APPENDIX O

KEMPER COUNTY IGCC PROJECT GROUND WATER WITHDRAWAL IMPACT ASSESSMENT

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KEMPER COUNTY IGCC PROJECT

DESCRIPTION OF THE GROUND WATER FLOW MODEL SIMULATIONS

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KEMPER COUNTY IGCC PROJECT
DESCRIPTION OF THE GROUND WATER FLOW MODEL SIMULATIONS

Mississippi Power Company (Mississippi Power) plans to obtain water for use at the Kemper County Integrated Gasification Combined-Cycle (IGCC) Project power plant primarily from two Meridian, Mississippi, publicly owned treatment works (POTWs). Up to 1 million gallons per day (MGD) of ground water withdrawn from deep onsite wells might also be used on an as-needed basis. As an alternative, the use of ground water to fully supply the water requirements for the proposed IGCC facility was also considered.

Ground water flow modeling was performed by Environmental Consulting & Technology, Inc. (ECT), to facilitate evaluation of potential impacts from the withdrawal of 1 MGD of ground water from the Massive Sand aquifer for a backup well field. Two wells withdrawing at a rate of 0.5 MGD each were simulated in cells R182 C92 and R183 C92 of the model. An alternative simulation, in which cooling water was obtained from a primary well field withdrawing ground water at a rate of 6.5 MGD, was also completed. In this alternative case, two wells withdrawing at a rate of 3.25 MGD each were simulated in cells R182 C92 and R183 C92 of the model.

The quasi three-dimensional Modular Three-Dimensional Finite Difference Ground Water Flow Model (MODFLOW) developed at the U.S. Geological Survey (USGS) by McDonald and Harbaugh (1988, 1996) was applied for this ground water modeling as presented herein. Ground Water Vistas, a pre- and postprocessing MODFLOW graphical design interface, was used to complete this modeling effort.

MODEL AREA

The ground water flow model was based on a 34,960-square-mile (mi^2) area in northeastern Mississippi modeled by Eric W. Strom of USGS as described in the USGS Water Resources Investigations Report 98-4171 (i.e., the Strom Model). The model includes the extent of aquifers in the Cretaceous- and Paleozoic-age sediments that are used as a source of fresh water. The Strom Model is within the Gulf Coastal Plain physiographic province on the eastern flank of the Mississippi embayment. The main surface water drainage affecting the ground water flow in the area aquifers are the Tombigbee and Black Warrior Rivers along the northeastern edge of the model (Strom, 1998).

HYDROGEOLOGY

The hydrogeology of the site area was conceptualized as a three-dimensional, six-layered system consisting of eight aquifers. The eight aquifers, from youngest to oldest, are the Coffee Sand, Eutaw-McShan, Gordo, Coker, Massive Sand, Lower Cretaceous, Paleozoic Iowa, and Devonian. The Coffee Sand, Eutaw-McShan, and Gordo aquifers are represented in the model by Layers 1, 2 and 3, respectively. The Coker and Iowa aquifers are jointly represented by Layer 4. The Massive Sand and Devonian are both represented by Layer 5 since their lateral boundaries do not coincide. Layer 6 represents the lower Cretaceous. Strom's Figure 18 (Strom, 1998) depicts a map illustrating the areal extent and overlap of the fresh water aquifers in the modeled area. (Referenced copies of the Strom Model report figures are presented in Appendix A of this report.)

Geologic and hydrogeologic data used by Strom to create the model was obtained from more than 600 borehole geophysical logs and drillers' logs combined with other published stratigraphic information (Strom, 1998). Hydraulic data in the Strom Model was based on the analyses of borehole geophysical and lithologic logs of water wells, test holes, and aquifer tests. Figure 1 depicts a generalized hydrogeologic cross-section representative of the model area. The sediments include gravel, sand, clay, chalk, and marl of fluvial-deltaic, continental, and marine shelf origins. Cretaceous sediments generally dip toward the axis of the Mississippi embayment at the rate of 40 feet per mile (ft/mi), while the Paleozoic sediments dip toward the south-southwest at rates ranging from 25 to 50 ft/mi. The thickness of these sediments also tends to increase in the down dip directions (*ibid.*).

COFFEE SAND AQUIFER—LAYER 1

The Coffee Sand aquifer outcrops in northeastern Mississippi and eastern Tennessee (Figure 6, Strom, 1998) and is composed of fine- to medium-grained, calcareous to glauconitic sand with lenses of silty sand and clay. Well logs indicate that the Coffee Sand

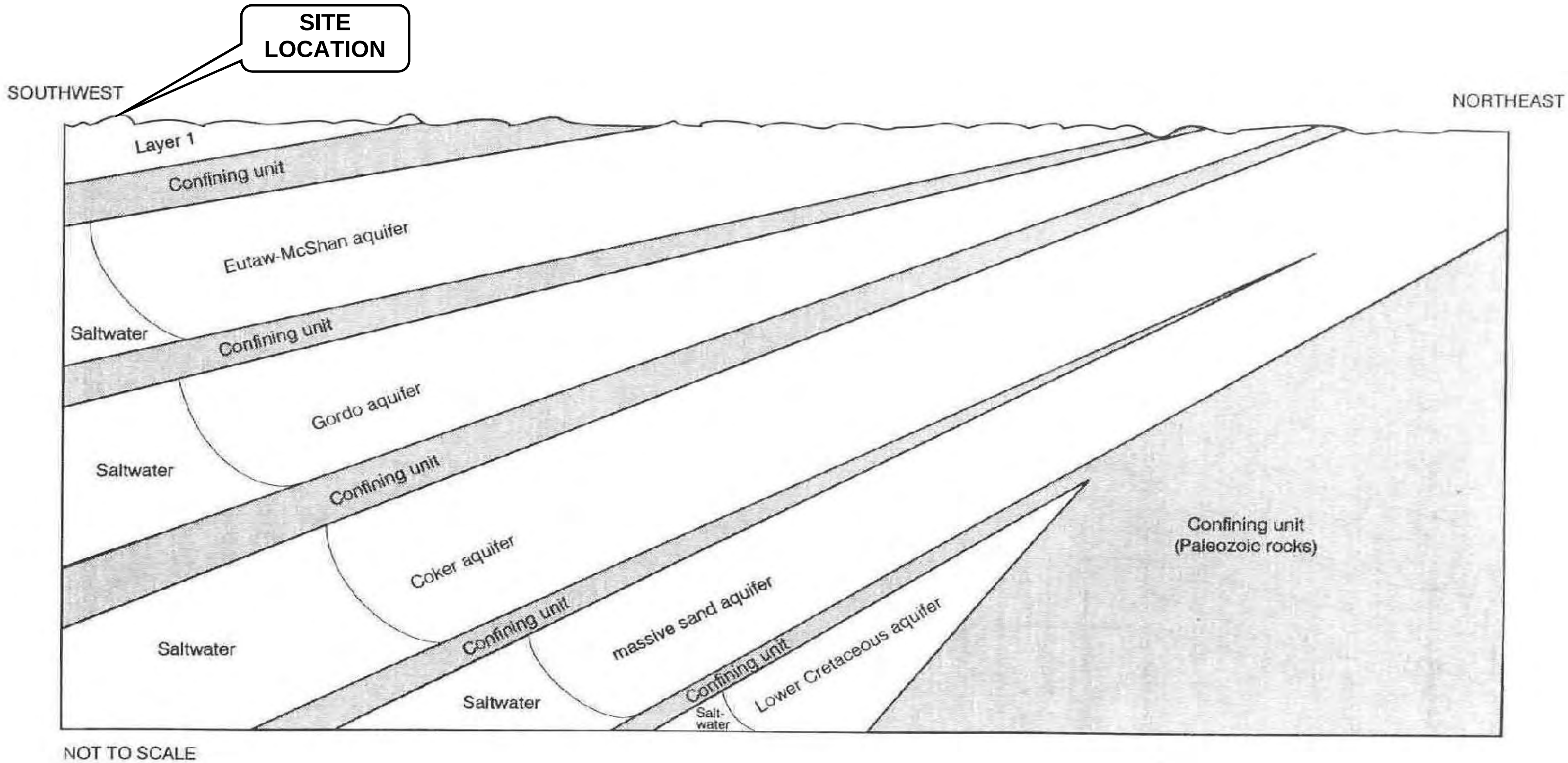

FIGURE 1.

HYDROGEOLOGIC CROSS-SECTION SCHEMATIC

Source: Strom and Mallory, 1995.

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ranges in thickness from 1 foot (ft) near the eastern outcrop to more than 200 ft in the western model area.

Horizontal hydraulic conductivity ranges from 10 to 40 feet per day (ft/day). Recharge to the aquifer results primarily from precipitation in the outcrop area. A thick overlying chalk layer confines the aquifer (Strom, 1998).

EUTAW-MCSHAN AQUIFER—LAYER 2

The Eutaw and McShan are considered a single aquifer because the sands are hydraulically connected. This aquifer outcrops in northeastern Mississippi and northwestern Alabama. The upper portions of the aquifer are finer grained and contain a high silt content. The lower portions of the aquifer consist of thin beds of glauconitic sand. Sand thickness ranges from 1 ft in the eastern outcrop area to more than 300 ft to the southwest (Figure 7, Strom, 1998). Data collected from the onsite test well (Earth Science & Environmental Engineering [ES&EE], 2007) indicate that the Eutaw-McShan aquifer and confining unit are 360 ft thick at the site with a total sand thickness of 150 ft.

Strom reports an average horizontal hydraulic conductivity of 12 ft/day was used in the model based on 50 aquifer tests. Recharge to the aquifer is primarily due to precipitation in the outcrop area. The Eutaw-McShan is separated from the overlying Coffee Sand by the Mooreville Chalk to the south. Where the chalk is absent to the north, the Eutaw-McShan is in contact with the Coffee Sand. However, the fine sediments of the upper portion of the Eutaw-McShan function as an aquitard, hydraulically separating it from the overlying Coffee Sand (Strom, 1998). Model transmissivity at the site location ranges between 1,924 and 1,982 square feet per day (ft^2/day).

GORDO AQUIFER—LAYER 3

The Gordo aquifer outcrops in extreme northeastern Mississippi and northwestern Alabama (Figure 8, Strom, 1998). The upper portion of the aquifer is interbedded sand and clay, while the lower sections are composed of coarse-grained quartz sand and chert gravel (Strom, 1998). Total sand thickness based on well log data ranges from 1 ft in the eastern outcrop area to approximately 300 ft to the west (Figure 8, Strom, 1998). Recent data collected from the onsite ES&EE test well indicate that the Gordo aquifer and confining unit are 470 ft thick at the site with a total sand thickness of 230 ft.

The average hydraulic conductivity defined in the Strom Model is 48 ft/day. This value was reportedly based on 33 aquifer tests. The Gordo aquifer receives recharge from precipitation in the outcrop area. Recharge has also been reported from the overlying and underlying aquifers according to Strom. The Gordo also is believed to discharge to topographic lows in the outcrop, the Coker in the updip area and the Eutaw-McShan in portions of the down-dip area. A clay and silt layer (up to 175 ft thick in the southernmost area of the model) separates the Gordo from the overlying Eutaw-McShan aquifer. (Strom, 1998).

COKER AQUIFER—LAYER 4

The Coker aquifer does not outcrop in Mississippi, but does outcrop in northwestern Alabama (Figure 9, Strom, 1998). The Coker consists of interbedded gray shale and lenticular beds of fine- to medium-grained sand. Strom reports that the total thickness of the Coker aquifer based on well log data ranges from 1 ft in the outcrop area to more than 300 ft in the western portion of the model area. Data collected from the ES&EE onsite test well indicate that the Coker aquifer and confining unit are 520 ft thick at the site with a total sand thickness of 120 ft. Model transmissivity at the site location in the Coker aquifer ranges between 6,990 and 7,120 ft^2/day.

Recharge to the Coker enters the aquifer from precipitation in the outcrop and from ground water seepage from the overlying and underlying aquifers. The Coker may discharge ground water to the Gordo in the down-dip area and to the massive sand in the updip area. A clay and silt layer, up to 175 ft thick in the west, acts as an aquitard between the Coker and the overlying Gordo aquifer.

MASSIVE SAND AQUIFER—LAYER 5

The Massive Sand of the Tuscaloosa Group (Upper Cretaceous) has been selected as a source of nonpotable water for the backup water supply for the facility. The Massive Sand aquifer does not outcrop and is reported to be in contact with the Coker in the easternmost areas of the model (Figure 10, Strom, 1998). A clay confining unit appears between the Coker and Massive Sand aquifers to the west that hydraulically separates the aquifers. The Massive Sand consists of nonmarine medium- to coarse-grained, brown to white sand with a lower zone of chert and quartz pea gravel. Sand thickness reported by Strom based on well log data ranges from 1 ft in the eastern portion of the model to more than 300 ft to the south. Data collected from the ES&EE onsite test well indicate that the Massive Sand aquifer and confining unit are 290 ft thick at the site with a total sand thickness of 260 ft.

A horizontal hydraulic conductivity of 60 ft/day was used for the Massive Sand aquifer in the down-dip portion of the model and approximately 120 ft/day in the up-dip areas (Strom, 1998).

Aquifer testing in the upper portion of the Massive Sand aquifer was performed by ES&EE at the power plant site. The test well has an 80-ft screen interval set from 3,362 to 3,442 feet below land surface (ft bls). Step drawdown and constant rate aquifer pumping tests were conducted in this well. The constant rate aquifer test was performed for 48 hours at a pumping rate of 800 gallons per minute (gpm). A transmissivity estimate of 2,900 ft^2/day was derived using the Hantush and Jacob (1955) analytical method. In addition, the results of the step drawdown test analysis yielded a transmissivity estimate of 4,400 ft^2/day using the Hantush (1962) analytical method (ES&EE, personal communication, October 2008). These transmissivity results are reflective of the upper 80 ft of the Massive Sand aquifer, whereas the total thickness of the Massive Sand aquifer is approximately 290 ft at the power plant site.

Using the total Massive Sand thickness of 260 ft, as determined in the test well, and the 60-ft/day horizontal hydraulic conductivity value representative of the entire Massive Sand aquifer used by Strom (1998), an estimated transmissivity of 15,600 ft^2/day is calculated for the site location. The site area was originally defined in the Strom Model as no-flow cells. Therefore, transmissivity values for the extended Massive Sand area were defined based on transmissivity information published in Strom and Mallory, 1995, and the ES&EE onsite well tests. Slightly conservative transmissivity values of 15,200 and

15,300 ft^2/day were assigned to the model cells representing the location of the proposed withdrawal wells.

LOWER CRETACEOUS AQUIFER—LAYER 6

The Lower Cretaceous aquifer does not outcrop in the model area. The aquifer pinches out toward the northeast and thickens toward the southeast (Figure 11, Strom, 1998). The Lower Cretaceous aquifer consists of shale, clay, sand, gravel, and calcareous sediments. Aquifer thickness based on well log data ranges from 1 ft in the northeast to more than 1,000 ft to the southwest (Figure 11, Strom 1998). The total thickness of the Lower Cretaceous at the site location is approximately 1,500 ft with a total sand thickness of 1,000 ft.

The Lower Cretaceous aquifer is believed to have similar hydraulic properties as the Massive Sand. An average hydraulic conductivity of 125 ft/day is estimated by Strom. The model cells corresponding to the site location are defined as no-flow cells in the Lower Cretaceous (Layer 6). Model transmissivity in this layer increases going southwestward from the outcrop area and ranges between 94,510 to 104,800 ft^2/day at the edge of the active model cells to the northeast of the site.

The Lower Cretaceous likely receives recharge from the Massive Sand aquifer in the up-dip area and discharges to the Massive Sand aquifer down-dip. A confining unit consisting of clay and silt up to 150 ft in the south has been identified above the Lower Cretaceous aquifer (Strom, 1998).

PALEOZOIC AQUIFER

For descriptions of the Iowa and Devonian aquifers, which are located in the northernmost portion of the model area, refer to Strom (1998).

MODEL GRID DESIGN

The Strom Model covers 34,960 mi^2 primarily in northeastern Mississippi but includes portions of northwestern Alabama, southwestern Tennessee, and eastern Alabama. The grid is oriented north-south with a 5,280- by 5,280-ft grid spacing. The lateral anisotropy used in the simulation was one. Each of the six grid layers consists of 230 rows and 152 columns (Figure 17, Strom, 1998).

GROUND WATER FLOW MODEL

ECT obtained a copy of the original Strom Model MODFLOW files that were used as the base for an *expanded* model. The original 1998 model files were imported into the ground water modeling software program Ground Water Vistas, where the simulations were run using the 1988/1996 version of MODFLOW.

The Strom Model is a transient model constructed with six layers, with each layer representing a regional aquifer as follows:

- Layer 1 is the Coffee Sand aquifer.
- Layer 2 is the Eutaw-McShan aquifer.
- Layer 3 is the Gordo aquifer.
- Layer 4 is the Coker aquifer.
- Layer 5 is the Massive Sand aquifer.
- Layer 6 is the Lower Cretaceous aquifer.

In the extreme northeastern corner of Mississippi, Layers 4 and 5 represent the Iowa aquifer and the Devonian aquifer, respectively; the Coker and Massive Sand aquifers do not extend to that area. Figure 18 (Strom, 1998) from Strom's report illustrates the overlapping nature of the aquifer layers.

There is a thick, impermeable sequence comprising the Selma Group above Layer 1, the Coffee Sand aquifer; therefore, the area overlying the Coffee Sand was simulated as no-flow (black cell boundary color). Layer 1 does represent the Coffee Sand in the northern portions of the model but is also used as an upper constant head boundary (dark blue cell boundary color) for the Eutaw-McShan aquifer (Layer 2). The constant heads in this area represent the surficial water levels on the chalk and clay overlying the Eutaw-McShan. However, vertical flow is limited due to the low vertical hydraulic conductivity of the confining unit (Strom, 1998).

The boundaries for each subsequent aquifer/model layer are defined by both the depositional or erosional extent of the aquifer and by the location of the freshwater-saltwater interface in the aquifer, which is defined by Strom as a total dissolved solids (TDS) concentration of 10,000 milligrams per liter (mg/L). The freshwater-saltwater interface represents no-flow lateral boundaries in the Strom Model for all of the aquifers/layers; all model cells located beyond the boundary are defined as no-flow boundaries and therefore are *inactive*. However, the proposed well field for the power plant is located approximately 4 miles south of (beyond) the published freshwater-saltwater boundary for the Massive Sand aquifer (Layer 5) and is thus situated in an inactive portion of Layer 5. Therefore, for the *extended* model boundaries, it was necessary to modify the Strom Model in only one way: Layer 5 (the Massive Sand aquifer) was extended further to the southwest, as shown in Figure 2. Representative values for transmissivity, as noted previously, were also defined for the extended Massive Sand aquifer area. No other changes were made to model boundaries or cell input parameters relative to the Strom Model in the initial expanded simulation.

Strom's calibrated transient model includes pumping stresses for numerous wells from 1900 through 1995, which is the last year modeled by Strom. The extended model continues the 1995 pumping stresses forward in time (1996 through 2010) and then adds a constant 1-MGD ground water withdrawal from the Massive Sand aquifer equally split between two wells pumping at a rate of 66,850 cubic feet per day (ft^3/day) at the power plant site for a 40-year period, while continuing the 1995 withdrawal rates at the numerous other wells (per Strom's model). As such, the expanded model was used to simulate the effects of the proposed 1-MGD ground water withdrawal over the projected 40-year life of the facility. All wells are entered into the models as cells representing well boundary conditions (red cell boundary).

