FRAMEWORK FOR FLOW ANALYSIS OF THE EUTAW-McSHAN AND TUSCALOOSA AQUIFERS IN NORTHEASTERN MISSISSIPPI AND ADJOINING PARTS OF ARKANSAS, TENNESSEE, AND ALABAMA

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INTRODUCTION

The U.S. Geological Survey, in cooperation with the Mississippi Department of Environmental Quality, Office of Land and Water Resources (OLWR), began an investigation of the Eutaw-McShan and Tuscaloosa aquifers in northeastern Mississippi to: (1) better understand the hydrogeology and the ground-water flow in the aquifers, and (2) use a ground-water flow model to simulate existing water-level data for prepumping and pumping conditions, and use the model simulations to project the possible effects of increased ground-water withdrawals.

The five aquifers studied, from youngest to oldest, are the Eutaw-McShan aquifer of the Eutaw Group, the Gordo, Coker, and massive sand aquifers of the Tuscaloosa Group, and the Lower Cretaceous aquifer (Figure 1). The Gordo, Coker, massive sand, and Lower Cretaceous aquifers form the Tuscaloosa aquifer system. The modeled area is 33,440 square miles primarily in northeastern Mississippi and includes parts of northwestern Alabama, southwestern Tennessee, and east-central Arkansas (Figure 2). The modeled area includes the extent of the Eutaw-McShan and Tuscaloosa aquifers and adjacent areas that affect the ground-water flow and availability in the area of concern. Most of the water for public, industrial, and domestic uses in northeastern Mississippi comes from the Eutaw-McShan and Gordo aquifers (Boswell 1963). This paper presents a brief overview of the framework assembled to construct a ground-water flow model of the Eutaw-McShan and Tuscaloosa aquifers in northeastern Mississippi.

DESCRIPTION OF STUDY AREA

The study area is located in the Gulf Coastal physiographic province, mainly on the eastern flank of the Mississippi embayment subprovince (Fenneman 1938). Surface elevations range from 19 feet above sea level in the southeastern part of the model area to 1,080 feet in the northeastern part. Geologic units that crop out in the model area range in age from the Quaternary to Devonian periods. The sediments that form the Eutaw-McShan and Tuscaloosa aquifers were deposited during the Cretaceous period.

The geologic framework of the study area is described by Mallory (1993) as resulting from subsidence that may have begun during the late Paleozoic era and continued through the Cretaceous period. This subsidence formed the basins of the Gulf Coast geosyncline and of the southward plunging syncline of the Mississippi embayment. Since the Cretaceous period, cyclic transgression and regression of the sea have subsequently deposited an assorted, but ordered array of sediments within these basins in northeastern Mississippi. The nature of the sediments is directly related to the past depositional environment which, in turn, is related to fluctuations of sea level and the shifting of the location of the shoreline. The sediments include gravel, sand, clay, chalk, and marl of fluvial-deltaic, continental, and marginal-marine origins. Older geologic units crop out in northeastern Mississippi, and sequentially younger units are present at land surface to the west and south toward the axis of the Mississippi embayment. The dip of the Cretaceous units generally is toward the axis of the embayment, and the sediments generally become thicker downdip.

DESCRIPTION OF AQUIFERS AND BOUNDARIES

The Eutaw-McShan and Tuscaloosa aquifer system are simulated as five separate aquifers. Each aquifer is separated, to some degree, from vertically adjacent aquifers by confining units. Thicknesses of these confining units were determined from geophysical well log data. Hydrogeological data indicate some degree of flow between the aquifers. One major objective of the modeling effort is to determine estimates on the amount of water exchanged between the aquifers and the likely areas where this exchange occurs.

Eutaw-McShan Aquifer

The Eutaw-McShan aquifer includes sediments of the Eutaw and McShan Formations, which are part of the Eutaw Group (Figure 1). These formations in Mississippi are considered a single aquifer because the sands are hydraulically connected; however, intervening beds of clay and silt may result in small localized vertical head gradients.

The Eutaw-McShan aquifer consists of thin beds of fine to medium glauconitic sand (Boswell 1963). Well log data indicate that total sand thickness within the modeled area ranges from about 1 foot in the eastern part of the outcrop area to more than 300 feet in the southwestern and southern parts of the modeled area. A median horizontal hydraulic conductivity value of about 13 feet/day based on aquifer test results was reported for the aquifer (Slack and Darden 1991). Major areas of water withdrawals include Clay, Lee, Monroe, Prentiss, and Union Counties (Wasson 1986).

