No. 143, Original

In the Supreme Court of the United States

STATE OF MISSISSIPPI,

Plaintiff,

v.

STATE OF TENNESSEE, CITY OF MEMPHIS, TENNESSEE, AND MEMPHIS LIGHT, GAS & WATER DIVISION,

Defendants.

On Motion for Leave to File Bill of Complaint in Original Action

THE STATE OF MISSISSIPPI'S MOTION FOR LEAVE TO FILE BILL OF COMPLAINT IN ORIGINAL ACTION, COMPLAINT, AND BRIEF IN SUPPORT OF MOTION

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MOTION FOR LEAVE TO FILE BILL OF COMPLAINT IN ORIGINAL ACTION

The State of Mississippi, pursuant to Supreme Court Rule 17, moves this Court for leave to file its Complaint (attached as an exhibit hereto) against the State of Tennessee, the City of Memphis, Tennessee, and Memphis Light, Gas & Water Division, for the reasons stated in the accompanying Brief in Support.

Respectfully submitted,

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June 6, 2014

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STATE OF TENNESSEE,
CITY OF MEMPHIS, TENNESSEE, AND
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Defendants.

COMPLAINT

The State of Mississippi, by its Attorney General, Jim Hood, brings this original action against the State of Tennessee, the City of Memphis, Tennessee, and Memphis Light, Gas & Water Division, as follows:

PARTIES

1.

1. Plaintiff, State of Mississippi ("Mississippi"), is a sovereign State of the United States of America ("United States"). Mississippi brings this suit in its capacity as sovereign, and as *parens patriae* for its citizens.

2. Defendant State of Tennessee ("Tennessee") is a sovereign State of the United States. Process may be served upon Tennessee as provided in Supreme Court Rules 17 and 29.

3. Defendant City of Memphis, Tennessee ("Memphis") is a political subdivision of Tennessee. Process may be served upon Memphis as provided in Supreme Court Rule 29.

4. Defendant Memphis Light, Gas & Water Division ("MLGW") is a division of Memphis. Process may be served upon MLGW as provided in Supreme Court Rule 29.

JURISDICTION

5. The exclusive and original jurisdiction of the Court over controversies between two States is invoked under Article III, Section 2, Clause 2 of the Constitution of the United States and 28 U.S.C. §1251(a)(2012). *See, e.g., Mississippi v. Louisiana*, 506 U.S. 73, 77 (1992).

6. The presence of the non-state Defendants, Memphis and MLGW, is consistent with, and does not operate to alter or offend, the Court's original jurisdiction. *See, e.g., Missouri v. Illinois*, 180 U.S. 208, 224-25 (1901).

7. Further, the Court has jurisdiction to grant the declaratory and injunctive relief sought against Tennessee, Memphis and MLGW, and to require Defendants to provide a full accounting and to pay damages, prejudgment interest, and all other monetary relief as prayed for herein relating to or resulting from Defendants' mechanical extraction of groundwater from the territory of the State of Mississippi from 1985 to date. *See Maryland v. Louisiana*, 451 U.S. 735-36 (1981) (Court's jurisdiction between states proper if "the complaining State has suffered a wrong through the action of the other State, furnishing ground for judicial redress, or is asserting a right . . . susceptible of judicial enforcement according to the accepted principles of the common law or equity systems").

FACTS

8. On December 10, 1817, Mississippi was admitted as the twentieth state to the Union on an equal footing with the original thirteen colonies and, thereupon, became vested with ownership, control, and dominion over the land and waters within its territorial boundaries. U.S. Const. art. IV, § 3, cl. 1; *Phillips Petroleum Co. v. Mississippi,* 484 U.S. 469, 479 (1988); *Oregon ex rel. State Land Bd v. Corvallis Sand & Gravel Co.*, 429 U.S. 363, 370-78 (1977); *Illinois Cent. R.R. Co. v. Illinois*, 146 U.S. 387, 452 (1892); *Pollard v. Hagan*, 44 U.S. 212, 222-23 (1845); *Martin v. Waddell's Lessee*, 41 U.S. 367 (1842). *See also Montana v. United States,* 450 U.S. 544, 551-52 (1981); *Idaho v. Coeur d'Alene Tribe*, 521 U.S. 261, 286-87 (1997).

9. Mississippi is sovereign over all matters not ceded to the federal government under the Constitution of the United States. U.S. Const. art. IV, § 3, cl. 1; U.S. Const. amend. X. It holds all right, title, and interest in, and lawfully possesses "full jurisdiction over the lands within its borders, including the beds of streams and other waters." *Rhode Island v. Massachusetts*, 37 U.S. 657, 733-35, 737-40 (1838).

10. The Mississippi Supreme Court affirmed the State's ownership and plenary authority over its water resources, including subterranean resources, in *Cinque Bambini P'ship v. Mississippi,* 491 So.2d 508, 511-14, 516-17 & 519-20 (1986), affirmed by this Court in *Phillips Petroleum Co. v. Mississippi*, 484 U.S. 469 (1988). The *Cinque Bambini P'ship* Court recognized that, once Mississippi had been admitted to the Union and the public trust had been created and funded, the role of the equal footing doctrine ended and the title to

and plenary authority over the lands and resources conveyed in trust became vested in the State. 491 So.2d at 512-13.

11. Ever since the federal sovereign ceded title to Mississippi, state law has controlled ownership and allocation of the use of Mississippi's natural resources. *Oregon ex rel. State Land Bd.*, 429 U.S. at 378-82; *Cinque Bambini P'ship*, 491 So.2d at 513, 516-19. It is, thus, the State's prerogative to control and preserve state-owned resources. *Id.* at 513, 517; *see also PPL Mont., LLC v. Montana*, 132 S. Ct. 1215, 1235 (2012) (finding that "[u]nder accepted principals of federalism, the States retain residual power to determine the scope of the public trust over waters within their borders").

12. In 1985, the Mississippi legislature codified the public trust doctrine, acknowledging the State's ownership of all groundwater resources within Mississippi when it enacted the "Omnibus Water Rights Act" declaring:

> All water, whether occurring on the surface of the ground or underneath the surface of the ground, is hereby declared to be among the basic resources of this state and therefore belong to the people of this state, and is subject to regulation in accordance with the provisions of this chapter. The control and development and use of water for all beneficial purposes shall be in the state, which, in the exercise of its police powers, shall take such measures to effectively and efficiently manage, protect and utilize the water resources of Mississippi.

Miss. Code Ann. §51-3-1 (2003). Under Mississippi's Act, "[b]oth surface water and groundwater are regarded as property of the State of Mississippi." Richard J. McLaughlin, "Mississippi" in 6 *Water and Water Rights*, 712 (Robert E. Beck, Ed., 1991 ed., repl. vol. 2005).

13. At the time Mississippi was admitted to the Union, its border with Tennessee, which had been admitted to the Union on June 1, 1796, was permanently established at the 35° latitude. The location of this border is not disputed.

14. This action arises from Defendants' authorization and intentional construction and operation of large commercial water well pumping fields by MLGW near the Mississippi-Tennessee border. MLGW's pumping forcibly extracts high quality groundwater from Mississippi into Tennessee for sale by MLGW. The groundwater mechanically taken from within Mississippi by Defendants is a limited natural resource which originated in Mississippi and was naturally stored and resided in Mississippi. Under natural conditions, it would not leave Mississippi's groundwater storage. By their actions, Defendants have invaded Mississippi's sovereign territory, committed trespass against Mississippi, converted Mississippi natural resources, and intentionally violated Mississippi water law.

15. Mississippi's groundwater at issue was naturally collected and stored in a distinct deep sandstone geological formation known as the "Sparta Sand." In north Mississippi, the Sparta Sand begins at a surface outcrop within Mississippi, and descends with an east-to-west/southwest slope while thickening

as it moves toward the Mississippi River. The Sparta Sand is sandwiched between upper and lower clay formations which are impermeable, or of very low permeability.

16. Originally, following the agency of natural laws, rainwater falling within Mississippi's current borders collected on the formation outcrops; was drawn by gravity into and down the natural east-to-west/southwest dip of the formation at a rate of about an inch a day; and was stored as groundwater within the territorial borders of Mississippi. This natural slope of the Sparta Sand formation and direction of water seepage was documented in United States Geological Survey ("USGS") reports.

17. Under these natural conditions, over thousands of years, the Sparta Sand beneath Mississippi was saturated with high quality groundwater stored as a fairly constant volume residing under significant hydrostatic pressure within Mississippi's borders. This high quality groundwater stored in Mississippi would never be available within Tennessee's territorial borders, as it is a finite, confined intrastate natural resource over which Mississippi became sovereign at the time it was admitted as a state in the United States. Under natural conditions, this groundwater volume and pressure would have remained within Mississippi as an available natural resource for Mississippi and its people.

18. MLGW is the nation's largest three service municipal utility providing water, gas, and electricity. For years MLGW has pumped groundwater from what it has called the "Memphis Sand Aquifer." By 1965, the USGS had determined that the Memphis Sand Aquifer

was supplied in large part by the Sparta Sand, which also underlies southwest Tennessee and Memphis, and that MLGW's pumping from its five well fields was having an impact on the pressure and groundwater storage within Mississippi's Sparta Sand.

19. Between 1965 and 1985, under the oversight of Memphis and Tennessee, MLGW significantly expanded its groundwater pumping operations from five to nine well fields and its total pumping from approximately 72 million gallons a day ("MGD"), to over 131 MGD. This included the significant increase of the pumping capacity of its Lichterman field—located within three miles of the Mississippi border—from approximately 4 MGD to over 21 MGD. MLGW also developed two additional well fields within three miles of the Mississippi border, Davis and Palmer, which were collectively pumping approximately 11.5 MGD.

20. As a result of improvements in geological and hydrological science and methods, and the continued study of the Sparta Sand, by 1985 Defendants knew that MLGW was pumping over 20 MGD out of Mississippi's natural groundwater storage in the Sparta Sand within Mississippi. MLGW, Memphis, and Tennessee also knew that this high quality groundwater would never be available to them absent MLGW's large scale pumping operation. These facts have been confirmed by studies of Shelby County, Tennessee, and surrounding areas, conducted by MLGW, the USGS, the University of Memphis Groundwater Institute, and the University of Tennessee's Energy, Environment and Resources Center. Despite this knowledge, MLGW continued to

increase the size and capacity of its system, which currently operates one of the world's largest groundwater pumping and distribution systems, now consisting of more than 170 wells in ten well fields pumping over 140 million gallons of groundwater daily for sale to MLGW's customers.

21. At all relevant times, Tennessee has supervised, authorized and regulated the construction, operation, and maintenance of Memphis-MLGW's public water system, including all features relating to quantity and source of water supply. Tennessee's control over public water systems extends to the location and drilling of water wells and the withdrawal of groundwater from MLGW wells. In this capacity, Tennessee has controlled, regulated, authorized, and supervised Memphis-MLGW's operations and groundwater pumping through acts of its legislature and the actions of state agencies, including the Tennessee Department of Environment and Conservation ("TDEC") and predecessor entities.

22. MLGW's wells mechanically pump groundwater from the Sparta Sand formation, which extends into western Tennessee. As part of its operations since 1972 and extending past 1985, MLGW consistently increased its capacity and pumping from its well fields near the Mississippi-Tennessee border, permanently taking between 20 and 27 MGD of Mississippi's natural groundwater storage out of the Sparta Sand. This groundwater is a valuable natural resource belonging to Mississippi which would have never, under natural conditions, resided or been available within Tennessee's boundaries.

23. Through its water well development and mechanical pumping operations, MLGW has forcibly siphoned into Tennessee hundreds of billions of gallons of high quality groundwater owned by Mississippi and held in trust by Mississippi for its people. This taking by Defendants was without Mississippi's permission, without payment of compensation to Mississippi, and by an intentional intrusion into Mississippi's sovereign territory.