RECHARGE

Based on reports from the National Oceanic and Atmospheric Administration (NOAA) included in the Strom (1998) report, the area of northeastern Mississippi can receive an average of 52 inches of precipitation in the outcrop areas along the northeastern sections

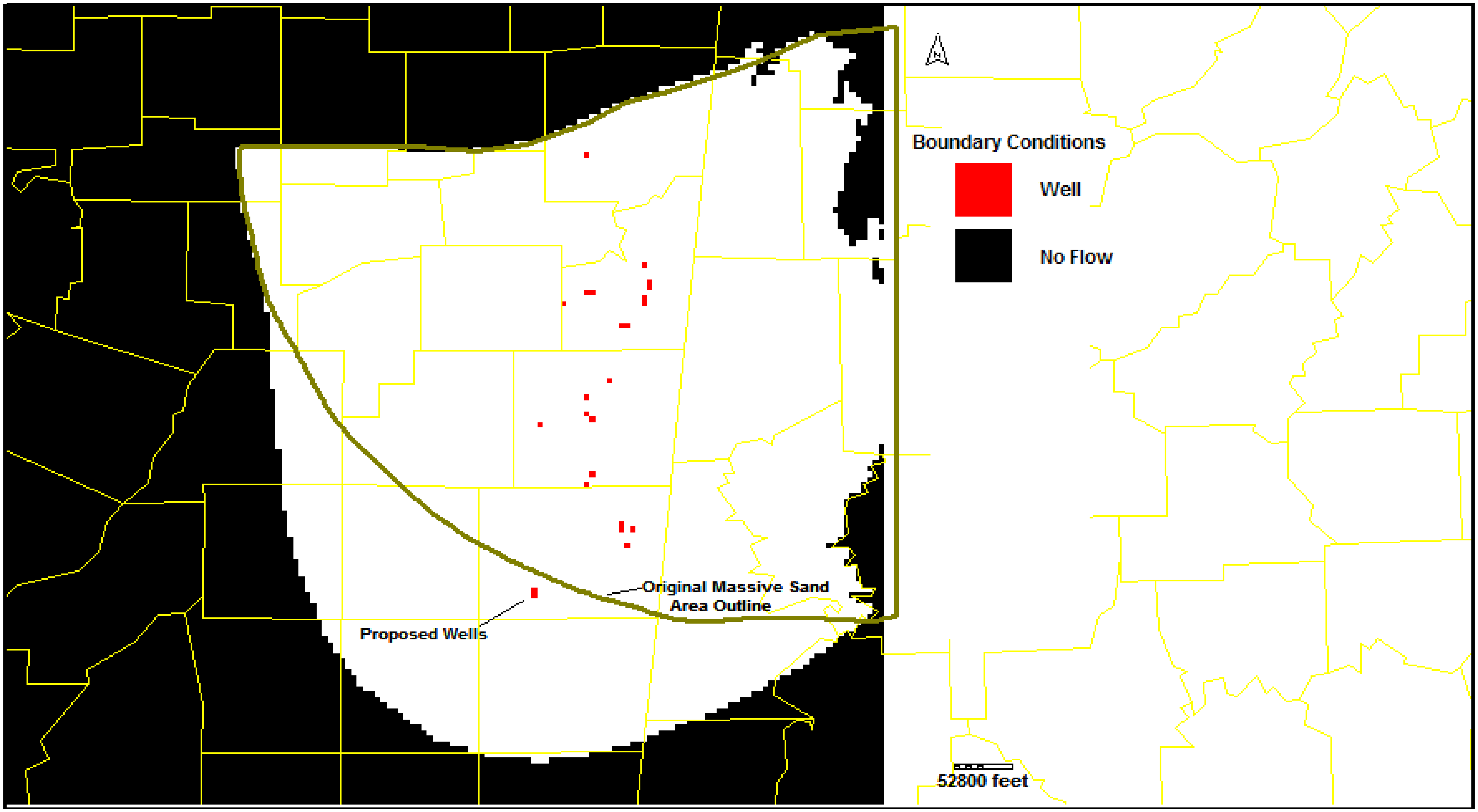

FIGURE 2.

MASSIVE SAND (LAYER 5) ACTIVE CELL EXTENSION TOWARD SW OVER SITE PROPOSED WELLS LOCATED SW OF SALTWATER-FRESHWATER BOUNDARY

Sources: Strom, 1998. ECT, 2009.

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of the Strom Model. The Strom Model simulates the intermediate and regional scale flow. The outcrop areas of the Coffee Sand, Eutaw-McShan, Gordo, and Coker aquifers were simulated with head-dependant flux boundaries (green cell boundary) using the river package in MODFLOW. Strom reports that the large base flows observed in even the small streams in the outcrop area indicate that recharge from precipitation-rich environment is sufficient to provide all the recharge that the aquifers can accept and much of the recharge is redirected as runoff.

STROM MODEL PARAMETERS AND CALIBRATION

The Strom Model calibration was based on transient conditions because of the lack of water level data in the predevelopment stage. Initial transmissivity grids were created by multiplying sand thickness data from well logs information with hydraulic conductivity data collected from aquifer tests. The Strom Model initial transmissivity grids were modified within a range of expected values during model calibration. Contour maps for the transmissivity values used in the Strom Model are illustrated on Strom's Figures 20 through 24 (Strom, 1998). Contour maps of the confining unit thickness are illustrated on Strom's Figures 27 through 31 (*ibid.*). A constant storage coefficient of 0.0001 was used for all aquifers with the exception of the Gordo, which used a constant value of 0.001 to represent the coarser grained material. There was no water level data in the Lower Cretaceous for calibration (*ibid.*).

An examination of the original Strom Model files indicated that the leakance value between the each confining unit and underlying aquifer was defined as 5.0×10^{-9} in the vicinity of the site location. As defined, the leakance values are two orders of magnitude lower than defined in an earlier model completed in the same area (Strom and Mallory, 1995) with the exception of the leakance between the Coffee Sand confining unit and the underlying Eutaw-McShan. As noted previously, the only changes made to the Strom Model were associated with the extension of the active cell area toward the southwest in the Massive Sand aquifer (Layer 5). However, an additional 1.0-MGD test simulation was run to check the sensitivity of the drawdown predictions to the leakance values. For the test simulation, the Strom Model leakance values in the vicinity of the site were revised from 5.0×10^{-9} in Layers 2, 3, 4, and 5 to 2.0×10^{-7}, 1.0×10^{-7}, 3.0×10^{-7}, 5.0×10^{-7}, respectively.

MODEL RESULTS

The 1.0-MGD model was first run without the addition of the two proposed pumping wells. Wells withdrawing at a rate of 0.5 MGD each were added in model cells R182 C92 and R183 C92, and the simulation was rerun. Drawdown was then computed by subtracting the head data from the initial simulation from the head data generated from the second simulation containing the proposed well withdrawals. The resulting drawdown after 40 years of pumping was contoured.

Figure 3 depicts the potentiometric surface drawdown estimated in the Massive Sand aquifer after 40 years of constantly pumping at the 1-MGD rate. The estimated drawdowns are widespread, yet of a low magnitude. The expanded model estimates approximately 6 ft of drawdown at the nearest existing user of the Massive Sand aquifer, which is located approximately 9.5 miles northeast of the proposed power plant in the town of De Kalb. The Mississippi Department of Environmental Quality (MDEQ) water well database (MDEQ, August 2008) suggests that several wells using the Massive Sand aquifer exist near the towns of Electric Mills and Scooba. Those wells are located approximately 21 to 22 miles east-northeast of the power plant site, and less than 5 ft of drawdown is predicted in the Massive Sand (Layer 5) at those well locations. These estimated drawdowns (6 ft or less) are not expected to cause any adverse impact to existing users of the water from the Massive Sand aquifer.

Smaller drawdowns would occur in the underlying and overlying aquifers. The expanded model estimated maximum drawdowns are 3.5 ft or less drawdown in the underlying Lower Cretaceous aquifer (Layer 6) as shown on Figure 4. Less than 3 ft of drawdown is predicted in the overlying Coker aquifer (Layer 4), as shown on Figure 5. A maximum of 1.5 ft of drawdown is predicted in the Gordo aquifer (Layer 3), with the highest drawdown observed along the western edge of the aquifer (Figure 6). A similar drawdown pattern is displayed for the Eutaw-McShan aquifer (Layer 2), with a maximum of 1.5 ft or less of drawdown (see Figure 7). Less than 1 ft of drawdown is predicted in the

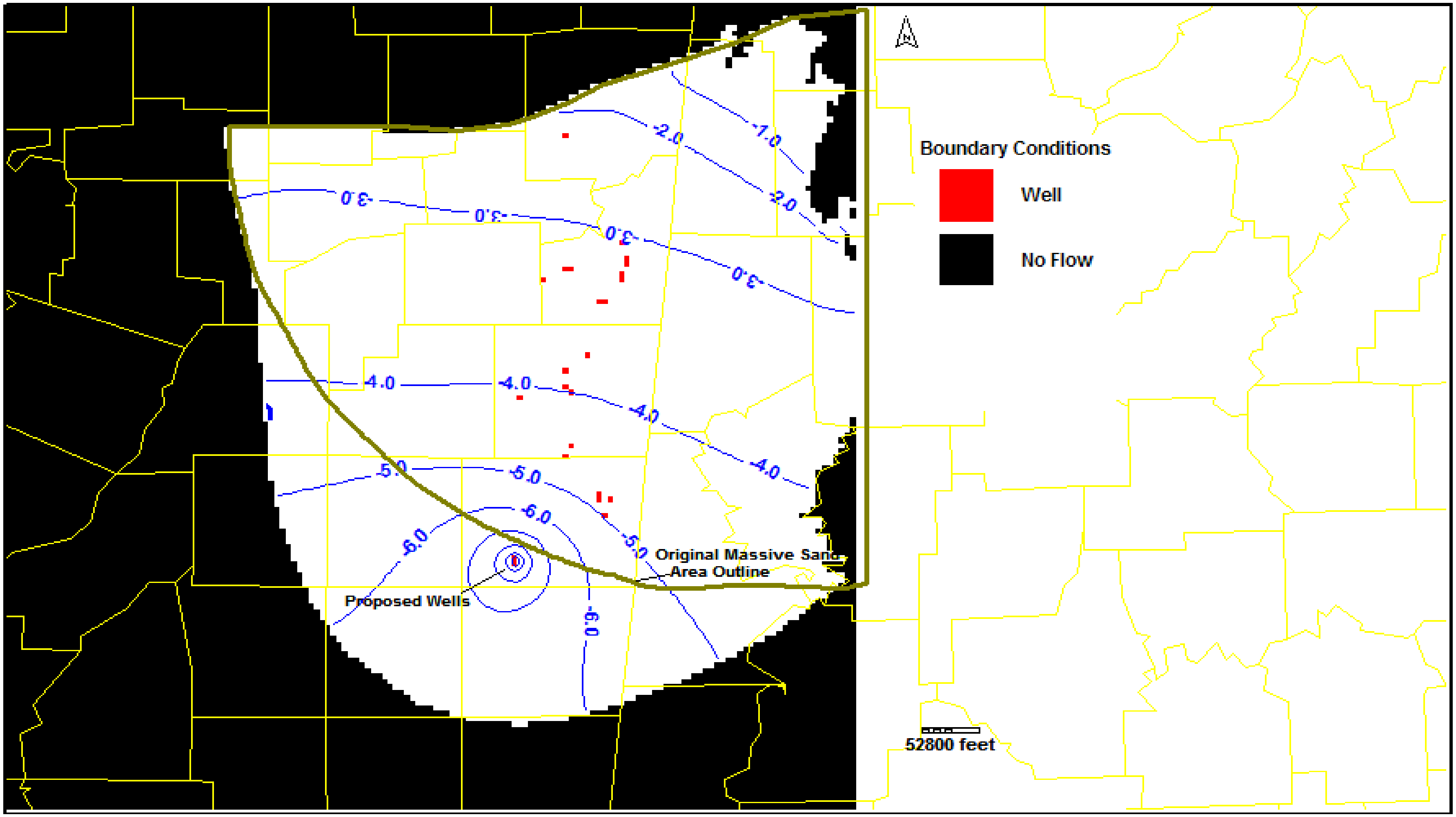

FIGURE 3.

PREDICTED DRAWDOWN IN MASSIVE SAND (LAYER 5) AT END OF 40 YEARS OF PUMPING BASED ON 1.0-MGD TOTAL WITHDRAWAL FROM MASSIVE SAND

Sources: Strom, 1998. ECT, 2009.

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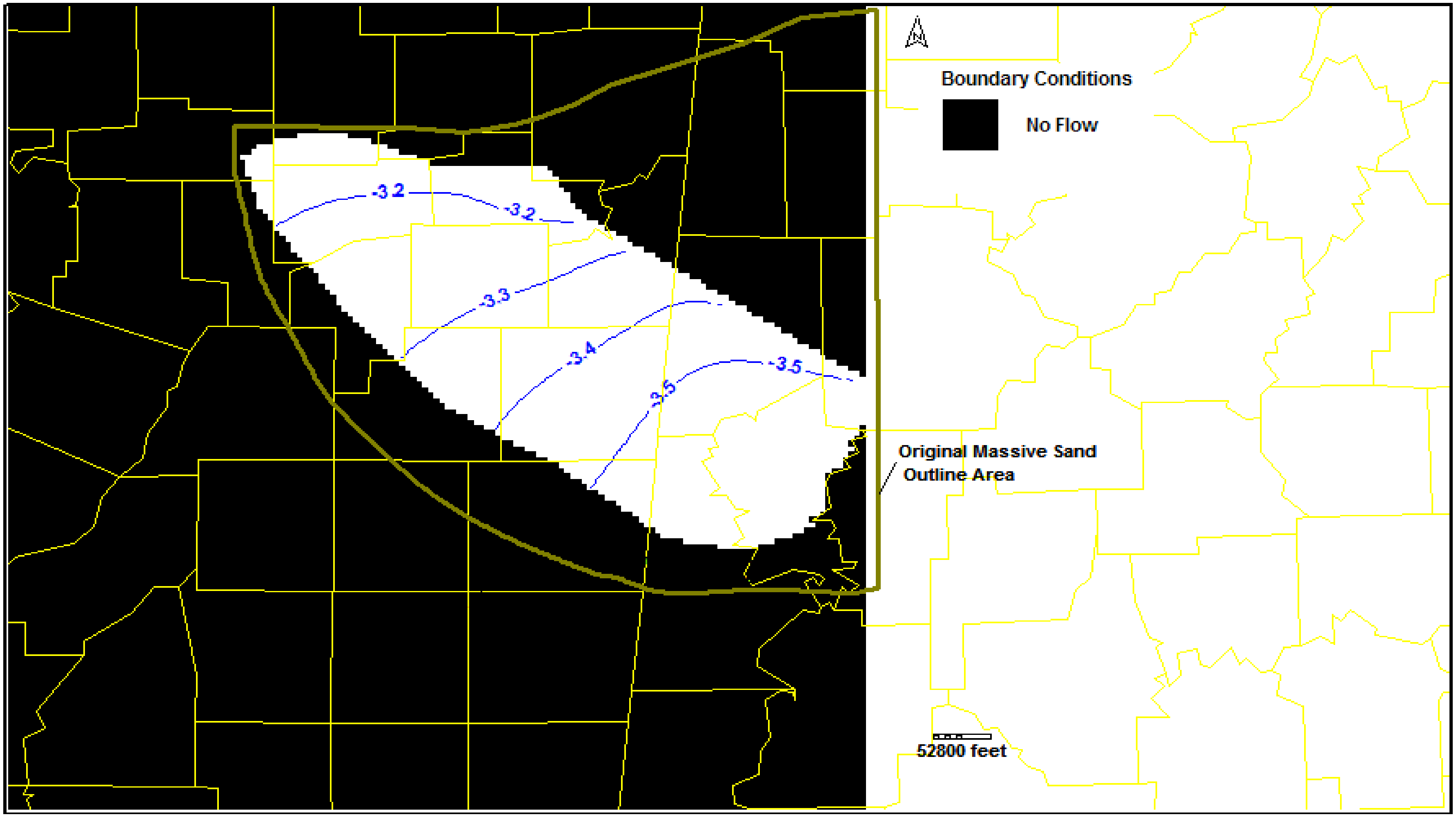

FIGURE 4.

PREDICTED DRAWDOWN IN LOWER CRETACEOUS AT END OF 40 YEARS OF PUMPING BASED ON 1.0-MGD TOTAL WITHDRAWAL FROM MASSIVE SAND

Sources: Strom, 1998. ECT, 2009.

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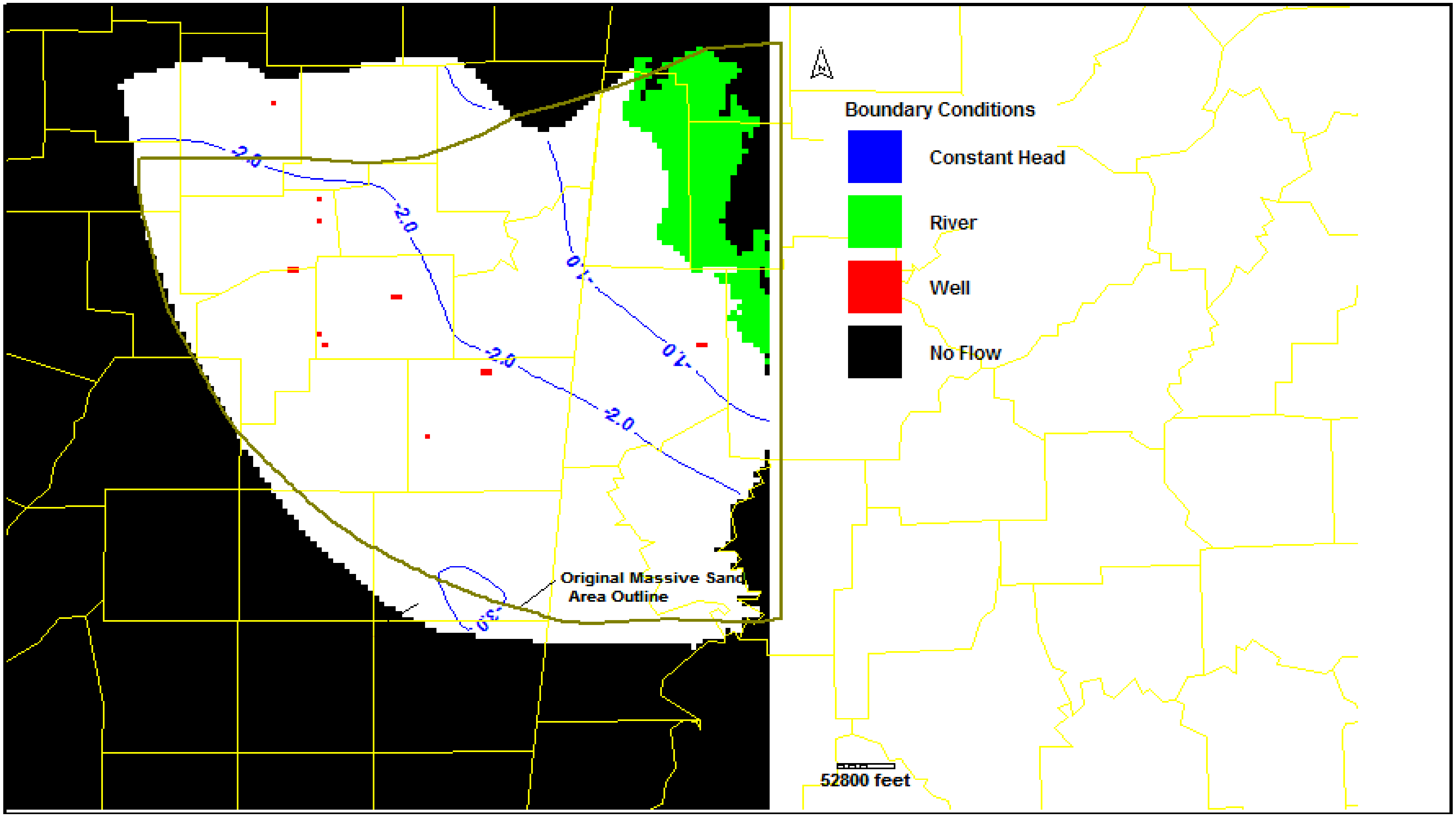

FIGURE 5.