The Eutaw-McShan aquifer is present in 15,031 square miles of the area modeled (Figure 2). Selecting representative flow boundaries for the aquifers is crucial so that the model can respond realistically to applied stresses. The selection of flow boundaries for the aquifers in this model were based on information reported by Boswell (1963), Boswell et al. (1965), Cushing (1966), Hardeman (1966), Moore (1969), Boswell (1978), Gandl (1982), Wasson (1986), and Davis (1987). The Eutaw-McShan aquifer is bounded laterally to the east by the extent of the aquifer outcrop area. A head-dependent flux boundary was used to simulate recharge and discharge from streams in the aquifer outcrop area. To the north and northwest, the limit of deposition of the sediment that is defined as aquifer serves as a lateral no-flow boundary. To the west, southwest, and south, the downdip extent of freshwater (defined for this paper as a concentration of 10,000 mg/L or less of dissolved solids) is used to define no-flow lateral boundaries for the aquifers simulated in the model. This boundary assumes that there is a stable downdip freshwater-saltwater interface. The assumption is made because the downdip extent of freshwater for the aquifers has remained unchanged since they were reported by Gandl (1982). For many of the aquifers, the region where the dissolved-solids concentrations are between 1,000 and 10,000 mg/L is relatively small, which also implies little mixing. If flow were across the interface in the downdip direction, it would eventually flow upward at some point to discharge; however, confining units above the Eutaw-McShan, the topmost aquifer, thicken to the southwest in the downdip direction to more than 1,500 feet near the freshwater-saltwater interface. The thick upper confining units to the southwest partially impede the upward movement of water. Any significant upward flow would be through secondary structural features of permeability enhancement such as faults. The southeast boundary is a no-flow boundary at a lateral ground-water flow divide formed by the Tombigbee and Black Warrior Rivers. Water-level data indicate that these rivers, particularly near their confluence, are major discharge areas for the aquifers and that all lateral flow is captured by the river channels (Gardner 1981). Consequently, no lateral flow moves southeast across the Tombigbee and Black Warrior Rivers. Water is allowed to discharge vertically at this boundary in the model by upward leakance through the confining unit.

Tuscaloosa Aquifer System

The Tuscaloosa aquifer system consists of the Gordo, Coker, and massive sand aquifers of the Tuscaloosa Group, and a Lower Cretaceous aquifer of undifferentiated sediments (Figure 1). These aquifers are confined to some extent by intervening clays and silts, but regionally maintain a hydraulic continuity and, therefore, constitute a system (Boswell 1978).

Gordo Aquifer

The Gordo aquifer generally is composed of a lower coarse quartz sand and chert gravel and an upper interbedded sand and clay (Boswell 1963). Well log data indicate that total sand thickness within the modeled area ranges from about 1 foot in the eastern part of the outcrop area to more than 350 feet in the southwestern and southern parts of the modeled area. A median horizontal hydraulic conductivity value of about 40 feet/day based on aquifer test results was reported for the aquifer (Slack and Darden 1991). Major areas of water withdrawals include Clay, Itawamba, Lee, Lowndes, Monroe, Oktibbeha, and Pontotoc Counties (Wasson 1986).

The Gordo aquifer is present in 11,558 square miles of the area modeled (Figure 3). The aquifer is bounded laterally to the east by the extent of the aquifer outcrop area. A head-dependent flux boundary was used to simulate recharge and discharge from streams in the aquifer outcrop area. To the north and northwest, the limit of deposition of the sediment that is defined as aquifer serves as a lateral no-flow boundary. To the west, southwest, and south, the downdip extent of freshwater is used to define a no-flow lateral boundary. To the southeast, a lateral ground-water flow divide is modeled with a no-flow boundary, with flow being allowed to move vertically through upward leakance as indicated by water-level data (Gardner 1981). The model grid boundaries are coincident with the borders shown in Figures 2-6. In the Gordo aquifer, and all subsequent aquifers discussed, the eastern grid-line boundary that truncates parts of the aquifers was modeled as a ground-water divide because the grid-line closely approximates the ground-water and surface-water flow divide between the Tombigbee and Black Warrior River drainage basins (Figures 3-6).