24. The Mississippi groundwater taken by Defendants from within Mississippi's borders would have never under normal, natural circumstances been drawn into Tennessee or available to Tennessee. Defendants' mechanical pumping is intended to and does pull Mississippi's groundwater out of natural storage in a northward direction, altering the water's natural east-to-west path. Defendants' actions use modern pumping technology to siphon Mississippi's groundwater northward at an accelerated velocity substantially in excess of the water's natural seepage rate. But for Defendants' massive pumping operation, the groundwater in dispute would still be stored within Mississippi's borders and available to Mississippi and its people for their use and economic development.

25. Defendants' wrongful taking is evidenced by a substantial drop in pressure and corresponding drawdown of stored groundwater in the Sparta Sand in Mississippi in a pattern covering substantially all of DeSoto County in northwest Mississippi across the state border from Memphis. This drawdown is illustrated by a potentiometric surface map showing a hydrologic feature called a "cone of depression," which was discovered by the USGS. This cone of depression

extends miles into north Mississippi and was formed by, and continues to expand, as a direct result of Defendants' water well development and pumping operations.

26. Through these actions, Defendants have wrongfully taken more than 252 billion gallons (approximately 15-20% of Memphis' total water supply) from within Mississippi since 1985. These groundwater quantities have been permanently taken from Mississippi and its people, even if MLGW's pumping immediately ceased altogether.

27. MLGW's water needs could have been, and can be, met without MLGW's wrongful taking from Mississippi's natural groundwater storage through its massive pumping operations. Available options include relocation of MLGW's water wells to the north and east of MLGW's distribution system, and/or use of Mississippi River water as an alternate or supplemental source of water supply. Rather than utilizing these available alternative water sources within Tennessee's sovereign territory for commercial sales to MLGW's customers, Defendants chose to utilize drilling and advanced pumping technology in commercial well fields located essentially on the Mississippi-Tennessee border to extract high quality groundwater from Mississippi's natural groundwater storage.

28. Since 1985, dozens of independent federal and state groundwater scientists, including experts from the USGS and the University of Memphis Ground Water Institute ("GWI") have recorded Defendants' huge forced extractions of groundwater from Mississippi into Tennessee, and the massive cone of

depression it has created in Mississippi. These scientific publications confirm that MLGW has not only mechanically extracted billions of gallons of groundwater belonging to Mississippi, but has, for all practical purposes, permanently altered the natural path and rate of seepage within the Sparta Sand in north Mississippi. Many of USGS's extensive, peer-reviewed publications, and GWI's research and studies were prepared for, and with funding and assistance from, the Defendants.

29. In the mid-1990's, the Mississippi Department of Environmental Quality proposed that Mississippi and Tennessee work together to jointly evaluate the impact of MLGW's massive pumping on Mississippi's groundwater storage, advising MLGW that Memphis was the largest pumper of groundwater from the Sparta Sand formation in northwest Mississippi. Defendants refused to participate in a cooperative effort.

30. In the late 1990's, Memphis news media published articles confirming the undisputed findings and conclusions of scientists and regulatory authorities, reporting that the cone of depression extending into Mississippi was created by heavy pumping of MLGW's water wells, which were, by artificial means, pulling Mississippi groundwater in a northward direction, into Tennessee, providing over 20% of Memphis' water supply.

31. In June 2000, Tennessee, through TDEC, commissioned a legal and water management policy study of MLGW's pumpage and the resulting taking of Mississippi groundwater. The TDEC report was directed to Defendants' senior officials and identified

the cone of depression extending into Mississippi as one of the most serious water supply problems facing Tennessee. Still, no action was taken to stop the mechanical extraction and forcible taking of groundwater from within Mississippi.

32. Since the 2000 report, MLGW has decreased its rate of pumping from most of its well fields further north in Tennessee, but it has not reduced the total volume being pumped from the well fields it located on the Mississippi-Tennessee border.

33. In March 2002, the Tennessee Comptroller's Office prepared a Special Report advising Tennessee's legislature that Memphis' extractions of Mississippi groundwater represented a serious water scarcity issue, the final resolution of which would probably include reducing MLGW's reliance on the Sparta Sand. Nonetheless, Tennessee took no action to cease or mitigate the past and continuing pumping out of Mississippi's Sparta Sand storage, or to offer compensation to Mississippi for its forcible taking of a Mississippi natural resource.

34. Recently, Tennessee and Mississippi officials called for a comprehensive study of Defendants' siphoning of groundwater from Mississippi into Tennessee, the cause of Mississippi's declining groundwater storage and pressures in the Sparta Sand. Regional study initiatives were undertaken; however, they have had little or no meaningful effect or impact upon Memphis-MLGW's continued excessive pumping authorized by Tennessee.

35. Prior attempts to litigate these issues have been unsuccessful. *Hood, ex rel. Mississippi v. City of*

Memphis, 533 F. Supp.2d 646 (N.D. Miss. 2008), *aff'd*, 570 F.3d 625 (5th Cir. 2009), *cert. denied, Mississippi v. City of Memphis*, 559 U.S. 904 (2010); *Mississippi v. City of Memphis*, 559 U.S. 901 (2010) (motion for leave to file bill of complaint denied without prejudice).

36. In May 2010, Mississippi's Attorney General directed correspondence to Tennessee's Attorney General proposing that the States work cooperatively to negotiate a settlement of Mississippi's claims, but Tennessee declined.

37. Neither State's legal regime provides any effective mechanism for resolving this dispute, absent voluntary measures by Tennessee, which has shown no inclination to enjoin this violation of Mississippi's sovereignty.

38. This case does not fall within the Court's equitable apportionment jurisprudence. For the reasons stated herein, the groundwater in dispute (a) naturally accumulated within Mississippi's sovereign territory before the formation of the States; and (b) would never through "the agency of natural laws" have moved into, or been available in Tennessee. It is not a shared natural resource. *Kansas v. Colorado*, 206 U.S. 46, 97-98 (1907). Rather, this is a dispute between sovereign States in which Defendants have violated one of Mississippi's core sovereign prerogatives under the Constitution of the United States: its right, title, and interest in the waters naturally residing within its boundaries. *See Tarrant Reg'l Water Dist. v. Herrmann,* 133 S. Ct. 2120, 2132-33, 2134 (2013).

39. By their actions, Defendants have, through mechanical and technological means, reached into and

invaded Mississippi's sovereign territory, and trespassed upon and wrongfully converted natural resources under the sovereign ownership and control of Mississippi.

REQUEST FOR DECLARATION OF OWNERSHIP AND FOR DAMAGES OR RESTITUTION

40. In prior litigation relating to this dispute, the United States District Court for the Northern District of Mississippi and the United States Court of Appeals for the Fifth Circuit held that, a determination of whether the Defendants' taking of groundwater from within the sovereign territory of Mississippi was wrongful, could not be made without first determining the relative rights of Mississippi and Tennessee to groundwater stored in the Sparta Sand formation. *See Hood ex rel Mississippi v. City of Memphis*, 570 F.3d 625, 629-30 (5th Cir. 2009). Those courts also held that Tennessee would be a necessary and indispensable party to any judicial proceeding by Mississippi seeking such a determination, and that "original and exclusive jurisdiction over a suit between Mississippi and Tennessee would reside in the United States Supreme Court." 570 F. 3d at 631. Mississippi, therefore, now requests that the Court enter a declaratory judgment establishing Mississippi's sovereign right, title and exclusive interest in the groundwater stored naturally in the Sparta Sand formation underlying Mississippi which would not, absent Defendant's pumping, be available to Defendants.

41. The geologic formation in which the groundwater is stored straddles two states, but the groundwater at issue is an intrastate natural resource,

not a naturally shared interstate resource. Mississippi's groundwater at issue is not part of an underground river, stream or lake, and it would never naturally move or flow north into Tennessee. Rather, it has been stored naturally in Mississippi and has been, and is being, drawn into Tennessee by scores of powerful, high volume, commercial pumps. Thus, this action presents a different factual and legal situation from the shared interstate river or stream disputes resolved under the Court's original and exclusive jurisdiction through "equitable apportionment," where opposing states have co-equal ownership and rights to use water traversing and freely flowing across two or more states under natural conditions.

42. As a sovereign State, Mississippi has declared that "[a]ll water, whether occurring on the surface of the ground or underneath the surface of the ground, is . . . among the basic resources of this state [and belongs] to the people of this state," and has further declared, as a sovereign State, that "[t]he control and development and use of water for all beneficial purposes shall be in the state, which, in the exercise of its police powers, shall take such measures to effectively and efficiently manage, protect, and utilize the water resources of Mississippi." Miss. Code Ann. § 51-3-1 (2003).

43. "Groundwater" is defined by Mississippi to mean "water occurring beneath the surface of the ground," Miss. Code Ann. § 51-3-3(n) (2003), and Mississippi regulates the withdrawal and use of groundwater contained within its borders. *See, e.g.*, Miss. Code Ann. § 51-3-5 (2003) (stating that "[n]o person who is not specifically exempted by this chapter

shall use water without having first obtained a permit as provided herein . . . .").

44. All groundwater located under Mississippi upon its admission to the Union in 1817 became the sovereign property of Mississippi at that time. Such groundwater and all other groundwater located and stored naturally under Mississippi is owned and held by Mississippi as a sovereign State and is subject to Mississippi's exclusive dominion and control.

45. Tennessee has similarly declared, as a sovereign State, "[t]hat the waters of the state are the property of the state and are held in public trust for the benefit of its citizens." Tenn. Code Ann. § 68-221-702 (2013). Tennessee law also specifically defines "ground water" to mean "water beneath the surface of the ground, whether or not flowing through known or definite channels." *Id.* § 68-221-703(13) (2013).

46. Based on the sovereign rights of Mississippi and Tennessee as States, and based on their respective, independent declarations and pronouncements of their sovereign rights to groundwater ownership, Mississippi respectfully requests that this Court declare that, as between Mississippi and Tennessee, (a) since its admission into the United States, Mississippi has owned and continues to own all right, title and interest in groundwater stored naturally in the Sparta Sand formation underneath Mississippi's borders which does not cross into Tennessee under natural pre-development conditions; and (b) since its admission as a State into the United States, Tennessee has owned and continues to own all right, title and interest in groundwater located naturally in the Sparta Sand

formation underneath Tennessee's borders which does not cross into Mississippi under natural conditions.

47. Mississippi further requests that, with regard to the Mississippi groundwater confined in the Sparta Sand formation claimed by Mississippi, the Court expressly declare that Mississippi's rights and remedies *vis-à-vis* the Defendants are to be determined based on its sovereign rights and the scientific evidence regarding the availability of groundwater within each state under natural, pre-pumping conditions.

48. Equitable apportionment principles have only been applied by this Court to those disputes in which two or more states possessed a claim to water available within each state under natural conditions such as rivers and other surface waters, and the watersheds supplying them. *See, e.g., Kansas v. Colorado*, 206 U.S. 46 (1907); *New Jersey v. New York*, 283 U.S. 336 (1931); *Nebraska v. Wyoming*, 325 U.S. 589 (1945); *South Carolina v. North Carolina*, 558 U.S. 256 (2010).

49. The fundamental premise of this Court's equitable apportionment jurisprudence—that each of the opposing States has an equality of right to use the waters at issue—does not apply to this dispute. For example, *Kansas v. Colorado*, 206 U.S. 46 (1907), concerned the Arkansas River, which flows through both States, and the controversy concerned the flow of that stream. *Id.* at 95. The Supreme Court recognized that it had been "called upon to settle that dispute in such a way as will recognize the *equal rights* of both [States] and at the same time establish justice between them." *Id.* at 97-98 (emphasis added). Similarly, the Court recognized in *Connecticut v. Massachusetts*, 282 U.S. 660 (1931), a case concerning the Connecticut

River, that "the principles of right and equity shall be applied having regard to the 'equal level or plane on which all the States stand, in point of power and right, under our constitutional system' and that, upon a consideration of the permanent laws of the contending States and all other relevant facts, this Court will determine what is an equitable apportionment of the use of such waters." *Id.* at 670-71.