PREDICTED DRAWDOWN IN COKER (LAYER 4) AT END OF 40 YEARS OF PUMPING BASED ON 1.0-MGD TOTAL WITHDRAWAL FROM MASSIVE SAND

Sources: Strom, 1998. ECT, 2009.

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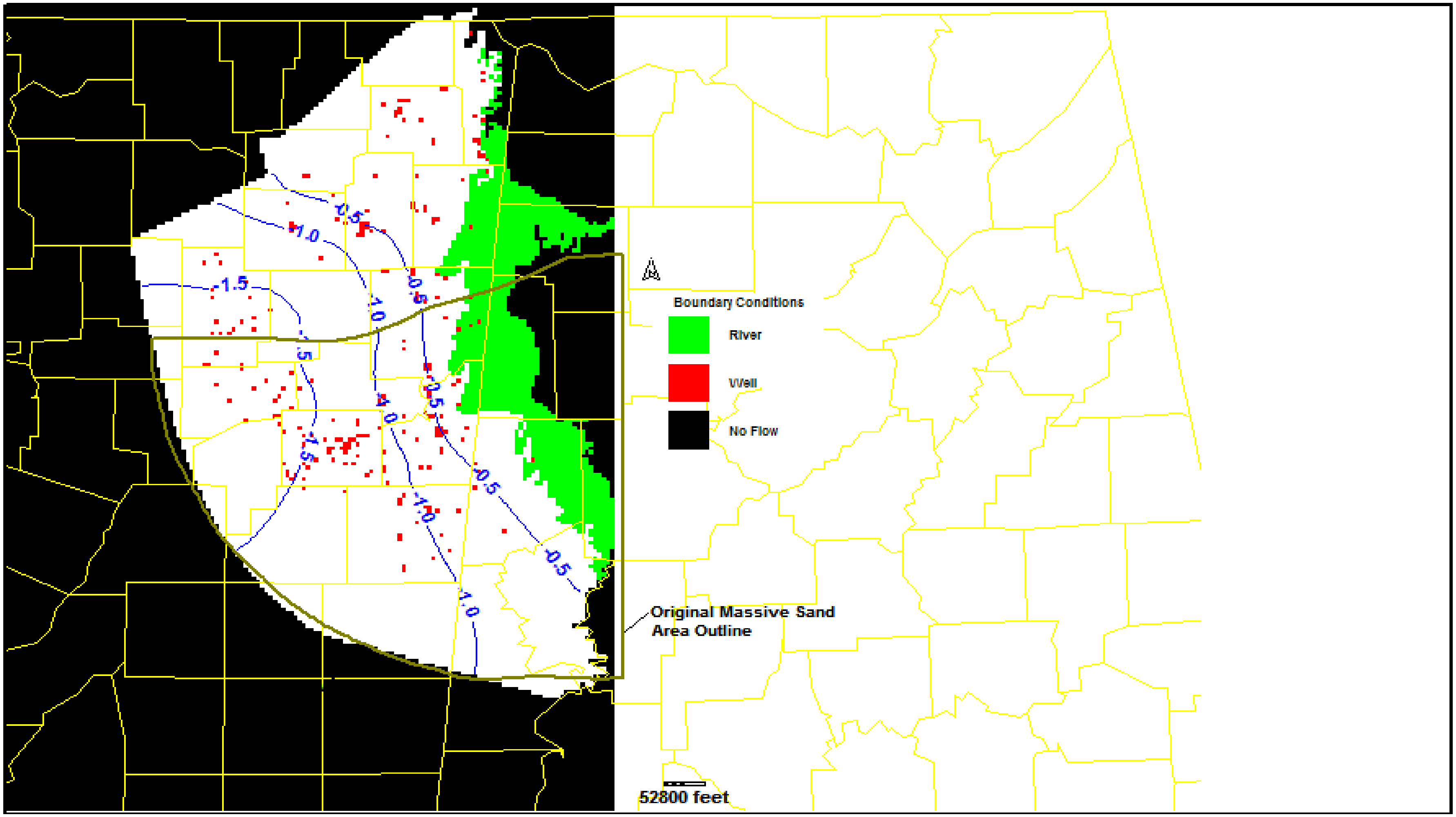

FIGURE 6.

PREDICTED DRAWDOWN IN GORDO (LAYER 3) AT END OF 40 YEARS OF PUMPING BASED ON 1.0-MGD TOTAL WITHDRAWAL FROM MASSIVE SAND

Sources: Strom, 1998. ECT, 2009.

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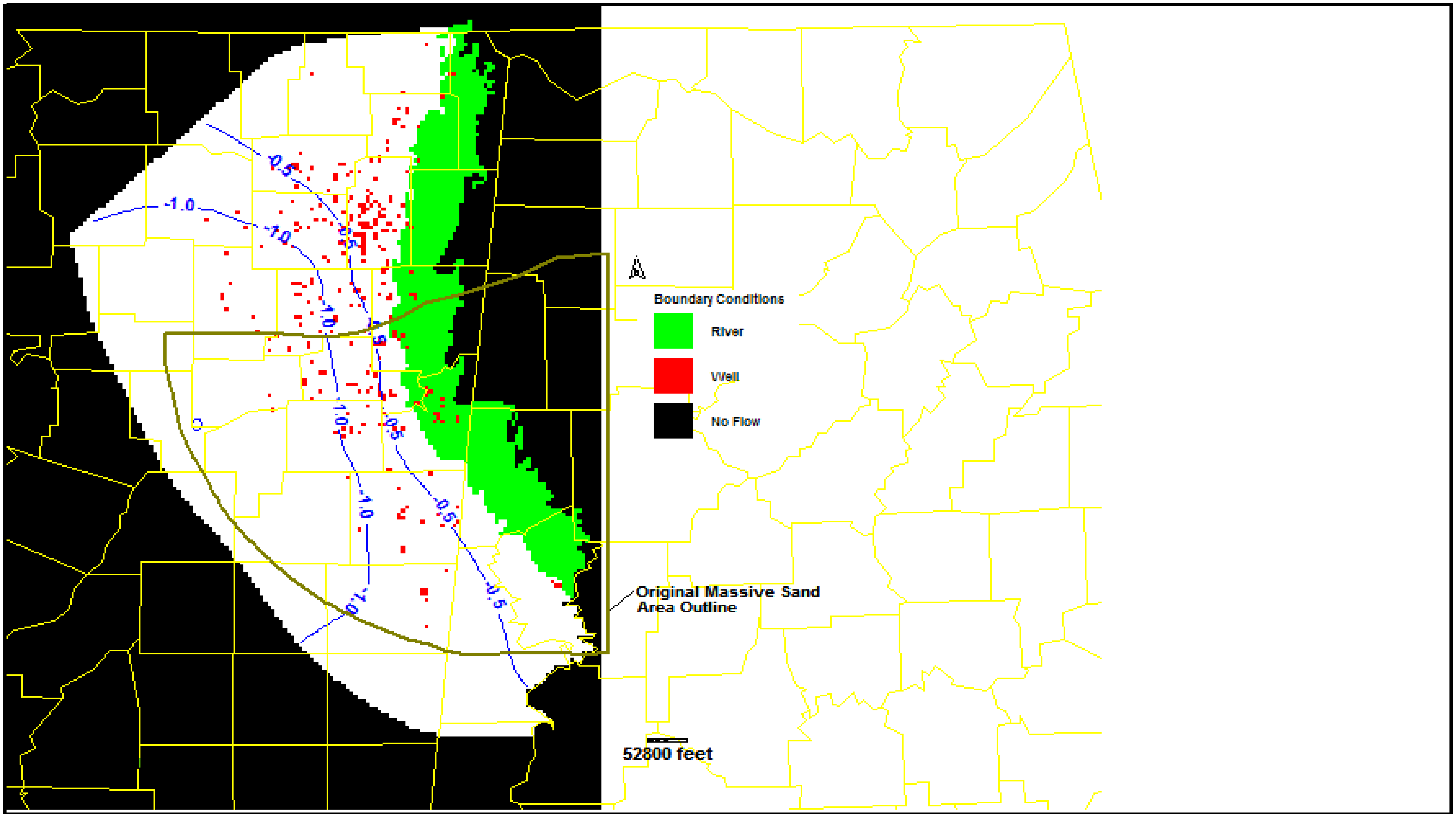

FIGURE 7.

PREDICTED DRAWDOWN IN EUTAW-McSHAN (LAYER 2) AT END OF 40 YEARS OF PUMPING BASED ON 1.0-MGD TOTAL WITHDRAWAL FROM MASSIVE SAND

Sources: Strom, 1998. ECT, 2009.

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simulation for the upper layer (Layer 1), the Coffee Sand (Figure 8). Generally, there is an increase in drawdown in the Coker, Eutaw-McShan, Gordo, and Coffee aquifers to the southwest, away from the recharge areas in the northeast portion of the model. The MDEQ water well database (MDEQ, August 2008) suggests that, within 20 miles of the proposed power plant site, no existing users of the water are present in the overlying Coker aquifer or the underlying Lower Cretaceous aquifer.

The results of the test simulation, conducted to investigate the sensitivity of the model to the lower leakance values defined in the vicinity of the site, did not indicate any change to the drawdown predicted in the Coffee Sand aquifer, Eutaw-McShan aquifer, or Gordo aquifer (Layers 1, 2, and 3, respectively). A slight decrease of 0.3 ft and 0.1 ft was observed in the Massive Sand aquifer (Layer 5) and the Lower Cretaceous aquifer (Layer 6), respectively. The drawdown changes in the Massive Sand aquifer (Layer 5) were limited to the area immediately adjacent to the proposed well and the southwestern freshwater-saltwater boundary.

Consideration was also given to the potential effects of the proposed withdrawal of 1 MGD on ground water quality. The Massive Sand aquifer at the site is known to be saline (e.g., the TDS concentration is 23,000 mg/L); as such, the site is situated on the saltwater side of the freshwater-saltwater interface as defined by 10,000 mg/L TDS. The estimated drawdowns do not suggest the likelihood for inducing any measurable saltwater migration into freshwater potions of any aquifer.

Based on the modeling assumptions and the fact that the actual ground water withdrawals will be on an as-needed basis, the 1-MGD model drawdown predictions are conservative. Therefore, the modeling results suggest that the withdrawal of 1 MGD of ground water from the Massive Sand aquifer will not cause any adverse impact to existing users of the water from the various underlying and overlying aquifers.

ALTERNATIVE 6.5 MGD SIMULATION

To evaluate the effect of using the well field to supply the entire 6.5-MGD water requirement of the facility, an additional simulation was run keeping all other parameters

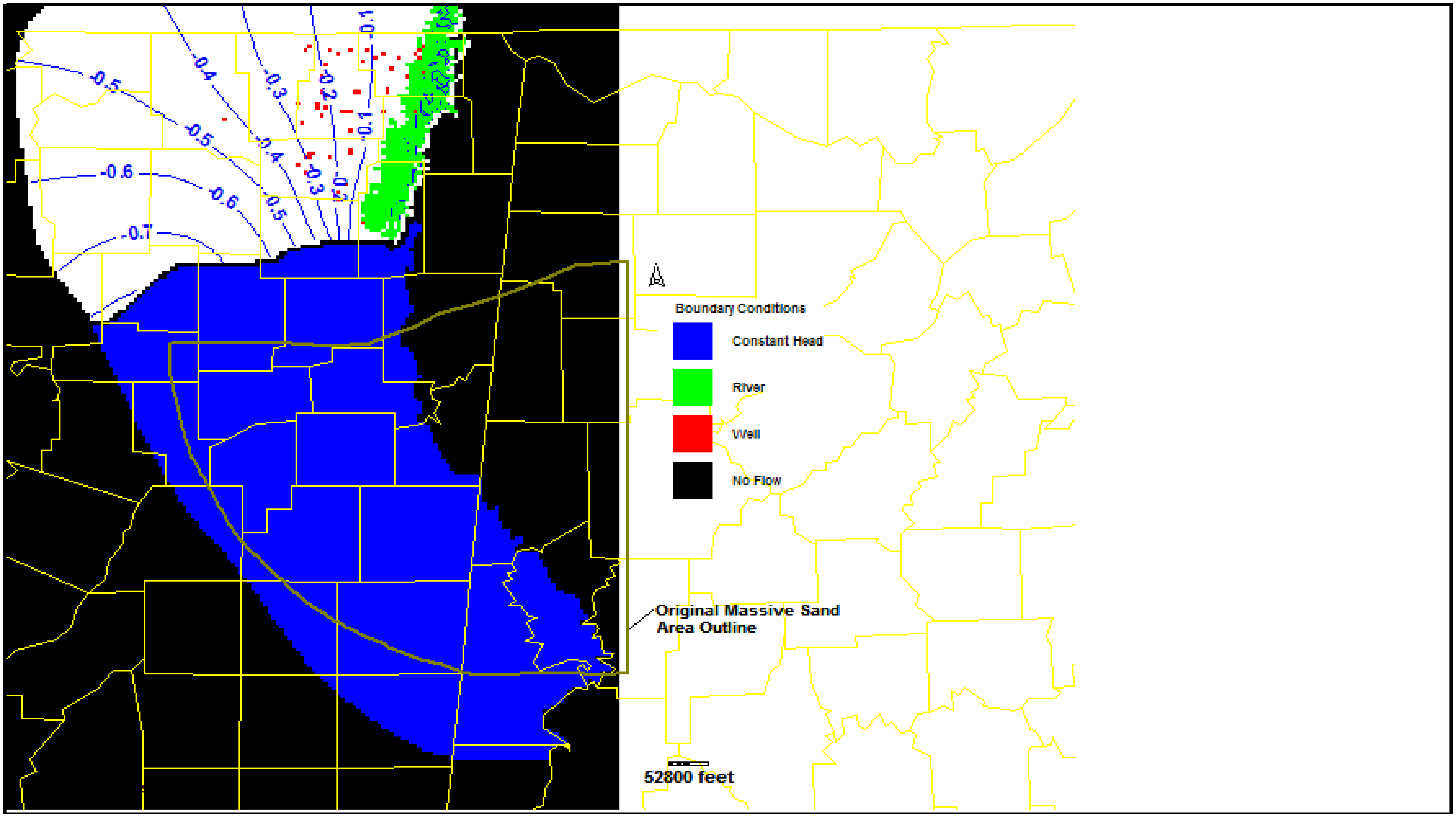

FIGURE 8.

PREDICTED DRAWDOWN IN COFFEE SAND (LAYER 1) AT END OF 40 YEARS OF PUMPING BASED ON 1.0-MGD TOTAL WITHDRAWAL FROM MASSIVE SAND

Sources: Strom, 1998. ECT, 2009.

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unchanged with the exception of increasing the total withdrawal rate to 6.5 MGD or 434,462 ft^3/day for each well. Drawdown after 40 years of pumping was calculated as described previously and contoured.

Figure 9 depicts the potentiometric surface drawdown predicted in the Massive Sand aquifer (Layer 5) after 40 years of constant pumping at the 6.5-MGD rate. The resulting estimated drawdown in the Massive Sand aquifer were widespread and of relatively high magnitudes. Predicted drawdown in the Massive Sand (Layer 5) after 40 years of constant pumping ranges between 28 to 70 ft in Kemper County, for example. The 6.5-MGD model predicts approximately 40 ft of drawdown at the nearest existing user of the Massive Sand aquifer, which is the town of De Kalb located approximately 9.5 miles northeast of the proposed power plant site. In addition, the 6.5-MGD simulation estimated approximately 31 ft or less of drawdown at the wells located in the towns of Electric Mills and Scooba, located approximately 21 to 22 miles east-northeast of the proposed power plant site. These estimated drawdowns would have the potential to cause adverse impacts to those existing users of the water from the Massive Sand aquifer (Layer 5).

The 6.5-MGD model also estimated widespread and moderate to low amounts of drawdown in the underlying and overlying aquifers. The 6.5-MGD model estimated approximately 20 to 23 ft of drawdown (Figure 10) in the underlying Lower Cretaceous aquifer (Layer 6); however, there are no water wells currently screened in that aquifer in this region, according to the MDEQ database. Approximately 18 to 20 ft of drawdown (Figure 11) was estimated in the overlying Coker aquifer (Layer 4) throughout Kemper County. Currently, there are no water wells screened in the Coker aquifer within at least 20 miles of the proposed power plant site. According to the MDEQ database, the closest well appears to exist approximately 30 miles to the north in Noxubbe County. The model estimated approximately 16 ft of drawdown at that Coker aquifer well location. Maximum drawdown estimates in the shallower Gordo aquifer (Layer 3) were 11 ft or less (Figure 12). Maximum drawdown estimates in the Eutaw-McShan aquifer (Layer 2) were 10 ft or less (Figure 13). Maximum drawdown estimates in the Coffee Sand aquifer (Layer 1) were 5 ft or less (Figure 14).

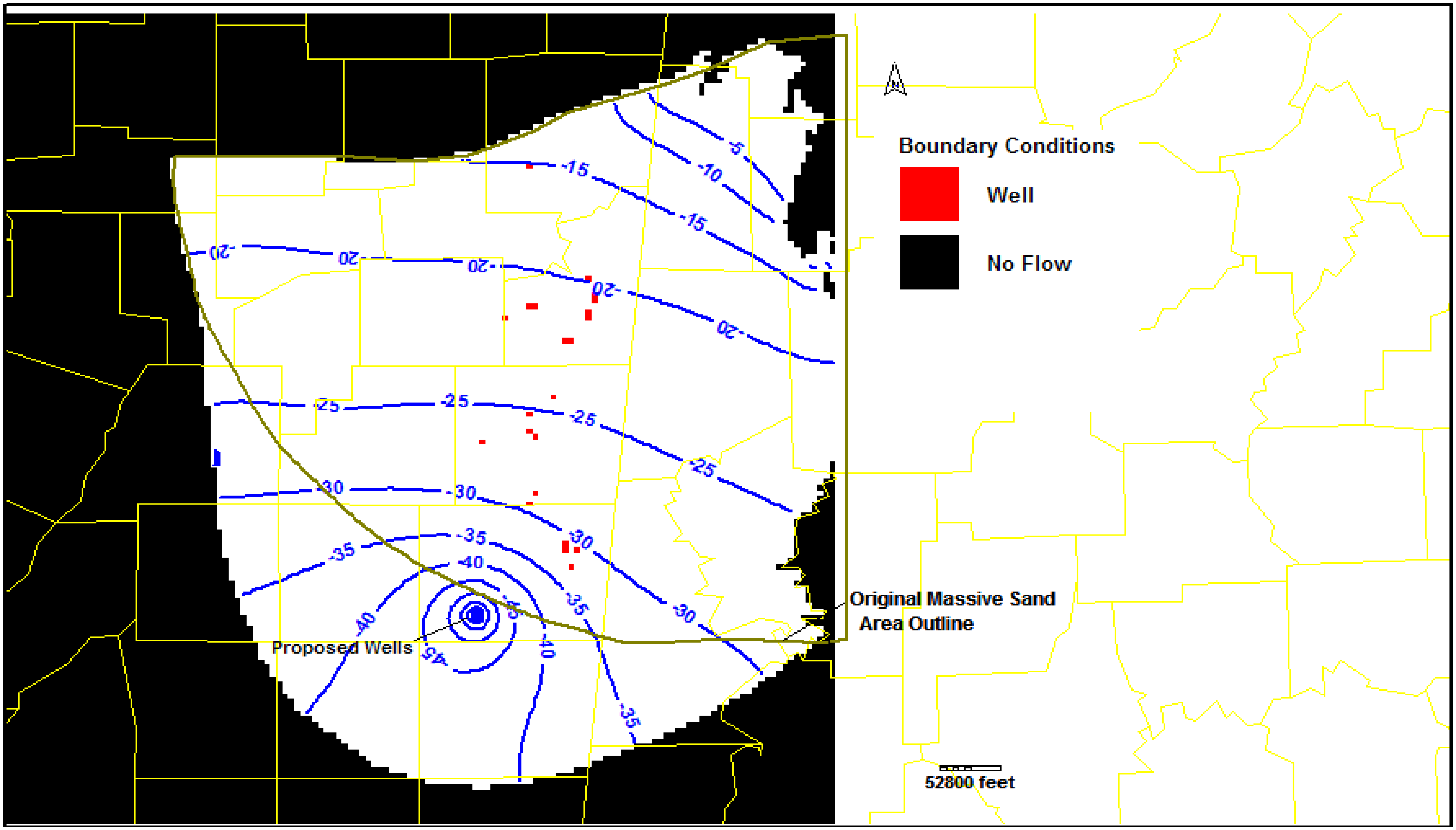

FIGURE 9.