Coker Aquifer

The Coker aquifer is composed of interbedded gray shale and lenticular beds of fine to medium sand (Boswell 1963). Well log data indicate that total sand thickness within the modeled area ranges from about 1 foot in the eastern part of the outcrop area to more than 350 feet in the southwestern and southern parts of the modeled area. An average horizontal hydraulic conductivity value of about 100 feet/day based on aquifer test results is estimated for the aquifer (W.T. Oakley, U.S. Geological Survey, oral commun. 1994). Re-examination of numerous geophysical logs, along with new data, indicate that many wells previously thought to be in the Coker aquifer are actually in the massive sand aquifer (J. H. Hoffmann, Mississippi Department of Environmental Quality, oral commun. 1994). Therefore, major areas of water withdrawals for the Coker aquifer are now thought to occur only in Monroe County.

The Coker aquifer is present in 9,778 square miles of the area modeled (Figure 4). The aquifer is bounded laterally to the northeast by the extent of the aquifer outcrop area. A head-dependent flux boundary was used to simulate recharge and discharge from streams in the aquifer outcrop area. To the north, the limit of deposition of the sediment that is defined as aquifer serves as a lateral no-flow boundary. To the west, southwest, and south, the downdip extent of freshwater is used to define a no-flow lateral boundary. To the southeast, a lateral ground-water flow divide is assumed and is modeled with a no-flow boundary, with flow being allowed to move vertically through upward leakance.

Massive Sand Aquifer

The massive sand aquifer predominantly contains nonmarine medium to coarse, brown to white quartz sand, commonly with a lower chert and quartz pea gravel (Boswell 1963). Well log data indicate that total sand thickness within the modeled area ranges from about 1 foot in the eastern parts of the modeled area to over 350 feet in the western part. An average horizontal hydraulic conductivity value of about 200 feet/day based on aquifer test results is estimated for the aquifer (W.T. Oakley, oral commun. 1994). Major areas of water withdrawals include Clay, Lowndes, and Monroe Counties (J. H. Hoffmann, oral commun. 1994).

The massive sand aquifer is present in 7,050 square miles of the area modeled (Figure 5). The massive sand aquifer often is assumed to be part of the Coker aquifer, but in this model they are simulated as separate aquifers. Justification for simulating two aquifers is that a confining unit separates the Coker and massive sand aquifers in much of the modeled area. The lateral eastern boundary for the massive sand is assumed to be coincident with the lateral eastern boundary for the Coker aquifer. Recharge to the massive sand aquifer may occur in the Coker aquifer outcrop area because the confining units separating the massive sand and Coker aquifers are relatively thin in the Coker outcrop area. To the north, northeast, and northwest, the limit of deposition of the sediment that is defined as aquifer serves as a lateral no-flow boundary. To the southwest and south, the downdip extent of freshwater is used to define a no-flow lateral boundary. To the southeast a lateral ground-water flow divide is assumed and is modeled with a no-flow boundary, with flow being allowed to move vertically through upward leakance.

Lower Cretaceous Aquifer

The Lower Cretaceous aquifer consists of shales, clays, sand, gravel, and calcareous strata (Boswell 1963). Well log data indicate that total sand thickness within the modeled area ranges from about 1 foot, where it pinches out against Paleozoic rocks in the northeast, to almost 1,000 feet along the west, southwest, and southern edge of the modeled area. An average horizontal hydraulic conductivity value of about 200 feet/day is estimated for the aquifer (W.T. Oakley, oral commun. 1994). There is no known water withdrawal from the aquifer in the modeled area.

The Lower Cretaceous aquifer is present in 4,301 square miles of the model area (Figure 6). The aquifer does not crop out within the model area. To the north and northeast, the limit of deposition of the subcrop where the aquifer pinches out against Paleozoic rocks represents a lateral no-flow boundary. To the west, southwest, and south, the downdip extent of freshwater is used to define a no-flow lateral boundary. To the southeast, a lateral ground-water flow divide is assumed and is modeled with a no-flow boundary, with flow being allowed to move vertically through upward leakance.