50. This case must be decided under Article IV, Section 3, Clause 1 of the United States Constitution under which Mississippi was created and brought into the Union, and the Tenth Amendment to the Constitution, based on the unique location and hydrologic characteristics of the groundwater at issue. The Sparta Sand formation underlies both Mississippi and Tennessee, but this Court's analysis must distinguish between the location of the geological formation on the one hand, and, on the other hand, the source, location and hydrologic characteristics of the groundwater stored in the formation under natural conditions. The groundwater at issue originated in Mississippi, was stored in the Sparta Sand formation in north Mississippi, and would have, under natural conditions, never been available in Tennessee. It is *neither* interstate water *nor* a naturally shared resource. This is evidenced and confirmed by the fact that Defendants must mechanically pump the water from underneath Mississippi's borders in order to produce and use it. In the absence of such pumping, the water would have remained in Mississippi. Defendants simply have *no right* to the groundwater at issue, and no right to forcibly take it from Mississippi. There is, therefore, no foundational basis for equitable apportionment, which is premised upon balancing the

interests of two or more states that have *equal rights* to waters flowing naturally between and within their respective boundaries. Indeed, in view of Mississippi's rights as a sovereign State and the powers preserved to it by the Tenth Amendment of the United States Constitution, Mississippi should not be—and cannot properly be—forced to "share" its natural resources with the Defendants under a claim by Tennessee to a right of equitable apportionment.

51. This case presents a state border and sovereignty issue, and the respective States' rights to the groundwater at issue should be determined based solely on Mississippi's and Tennessee's sovereign rights as States over their own territory; and should limit Tennessee's sovereign rights to groundwater resources stored naturally within, or naturally flowing through, its boundaries, and hold that Defendants have no right to invade Mississippi's sovereign territory through artificial, mechanical, or technological means to obtain groundwater or any other natural resource. Declaring a right to the groundwater at issue on any other basis would deprive Mississippi of its sovereign rights under the Constitution of the United States as confirmed by the Tenth Amendment.

52. For the reasons pleaded herein, Mississippi requests this Court to declare that Defendants have never been, and are not, entitled to take any groundwater from within Mississippi's borders by artificial mechanical means, and that Defendants' takings, as described hereinabove, constitute a violation of Mississippi's retained sovereign rights under the United States Constitution, and a wrongful and actionable trespass upon, and conversion, taking

and misappropriation of, property belonging to Mississippi and its people.

53. Defendants' actions have resulted in a permanent taking of groundwater owned and held by Mississippi in trust for its people and which would never have resided naturally in, been owned by, or been available to Tennessee without Mississippi's permission and compensation for this natural resource. Mississippi has never consented to Defendants' taking of the groundwater at issue from Mississippi.

54. Mississippi has suffered actual, present, and substantial injury and damages as the proximate result of Defendants' wrongful conduct, including but not limited to the following:

(a) MLGW's pumpage presently siphons approximately 21 million gallons of groundwater each day, or 7.6 billion gallons annually, from storage within Mississippi's state boundaries into Tennessee to replace the groundwater taken out of storage within Tennessee beneath Memphis. Between 1985 and the present, an estimated volume of over 252 billion gallons of groundwater has been wrongfully taken from Mississippi into Tennessee. These volumes of high quality groundwater have been permanently lost to Mississippi.

(b) MLGW's pumpage has caused the groundwater storage and pressures in the Sparta Sand formation in north Mississippi to be drawn down dramatically, as the groundwater is being drawn down more rapidly than the Sparta Sand in north Mississippi can be recharged or replenished. As a result, water wells located in the Sparta Sand formation in Mississippi must now be drilled and pumps lowered to substantially greater depths, thereby imposing on the people of Mississippi well installation and electric operations costs for water wells located in north Mississippi that are significantly greater than the costs they would have borne in the absence of Defendants' wrongful conduct.

(c) Defendants' operations have materially altered Mississippi's groundwater budget or inventory, completely, artificially and materially changing the natural steady state equilibrium of groundwater in the Sparta Sand formation in north Mississippi, siphoning water at an accelerated, unnatural velocity and northward direction out of Mississippi directly into Defendants' wells.

55. Mississippi is entitled to recover damages from the Defendants, jointly and severally, in an amount equal to the value of the Mississippi groundwater Defendants have wrongfully taken, plus prejudgment interest thereon. It is estimated that such damages are not less than $615 million.

56. Mississippi alternatively asserts a claim for restitution and unjust enrichment. The law does not permit a person to profit by his own wrong. Defendants have obtained benefits by acts of trespass or conversion or comparable tortious interference with Mississippi's protected interests in tangible property and have been

unjustly enriched by their receipt and retention of such benefits. Defendants are, therefore, liable in restitution for the value of all groundwater wrongfully taken from Mississippi. Furthermore, Defendants have drawn Mississippi groundwater into Tennessee despite a known risk that their conduct violates Mississippi's rights. As conscious wrongdoers, Defendants should be stripped of all gains they have realized from their nonconsensual taking of and interference with Mississippi's property, and should be required to render an accounting and disgorge and pay over to Mississippi all profits, proceeds, consequential gains, saved expenditures, and other benefits realized by Defendants, or any of them.

57. The wrongful taking of groundwater from Mississippi into Tennessee will never stop until Defendants are required to take affirmative actions to alter their pumping operations. Defendants should be required to prospectively take all actions necessary to eliminate the cone of depression *vis-á-vis* Mississippi, including, *inter alia*, the funding, construction and modification or restructuring of Memphis-MLGW's groundwater pumping systems and/or the development of systems using water from the Mississippi River as an alternate or supplemental source of water supply.

PRAYER FOR RELIEF

WHEREFORE, the State of Mississippi prays:

A. That the Court enter a decree declaring Mississippi's ownership of and exclusive dominion and control over groundwater located naturally in the Sparta Sand formation underlying the sovereign borders of Mississippi;

B. That the Court enter a decree finding that the actions of Defendants described hereinabove constitute a violation of Mississippi's retained sovereign rights under the United States Constitution and a wrongful and actionable trespass upon, and conversion, taking, and misappropriation of, property belonging to Mississippi and its people;

C. That the Court enter a decree against Defendants, jointly and severally, (1) awarding Mississippi damages for retroactive periods from 1985 through the present in an amount equal to the value of the groundwater taken wrongfully by Defendants from Mississippi, plus prejudgment interest thereon; and/or (2) requiring Defendants to render an accounting and disgorge and pay over to Mississippi all profits, proceeds, consequential gains, saved expenditures, and other benefits realized by Defendants, or any of them, due to their nonconsensual taking of and interference with Mississippi's property, plus prejudgment interest thereon;

D. That the Court require Defendants to prospectively take all actions necessary to eliminate the subject cone of depression *vis-á-vis* Mississippi, including, *inter alia*, the funding, construction and modification or restructuring of Memphis-MLGW's groundwater pumping systems and/or the development of systems using Mississippi River water as an alternate or supplemental source of water supply; and

E. For such other or further relief as the Court may deem proper.

Respectfully submitted,

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State of Mississippi

June 6, 2014

No. ______, Original

In the
Supreme Court of the United States

STATE OF MISSISSIPPI,
Plaintiff,
v.

STATE OF TENNESSEE,
CITY OF MEMPHIS, TENNESSEE, AND
MEMPHIS LIGHT, GAS & WATER DIVISION,
Defendants.

On Motion for Leave to File Bill of Complaint in Original Action

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STATE OF MISSISSIPPI'S BRIEF IN SUPPORT OF MOTION FOR LEAVE TO FILE BILL OF COMPLAINT IN ORIGINAL ACTION

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QUESTIONS PRESENTED FOR REVIEW IN ORIGINAL ACTION

This is a dispute between two States over their retained sovereign territorial rights. Since 1985, the Tennessee Parties have used a massive commercial pumping operation to reach across the border into Mississippi's sovereign territory and forcibly take approximately 252 billion gallons of high quality groundwater. The groundwater taken is not a naturally shared interstate resource; rather, it is intrastate groundwater naturally collected and stored within Mississippi's borders in a sandstone formation over thousands of years. The geology of the sandstone naturally retained and stored water seeping into and through the formation at one to two inches a day in an east-to-west/southwest direction across north Mississippi, and this stored groundwater has never been naturally available within Tennessee. Will the Court grant Mississippi leave to file an original action to seek relief from the Tennessee Parties' intentional violation of Mississippi's retained sovereignty over its lands and waters under the United States Constitution?

Under northwest Mississippi, the Sparta Sand is a deep sandstone formation confined above and below by geologic formations of very low permeability, allowing water to be trapped in the sandstone. In Mississippi, this sandstone formation surfaces at outcrops in west Mississippi and dips predominantly east-to-west/southwest toward the Mississippi River. Following laws of physics, under natural conditions a substantial, but limited amount of high quality groundwater was stored under pressure in the sandstone within Mississippi's borders over thousands of years. Absent the Tennessee Parties' intentional cross-border pumping, the Mississippi groundwater would never be available within Tennessee's borders. Will the Court confirm Mississippi's sole sovereign authority over and control of groundwater naturally stored within its borders?

Is Mississippi entitled to damages, injunctive and other equitable relief for the Mississippi intrastate groundwater intentionally and forcibly taken by the Tennessee Parties?

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JURISDICTION

Mississippi's dispute with Tennessee and the other Tennessee Parties falls within the Court's exclusive and original jurisdiction over controversies between States under Article III, Section 2, Clause 2 of the United States Constitution and 28 U.S.C. § 1251(a): a conflict between two states over the extent, exercise, and right to protection of their retained sovereign rights under the Constitution.[1]

For the Court to exercise its original jurisdiction, the dispute between States must be "of that character and dignity which makes the controversy a justiciable one under our original jurisdiction." *Nebraska v. Wyoming*, 507 U.S. 584, 593 (1993) (quoting *Nebraska v. Wyoming*, 325 U.S. 589, 610 (1945)). "The model case for invocation of this Court's original jurisdiction is a dispute between States of such seriousness that it would amount to *casus belli* if the States were fully sovereign." *Mississippi v. Louisiana*, 506 U.S. 73, 77 (1992) (quoting *Texas v. New Mexico*, 462 U.S. 554, 571 n. 18 (1983)).[2] This is a model case.

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[1] "Mississippi" refers to the State of Mississippi; "Tennessee" refers to the State of Tennessee; "Memphis" refers to the City of Memphis, Tennessee; and "MLGW" refers to Memphis Light Gas & Water Division. Tennessee, Memphis, and MLGW will sometimes be collectively referred to herein as "the Tennessee Parties."

[2] In *Mississippi v. City of Memphis*, 559 U.S. 901 (2010), the Court cited *Virginia v. Maryland*, 540 U.S. 56, 74 n. 9 (2003), and *Colorado v. New Mexico*, 459 U.S. 176, 187 n.13 (1982) in a note to its denial, without prejudice, of Mississippi's previous motion for leave to file a bill of complaint. Counsel have studied these and

REASONS THE COURT SHOULD TAKE JURISDICTION

Character of Controversy

Over the last four decades, Memphis and MLGW have, under Tennessee's supervision, knowingly pumped 20 to 28 million gallons a day of high quality groundwater out of Mississippi's natural storage. This groundwater was never naturally available in Tennessee, and is permanently lost to Mississippi. The Tennessee Parties knowingly pumped this groundwater out of Mississippi's sovereign territory for commercial sale by MLGW without notice to, permission from, or compensation to Mississippi.

These actions constitute an intentional violation of Mississippi's retained sovereignty of the type for which the Court's Article III original and exclusive jurisdiction was created. *See* The Federalist No. 7 (Alexander Hamilton).[3] This violation of Mississippi's

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other cases involving actions between states and understand the burden carried by states making claims against other states in original actions. However, Mississippi has found no directly applicable opinions of the Court creating a presumption that groundwater trapped within a deep confined sandstone formation in one state—which would not naturally move to a sister state absent pumping—is as a matter of law, a naturally shared resource. Mississippi submits that the separate states' sovereign authority over such groundwater is an undecided Constitutional question of great seriousness and magnitude which must be resolved by this Court before equitable apportionment can even be discussed.