PREDICTED DRAWDOWN IN MASSIVE SAND (LAYER 5) AT END OF 40 YEARS OF PUMPING BASED ON 6.5-MGD TOTAL WITHDRAWAL FROM MASSIVE SAND

Sources: Strom, 1998. ECT, 2009.

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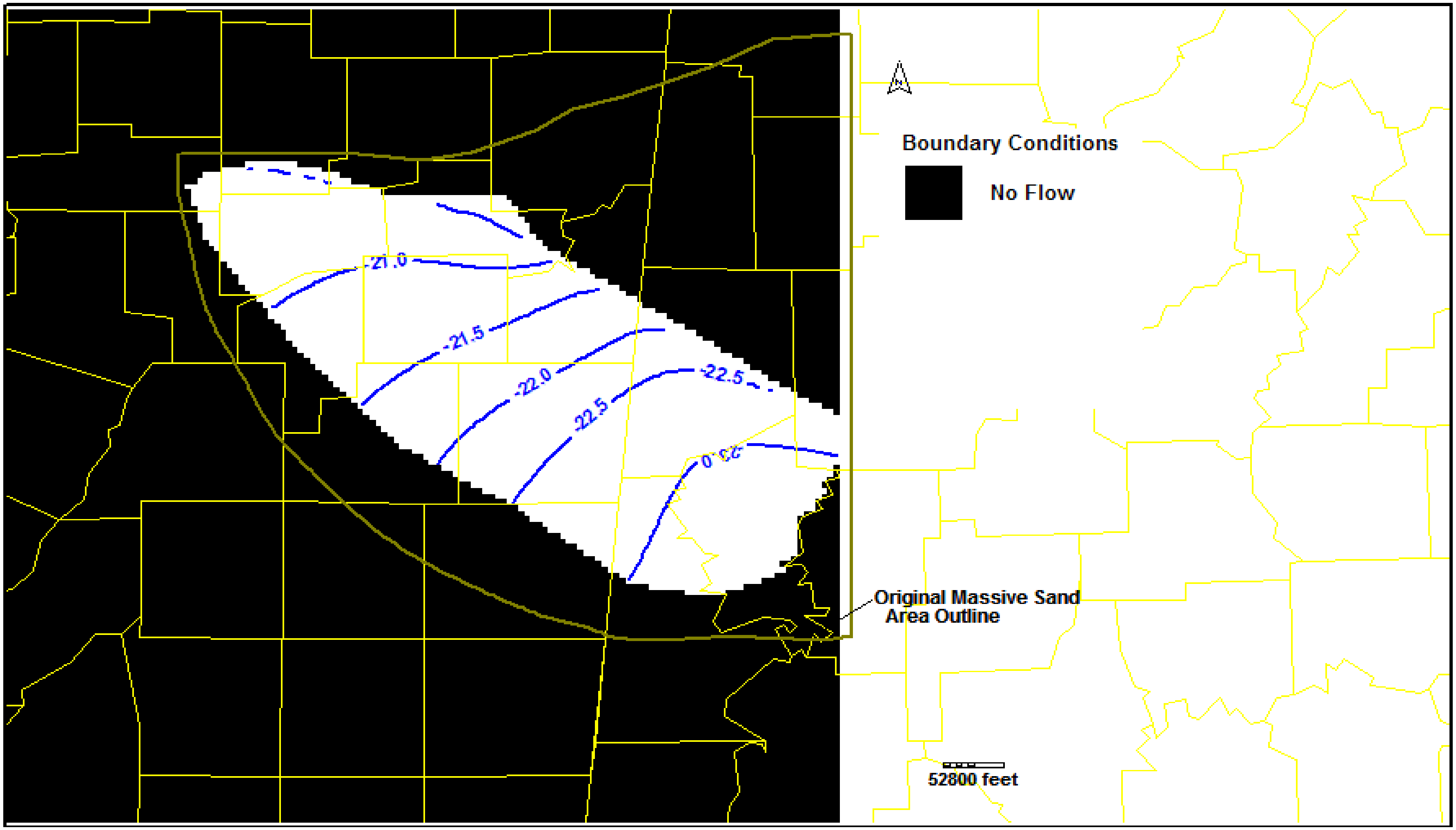

FIGURE 10.

PREDICTED DRAWDOWN IN LOWER CRETACEOUS (LAYER 6) AT END OF 40 YEARS OF PUMPING BASED ON 6.5-MGD TOTAL WITHDRAWAL FROM MASSIVE SAND

Sources: Strom, 1998. ECT, 2009.

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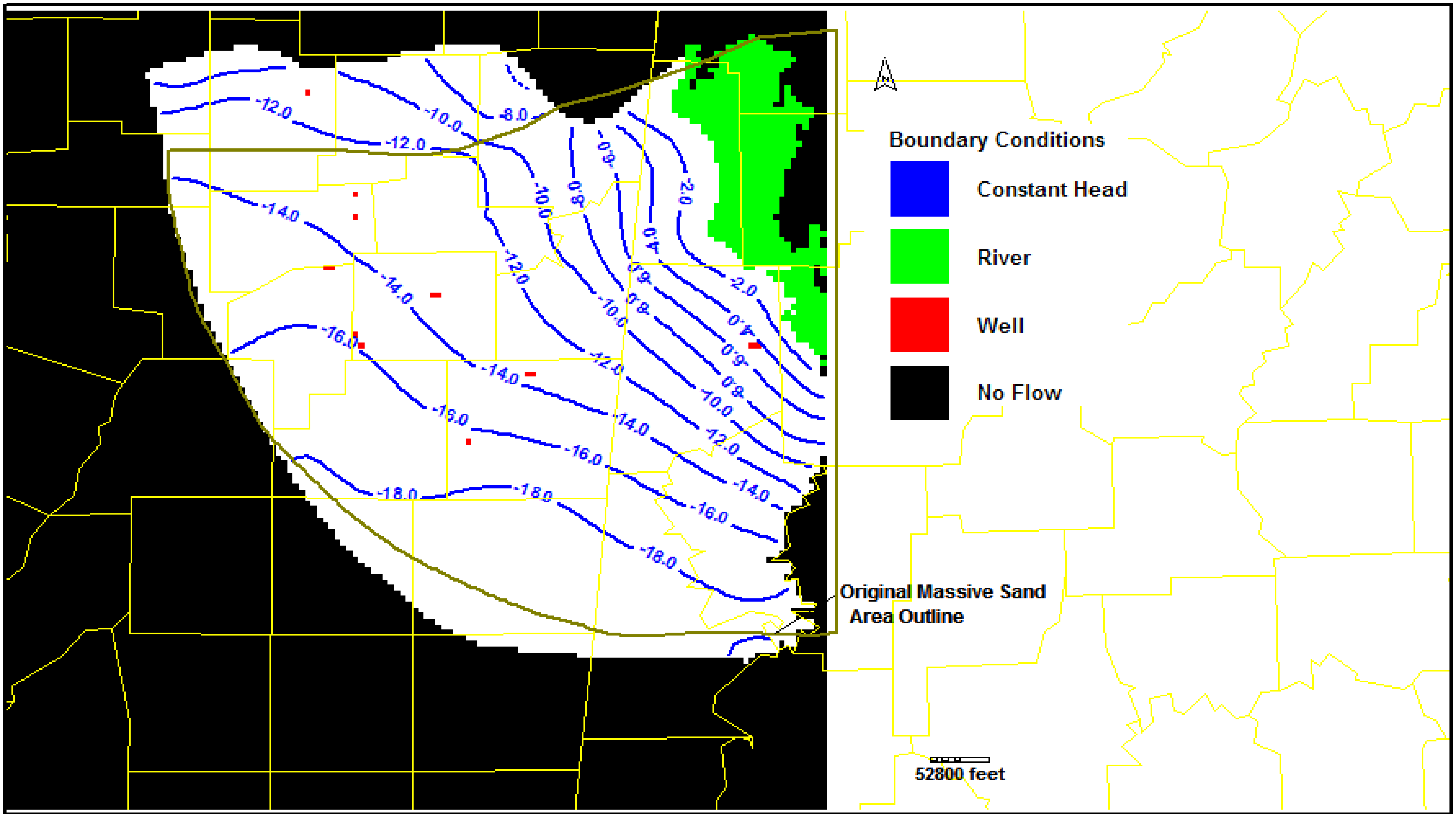

FIGURE 11.

PREDICTED DRAWDOWN IN COKER (LAYER 4) AT END OF 40 YEARS OF PUMPING BASED ON 6.5-MGD TOTAL WITHDRAWAL FROM MASSIVE SAND

Sources: Strom, 1998. ECT, 2009.

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Environmental Consulting & Technology, Inc.

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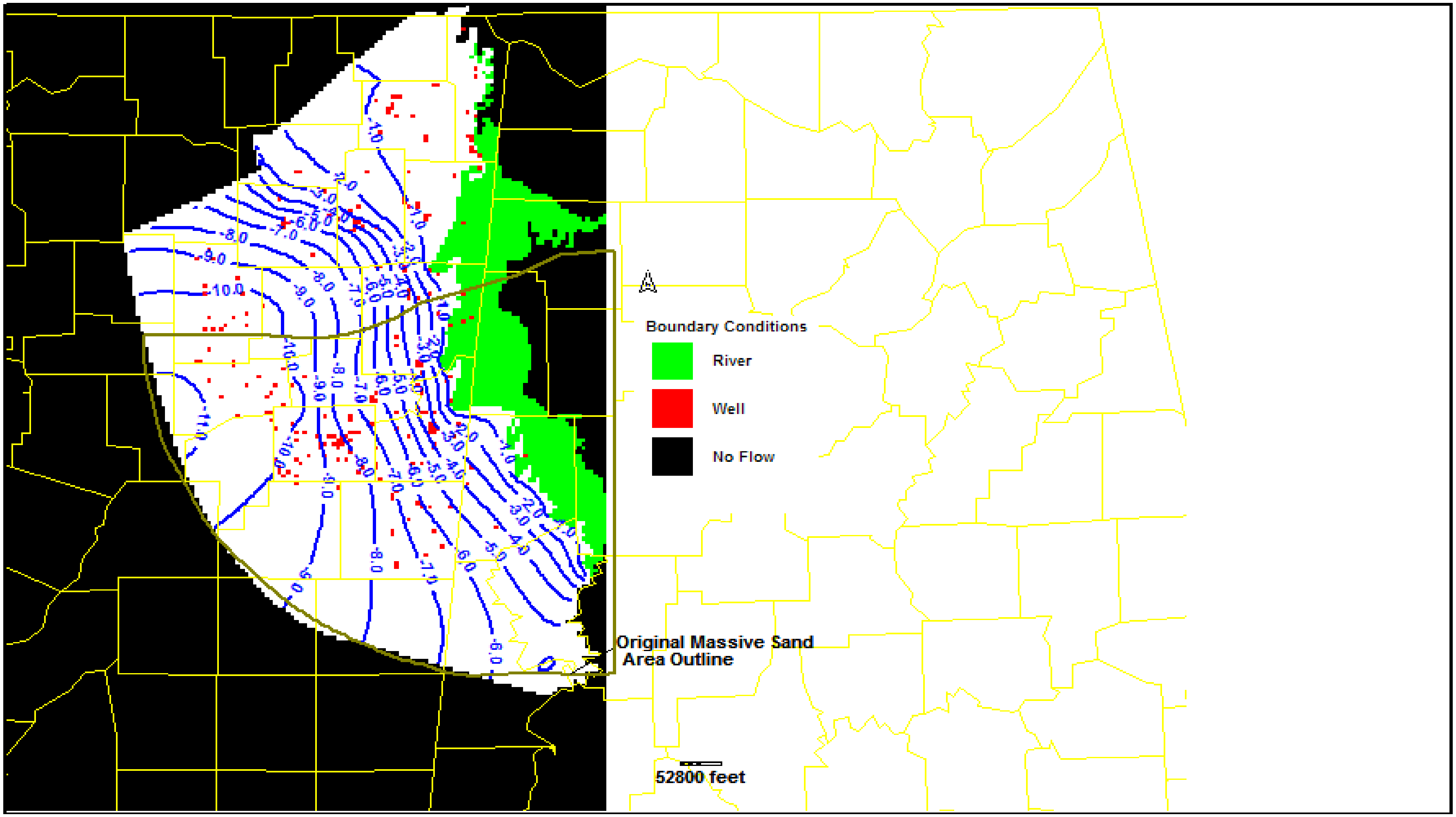

FIGURE 12.

PREDICTED DRAWDOWN IN GORDO (LAYER 3) AT END OF 40 YEARS OF PUMPING BASED ON 6.5-MGD TOTAL WITHDRAWAL FROM MASSIVE SAND

Sources: Strom, 1998. ECT, 2009.

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Environmental Consulting & Technology, Inc.

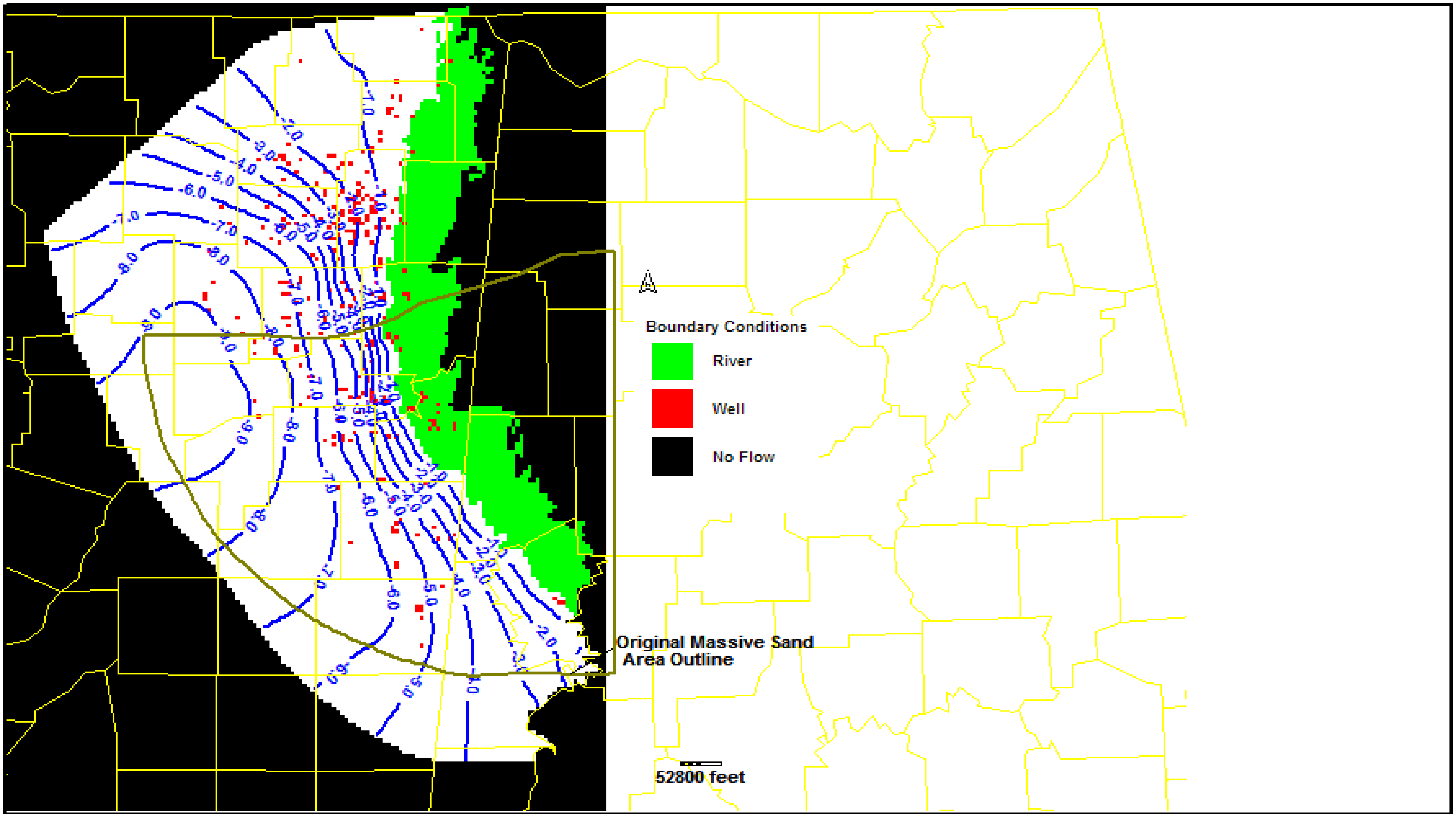

FIGURE 13.

PREDICTED DRAWDOWN IN EUTAW-McSHAN (LAYER 2) AT END OF 40 YEARS OF PUMPING BASED ON 6.5-MGD TOTAL WITHDRAWAL FROM MASSIVE SAND

Sources: Strom, 1998. ECT, 2009.

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Environmental Consulting & Technology, Inc.