SUMMARY

The Eutaw-McShan and Tuscaloosa aquifers are the source of most of the ground-water used for public and industrial supply in northeastern Mississippi. A ground-water flow model provides a useful tool for better understanding the flow dynamics of the aquifers and may aid in estimating the effects of increased ground-water withdrawal on water levels. Model boundaries for the aquifers include head-dependent flux boundaries in the areas of aquifer outcrop, no-flow boundaries representing depositional extent of the aquifer sediments, no-flow boundaries at the downdip extent of freshwater (10,000-mg/L dissolved-solids concentration), and lateral no-flow boundaries at the lateral ground-water flow divides.

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<table>
<tr><th>Erathem</th><th>System</th><th>Series</th><th>Group</th><th>Geologic unit</th><th colspan="2">Hydrogeologic unit</th></tr>
<tr><td rowspan="10">Mesozoic</td><td rowspan="10">Cretaceous</td><td rowspan="8">Upper Cretaceous</td><td rowspan="2">Eutaw Group</td><td>Eutaw Formation</td><td colspan="2" rowspan="2">Eutaw-McShan aquifer</td></tr>
<tr><td>McShan Formation</td></tr>
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<tr><td>Coker aquifer</td></tr>
<tr><td rowspan="2">Massive sand</td><td>Unnamed confining unit</td></tr>
<tr><td>Massive sand aquifer</td></tr>
<tr><td rowspan="2">Lower Cretaceous</td><td rowspan="2"></td><td rowspan="2">Lower Cretaceous sediments</td><td>Unnamed confining unit</td></tr>
<tr><td>Lower Cretaceous aquifer</td></tr>
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Figure 1. Generalized stratigraphic column of the modeled units.