[3] When Alexander Hamilton argued for New York's ratification of the Constitution and the creation of the Court's Article III original

retained sovereignty and "full jurisdiction over the lands *within its borders, including the beds of streams and other waters,*" *Kansas v. Colorado,* 206 U.S. 46, 93 (1907) (citations omitted) (emphasis added), goes to the foundations of the Union. *See Rhode Island v. Massachusetts,* 37 U.S. 657, 731 (1838) (exercise of jurisdiction over border disputes necessary to perfect bond of the Union and enforce domestic tranquility).

Mississippi Has Suffered Real and Substantial Damage

The actions of the Tennessee Parties have effectuated and continue to effectuate a permanent taking of a limited natural resource belonging to Mississippi and its people. *See* App., 20a-54a. MLGW's pumping from the Sparta Sand has dramatically increased since 1965, withdrawing 411.3 billion gallons out of Mississippi natural storage which would not have ever been naturally available in Tennessee. App., 22a & 53a. The value of Mississippi groundwater pumped by MLGW from 1985 to date is estimated at $615 million, including prejudgment interest. App., 137a.

No Other Forum Can Resolve This Dispute

Mississippi's efforts to negotiate a resolution with Tennessee after learning that MLGW was the largest pumper from the north Mississippi Sparta Sand failed. In 2005, Mississippi filed suit against Memphis and MLGW, but the suit was dismissed for failure to join

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and exclusive jurisdiction—as an alternative to armed conflict—he explained that the "competitions of commerce would be another fruitful source of contention." *Id.*

Tennessee as an indispensable party. *Hood ex rel. Mississippi v. City of Memphis,* 533 F. Supp. 2d 646 (N.D. Miss. 2008), *aff'd* 570 F.3d 625 (5th Cir. 2009), *cert. denied* 559 U.S. 904 (2010). Mississippi cannot invade Tennessee and destroy well fields in Tennessee to stop the Tennessee Parties' conversion of Mississippi's groundwater. This Court is Mississippi's only avenue of relief for these violations of its territorial sovereignty. *Rhode Island,* 37 U.S. at 724-25, 731.

CONSTITUTIONAL AND STATUTORY PROVISIONS INVOLVED

The relevant constitutional and statutory provisions involved are Article III, Section 2, Clause 2 of the United States Constitution; Article IV, Section 3, Clause 1 of the United States Constitution; the Tenth Amendment of the United States Constitution; 28 U.S.C. § 1251(a) (2012); Mississippi Code Annotated Sections 51-3-1 (2003), 51-3-3(n) (2003), and 51-3-5 (2003); and Tennessee Code Annotated Sections 68-221-701 (2013), 68-221-702 (2013), 68-221-703(13) (2013), 68-221-706 (2013), 69-3-102(a), 69-7-303(5) (2013), and 69-10-101 (2013), all of which are reproduced verbatim at Appendix A.

STATEMENT OF THE CASE

Mississippi's Sovereign Rights Over Groundwater Naturally Stored Within Mississippi's Borders

On December 10, 1817, Mississippi was admitted to the Union on an "equal footing" with the original thirteen colonies. *Pollard v. Hagan*, 44 U.S. 212, 223 (1845); *see also Coyle v. Smith*, 221 U.S. 559, 573 (1911). On admission, Mississippi was granted "full jurisdiction over the lands within its borders, including the beds of streams and other waters." *Kansas v. Colorado*, 206 U.S. 46, 93 (1907) (citations omitted). As a sovereign State, Mississippi holds and retains full control and authority over the groundwater stored naturally within its territorial borders. *Phillips Petroleum Co. v. Mississippi*, 484 U.S. 469, 475-76 (1988), *aff'g Cinque Bambini P'ship v. State*, 491 So.2d 508 (Miss. 1986); *see also PPL Mont., LLC v. Montana*, 132 S. Ct. 1215, 1235 (2012) ("States retain residual power to determine the scope of the public trust over waters within their borders. . . .").

Mississippi has consistently confirmed its sovereign rights over groundwater within its borders, and its legislature has declared by statute that all groundwater underlying its territory is a natural resource of the State belonging to its people; and, that "[t]he control and development and use of water for all beneficial purposes shall be in the state, which, in the exercise of its police powers, shall take such measures to effectively and efficiently manage, protect and utilize the water resources of Mississippi." Miss. Code Ann. § 51-3-1 (2003). Accordingly, Mississippi regulates the withdrawal and use of groundwater stored within its borders. *See* Miss. Code Ann. § 51-3-5 (2003) (stating, *inter alia*, that "[n]o person who is not specifically exempted by this chapter shall use water without having first obtained a permit as provided herein. . . .").

Under the United States Constitution, Tennessee has no legitimate sovereign claim to groundwater naturally stored within Mississippi's borders which, under natural conditions, would never be available in Tennessee. Despite this fact, the Tennessee Parties constructed one of the world's largest groundwater pumping, distribution and sales systems with which they have reached into Mississippi and taken its valuable natural resource without notice, permission or compensation. These actions constitute an intentional invasion of Mississippi's territory and violation of Mississippi's retained sovereignty, giving rise to its claims and its requests for equitable relief.

A brief explanation of the Sparta Sand's geology and hydrology, together with an explanation of the natural behavior of the groundwater stored within Mississippi's Sparta Sand, illustrate the foundation for Mississippi's claims under the United States Constitution.

Mississippi's Natural Groundwater Storage

Mississippi seeks recovery for groundwater naturally stored and residing within its sovereign borders which would never have been available to Tennessee under natural conditions. Such water, which does not naturally move from one state to another, is not a shared natural resource. It is intrastate water. Mississippi's groundwater which the Tennessee Parties have taken and continue to take is not a shared natural resource, because it originated in and is stored in

Mississippi and its natural movement (seepage)—in the absence of pumping—is east-to-west/southwest, down dip in the confined formation within Mississippi.[4]

The Sparta Sand in north Mississippi is a dense, permeable sandstone formation confined between the Flour Island and the upper Jackson formations. These confining formations are composed of impermeable, or very low permeability, clays, silts and fine sands. App.,20a, 28a-31a &67a. In north Mississippi and west Tennessee, the Sparta Sand outcrops (appears unconfined at or near the surface) in an essentially north-to-south strike crossing the border between Mississippi and Tennessee and extending into each State. From the outcrops in Mississippi, the formation has a predominant east-to-west/southwest dip toward the axis of the formation deep below the Mississippi River. App., 68a & 69a. It occurs at a depth of 0 feet (surface) at its outcrop to 600 feet deep, and the formation varies from 200 to 900 feet in thickness. App., 29a & 71a.[5]

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[4] *See* App., 77a (Figure 14, showing pre-pumping hydraulic gradients); and App., 70a (Figure 7 with directional groundwater movement lines shown). *See also* Preface to United States Geological Survey *Basic Ground-Water Hydrology*, Water-Supply Paper (2004) (App., 222a-243a), which explains that groundwater is subject to many widespread misconceptions, including "the belief that ground water occurs in underground rivers resembling surface streams" or reservoirs. App., 228a. In fact, groundwater movement depends on the complex subsurface environment in which it is stored. App., 231a, 233a, 242a-243a.

[5] App., 71a (Figure 8) reflects a commonly used method to demonstrate the general directional slope and thickness of the

Given its geology, before pumping, rainwater entering the Sparta Sand at Mississippi outcrops was naturally drawn by the force of gravity and seeped through pores in the sandstone, migrating down dip at about an inch a day in a direction essentially parallel to the border between Mississippi and Tennessee. App., 28a-31a & 77a.[6] Over time the Sparta Sand within Mississippi became saturated with high quality groundwater stored under significant pressure. As the formation moves deeper, the natural pressures increase, and the very high pressure at the axis below the Mississippi River acts as a hydraulic boundary. Appendix Figure 14 (App., 77a) shows the natural pressure gradients within the formation and the resulting east-to-west/southwest direction of groundwater seepage in north Mississippi under natural conditions, before pumping. Appendix Figure 7 (App., 70a) is a duplicate of Figure 14 with lines superimposed to show the natural pre-pumping direction of seepage and storage within the Sparta Sand in both Mississippi and Tennessee.

Because of the geological structure of the Sparta Sand in Mississippi, rainwater falling within Mississippi and trapped in this confined formation was naturally stored in Mississippi. Under natural conditions, this groundwater remained within Mississippi in storage under pressure as an available

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geological formations in the relevant area, although the vertical scale is greatly exaggerated.

[6] App., 77a (Figure 14) is based on United States Geological Survey modeling which established the pre-pumping conditions and is widely used.

natural resource for Mississippi and its people, and would never have been available within Tennessee's territorial borders.[7]

Tennessee Groundwater Pumping

As an exercise of its retained sovereignty, Tennessee has controlled, regulated, authorized and supervised Memphis and MLGW through acts of its legislature and the actions of a state agency, the Tennessee Department of Environment and Conservation ("TDEC"), and predecessor entities.

MLGW is the nation's largest three service municipal utility providing water, gas, and electricity. In 1965, it sold approximately 26 billion gallons of water in and around Memphis. By 2000, MLGW's sales had increased to approximately 59 billion gallons a year. While Memphis is located on the Mississippi River, and has access to several other sources of surface water and groundwater to the north and east within Tennessee, MLGW has intentionally elected to exclusively utilize groundwater, primarily pumped from the Sparta Sand, to obtain the lowest cost of both water and water transport for its sales. App., 138a-144a. MLGW's pumping has been consistently increased without regard to the depletion and draw down of natural groundwater storage in the Sparta Sand, and its well fields have been intentionally developed to reach into Mississippi and forcibly take Mississippi groundwater out of storage.

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[7] Water which might enter Tennessee from the yellow highlighted area on Figure 7, App., 70a is not included in Mississippi's claim. *See* App., 37a-43a. (discussion of groundwater modeling).

As part of the expansion of its groundwater pumping operations between 1965 and 2000, MLGW increased the number of its well fields from five fields to ten, and increased its daily pumping capacity from approximately 72 million gallons a day ("MGD") to 163 MGD. This expansion included three well fields located and developed within two and a half miles of the Mississippi border which were pumping approximately 41.5 MGD in 2000. App., 58a. During this massive expansion of groundwater pumping by MLGW, an increasing number of studies were performed by the United States Geological Survey ("USGS") and Tennessee in the 1970s, 80s and 90s which clearly established that MLGW was pulling tens of millions of gallons of groundwater out of the Mississippi Sparta Sand, while claiming all its water came from what it called the Memphis "500-foot sand" (and subsequently called the "Memphis Sand"). App., 24a-28a, 31a-37a & 39a-43a. These studies also reported, as early as 1980, that MLGW's continuous expansion of well fields and commercial pumping was consistently drawing down groundwater storage in the Sparta Sand and progressively reaching further and further into Mississippi, taking groundwater out of natural storage in Mississippi to augment pumping from within Tennessee's borders. *Id.*

By 1995, MLGW's taking of Mississippi's natural groundwater resources through MLGW's pumping operation was notorious, and it was reported that MLGW was the largest pumper of groundwater from the Sparta Sand in Mississippi. App., 183a, 188a-189a & 191a-192a. *See also* App., 60a-61a. The Tennessee Parties had never either given notice of this activity to Mississippi, nor applied for a Mississippi permit; and the Mississippi Director of the Office of Land and Water Resources objected to MLGW's past and continued pumping, and proposed a joint cooperative study with MLGW, TDEC, and the USGS to establish the natural Sparta Sand groundwater storage within each State and the full effects of MLGW's groundwater pumping. App., 183a-189a.