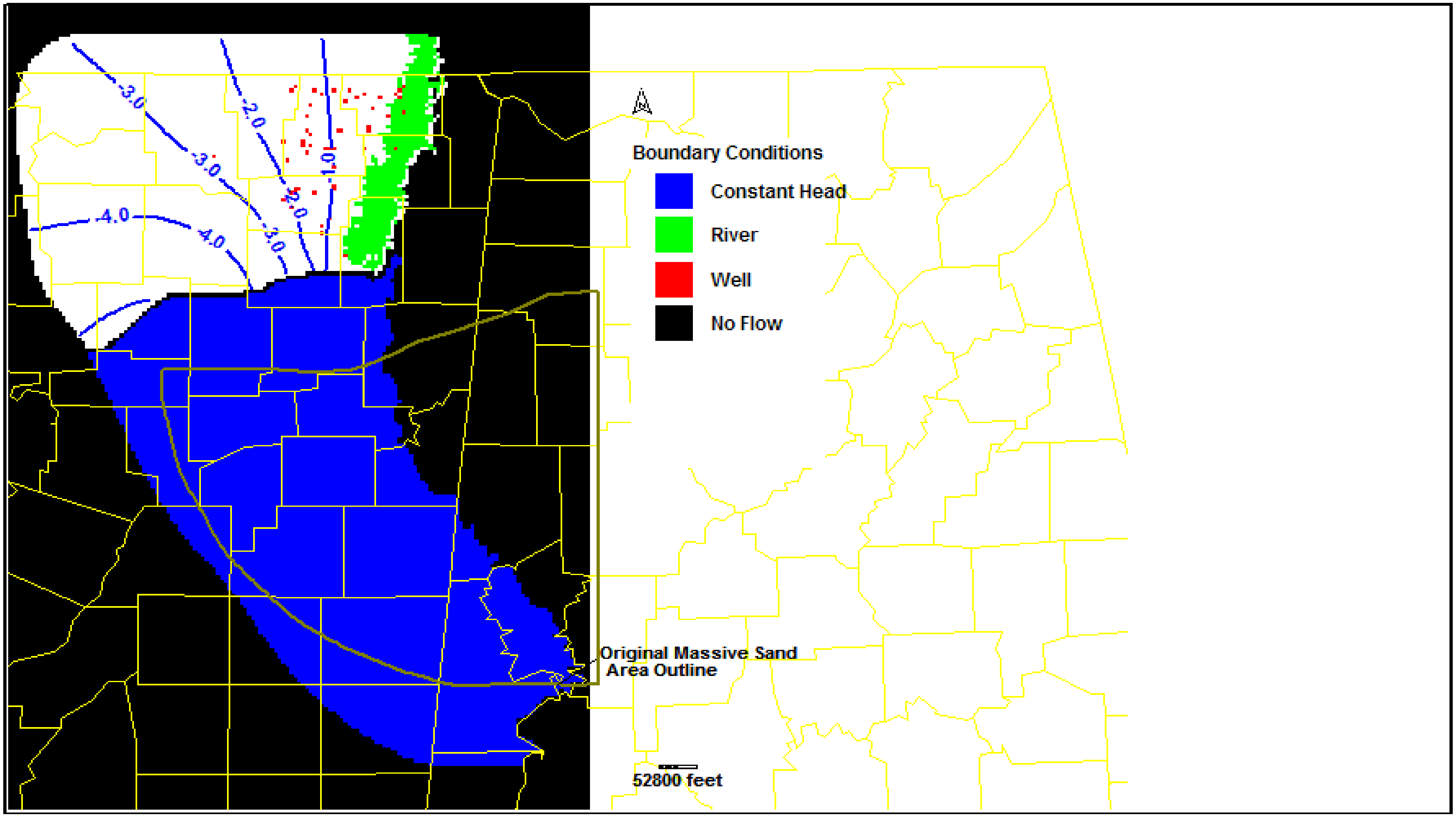

FIGURE 14.

PREDICTED DRAWDOWN IN COFFEE SAND (LAYER 1) AT END OF 40 YEARS OF PUMPING BASED ON 6.5-MGD TOTAL WITHDRAWAL FROM MASSIVE SAND

Sources: Strom, 1998. ECT, 2009.

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The 6.5-MGD simulation suggests that these estimated drawdowns have the potential to cause adverse impacts to existing Massive Sand aquifer users and would have some potential to cause minor adverse impact to existing users of ground water from the Coker and possibly the Gordo aquifers. No significant impacts would be expected relative to the existing users of ground water from the Eutaw-McShan aquifer or the Coffee Sand aquifer. Actual impacts to a water user's well are relative not only to the amount of drawdown experienced but also to the specific construction and condition of each well. However, such impacts could likely be mitigated by retrofitting and/or upgrading well pumps at impacted wells.

MODEL LIMITATIONS AND DISCUSSION

The southwest boundary of the model layers have been defined as a sharp contact representing the freshwater to the northeast of the boundary and the saline ground water to the southwest of the boundary. While this freshwater-saltwater boundary is typically represented as a sharp contact in ground water flow modeling, implying that the fluids are immiscible liquids, this is not actually correct. The transition zones between fresh and saline ground water can vary between a few tens of feet to more than a few miles.

The proposed wells will be withdrawing from the saline portion of the Massive Sand aquifer approximately 3 to 4 miles to the southwest of the freshwater-saltwater boundary defined for the area by Strom (1998). The location of the existing freshwater-saltwater boundary is based on the equilibrium of the ground water flow system. Placing pumping wells close to this boundary will change this equilibrium and likely cause a shift in the boundary location. The variable dissolved solid concentrations found in the saline ground water affects the ground water density and consequently ground water flow. MODFLOW, a single density fluid model, does not account for variable density affects that would occur in the vicinity of the freshwater-saltwater boundary. The Strom Model and expanded 1.0-MGD model, therefore, are not designed to estimate the movement of the freshwater-saltwater boundary or consider spatial variations in fluid density that can affect ground water flow and predicted drawdown.

The actual head values in the saline portion of the aquifer (at equal elevation/pressure) would be lower than predicted by the current MODFLOW simulations, which only calculate head distributions based on freshwater/low density ground water. Based on the potential gradients the actual lower head values would tend to induce and considering the modeling performed for the Red Hills Final Environmental Impact Statement (TVA, 1998) under similar circumstances of pumping, position relative to the freshwater-saltwater interface, and hydrogeologic conditions, it is likely that the boundary would migrate on the order of 1,000 to 2,000 ft to the southwest. This would expand the transition zone and/or the freshwater section of the Massive Sand aquifer toward the southwest in the vicinity of the proposed power plant. In addition, the current MODFLOW simulations will slightly overestimate the drawdown observed at greater distances from the freshwater-saltwater boundary and toward the recharge areas and underestimate the drawdown in the vicinity of the site.

The Strom Model was developed using average heads calculated for the entire 1-mi^2 cell area and therefore should be used for analyzing ground water flow on a regional scale. Transmissivity and other hydraulic properties of the aquifers modeled are assumed to be constant within each 1-mi^2 grid cell. Therefore, the expanded model is valid as a regional assessment tool.

The hydraulic property data (transmissivity, leakance, hydraulic conductivity, etc.) used to develop the Strom Model is limited to wells drilled before 1995. There are likely other new wells, in addition to the ES&EE onsite test well, that could provide updated hydraulic property data that may have an impact on the model predictions.

No-flow boundaries have been used to define the layer boundaries at the depositional edge of the aquifers and at the freshwater-saltwater boundary. In reality, the up-dip, depositional edges of the aquifers may not be isolated but rather in contact with other saturated sediments. Similarly, the fresh and saline ground waters are not truly immiscible fluids, so there will likely be some degree of flow associated with the freshwater-saltwater boundary. These conditions will tend to cause the 1.0-MGD model to slightly overestimate the predicted drawdown.

Since only the southwestern extent of the Massive Sand aquifer (Layer 5) was extended to include active cells in the area of the proposed wells, the cells in the Layers 3 and 6 above and below the extension remain no-flow cells. While active cells are present in the Coker aquifer (Layer 4) overlying the proposed site wells, they are only a few miles from the freshwater-saltwater boundary defined in that layer. This may cause a slight overestimation in the drawdown in the Massive Sand aquifer (Layer 5) and Lower Cretaceous (Layer 6) and an underestimation in the drawdown in the overlying Layers 3 and 4, the Gordo and Coker aquifers, respectively. However, at the 1.0-MGD pumping rate, the resulting effects on the predicted drawdown is expected to be insignificant.

Similarly, the low leakance values of 5.0×10^{-9}, used in the Strom Model over much of the west and southwest portion of the aquifers, is two orders of magnitude lower than would be expected based on information published leakance values for an earlier USGS MODFLOW simulation completed in the same area (Strom and Mallory, 1995). The test simulation indicates that this lower leakance value tends to overestimate the drawdown predicted in the Massive Sand aquifer (Layer 5) and Lower Cretaceous aquifer (Layer 6). The effect of the lower leakance value on the predicted drawdowns for the 1.0-MGD model is expected to be insignificant.

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APPENDIX A

STROM MODEL REPORT FIGURES

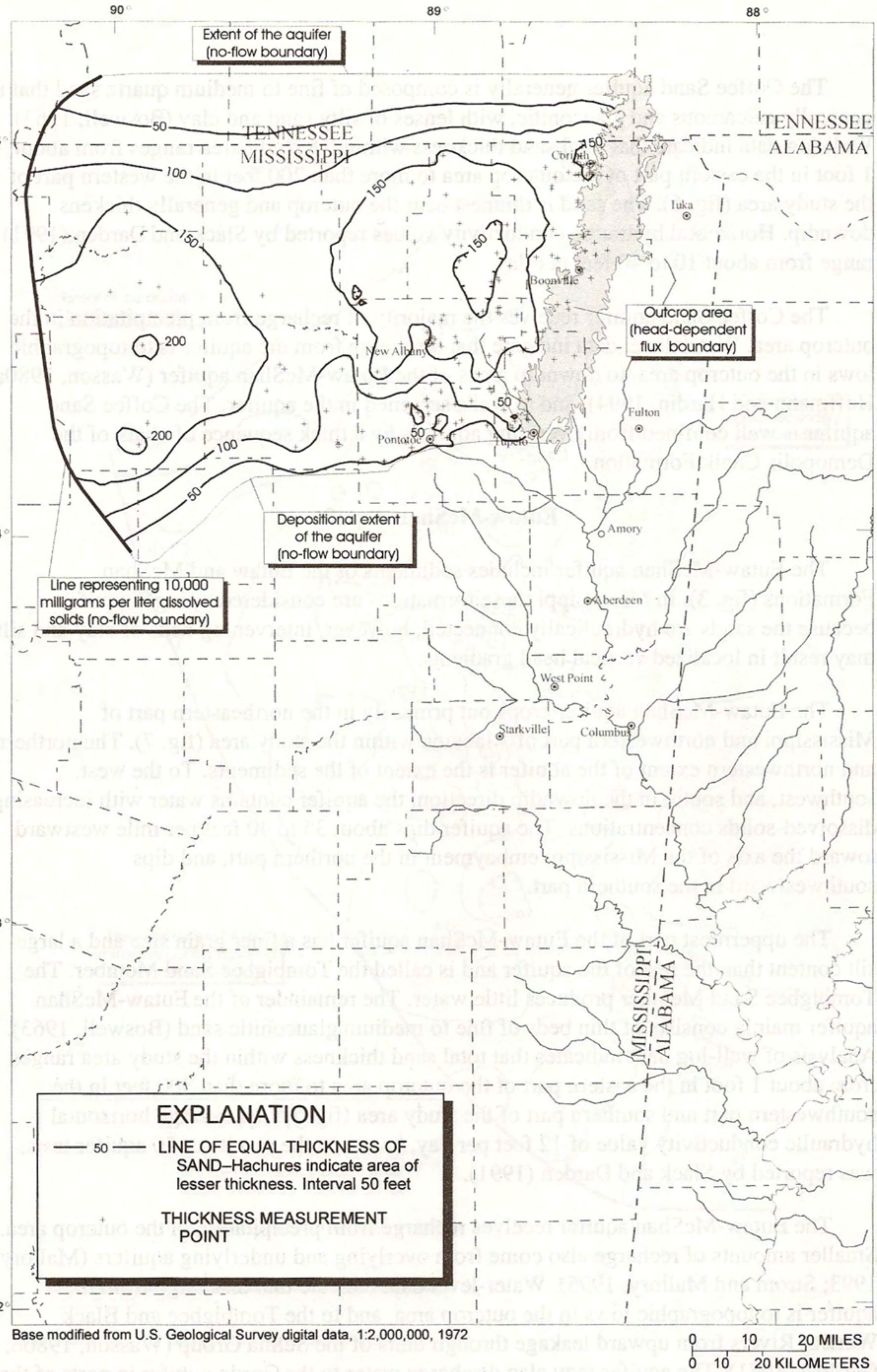

Figure 6. Extent and total sand thickness of the Coffee Sand aquifer and location of measurements.

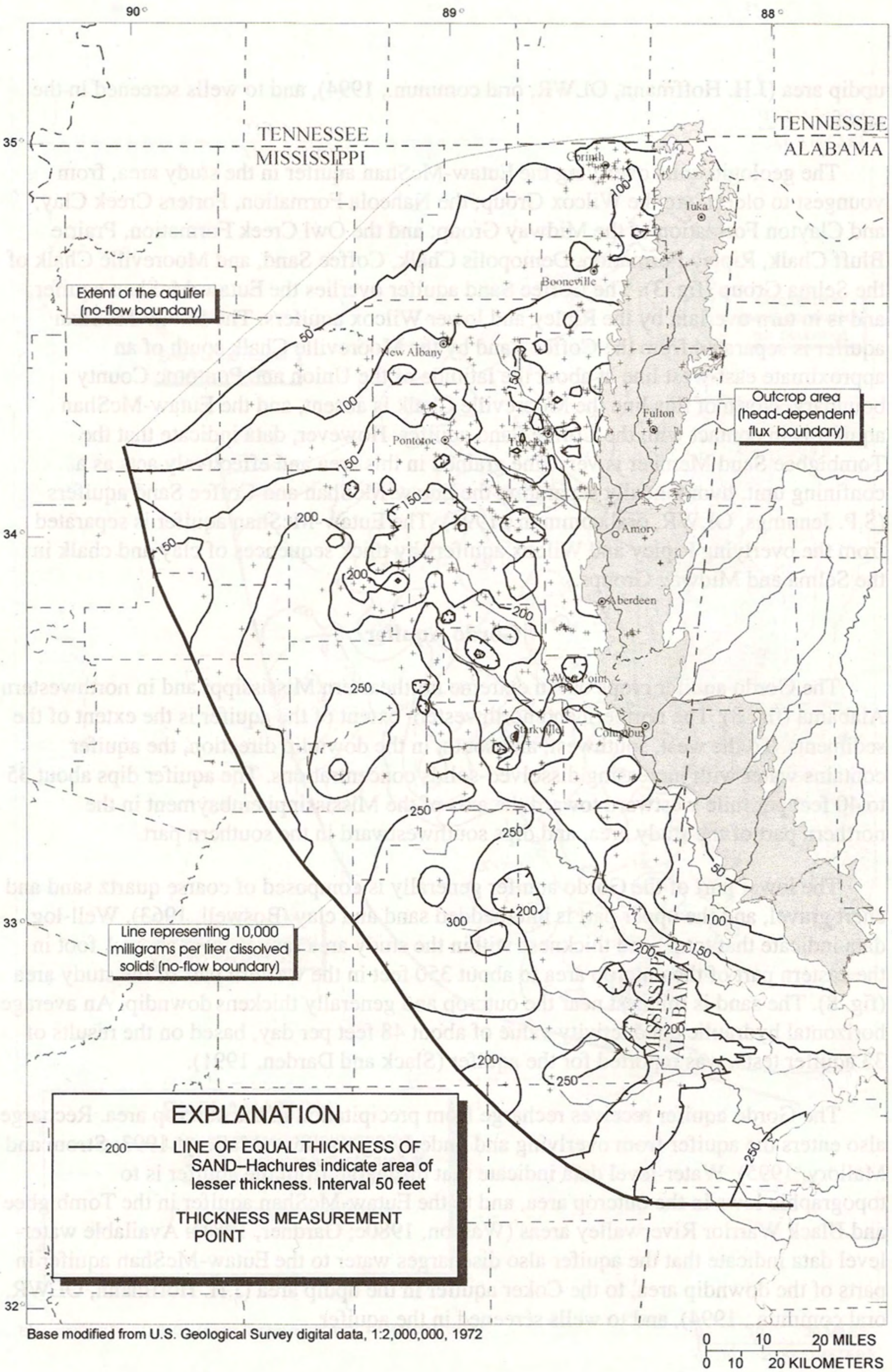

Figure 7. Extent and total sand thickness of the Eutaw-McShan aquifer and location of measurements.

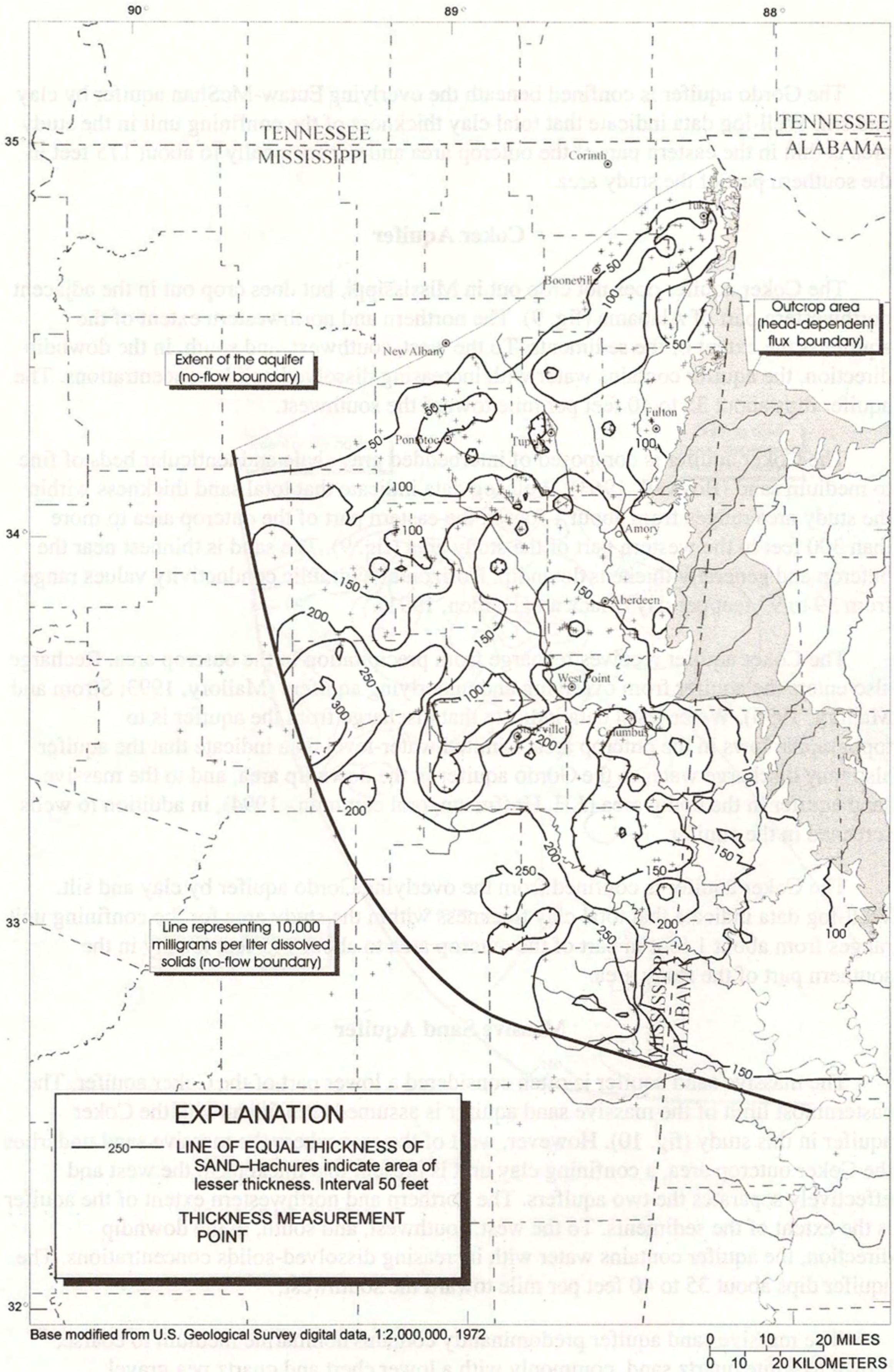

Figure 8. Extent and total sand thickness of the Gordo aquifer and location of measurements.