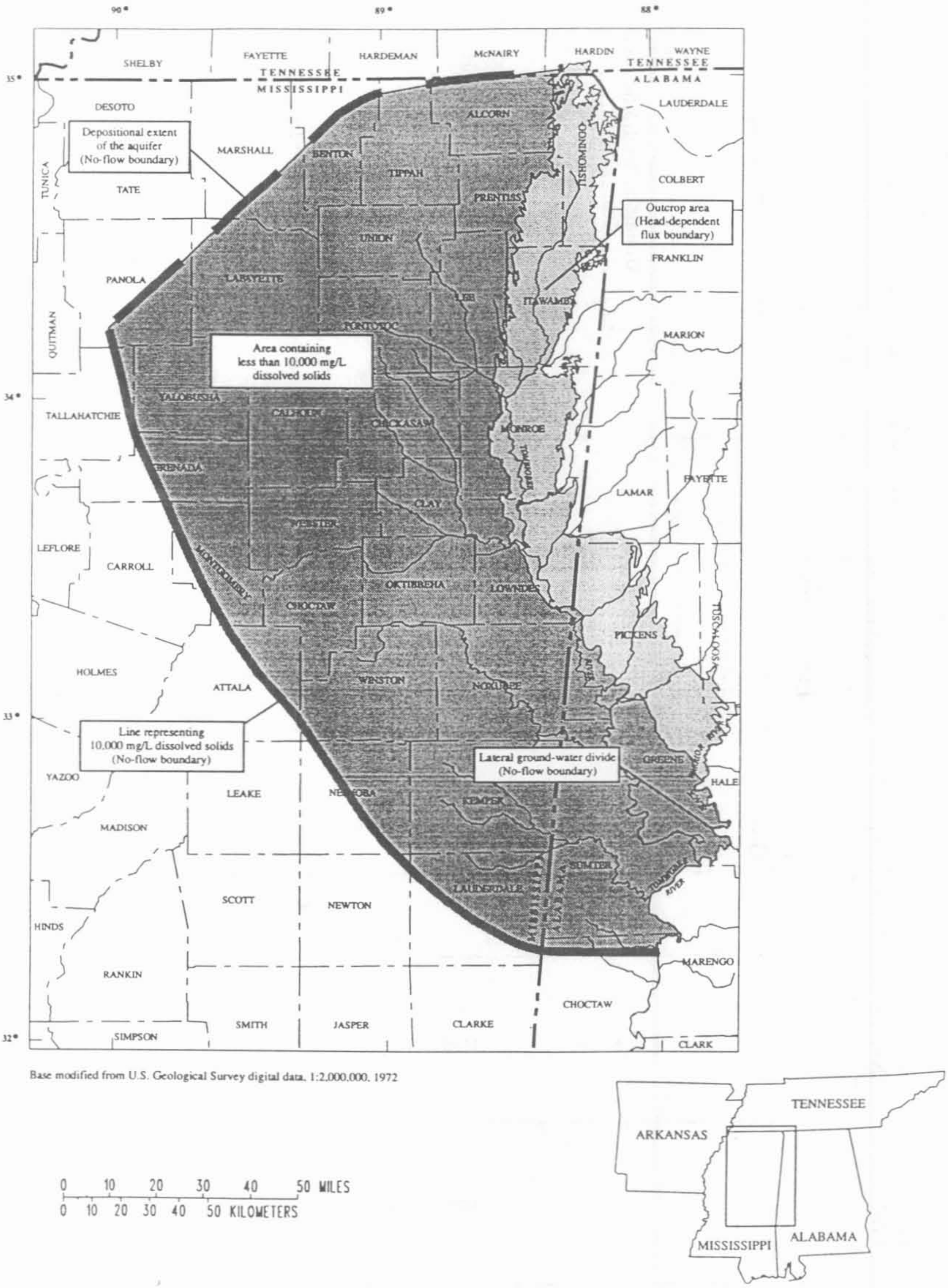


Figure 2. Modeled area (shaded) and flow boundaries of the Eutaw-McShan aquifer.