MLGW would not participate and continued to increase its taking of Mississippi's groundwater. App., 189a. *See also* App., 60a-61a. A November 16, 1998, Memphis *Commercial Appeal* article, following interviews with Memphis, MLGW, USGS, and University of Memphis Groundwater Institute ("GWI") spokesmen, observed that "heavy pumping of municipal wells in Memphis" had created "'cones of depression' that pull water from [Mississippi];" and that "Memphis each day sucks 20 million to 40 million gallons from under the feet of its neighbors in Desoto County [Mississippi], where wells already are straining to meet demand from rapid growth." App., 190a-193a. In the article, a USGS engineer stated preliminary analysis suggested 20-30% of MLGW's water came from Mississippi, and the former director of GWI acknowledged: "As we've increased our pumping rates, we've forced more water to come north from Mississippi into Shelby County." App., 194a.

A state wide water policy and legal study dated June 2000 by the University of Tennessee's Energy, Environment and Resources Center included findings on MLGW's pumping and cross-border taking from Mississippi's natural groundwater storage in the Sparta Sand and the resulting stress put on groundwater resources. App., 196a-215a. It noted a suit by Mississippi could have unfavorable results because "there is another source, the Mississippi River," for Memphis water. App., 209a-210a. In apparent response to the reported stresses on Tennessee groundwater resources, MLGW decreased its total pumping between 2000 and 2012; however, it maintained essentially constant pumping from the Mississippi border well fields: 41.5 MGD in 2000 and 42.0 MGD in 2012. App., 58a.

A March 5, 2002, *Special Report* from Tennessee's Comptroller, John Morgan, concluded that the MLGW pumping of groundwater from the Sparta Sand presented an interstate water scarcity issue which required Memphis' reduction of its reliance on the Sparta Sand formation as a source of water supply. App., 216a-220a. Mississippi's efforts to cooperatively address this issue with Tennessee never gained traction.

From 2005 to 2010, Mississippi pursued litigation with Memphis and MLGW in federal district court. *See Hood ex rel. Mississippi v. City of Memphis*, 533 F. Supp. 2d 646 (N.D. Miss. 2008), *aff'd* 570 F. 3d 625 (5th Cir. 2009), *cert. denied*, *Mississippi v. City of Memphis*, 559 U.S. 904 (2010); *Mississippi v. City of Memphis*, 559 U.S. 901 (2010) (motion for leave to file bill of complaint denied without prejudice). Following the dismissal of Mississippi's initial action—without prejudice—for failure to join Tennessee as a necessary party, Mississippi's Attorney General attempted to reopen discussions with Tennessee without success. Throughout Mississippi's efforts since 1995 to cooperatively resolve this dispute, the Tennessee Parties have consistently remained recalcitrant.

PRESENT AND FUTURE DAMAGE TO MISSISSIPPI

Mississippi's expert hydrogeologists have collected available well data and relevant studies by others and performed groundwater modeling using scientifically valid methods, to determine the past, present, and probable future impact of the Tennessee Parties' massive commercial pumping operation on Mississippi's natural groundwater storage and the changes it has created in the Sparta Sand within Mississippi. App., 20a-130a. Its economic experts have taken the results of this work and calculated the economic impact on Mississippi. App., 131a-182a.

The results of this work can be summarized as follows:

(1) MLGW has been pumping high quality groundwater out of Mississippi's sovereign territory since at least 1965. App. 20a-22a

(2) Despite the Tennessee Parties' knowledge that MLGW was pumping Mississippi groundwater not naturally available within Tennessee, MLGW continually increased its pumping capacity and developed additional well fields on the Mississippi border. App., 58a-62a.

(3) MLGW's massive pumping has drawn down Mississippi's naturally stored groundwater, permanently taking an estimated 252 billion gallons out of Mississippi groundwater storage since 1985, and creating a gigantic cone of depression centered under Memphis and reaching into substantially all of DeSoto

County, Mississippi, which will extract groundwater from Mississippi's natural storage for years to come, even if all MLGW pumping stopped today. App., 20a-22a & 24a-28a.[8]

(4) MLGW's current rate of pumping permanently takes approximately 21 MGD (or 7.6 billion gallons annually) of Mississippi groundwater out of its natural storage into Tennessee. App., 58a-62a.

(5) A conservative estimate of the value of Mississippi groundwater converted by the Tennessee Parties since 1985 is $615 million, including prejudgment interest. App., 134a-182a.

SUMMARY OF ARGUMENT

This is a dispute between states over their retained sovereign territorial rights. *Rhode Island v. Massachusetts*, 37 U.S. 657, 731 (1838). Individual states retained sovereignty over all waters within their borders under the Constitution, and this sovereignty over intrastate waters was affirmed in *Kansas v. Colorado*, 206 U.S. 46, 93 (1907). In *Kansas v. Colorado*, the Court created equitable apportionment

[8] Technically, with the cessation of all pumping, and unchanged climatological conditions, groundwater storage *may* eventually be replenished naturally in the distant future, but the high quality water which has already been and will be taken is permanently gone, and an eventual natural recharge of the equivalent natural resource within any reasonable time is, at best, far from certain. In no event would this compensate Mississippi for what the State and its citizens have already lost.

as a remedy to address disputes over an obviously shared natural resource: "Before either Kansas or Colorado was settled the Arkansas River was a stream running through the territory which now comprises these two States." *Id.* at 98-99.

This fact—that the disputed natural resource was shared under pre-existing conditions of nature—has been a prerequisite to the Supreme Court's application of equitable apportionment in every case we have found. Each case involved a volume of water (or salmon in one instance) which, under the conditions established by nature, was available to two or more states without human intervention. The apportioned resource was, by definition, an interstate natural resource shared by the competing states under the conditions put into place by nature. The Court's intervention was required because one state, through human intervention, was denying another state a shared sovereign attribute of that other state.

In contrast, this case is about the Tennessee Parties reaching beneath the state border into Mississippi's territory to seize and convert a Mississippi natural resource to which they have no such sovereign claim. It is a dispute over the Tennessee Parties' violation of Mississippi's sovereign territory. While the case involves very valuable groundwater, Tennessee has no sovereign claim to the water at issue, which is not naturally shared. Tennessee's operation of over 170 commercial water wells in ten well fields, three of which are just barely in Tennessee (*see* App., 64a), to admittedly take groundwater out of Mississippi storage, is not natural.

Tennessee has never attempted to establish any sovereign right to reach into Mississippi and take the Mississippi groundwater. It has just taken it. Likewise, Tennessee has never offered any evidence that the groundwater residing and moving only within Mississippi's borders would ever enter into or reside in Tennessee under natural conditions.

Tennessee can make no sovereign claim of right to groundwater collected and stored in Mississippi under natural conditions which the Tennessee Parties have only obtained, and continue to obtain, through a massive pumping operation. Were such a claim raised, it might create a question of fact, but not a right to reach across the border into Mississippi territory—as the Tennessee Parties have admittedly done for decades—to forcibly extract Mississippi's naturally stored groundwater. Absent evidence establishing that Mississippi's groundwater would be available within Tennessee without its pumping, Tennessee has no legal basis for an argument that shared interstate groundwater is at issue. And even if it were, the Tennessee Parties have no right to use MLGW's massive pumping operation to literally reach through this confined geological formation into Mississippi and draw down the natural water pressures to seize water from within Mississippi.

The core issue in this case is the violation of sovereign territorial rights held by Mississippi under the United States Constitution. Mississippi has alleged, and tendered evidence to support, a *prima facie* case that the Tennessee Parties have intentionally violated Mississippi's sovereignty and converted its natural resources. *See* App., 11a-243a.

This is a proper case for the Court's exercise of its jurisdiction to determine this dispute, and to provide all relief to which Mississippi may be entitled.

ARGUMENT

I. MISSISSIPPI'S SOVEREIGN RIGHTS OVER GROUNDWATER WITHIN ITS STATE BORDERS

Under the United States Constitution and the equal footing doctrine, Mississippi was admitted to the Union with sovereignty over all its "lands within its borders, including the beds of streams and other waters." *Kansas*, 206 U.S. at 93; *see also Shively v. Bowlby*, 152 U.S. 1, 14-15 (1894); *Rhode Island,* 37 U.S. at 733-38. The right of a state to control and regulate the use of natural resources within the state's territory "is an essential attribute of sovereignty." *Tarrant Reg'l Water Dist. v. Herrmann*, 133 S. Ct. 2120, 2132 (2013) (*quoting United States v. Alaska*, 621 U.S. 1 (1997)); *see also Oregon ex rel. State Land Bd. v. Corvallis Sand & Gravel Co.*, 429 U.S. 363, 377 (1977); *Phillips Petroleum Co.*, 484 U.S. at 475.

Both Mississippi and Tennessee claim all groundwater within their respective territorial borders as a natural resource controlled by the State under its retained sovereignty. Miss. Code Ann. § 51-3-1 (2003); Tenn. Code Ann. §§ 68-221-701 and 69-3-102(a) (2013).

This case must be decided under Article IV, Section 3, Clause 1 of the United States Constitution under which Mississippi was created and brought into the Union, and based upon the sovereign rights reserved to Mississippi by the Tenth Amendment to the Constitution. Neither *Kansas v. Colorado*, 206 U.S. 46

(1907) nor the cases following it diminish the power of the separate state's retained sovereignty over waters within their borders under the Constitution and laws of the United States. Indeed, it is the individual states' sovereignty, and their inability to impose their water policies on their neighboring states, "*coupled with its effect upon a stream passing through the two States*," which made the dispute over the Arkansas River "a matter for investigation and determination by this court." *Id.* at 95-96 (emphasis added). Intrastate water simply cannot be subject to equitable apportionment, because it is not a naturally shared natural resource; rather, it falls under the exclusive sovereignty of the state in which it resides.

The Tennessee Parties' arguments for equitable apportionment rely on an image of the Sparta Sand geological formation as an underground river or a lake within a cave. Such arguments rely on widespread misconceptions, as noted in the USGS Water-Supply Paper presented at App., 222a-243a. The Preface of this Paper, and its opening chapter titled *Ground-Water Hydrology*, both immediately point out that unlike surface water, or even flowing water in a limestone cave, groundwater is trapped in "myriad openings that exist between the grains of sand and silt, between particles of clay . . ." (App., 232a); and unlike the rapid movement of flowing water, "the movement of most groundwater is exceedingly slow." App., 233a.

Beyond these basic differences, the occurrence and movement of groundwater in a confined aquifer must be determined by the application of the physical and mathematical sciences to a complex subsurface environment. The studies performed on the Sparta

Sand since the mid-1960s have uniformly found pre-pumping groundwater storage, pressures, and directional movements in Mississippi across north Mississippi and not into Tennessee. This represents the natural condition of Sparta Sand groundwater stored exclusively in Mississippi's sovereign territory and seeping predominantly east-to-west/southwest since before Mississippi became a state. This groundwater naturally stored in a confined aquifer within Mississippi's borders does not meet the first requirement for equitable apportionment. It is not naturally shared.

Accordingly, the Tennessee Parties have never had and simply do not have any claim of right to the Mississippi groundwater under the Constitution and laws of the United States. Absent proof that the groundwater in Mississippi would ever naturally reside (even moving at an inch a day) within Tennessee's borders, there is no basis for the court to apply the cardinal rule of "equality of right" between states. There is no naturally shared resource to subject to legitimate competing claims. Indeed, in view of Mississippi's rights as a sovereign State and the powers preserved to it by the Tenth Amendment of the United States Constitution, Mississippi should not be—and cannot properly be—forced to "share" its natural resources with the Tennessee Parties under a claim by Tennessee to a right of equitable apportionment.

Tennessee has never denied that MLGW's massive pumping operation, developed and operated under its oversight, has been reaching across the State border into Mississippi for decades and forcibly seizing

Mississippi groundwater and siphoning it into Tennessee. This act alone violates Mississippi's sovereignty by imposing Tennessee's groundwater policy on Mississippi. *Kansas v. Colorado*, 206 U.S. at 95 ("Neither State can legislate for or impose its own policy upon the other.").

