parts per million (ppm)(Boswell and others, 1965). The Nacatoch Sand's total dissolved-solids concentration 2-20 miles down dip from the outcrop is considered to render the groundwater as unusable, with reported total dissolved-solids concentrations as great as 6,500 ppm. Above 500 ppm, increases in total dissolved-solids are attributed to greater concentrations of sodium and chloride (Boswell and others, 1965). In these areas of poor water quality, other shallower aquifers are used for water supply, and as a result of other readily available sources of water, limited water-quality data are available for deeper aquifers with poor water quality. Further characterization of the quality and extent of these waters is needed in order to evaluate potential use as the fresher groundwater in those aquifers is depleted.

### **OBJECTIVES**

The objectives of the proposed study are to improve the understanding and delineation of the water quality of aquifers that are not widely used as water supplies due to elevated salinity, and to estimate the amount of groundwater available from these aquifers. To accomplish these objectives, the following tasks will be completed:

1. Identify existing borehole geophysical logs of wells penetrating saline waters that have a usable resistivity or spontaneous potential log.
2. Update the existing geophysical log database to include the interpretive picks in aquifers of the Nacatoch Sand and the Tokio Formation.
3. Estimate the total dissolved-solids concentrations in the aquifers from the geophysical logs.
4. Refine a relationship between total dissolved solids and salinity using existing water-quality data from the specific aquifers.
5. Repeat geophysical logging in selected wells to determine if the existing resistivity logs are a reasonable representation of the current system.
6. Create salinity concentration maps of the aquifers.
7. Using thickness of formations and the storage of the aquifers, estimate the volume of saline water available.

### **APPROACH**

A three year study will develop salinity concentration maps for selected aquifers using geochemical, geophysical, and geostatistical methods in parts of Arkansas, Louisiana, and Mississippi (fig. 1) and estimated the volume of saline water available. A tentative workplan is presented in table 1.

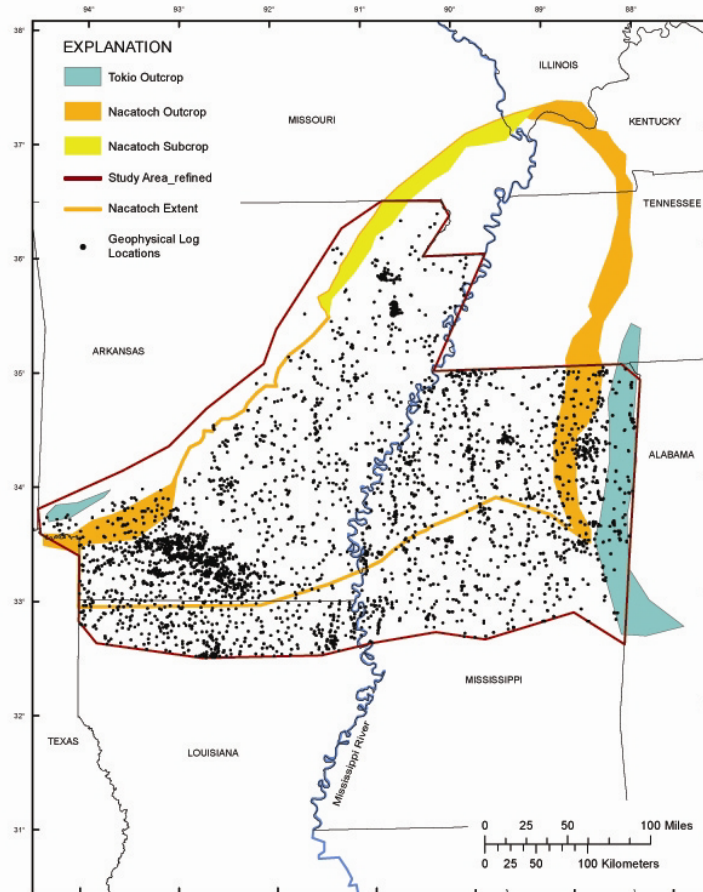


Figure 1. Study area, showing known outcrops and extents of the Nacatoch Sand and Tokio Formation, and locations of geophysical logs used in the Mississippi Embayment Regional Aquifer Study.

Conductivity of groundwater can be derived from resistivity and spontaneous potential (SP) logs. Resistivity logs record the ability of a formation to conduct electricity. Dry rock is a good electrical insulator. The electrical current can only pass through the formation because of the conductive water it contains. Consequently, subsurface formations have finite, measurable resistivities because of the water in their pores or absorbed in their interstitial clays (Schlumberger Wireline and Testing, 1989). Conductivity and resistivity are both measures of the ability of a fluid to conduct electrical current. Conductivity is simply the reciprocal of resistivity:  $\text{conductivity} = 1/\text{resistivity}$  (Paparone, 2009). The SP curve records the electrical potential (voltage) produced by the interaction of the formation connate water, conductive drilling fluid if used, and certain ion-selective rocks and therefore permits the determination of formation water resistivity. In many cases, a good value of the resistivity of the formation water can easily be found from the SP curve recorded in clean (nonshaly) formations. The static SP value in a clean formation is related to the chemical activities of the formation water and the mud filtrate through the formula:

$$SSP = -K \log \frac{a_w}{a_{mf}}$$

Where  $a_w$  is the chemical activity of the formation water,  $a_{mf}$  is the chemical activity of the mud filtrate, and  $K$  varies in direct proportion to the temperature. For NaCl,  $K$  is defined as:

$$K=65+0.24T_c$$

(Schlumberger Wireline and Testing, 1989)

Total dissolved-solids concentrations can then be estimated. Using existing water quality data, a relationship between conductance and salinity can be established (Brownlow, 1979).