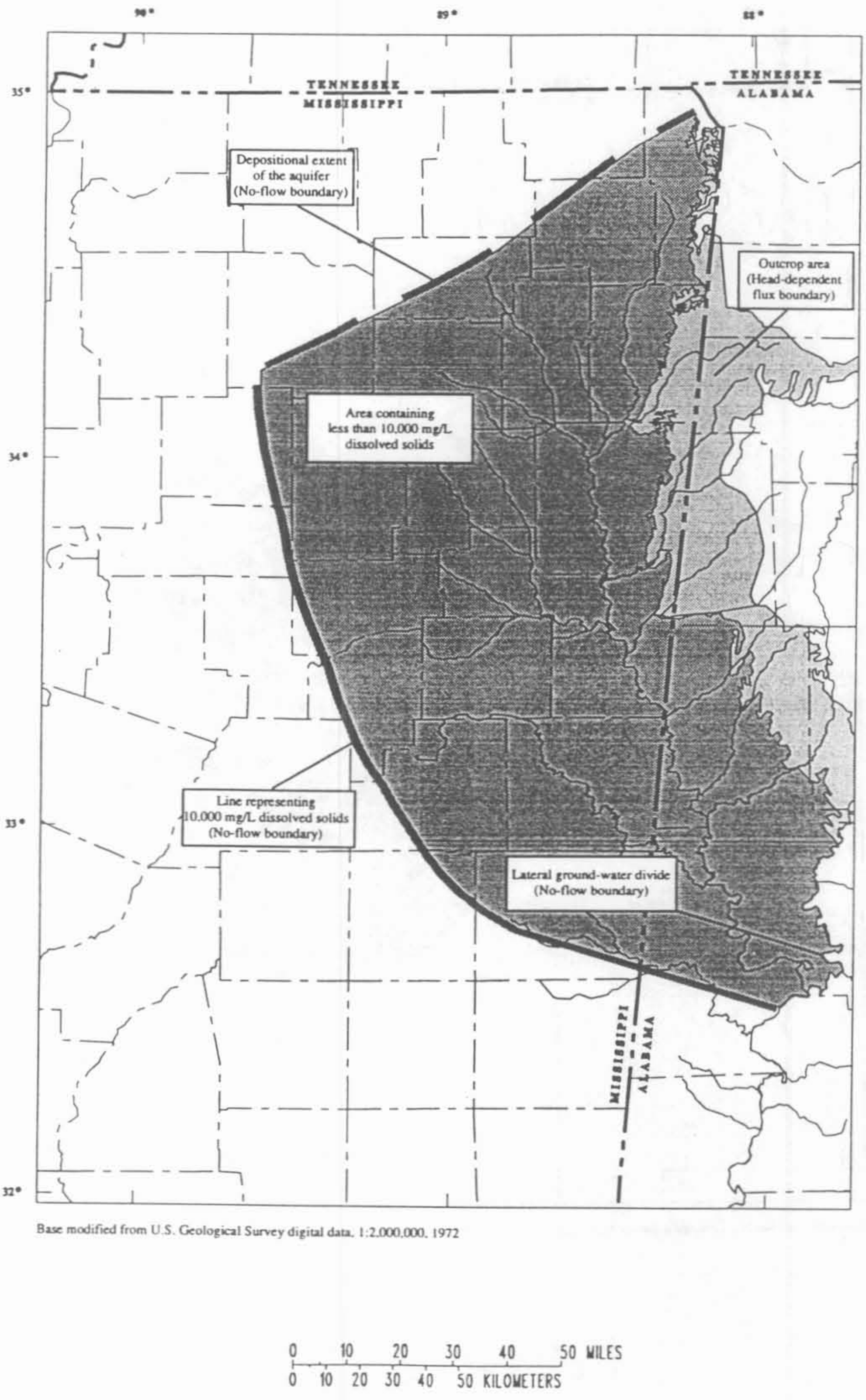
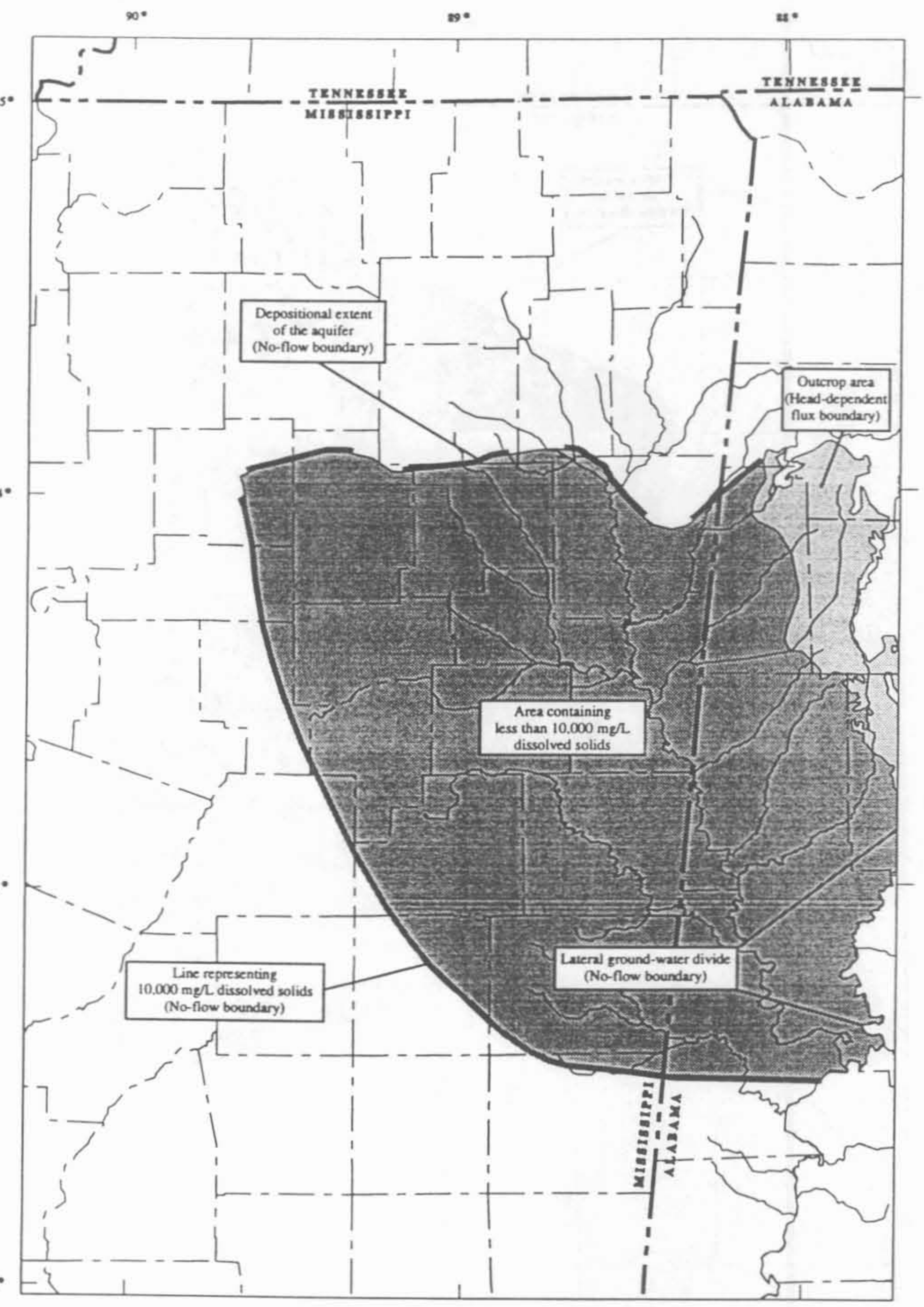


Figure 3. Modeled area (shaded) and flow boundaries of the Gordo aquifer.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

0 10 20 30 40 50 MILES

0 10 20 30 40 50 KILOMETERS

Figure 4. Modeled area (shaded) and flow boundaries of the Coker aquifer.