The Tennessee Parties have knowingly taken these actions in defiance of Mississippi's sovereign territorial rights. They have never made any effort to establish a legitimate claim to the Mississippi groundwater; to notify Mississippi that the groundwater was being taken from within Mississippi; to obtain a permit from Mississippi to take groundwater residing within its borders; or to offer compensation to Mississippi for the taking of a limited natural resource from within Mississippi's borders.[9] Mississippi has found no authority supporting these actions of Tennessee and its political subdivisions. Were Mississippi entitled under the Constitution to declare war on Tennessee, it would have just cause; that is, *casus belli*.

The honoring of territorial boundaries has always been, and continues to be at the foundation of the Union. *Rhode Island,* 37 U.S. at 733 ("when a place is within the boundary, it is a part of the territory of a state; title, jurisdiction, and sovereignty, are inseparable incidents, and remain so till the state

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[9] Even the Texas water district in the Court's recent *Tarrant* decision advanced a claim of right to surface water stored within Oklahoma and applied for a permit to obtain the water in recognition of Oklahoma's police power within its sovereign territory and then filed suit in Federal District Court to confirm its rights. *Tarrant Reg'l Water Dist.*, 133 S.Ct. at 2128-29.

makes some cession."). The right to preserve, protect, control and regulate the use of water within those boundaries continues to be a fundamental incident of that sovereignty. *Tarrant Reg'l Water Dist.*, 133 S. Ct. at 2132.

As between sovereigns, the Court has consistently found that the territorial boundary is the beginning and end of each state's sovereign rights. *See United States v. Louisiana,* 363 U.S. 1 (1960)(dispute between the United States and five states on Gulf of Mexico over lands, minerals and other natural resources); *Louisiana v. United States*, 656 F. Supp. 1310, 1312 (W.D. La. 1986), *aff'd sub nom. Louisiana ex rel. Guste v. United States*, 832 F.2d 935 (5th Cir. 1987) (Louisiana suit for drainage dismissed because United States had already paid for drainage beneath Louisiana sovereign lands).

II. THE TENNESSEE PARTIES ARE LIABLE TO MISSISSIPPI FOR THE UNLAWFUL TAKING OF MISSISSIPPI GROUNDWATER

Through the TDEC, Tennessee exercises supervisory power over the construction, operation, and maintenance of the State's public water systems, including all features or aspects regarding quantity and quality of water supply. Tenn. Code Ann. §§ 68-221-706(a)(2) and 68-221-707(b) (2013). Tennessee also regulates the drilling and maintenance of water wells within the State, *see* Tenn. Code Ann. § 69-10-101 (2013), and under its Water Resources Information Act, Tennessee regulates and requires the registration of withdrawals of groundwater "from any source on a regular or recurring basis by means of an intake structure, pipe and pump that diverts water away from a source, or by any other conveyance with or without the use of suction." Tenn. Code Ann. at § 69-7-303(5). Tennessee has also enacted a variety of rules and regulations to implement its powers to control and authorize groundwater well pumpage and public water supply facilities. *See, e.g.*, Tenn. Comp. R. & Regs. 1200-4-9-.01 & 1200-5-8-.01.

The Tennessee Parties' intentional actions to reach into Mississippi to forcibly extract Mississippi groundwater from within Mississippi into Tennessee, and to create the cone of depression underlying Mississippi constitute trespass,[10] conversion,[11] and

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[10] *Great N. Nekoosa Corp. v. Aetna Cas. & Sur. Co.*, 921 F. Supp. 401, 415 (N.D. Miss. 1996) (discussion of trespass law in Mississippi); *Morrison v. Smith*, 757 S.W.2d 678, 681 (Tenn. Ct. App. 1988) (*quoting Daughtery v. Stepp*, 19 N.C. 371 (N.C. 1835) ("[E]very unauthorized, and therefore unlawful, entry into the close of another, is a trespass."). *See* Restatement (Second) of Torts § 158 (one is subject to liability for trespass if he intentionally enters land in the possession of another or causes a thing to do so); *id.*, § 159 (trespass may be committed beneath the surface of the earth); *id.* § 161(1) (trespass may be committed by the continued presence on the land of a thing the actor has tortiously placed there, whether or not the actor has the ability to remove it). *See also Gregg v. Delhi-Taylor Oil Corp.*, 344 S.W.2d 411, 416 (Tex. 1961) (*quoting Glade v. Dietert*, 295 S.W.2d 642, 645 (Tex. 1956) ("entry upon another's land need not be in person, but may be made by causing or permitting a thing to cross the boundary of the premises"); *Forbell v. City of New York*, 164 N.Y. 522, 526 (N.Y. 1900) (trespass when city constructed pumping stations that caused water underlying plaintiff's land to flow into its own wells).

[11] *Mississippi Motor Fin., Inc. v. Thomas*, 149 So. 2d 20 (1963) (conversion is the exercise of dominion or control over property inconsistent with the true owner's rights). *See also Barger v. Webb*, 391 S.W.2d 664, 665 (Tenn. 1965) (conversion is the appropriation

intentional tortious conduct.[12] Mississippi seeks damages in an amount equal to the value of the water wrongfully taken. In addition, the Tennessee Parties' actions present a classic claim for restitution. The Tennessee Parties have violated Mississippi's territorial sovereignty to take natural resources held by Mississippi in trust for its citizens, without consent or compensation.[13] Mississippi is entitled to recover the

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of property to defendant's "own use and benefit, by the exercise of dominion over it, in defiance of plaintiff's right").

[12] *Capital Elec. Power Ass'n v. Hinson*, 92 So. 2d 867, 871 (Miss. 1957) ("A tortious act has also been defined as the commission or omission of an act by one, without right, whereby another receives some injury, directly or indirectly, in person, property, or reputation.") (citation omitted); *Stokes v. Newell*, 165 So. 542, 545 (Miss. 1936) ("It is a general principal of law that the breach of a legal duty owed by one person to another when damages have resulted therefrom gives the right to a cause of action."). *See also* Restatement (Second) of Torts § 927 (remedy for "destruction or impairment of any legally protected interest in the land or other thing").

[13] *Magnolia Fed. Sav. & Loan Ass'n v. Randal Craft Realty Co.*, 342 So. 2d 1308, 1311 (Miss. 1977) (unjust enrichment and restitution recognize that a person should not be allowed to enrich himself unjustly through his retention or use of property or money which belongs to another); *Freeman Indus., LLC v. Eastman Chem. Co.*, 172 S.W.3d 512, 524-25 (Tenn. 2005) (elements of unjust enrichment claim). *See* Restatement (Third) of Restitution and Unjust Enrichment § 40 (2011) ("A person who obtains a benefit by an act of trespass or conversion, by comparable interference with other protected interests in tangible property, or in consequence of such an act by another, is liable in restitution to the victim of the wrong."). *See also id.* § 1 ("A person who is unjustly enriched at the expense of another is subject to liability and restitution."); *id.* § 3 ("A person is not permitted to profit by his own wrong.").

value of the benefits conferred and an accounting and disgorgement of all proceeds and consequential gains realized by the Tennessee Parties as "conscious wrongdoers."[14]

III. THE COURT'S DECISIONS AUTHORIZE THE AWARD OF DAMAGES AND/OR RESTITUTION IN AN ORIGINAL ACTION

The Court's precedent confirms the propriety of damages awards in actions brought by a state against another state. In *Kansas v. Colorado,* 533 U.S. 1, 7-9 (2001) (citation omitted), the Court held that "a State may recover monetary damages from another State in an original action," and accepted the Special Master's recommendation that Kansas be awarded monetary damages against Colorado for violation of the Arkansas River Compact. *See also Texas v. New Mexico*, 482 U.S. 124, 128 (1987) (permitting damages for violation of compact). Such damages should include prejudgment interest. *West Virginia v. United States*, 479 U.S. 305, 310-11, n. 2 (1987).

The fact that Mississippi also demands damages, restitution and injunctive relief from the non-state entities, Memphis and MLGW, does not alter the Court's powers to award such relief. Provided at least one state is on each side of the controversy, the

[14] *Id.* §§ 49 and 51. *See also id.* § 51(3)(b) (a "conscious wrongdoer" is a defendant who is enriched by misconduct and acts "despite a known risk that the conduct in question violates the rights of the claimant"). Such consequential gains include, *inter alia*, saved expenditures, such as where a defendant's unauthorized taking or use of the claimant's property has saved the defendant the "greater cost of making alternative arrangements." *Id.* § 1, cmt. d.

presence of non-state parties, even indispensable parties, does not affect the exclusive original jurisdiction of the Supreme Court. *See, e.g., Arizona v. California*, 373 U.S. 546, 564 (1963); *California v. Arizona*, 440 U.S. 59, 61 (1979); *see also Maryland v. Louisiana,* 451 U.S. 725, 735-44 (1981); *Louisiana v. Mississippi*, 516 U.S. 22 (1995) (settling a boundary dispute between Louisiana and Mississippi and denying Louisiana's title claim against a private defendant).

Mississippi's expert economist has conducted detailed analyses of the value of the groundwater wrongfully taken from Mississippi. The principal amount of the State's monetary damages is approximately $197 million for wrongful takings of Mississippi's groundwater from 1985-2012, plus prejudgment interest of $418 million, for total damages approximating $615 million. App., 137a.

IV. THIS IS AN APPROPRIATE CASE FOR THE IMPOSITION OF INJUNCTIVE RELIEF

Unless the Tennessee Parties are required to restructure their pumping system, or to construct and operate a system to obtain water from other readily available sources, such as the Mississippi River, MLGW's pumping from Mississippi will continue until Mississippi's natural resource is exhausted. Three of MLGW's well fields are essentially on the Mississippi border, and the cone of depression created by MLGW's total pumping will continue to draw down the hydraulic pressures further and further into Mississippi.

The Court has granted injunctive relief in cases brought as original actions involving or threatening territorial encroachments. *Missouri v. Illinois*, 180 U.S. 208, 218, 224 & 248-49 (1901) (injunction against city's drainage district, a public corporation controlled by the State of Illinois, to stop construction of a channel that would reverse the flow of the Chicago River causing the natural flow of sewage to be discharged into the Mississippi River); *Wisconsin v. Illinois*, 278 U.S. 367, 420-21 (1929) (injunction granted "as a means of avoiding the diversion [of lake water] in the future" and requiring "the District to devise proper methods for providing sufficient money and to construct and put in operation with all reasonable expedition adequate plants for the disposition of the sewage through other means than the Lake diversion.").

Tennessee's internal water management and long-term planning studies suggest that Memphis may have to reduce its reliance upon Mississippi groundwater and use Mississippi River water as a supplemental source of supply. App., 220a. Memphis and MLGW have long been on notice that the Court may enjoin their taking of Mississippi groundwater. *Cf. New Jersey v. New York*, 283 U.S. 336, 346 (1931) (limiting New York to diverting no more than "440 million gallons of water daily" from the Delaware River or its tributaries).

CONCLUSION

Groundwater trapped in a confined formation such as the Sparta Sand bears no resemblance to a river, stream, lake or other body of surface water. Equitable apportionment assumes the existence of interstate surface water which visibly moves freely from one state to another without human intervention. This assumption cannot be automatically applied to deep confined groundwater consistent with state territorial sovereignty under the Constitution. Such groundwater may, or may not, be naturally shared. This is a matter of evidence, not unsupported presumptions.

Mississippi has put evidence before the Court with its Motion which disputes any conclusion that the groundwater at issue is naturally shared with Tennessee, and respectfully requests the Court's leave to file its Complaint, and an order appointing a Special Master, *see, e.g., South Carolina v. Regan*, 465 U.S. 367 (1984); *United States v. Raddatz*, 447 U.S. 667, 683 n. 11 (1980), to enable full development of the record and to make recommended findings of fact and conclusions of law supporting Mississippi's claims for damages, restitution, and injunctive relief as set forth herein.