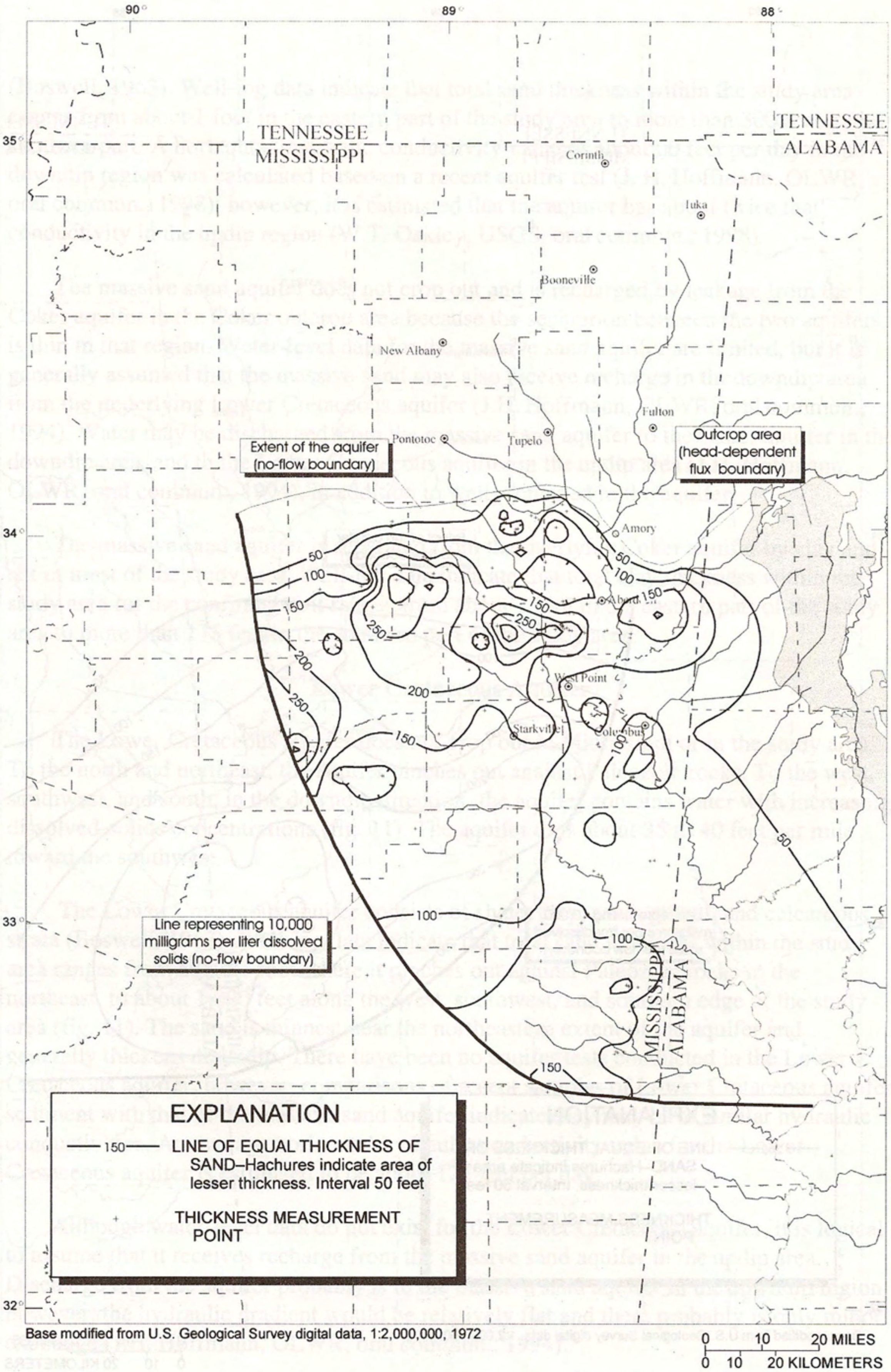

Figure 9. Extent and total sand thickness of the Coker aquifer and location of measurements.

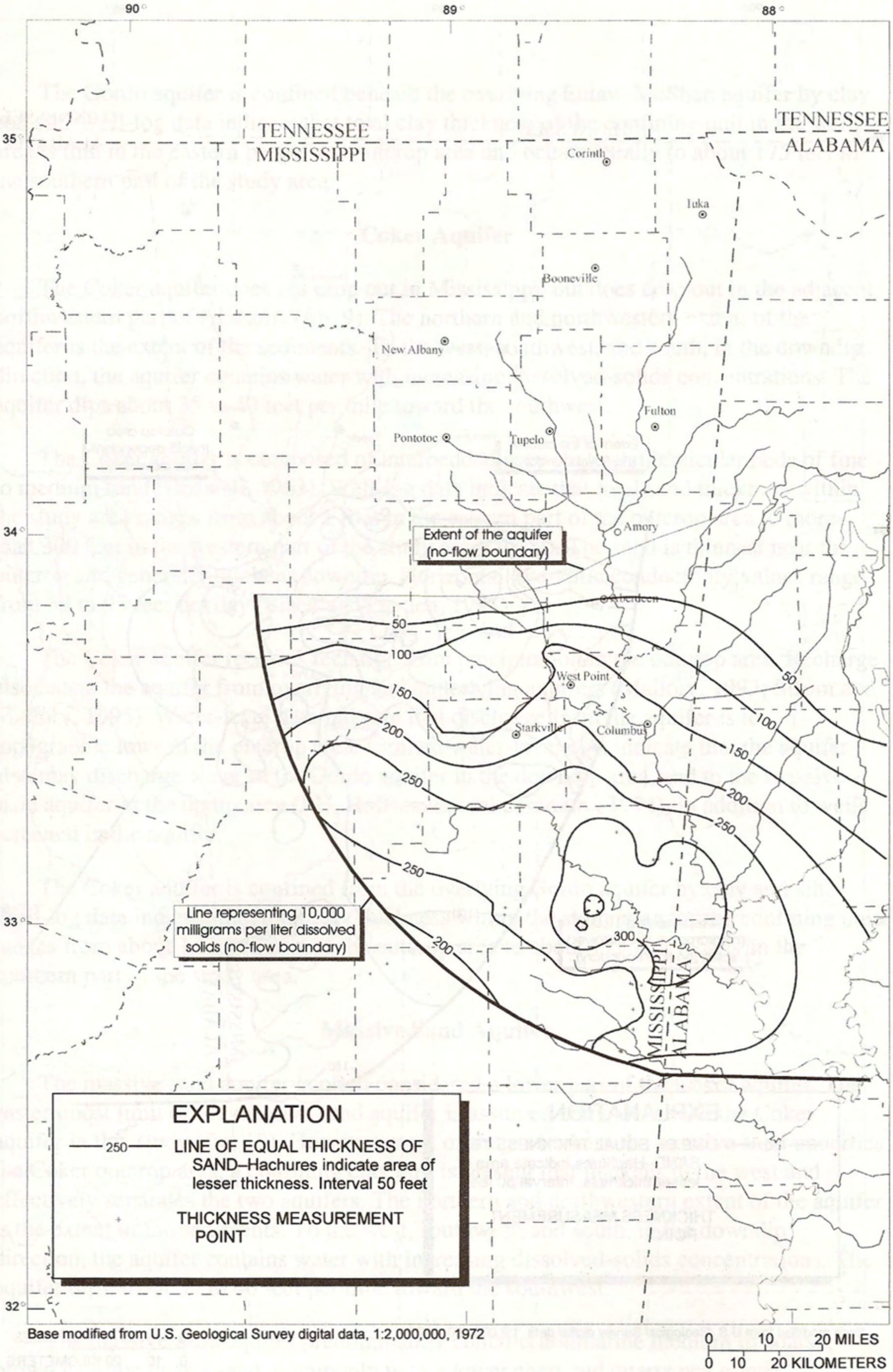

Figure 10. Extent and total sand thickness of the massive sand aquifer and location of measurements.

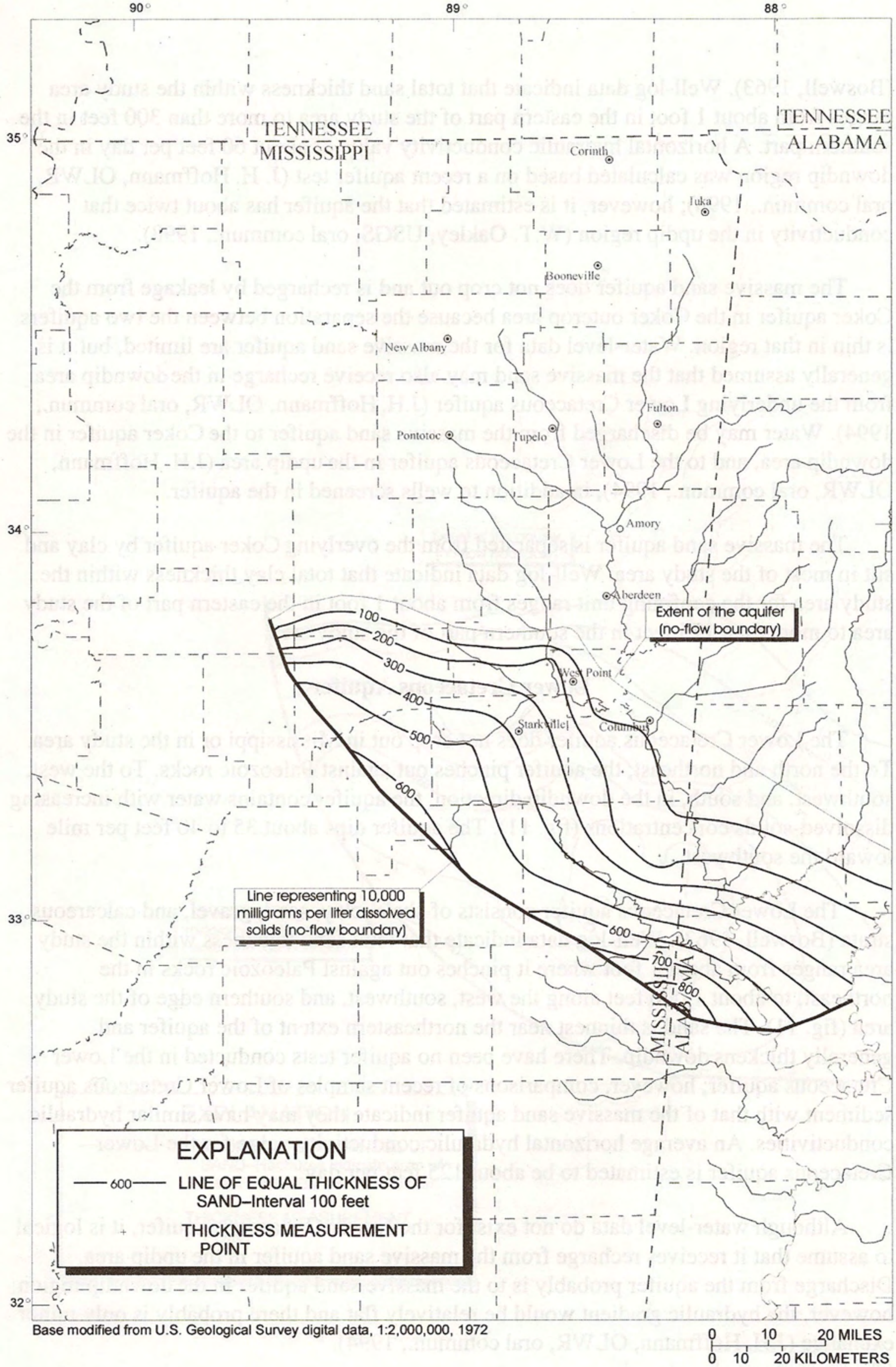

Figure 11. Extent and total sand thickness of the Lower Cretaceous aquifer and location of measurements.

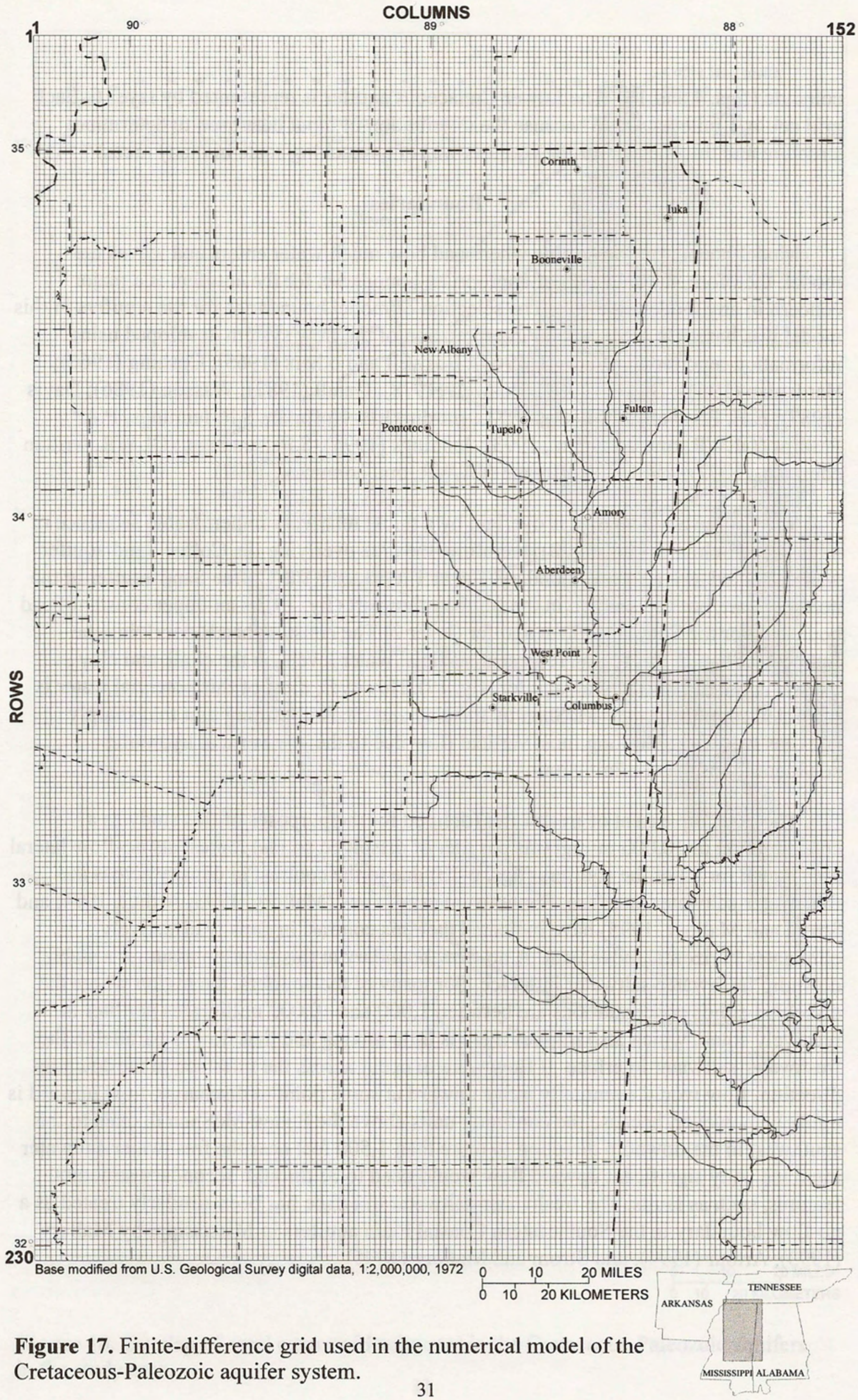

Figure 17. Finite-difference grid used in the numerical model of the Cretaceous-Paleozoic aquifer system.

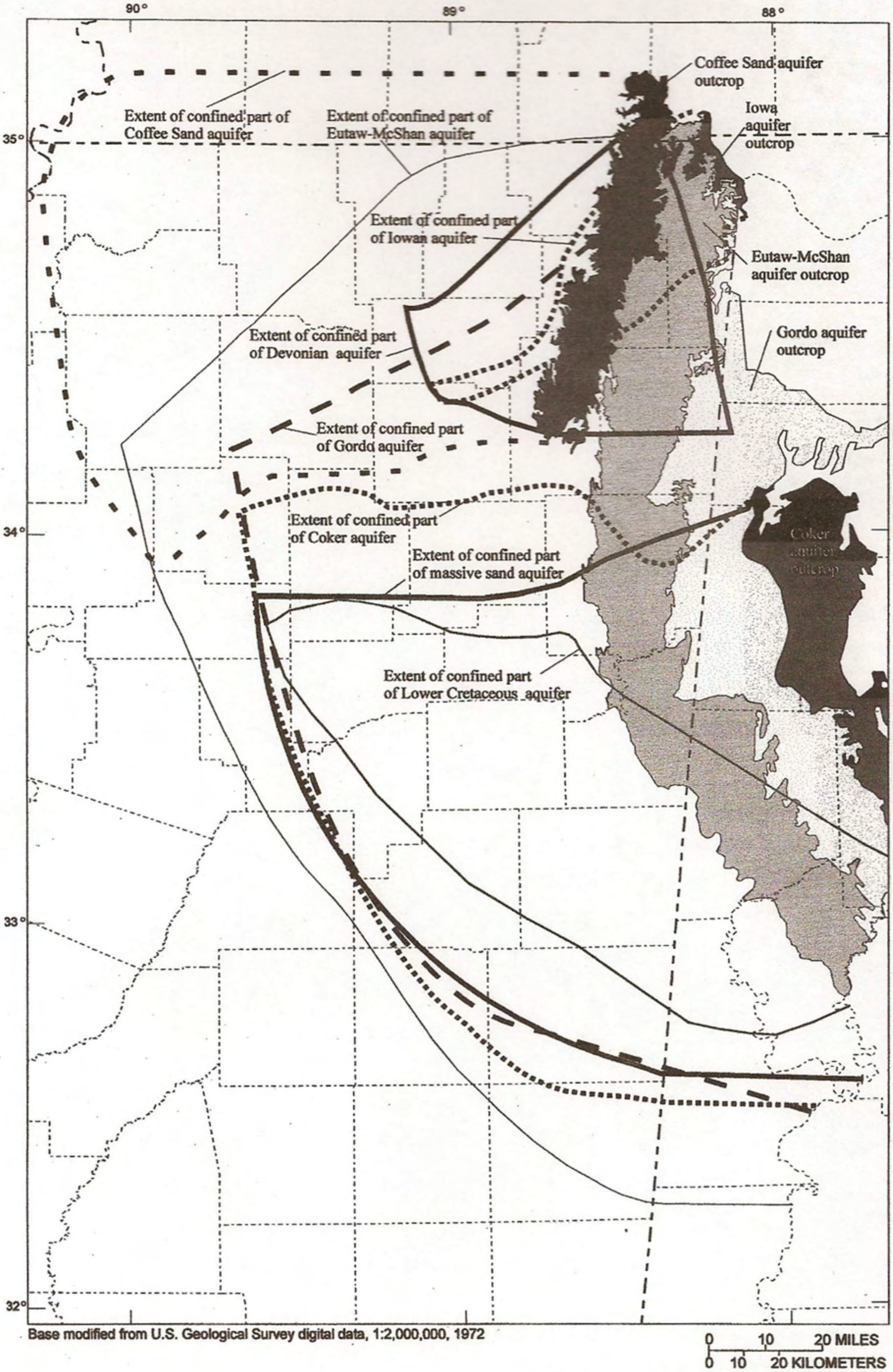

Figure 18. Overlap of areal extent of freshwater in the Cretaceous-Paleozoic aquifers in the study area.