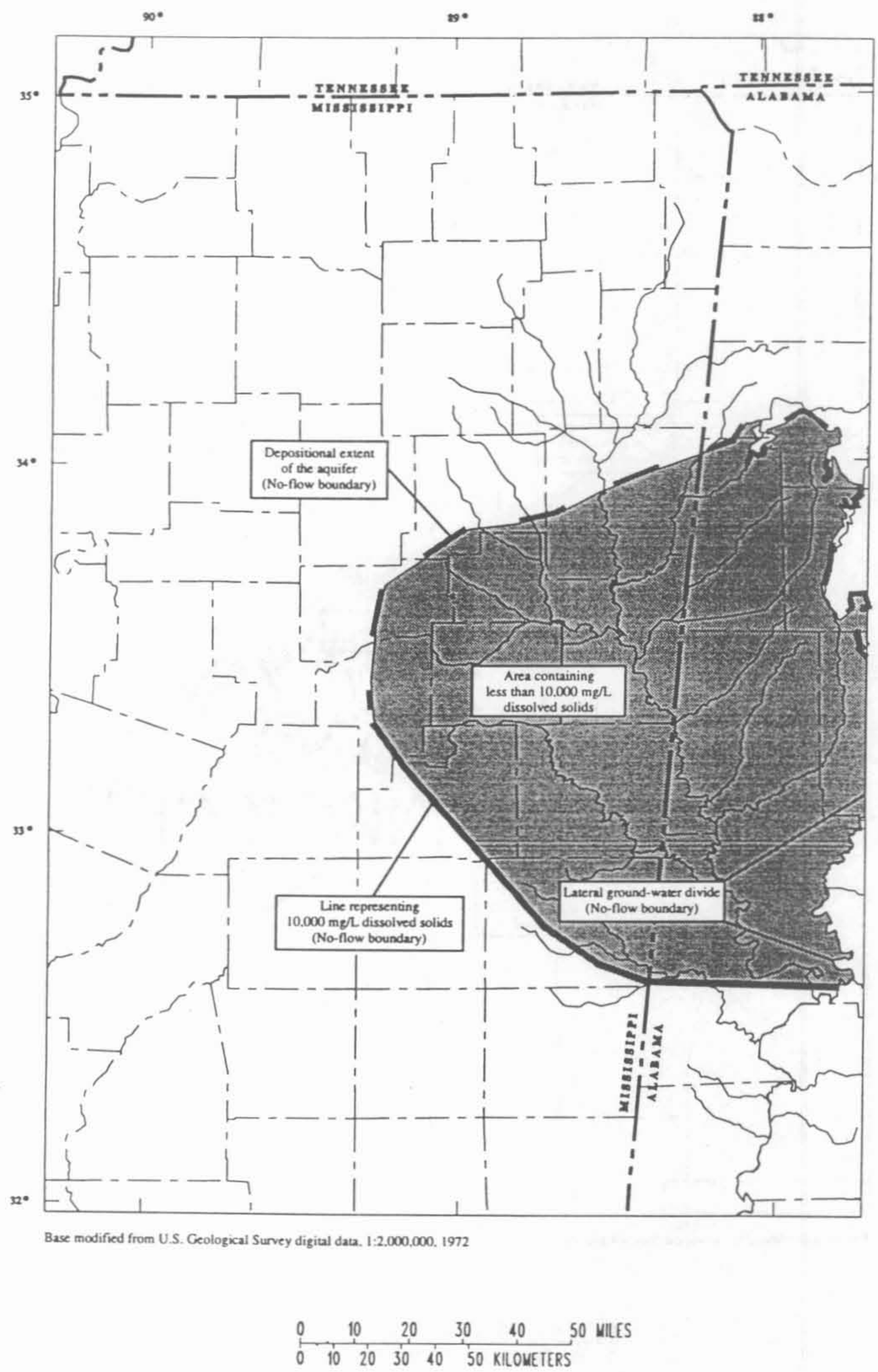


Figure 5. Modeled area (shaded) and flow boundaries of the massive sand aquifer.