Respectfully submitted,

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June 6, 2014

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APPENDIX A

CONSTITUTION OF THE UNITED STATES OF AMERICA

ARTICLE III. JUDICIAL POWER

U.S. Const. art. III, § 2, cl. 2

In all Cases affecting Ambassadors, other public Ministers and Consuls, and those in which a State shall be Party, the supreme Court shall have original Jurisdiction. In all the other Cases before mentioned, the supreme Court shall have appellate Jurisdiction, both as to Law and Fact, with such Exceptions, and under such Regulations as the Congress shall make.

ARTICLE IV. RELATIONS BETWEEN STATES

U. S. Const. art. IV, § 3, cl. 1

Admission of new states.

New States may be admitted by the Congress into this Union; but no new State shall be formed or erected within the Jurisdiction of any other State; nor any State be formed by the Junction of two or more States, or Parts of States, without the Consent of the Legislatures of the States concerned as well as of the Congress.

AMENDMENTS

U.S. Const. amend. 10

Powers reserved to states or people.

The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people.

UNITED STATES CODE SERVICE
TITLE 28. JUDICIARY AND JUDICIAL PROCEDURE
PART IV. JURISDICTION AND VENUE
CHAPTER 81. SUPREME COURT

28 U.S.C. § 1251 Original jurisdiction

(a) The Supreme Court shall have original and exclusive jurisdiction of all controversies between two or more States.

MISSISSIPPI CODE of 1972 ANNOTATED
TITLE 51. WATERS, WATER RESOURCES, WATER DISTRICTS, DRAINAGE, AND FLOOD CONTROL
CHAPTER 3. WATER RESOURCES; REGULATION AND CONTROL
ARTICLE 1. GENERAL PROVISIONS

Miss. Code Ann. § 51-3-1. Declaration of policy on conservation of water resources

It is hereby declared that the general welfare of the people of the State of Mississippi requires that the water resources of the state be put to beneficial use to the fullest extent of which they are capable, that the waste or unreasonable use, or unreasonable method of use, of water be prevented, that the conservation of such water be exercised with the view to the reasonable and beneficial use thereof in the interest of the people, and that the public and private funds for the promotion and expansion of the beneficial use of water resources shall be invested to the end that the best interests and welfare of the people are served.

It is the policy of the Legislature that conjunctive use of groundwater and surface water shall be encouraged for the reasonable and beneficial use of all water resources of the state. The policies, regulations and public laws of the State of Mississippi shall be interpreted and administered so that, to the fullest extent possible, the ground and surface water resources within the state shall be integrated in their use, storage, allocation and management.

All water, whether occurring on the surface of the ground or underneath the surface of the ground, is hereby declared to be among the basic resources of this state to therefore belong to the people of this state and is subject to regulation in accordance with the provisions of this chapter. The control and development and use of water for all beneficial purposes shall be in the state, which, in the exercise of its police powers, shall take such measures to effectively and efficiently manage, protect and utilize the water resources of Mississippi.

Miss. Code Ann. § 51-3-3. Definitions

The following words and phrases, for the purposes of this chapter, shall have the meanings respectively ascribed to them in this section unless the context clearly indicates a different meaning:

* * * * *

(n) "Groundwater" means that water occurring beneath the surface of the ground.

Miss. Code Ann. § 51-3-5. Permit requirement; notice of preexisting rights or beneficial usage

(1) No person who is not specifically exempted by this chapter shall use water without having first obtained a permit as provided herein and without having otherwise complied with the provisions of this chapter, the regulations promulgated hereunder and any applicable permit conditions.

(2) All persons having acquired a right to use surface water prior to April 1, 1985 are entitled to continue such use, provided that such right shall be contingent upon filing a notice of claim to such use with the commission on a form promulgated by the commission. Any person who shall fail to file said notice within three (3) years of April 1, 1985 shall be deemed to have abandoned such use and the right to such use shall automatically terminate without further action of the board.

(3) Any person using groundwater prior to April 1, 1985 for a beneficial use shall be entitled to continue such use upon the filing with the commission of a notice of claim on a form promulgated by the

commission within three (3) years from April 1, 1985. Any such person failing to file said notice of claim within the prescribed period shall be deemed to have abandoned such use and the right to such use shall automatically terminate without further action by the board.

(4) Notwithstanding rights as envisioned in subsections (2) and (3) of this section, all users of water shall continue to be subject to regulations promulgated by the commission regarding the use of surface water and groundwater for the benefit of the health and public welfare of citizens of this state.

(5) As soon as practicable after April 1, 1985, the board shall give notice to all persons affected by the provisions of subsections (2) and (3) of this section regarding the requirement to file the notices of claims mentioned therein. If the names and mailing addresses of such affected persons are available to the board, actual written notice, by certified mail, shall be given by the board. If such names and mailing addresses are not available to the board, notice shall be given by publication at least one (1) time per week for not less than three (3) consecutive weeks in one or more newspapers of general circulation in each county of the state.

TENNESSEE CODE ANNOTATED
Title 68 Health, Safety and Environmental Protection Environmental Protection
Chapter 221 Water and Sewerage
Part 7 Tennessee Safe Drinking Water Act of 1983

Tenn. Code Ann. § 68-221-701. Short title.

This part shall be known and may be cited as the "Tennessee Safe Drinking Water Act of 1983."

Tenn. Code Ann. § 68-221-702. Declaration of policy and purpose.

Recognizing that the waters of the state are the property of the state and are held in public trust for the benefit of its citizens, it is declared that the people of the state are beneficiaries of this trust and have a right to both an adequate quantity and quality of drinking water.

Tenn. Code Ann. § 68-221-703. Part definitions.

As used in this part, unless the context otherwise requires:

* * * * *

(13) "Ground water" means water beneath the surface of the ground, whether or not flowing through known or definite channels;

Tenn. Code Ann. § 68-221-706. Supervision over construction of public water systems.

(a) (1) The department shall exercise general supervision over the construction of public water systems throughout the state.

(2) Such general supervision shall include all

of the features of construction of public water systems which do or may affect the sanitary quality or the quantity of the water supply.

(3) No new construction shall be done nor shall any change be made in any public water system until the plans for such new construction or change have been submitted and approved by the department.

(4) In granting approval of such plans, the department may specify such modification, conditions and regulations as may be required for the protection of the public health and welfare.

(5) The source of raw water and the quantity of raw water to be drawn from the waters of the state are subject to review and approval by the department.

(6) (A) Records of construction, including plans and descriptions of existing works, shall be made available to the department upon request.

(B) The person in charge of the public water supply shall promptly comply with such request.

(b) (1) Any unit of local government which imposes standards and requirements for the construction of public water systems may apply to the commissioner for the commissioner's certification that the locally imposed standards and requirements are at least as sufficient to protect the public health as those of the department.

(2) After certification, submission of plans to and approval by the local government for construction and changes in public water systems shall be sufficient in lieu of approval by the department as otherwise required by this section.

(3) The commissioner may periodically review the local standards and requirements and prescribe changes upon which continued certification may be conditioned.

TENNESSEE CODE ANNOTATED
Title 69 Waters, Waterways, Drains And Levees
Chapter 3 Water Pollution Control
Part 1 Water Quality Control Act

Tenn. Code Ann. § 69-3-102. Declaration of policy and purpose.

(a) Recognizing that the waters of Tennessee are the property of the state and are held in public trust for the use of the people of the state, it is declared to be the public policy of Tennessee that the people of Tennessee, as beneficiaries of this trust, have a right to unpolluted waters. In the exercise of its public trust over the waters of the state, the government of Tennessee has an obligation to take all prudent steps to secure, protect, and preserve this right.

TENNESSEE CODE ANNOTATED
Title 69 Waters, Waterways, Drains And Levees
Chapter 7 Water Management
Part 3 Tennessee Water Resources Information Act

Tenn. Code Ann. § 69-7-303. Part definitions.

As used in this part, unless the context otherwise requires:

* * * * *

(5) "Withdraw" means to take water from any source on a regular or recurring basis by means of an intake structure, pipe and pump that diverts water away from a source, or by any other conveyance with or without the use of suction. This does not include nonrecurring withdrawals, including, but not limited to, the filling of a swimming pool from a residential

water well or accidental withdrawals caused by failure of pipes or equipment.

TENNESSEE CODE ANNOTATED
Title 69 Waters, Waterways, Drains And Levees
Chapter 10 Well Drilling

Tenn. Code Ann. § 69-10-101. Chapter definitions.

As used in this chapter, unless the context otherwise requires:

(1) "Board" means the board of ground water management;

(2) "Commissioner" means the commissioner of environment and conservation, the commissioner's duly authorized representative and, in the event of the commissioner's absence or a vacancy in the office of commissioner, the deputy commissioner of environment and conservation;

(3) "Department" means the department of environment and conservation;

(4) "Drill" means to dig, drill, redrill, construct, deepen or alter a well;

(5) "Geothermal well" means a hole drilled into the earth, by boring or otherwise, greater than twenty feet (20') in depth constructed for the primary purpose of adding or removing British Thermal Units (BTUs) from the earth for heating or cooling;

(6) "Inactive well" means any well that is not in use and that does not have functioning equipment, including bailers, associated either with or attached to the well;

(7) "Installer" means any person who installs or repairs well pumps or who installs filters and water treatment devices;

(8) "Log" means a record of the consolidated or unconsolidated formation penetrated in the drilling of a well, and includes general information concerning construction of a well;

(9) "Monitoring well" means a hole drilled into the earth, by boring or otherwise, constructed for the primary purpose of obtaining information on the elevation or physical, chemical, radiological or biological characteristics of the ground water or for the recovery of ground water for treatment, or both;

(10) "Person" means any individual, organization, group, association, partnership, corporation, limited liability company, utility district, state or local government agency or any combination of them;

(11) "Water well" means a hole drilled into the earth, by boring or otherwise, for the production of water;

(12) "Well" means one of these three (3) types of holes in the earth: a geothermal well, a monitoring well, or a water well; and

(13) "Well owner" means the person who owns the real property on which a well exists or is to be drilled; provided, however, that in the case of any monitoring or remediation required by the department or the commissioner, the well owner shall be the person responsible for such monitoring or remediation.

APPENDIX B

In the
Supreme Court of the United States

No. ______, Original

[Dated April 29, 2014]

STATE OF MISSISSIPPI,	)
Plaintiff,	)
	)
v.	)
	)
STATE OF TENNESSEE, CITY OF	)
MEMPHIS, TENNESSEE, AND	)
MEMPHIS LIGHT, GAS & WATER	)
Defendants.	)
	)

AFFIDAVIT OF C. MICHAEL ELLINGBURG

STATE OF MISSISSIPPI	)
	) ss.
COUNTY OF LAFAYETTE	)

I, C. Michael Ellingburg, counsel of record for the State of Mississippi ("Mississippi"), being first duly sworn, do hereby swear and affirm under oath the following:

1. My name is C. Michael Ellingburg. I am over twenty-one (21) years of age and am competent to make this Affidavit. This Affidavit is based on my personal knowledge.

2. I am counsel of record for Mississippi in the above-styled cause. I am submitting this Affidavit solely in my capacity as attorney for Mississippi and not as a real party-in-interest or potential witness in this or any related proceedings. This Affidavit is submitted for the purpose of identifying and authenticating certain documents and materials presented by Mississippi in support of its Motion for Leave to File Bill of Complaint in Original Action. Some of the documents are excerpts from the Record on Appeal to the Fifth Circuit Court of Appeals in *Hood, ex rel. State of Mississippi v. City of Memphis, Tennessee*, 533 F. Supp.2d 646 (N.D. Miss. 2008), *aff'd*, 570 F.3d 625 (5th Cir. 2009), as evidenced by the alphanumerical designation at the lower right corner of each page of such excerpts beginning with the designation "USCA5."