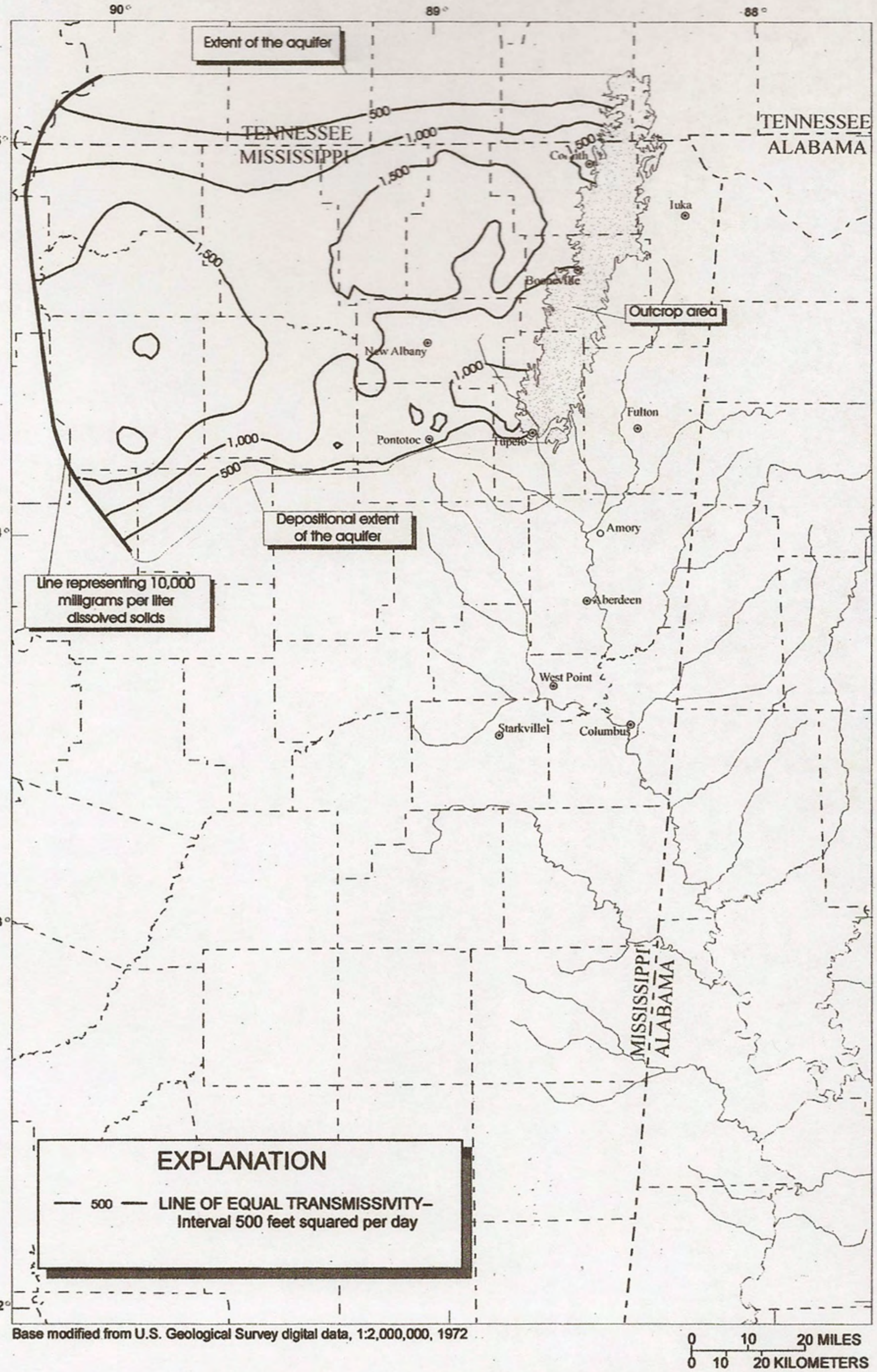

Figure 20. Transmissivity of the Coffee Sand aquifer used in model simulations.

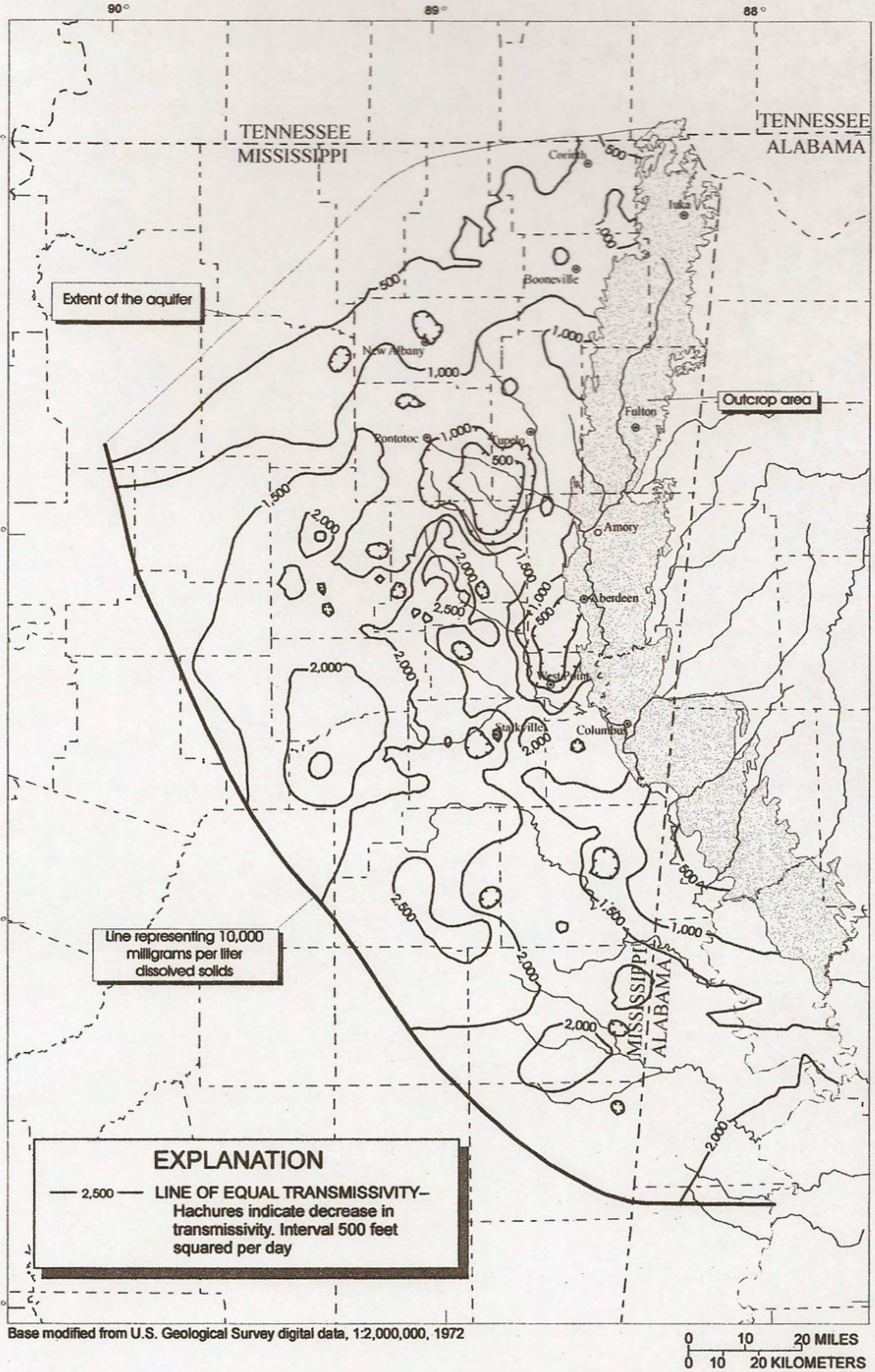

Figure 21. Transmissivity of the Eutaw-McShan aquifer used in model simulations.

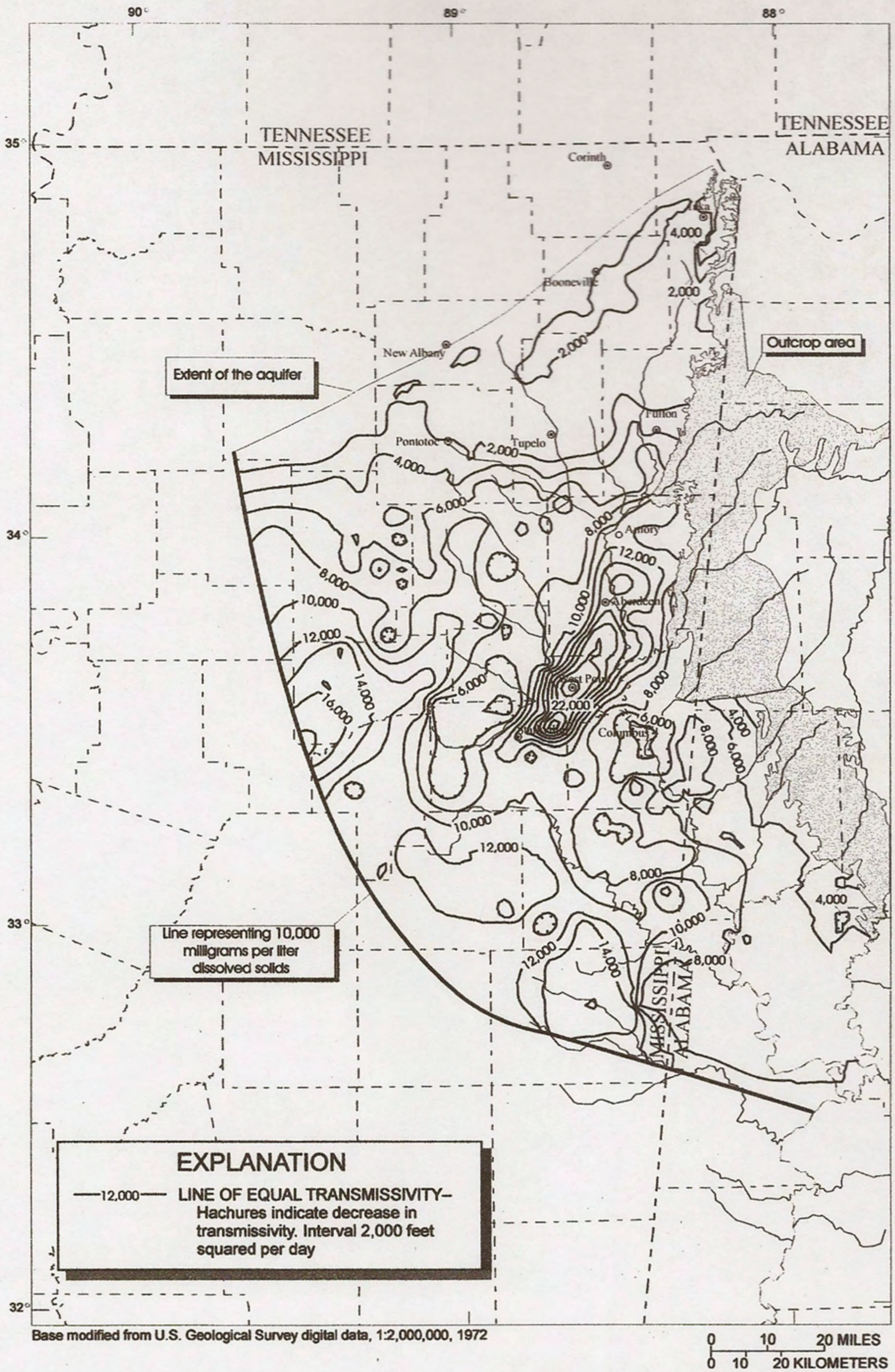

Figure 22. Transmissivity of the Gordo aquifer used in model simulations.

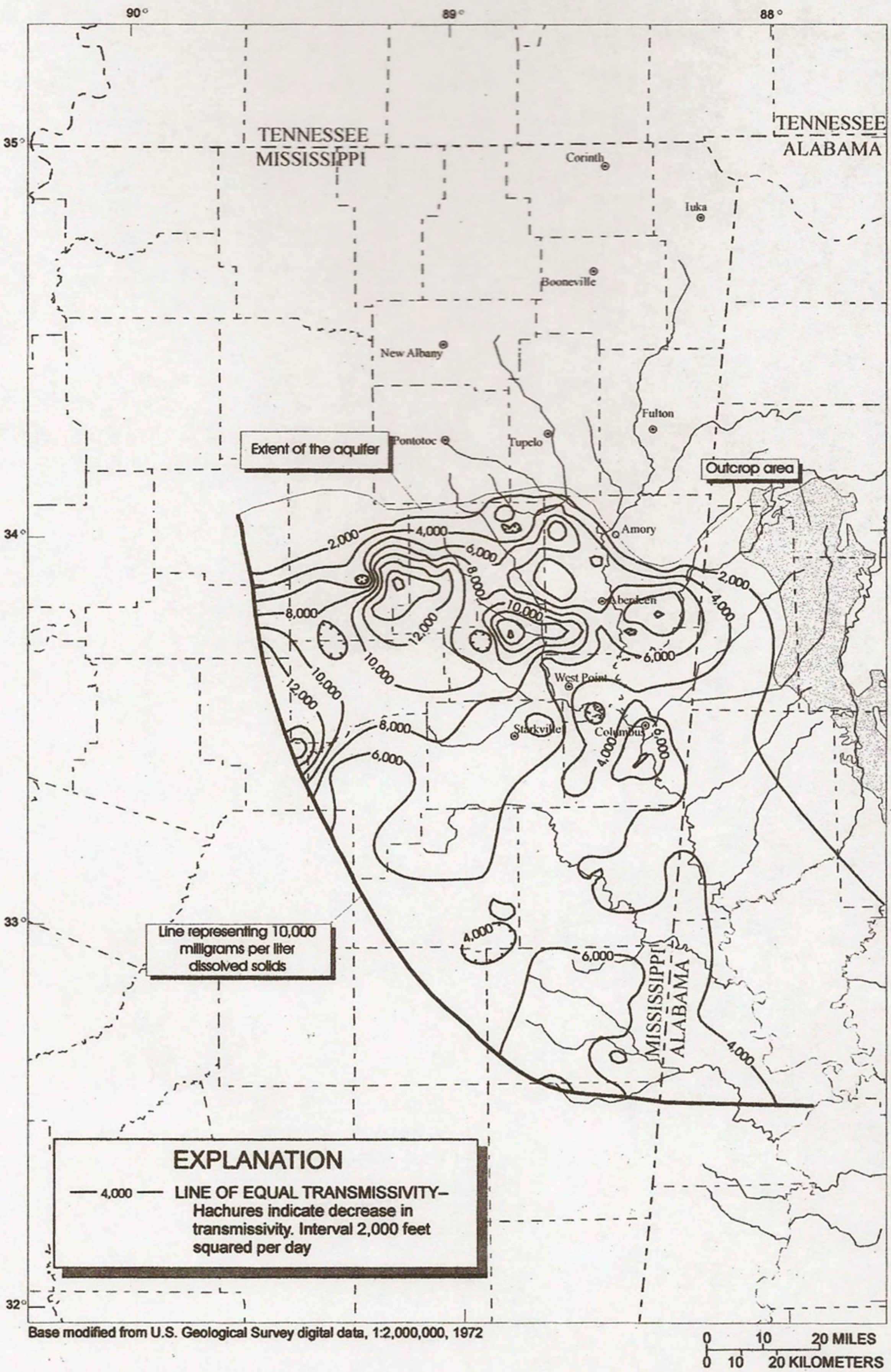

Figure 23. Transmissivity of the Coker aquifer used in model simulations.

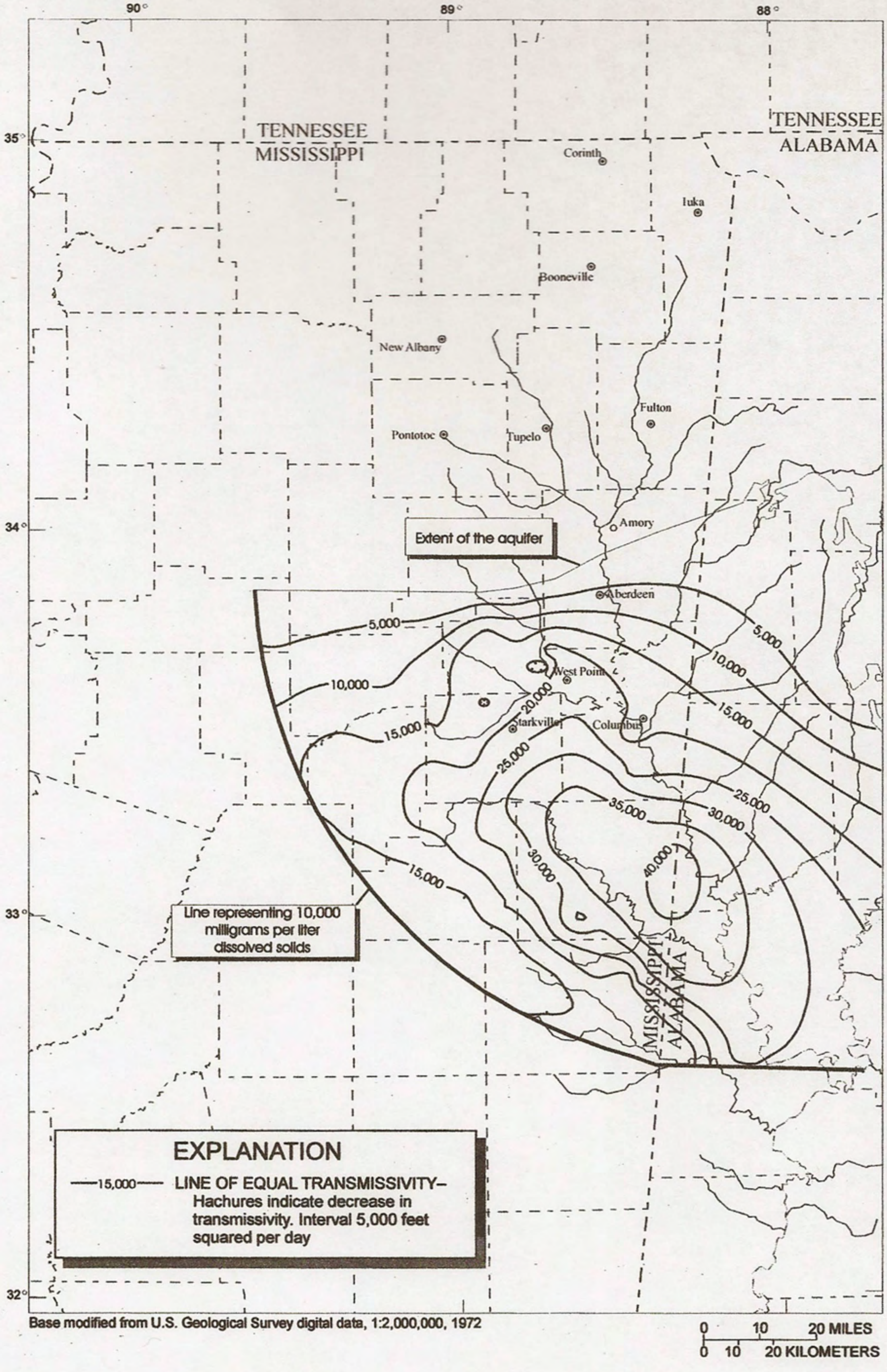

Figure 24. Transmissivity of the massive sand aquifer used in model simulations.