An existing geophysical log database of more than 2,600 wells in the Mississippi Embayment (Hart and Clark, 2008) will be queried to locate usable geophysical logs penetrating aquifers with poor water quality. The existing geophysical log database was used to pick formations within the Mississippi Embayment aquifer system which terminated at the Tertiary aged Midway Formation. The Nacatoch Sand and the Tokio Formation are below the existing geologic unit picks in the database. The extent of the formations is not well known due to the poor water quality and subsequent lack of use. Therefore, additional formation picks will be made for these units and added to the database. Using the above described methods, selected geophysical logs will be used to estimate the salinity of the groundwater. In an effort to ensure that the existing geophysical logs represent the current extent and concentration of total dissolved-solids within the aquifer, a small number of wells will be selected for repeat geophysical logging. If it is not possible to repeat geophysical logging in the same well, a nearby well of comparable depth may be logged. The wells will be logged with a multi-parameter geophysical logging tool that includes measurements of natural gamma, short (16") normal resistivity, long (64") normal resistivity, temperature, spontaneous potential, fluid resistivity, lateral resistivity, and single point resistance. The additional logs will be entered into the geophysical log database. Once salinity concentrations are established for wells within these aquifers, the data will be input into a geographic information system (GIS) and salinity values for each aquifer will be contoured using geostatistical methods to develop concentration maps.

Additionally, formation thicknesses interpreted from the geophysical logs and the storage of the aquifers will be used to estimate the volume of saline water available.

## PRODUCTS

1. A USGS Scientific Information Report (SIR) describing the methods used to produce the maps, presenting the salinity concentration maps, and an estimate of water availability from aquifers in the Nacatoch Sand and Tokio Formation.
2. Online interactive maps showing the geophysical logs used to create the salinity concentration maps as well as the concentration lines. A query feature will be used to determine salinity concentration and the thickness of aquifers in the Nacatoch Sand and Tokio Formation at any point within the area of the salinity concentration maps.

## BUDGET

The proposed three year study budget is based on the estimated man hours needed to accomplish the listed tasks. The first and second years are mainly dedicated to data acquisition, documentation, and analysis, while the third year is mainly dedicated to the final data analysis and writing the report. The budget is shown by year and task in table 2. Proposed personnel are shown in table 3.

Table 1. Tentative workplan by year.

Task	2010		2011		2012	
	Data acquisition	Query log database for qualifying wells, query NWIS for water quality data	Add data from additional logging	Add data from additional logging	Add data from additional logging	
Log database expansion	Interpret Nacatoch Sand and Tokio Formation tops	Interpret Nacatoch Sand and Tokio Formation tops	Enter additional logs	Enter additional logs		
Geophysical logging	Well selection	Well selection	Log selected wells	Log selected wells		
Data analysis and interpretation	Develop relationship between resistivity/ spontaneous potential and conductance	Develop relationship between conductance and salinity	Derive salinity values for wells	Geostatistical contouring of salinity values	Geostatistical contouring of salinity values	
Development of online interface				Web page development	Web page development	
Report preparation	Report outline	Methods	Conference papers/Data interpretation	Results	Results / final maps	Final report

Table 2. Budget by year and task.

Task	2010	2011	2012
Data acquisition	\$28,000	\$16,000	
Log database expansion	\$26,000	\$16,000	
Geophysical logging	\$6,000	\$15,000	
Data Analysis and Interpretation	\$20,000	\$32,000	\$32,000
Development of online interface		\$7,000	\$7,000
Report Preparation	\$20,000	\$15,000	\$62,000
Total	\$100,000	\$100,000	\$100,000

Table 3. Proposed personnel.

Data acquisition	Jonathan Gillip (GS-09), Rheannon Hart (GS-11), Brian Clark (GS-13), Drew Westerman (GS-07)
Log database expansion	Rheannon Hart, Drew Westerman, GS-05 student
Geophysical logging	Jonathan Gillip, Rheannon Hart, Drew Westerman
Data Analysis and Interpretation	Jonathan Gillip, Rheannon Hart, Brian Clark
Development of online interface	Barry Jackson (GS-11), Brian Clark
Report Preparation	Jonathan Gillip, Brian Clark, Drew Westerman

## REFERENCES

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