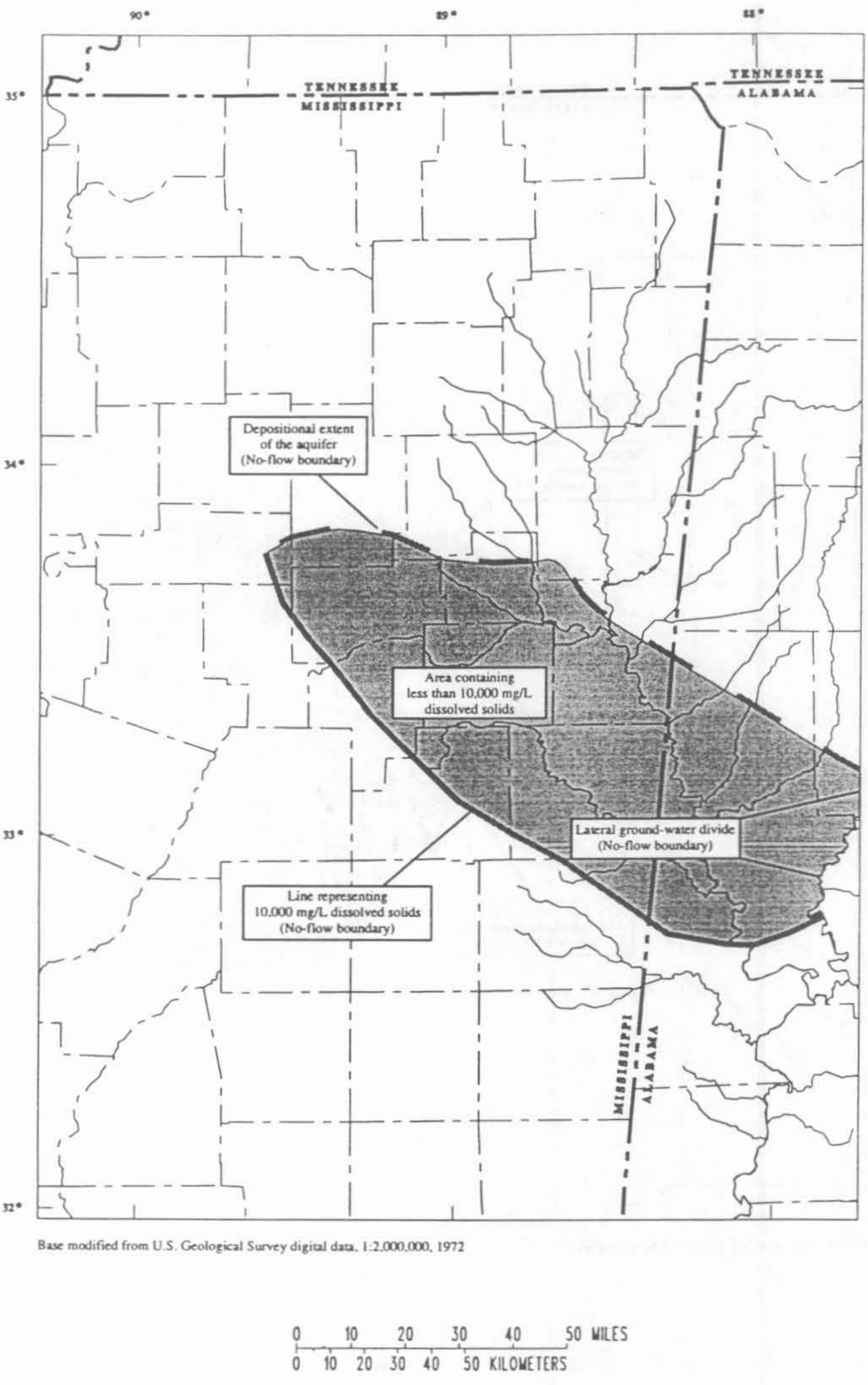


Figure 6. Modeled area (shaded) and flow boundaries of the Lower Cretaceous aquifer.