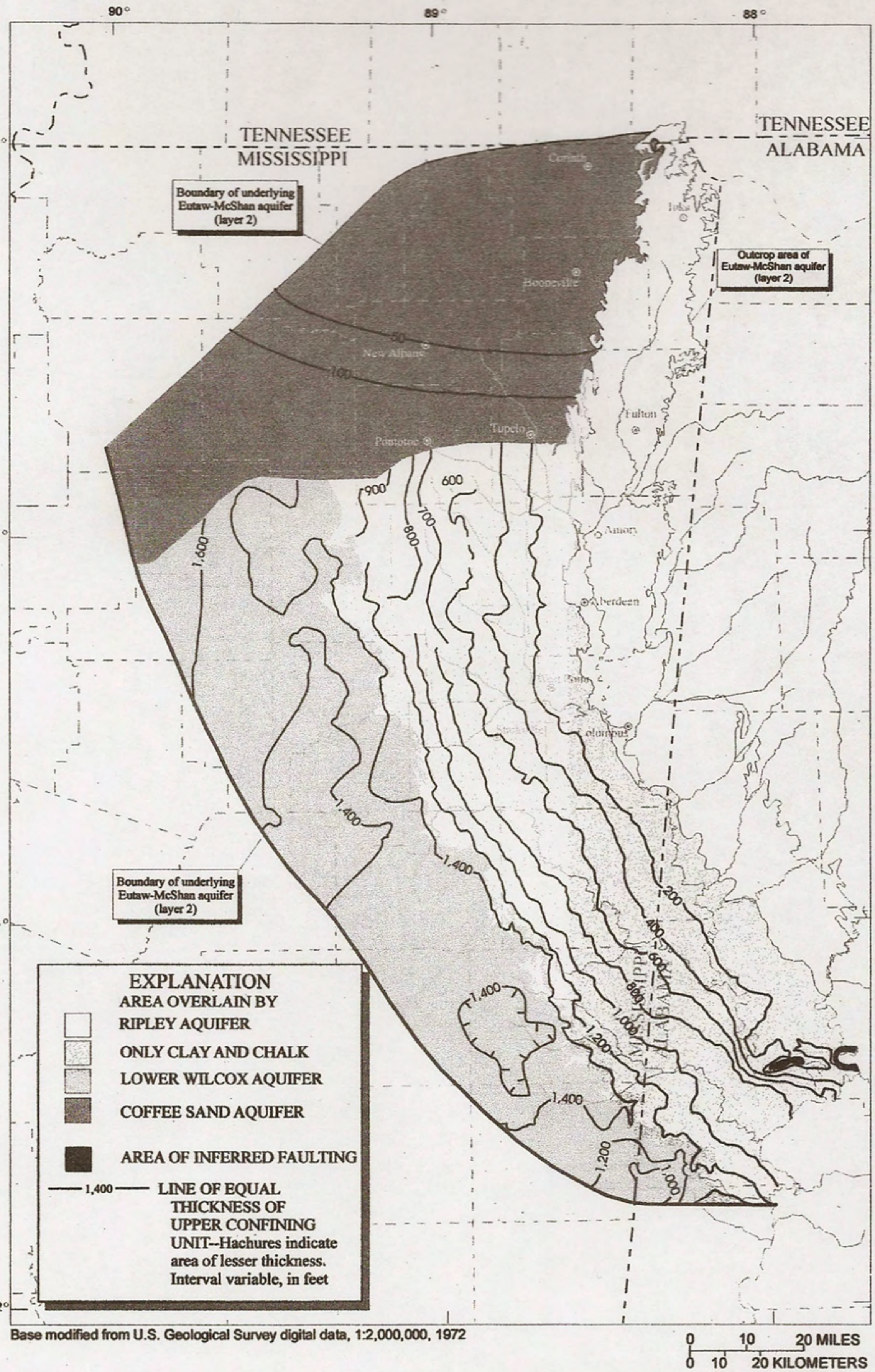

Figure 27. Thickness of the confining unit overlying the Eutaw-McShan aquifer used in model simulations.

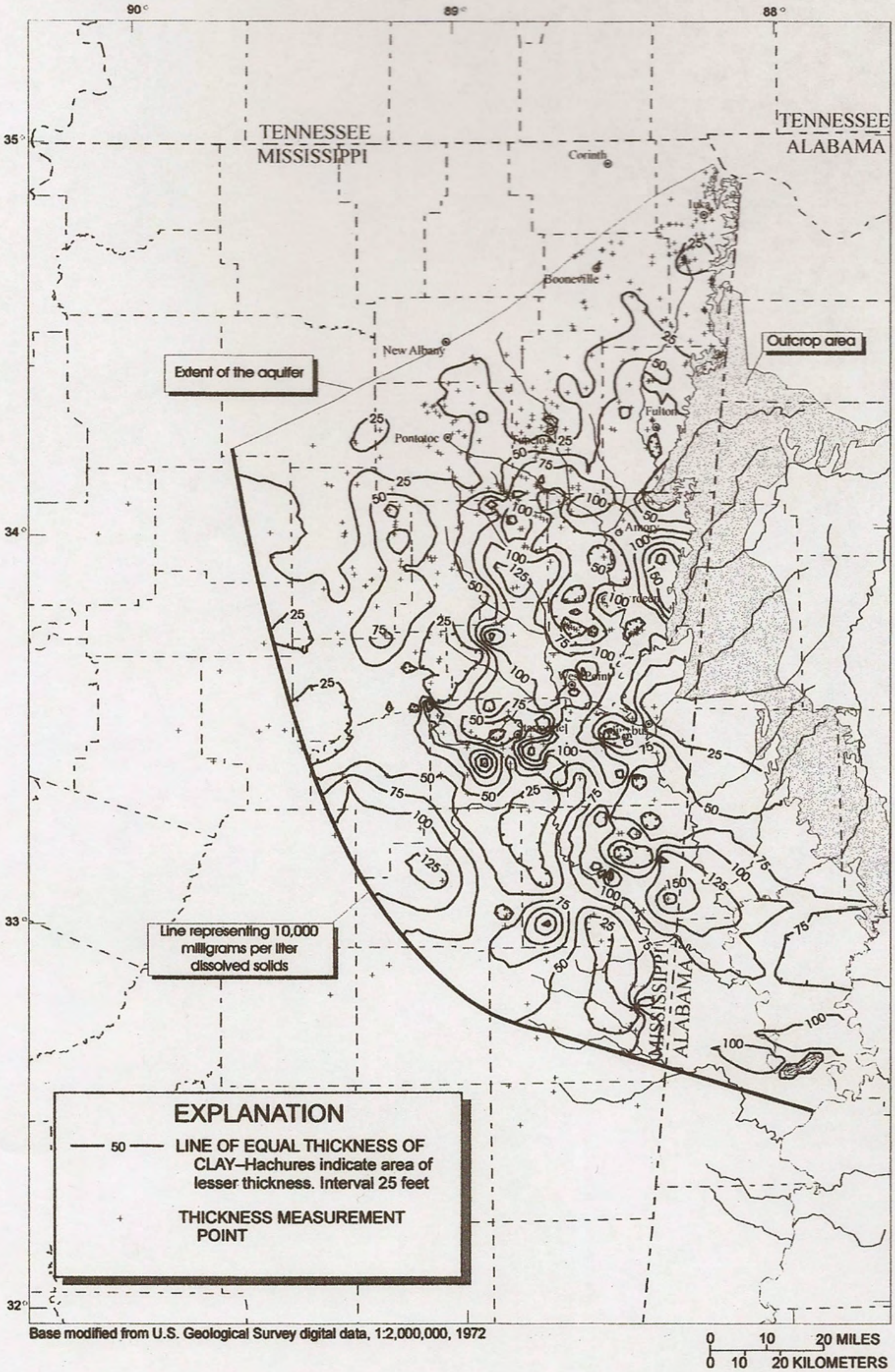

Figure 28. Total overlying clay thickness of the Gordo aquifer and location of measurements.

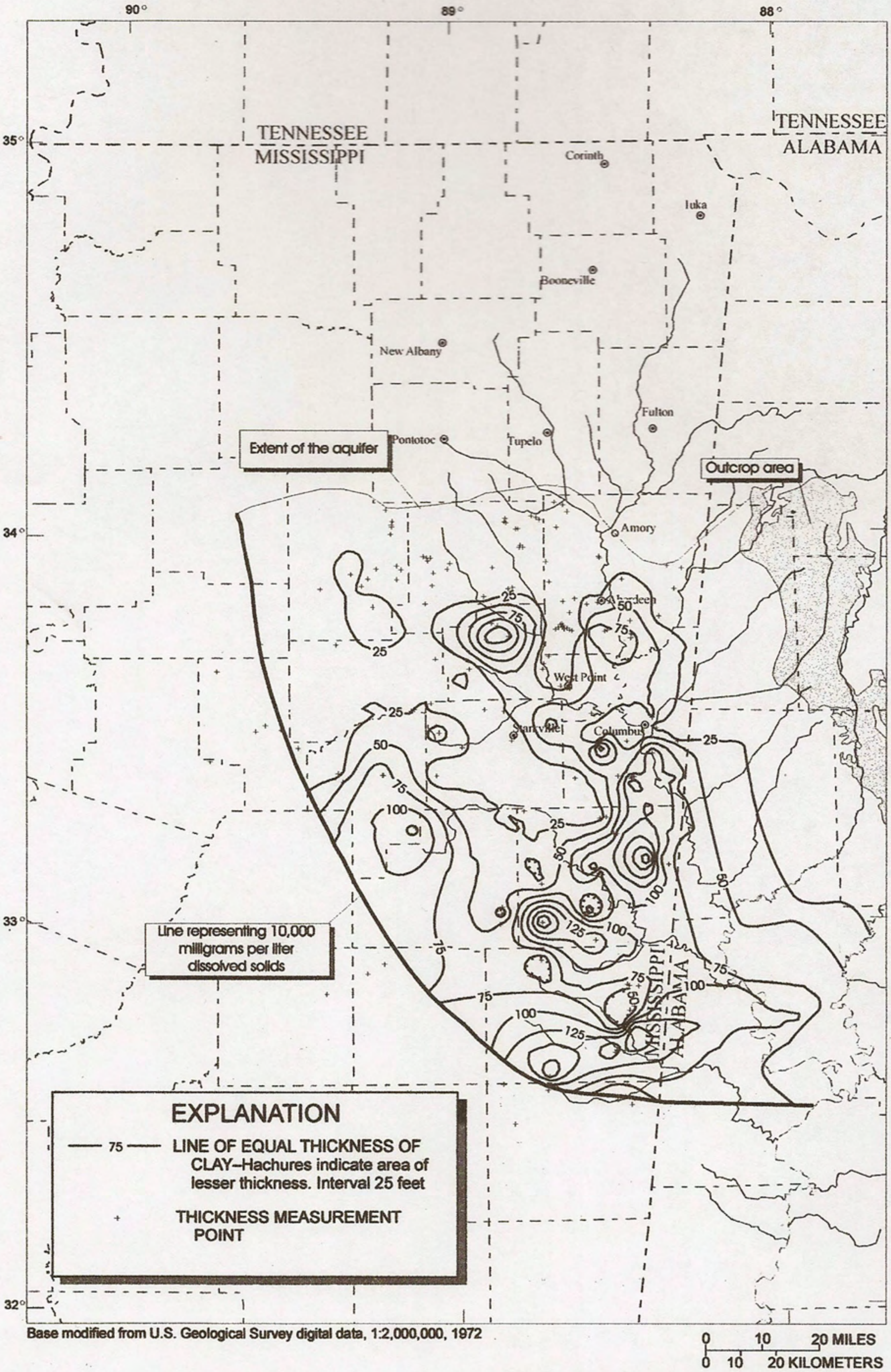

Figure 29. Total overlying clay thickness of the Coker aquifer and location of measurements.

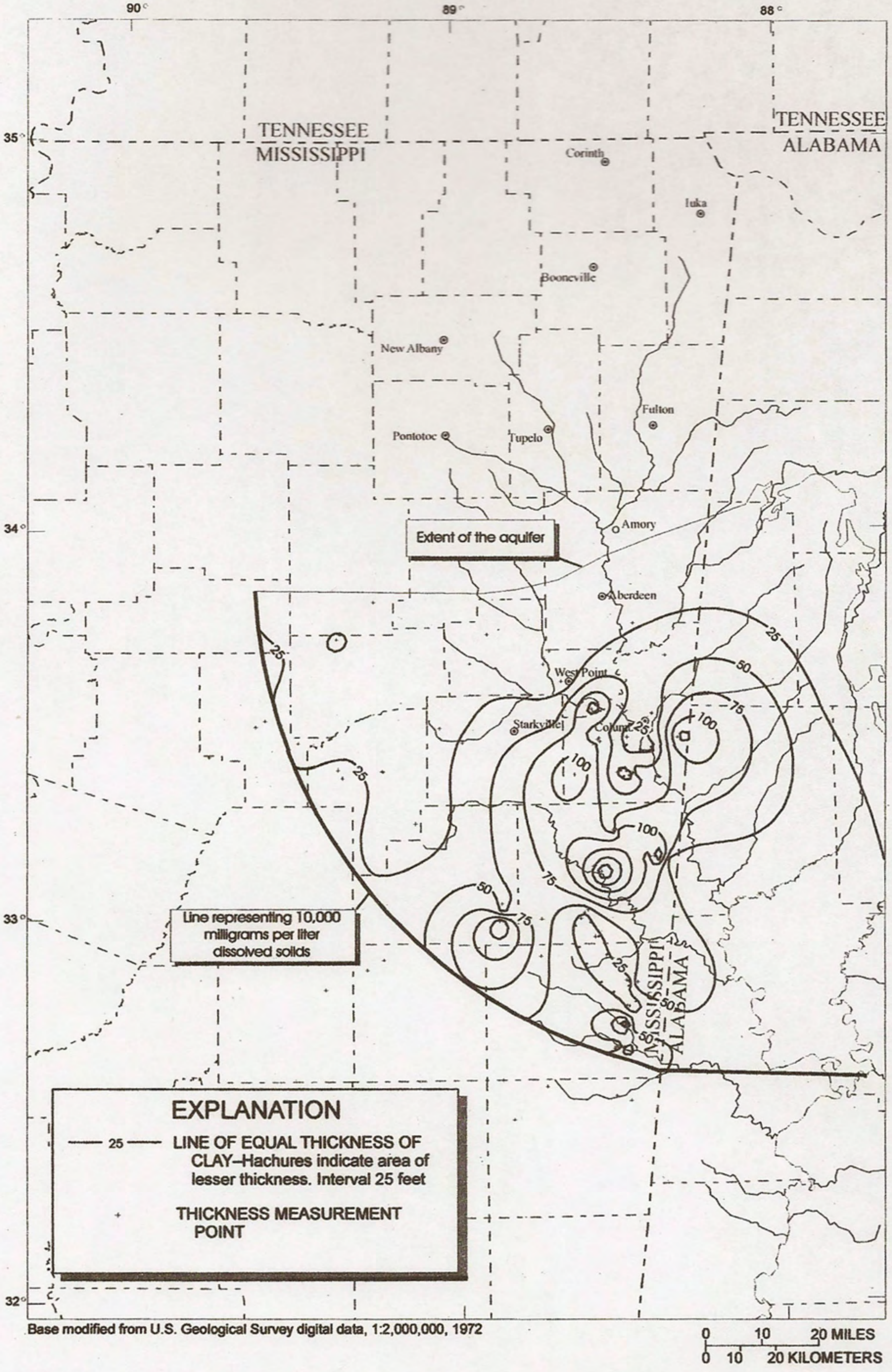

Figure 30. Total overlying clay thickness of the massive sand aquifer and location of measurements.

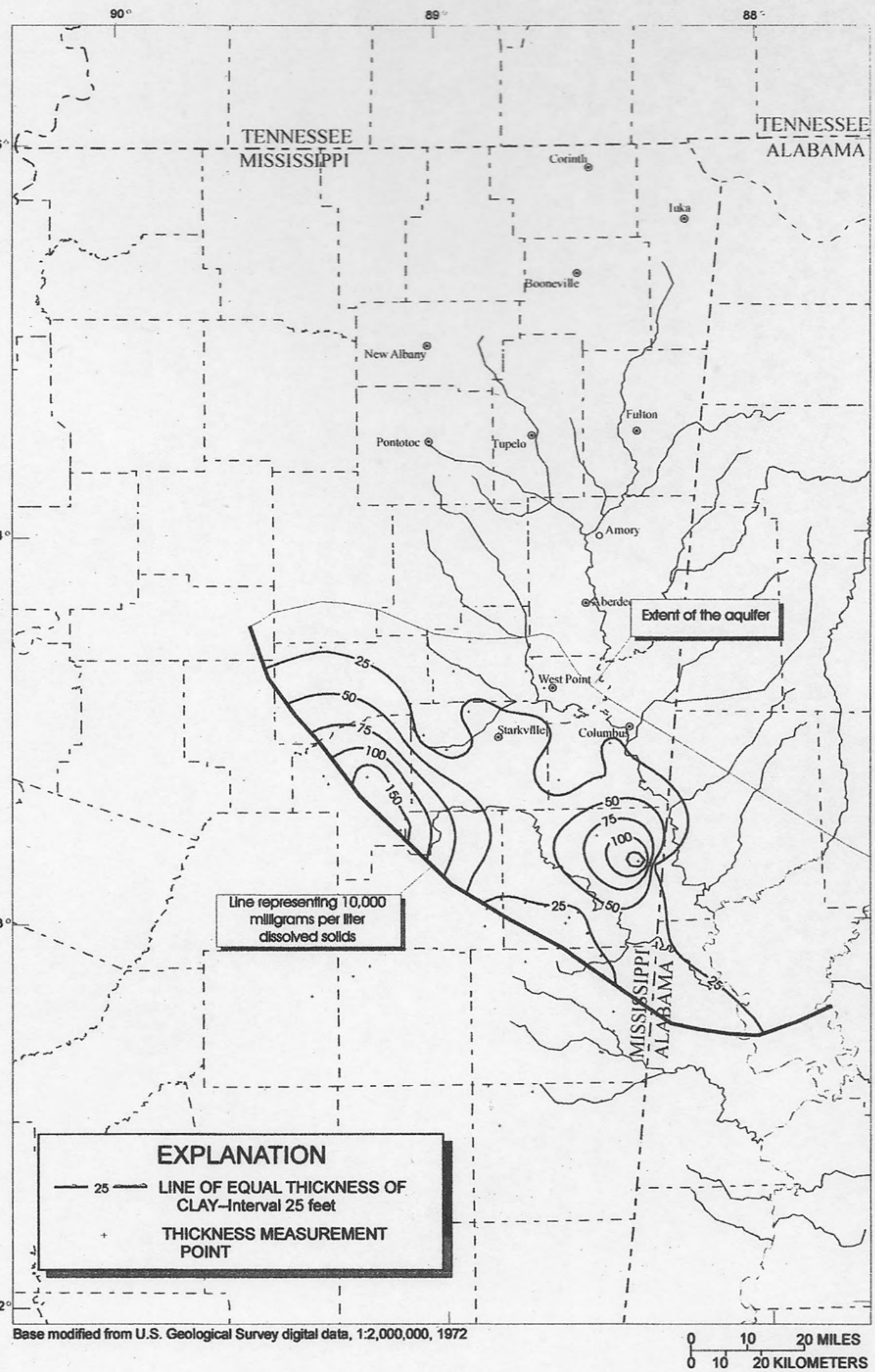

Figure 31. Total overlying clay thickness of the Lower Cretaceous aquifer and location of measurements.

Figure 52. Areas of simulated 1995 recharge and discharge in aquifer outcrops.

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