3. Annexed hereto are true and correct copies of the following:

Exhibit 1	Expert Report of David A. Wiley (partner with Leggette, Brashears & Graham, Inc. and Professional Geologist certified by the American Institute of Professional Geologists) dated April 14, 2014
Exhibit 2	Expert Report of William G. Foster, Ph.D. (Economist) dated April 28, 2014
Exhibit 3	Affidavit of Charles T. Branch, former Director of the Office of Land and Water Resources of the Mississippi Department of Environmental Quality

(without exhibits) [USCA5 1962-USCA5 1966]

Exhibit 4 Tom Charlier, *Memphis Taps Into Desoto County's Water Levels*, The Commercial Appeal (November 16, 1998) [USCA5 1990]

Exhibit 5 Excerpts from David Lewis Feldman, Ph.D., & Julia O. Elmendorf, J.D., *Final Report - Water Supply Challenges Facing Tennessee: Case Study Analyses and the Need for Long-Term Planning* (Environmental Policy Office, Tennessee Department of Environment and Conservation, 2000)[USCA5 1992-USCA5 2000]

Exhibit 6 Excerpts from John G. Morgan, *Special Report - Tennessee's Water Supply: Toward a Long-Term Water Policy for Tennessee*, Treasury of the State of Tennessee (Office of Research) (2002) prepared by Dan Cohen-Vogel, Ph.D. (Principal Research Analyst) and Greg Spradley (Senior Research Analyst), Office of Research

Exhibit 7 Excerpts from United States Geological Survey *Basic Ground-Water Hydrology,* Water-Supply Paper 2220 (2004)

AND FURTHER AFFIANT SAITH NOT.

Executed, this the 29th day of April, 2014.

/s/C. Michael Ellingburg
C. MICHAEL ELLINGBURG

Subscribed and sworn to before me this 29th day of April, 2014 by C. MICHAEL ELLINGBURG.

MY COMMISSION
EXPIRES:
[SEAL]

/s/Melissa D. Kitchens
NOTARY PUBLIC

EXHIBIT 1

UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE

Prepared For:

Jim Hood, Attorney General
of the State of Mississippi

April 14, 2014

Prepared By:

LEGGETTE, BRASHEARS & GRAHAM, INC.
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UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF MISSISSIPPI

EXECUTIVE SUMMARY

The primary source of high quality groundwater in northwest Mississippi is a deep sandstone formation (the Sparta Sand) sandwiched between two confining clay formations. The Sparta Sand is a distinct geological unit in the Middle Claiborne Group. Within north Mississippi and at the common border between Mississippi and Tennessee, the Sparta Sand outcrops at or near the surface at its eastern point of termination, and dips down gradient in a predominantly west/southwest direction as it moves deeper and thickens under Marshall and DeSoto Counties, Mississippi. Rainwater falling over thousands of years on the eastern outcrop areas within Mississippi's borders seeped down gradient at about an inch a day through tiny pores in the sandstone under the force of gravity and hydraulic pressure. Ultimately, the confined Sparta Sand was saturated with high quality groundwater stored under significant pressure beneath northwest Mississippi and southwest Tennessee. Because of the natural east to west/southwest dip of the Sparta Sand in Mississippi, absent pumping, very little of the stored groundwater in northwest Mississippi would ever be available in Tennessee under natural conditions.

Memphis Light, Gas and Water ("MLGW") has pumped groundwater for commercial sale since 1939. For most of this time its pumping was from what it called the "500-foot sand" beneath Memphis. During the latter part of the 1960s and thereafter, MLGW, the City of Memphis and the State of Tennessee became aware that the primary contributor to the groundwater pumped from the 500-foot sand (later "Memphis Sand Aquifer") was in fact the Sparta Sand formation underlying Tennessee and Mississippi. Between 1965 and 2000 MLGW aggressively improved its commercial wells, increased the number of wells, and increased the number of well fields it used to exploit the available groundwater. Pumping increased from approximately 72 million gallons per day (MGD) in 1965 to 162 MGD in 2000. MLGW pumping has significantly exceeded the rate that the groundwater taken out of storage in the confined Sparta Sand could be replenished by natural recharge and as part of MLGW's expansion of groundwater pumping, it developed three well fields (Lichterman, Davis and Palmer) within 3 miles of the Mississippi/Tennessee border. Between 1965 and 2000 the amount of groundwater MLGW pumped from these three Mississippi/Tennessee border well fields increased from approximately 4 MGD in 1965 to approximately 41 MGD in 2000. MLGW's consistently increasing withdrawals and associated drawdown out of natural groundwater storage has been reflected in drops in potentiometric pressure throughout Shelby County, Tennessee, and DeSoto County, Mississippi. In 2000 MLGW cut back its total pumping out of the Sparta Sand from its ten well fields, but they did not cut back their total pumping from the three Mississippi/Tennessee border well fields, and has continued to pump a daily average of approximately 38 and 42 MGD from these three well fields since 2000.

Our analyses show that MLGW has been pumping high quality groundwater out of Mississippi's natural storage in the Sparta Sand into Tennessee since 1965. The magnitude of its pumping from within Mississippi was clearly established in Tennessee by no later than 1985. Between 1985 and 2000, MLGW consistently and materially increased its total pumping from the Mississippi/Tennessee border well fields and has maintained that rate. Based on our analysis of the MLGW pumping and groundwater modeling, it is our opinion that 25 to 35% of the groundwater currently residing beneath Shelby County, Tennessee, was pumped by MLGW out of Mississippi's natural groundwater storage in the Sparta Sand , and that MLGW continues to pump approximately 21 to 24 MGD out of Mississippi's natural storage. In total, we estimate that since 1965 MLGW has pumped approximately 411.3 billion gallons of high quality groundwater out of Mississippi's natural groundwater storage which would never have been available within Tennessee absent MLGW's commercial pumping. The amount taken since 1985 is approximately 252 billion gallons. This groundwater is, for all practical purposes, permanently lost to Mississippi.

1.0 INTRODUCTION

This report was prepared at the request of the Attorney General of the State of Mississippi. It updates and confirms previous work performed for the Attorney General to determine the effect of MLGW's consistent, significant expansion of the commercial water well pumping operations between 1965 and 2000 on Mississippi's natural groundwater storage. Our update report incorporates information from reports issued in the case styled *The State of Mississippi v. The City of Memphis, Tennessee, and Memphis Light, Gas & Water Division* and utilizes consistent methodology, the results of which have been confirmed by the additional data.

This report presents the results of our evaluation of the effects of MLGW's progressively increasing groundwater pumpage on the natural groundwater storage within the confined Sparta Sand within northwest Mississippi. The area of study for the report is shown in **Figure 1**. The tasks performed for this update report by LBG to support our opinions include: confirming existing information regarding the natural pre-development direction of groundwater movement in the Sparta Sand; collecting data on Sparta Sand, and groundwater modeling to show the change in direction of groundwater movement beneath Mississippi caused by changes in the natural hydraulic gradients resulting directly from MLGW pumping; and, performance of calculations to determine the volume of groundwater pumped into the Shelby County, Tennessee, area by MLGW out of Mississippi's natural groundwater storage in the Sparta Sand. These calculations were performed using the flow net methodology and an existing groundwater flow model developed by the USGS. It is our opinion that the results obtained are within the expected range, and consistent with information developed and conclusions presented by other reliable scientific evaluations. Those analyses, and ours, clearly demonstrate that MLGW pumping has withdrawn billions of gallons of Mississippi groundwater from storage in the Mississippi Sparta Sand, permanently taking it out of Mississippi into Tennessee for sale and use in Tennessee.

2.0 BACKGROUND

The primary source of water supply for most of northwest Mississippi and the Memphis, Tennessee areas is the Sparta Sand within the Claiborne Geological Group. The confined Sparta Sand formation beneath northwest Mississippi and southwest Tennessee is a discrete geological formation which has existed for thousands of years. Since its formation, a significant but not unlimited quantity of high quality groundwater was collected and was stored under hydrostatic pressure from rainwater falling on outcrops within each state's current borders. Because it allows the transmission and storage of groundwater in usable quantities and is overlaid by a confining layer, the Sparta Sand is classified as a confined aquifer. But the fact that the geological formation underlies both states does not mean that any meaningful quantity of the groundwater stored over time within either state has ever been naturally shared between the states.

Substantially all of the groundwater naturally collected and stored within the Sparta Sand in each state originated, and was stored inside that state's borders over thousands of years. As a confined aquifer, the natural groundwater storage in each state has resided in the current borders of that state because it naturally seeped from the outcrops in the state and moved exceedingly slowly in a predominantly east to west/southwest direction in Mississippi and an east to west/northwest direction in Tennessee.

The water supply in Shelby County, Tennessee, is primarily provided by groundwater, and most of the groundwater pumped in the county is pumped by MLGW, a public utility owned by the City of Memphis.

Since its creation in 1939, MLGW has relied exclusively on groundwater from what was originally called the "500-foot Sand". In the mid-1960's Tennessee learned that the upper part of the "500-Foot Sand" was correlated with the Sparta Sand (Moore, 1965). Based on available records since 1965, MLGW has consistently, annually increased its groundwater pumping for governmental use and sale in Shelby County and surrounding areas. Between 1965 and 2000, MLGW developed one of the largest artesian water pumping operations in the world, with over 170 commercial water wells located in 10 well fields. Three of these well fields are within 2 to 3 miles of the Mississippi State line just above DeSoto County, Mississippi. **Figure 1** shows the location of MLGW's ten well fields pumping from the Sparta Sand and the approximate quantities pumped in 2012.

Using their very large artesian groundwater pumping and distribution system, between 1965 and 1985 MLGW pumping increased from approximately 72 million gallons per day (MGD) to 132 MGD. As of 1985 (Brahana & Broshears, 2001), Shelby County, Tennessee, groundwater pumping had increased to a rate of approximately 200 MGD. This rate of MLGW pumping continued to increase after 1985 until 2000, and the Sparta Sand in Tennessee has been continuously pumped at a higher rate than it can be naturally recharged based on its geology. As a result, the natural static head pressure within the aquifer has been drawn down by MLGW's pumping in the form of a funnel which reaches into Mississippi as far as south DeSoto County, Mississippi. This area in which the MLGW wells have reduced the pressure and changed the hydraulic gradients can be described as the area of influence of the MLGW wells and is further described in groundwater movement terms as a "cone of depression". This "cone of depression" is centered in and drawing groundwater into MLGW wells and expands outward from there into northwest Mississippi, pulling groundwater into Tennessee which would never have resided within Tennessee under natural conditions. **Figure 2** shows generalized hydrogeological cross sections and has been prepared to distinguish the natural pressure (pre-pumping conditions) in the aquifer from the current pumping conditions. The non-pumping groundwater pressure will raise the water to the level shown as the horizontal dashed blue line labeled pre-development or pre-pumping potentiometric surface. Potentiometric surface is defined in the literature: For a well penetrating a confined aquifer the potentiometric surface is the elevation to which the water rises due to the natural pressure within the aquifer. The upper figure shows several wells pumping with each of their respective potentiometric surface (groundwater level) drawdown cones. This drawdown of the groundwater level around the well forms a cone of depression as shown in the figure. This cone of depression is actually in the shape of a cone or funnel as would be seen three dimensionally and draws the water toward the low point.

While all wells create a cone of depression, the shape and extent, or size, of the cone depends on the rate and duration of the pumping, and the hydraulic properties of the aquifer (groundwater system). If pumping exceeds the rate of recharge, the depth to which a pump is lowered will have to be increased, and the area drained by the cone of depression will continue to grow. The upper part of **Figure 2** with only a few wells pumping shows that the cones of depression for each well do not overlap by exceeding the pre-pumping potentiometric surface causing a regional cone of depression. The lower part of **Figure 2** shows a greater number of wells closer together and their respective cones of depression. In this figure the cones of depression for these wells overlap and stay below the pre-pumping potentiometric surface causing a regional cone of depression. Historically recorded observations show that potentiometric surface (water levels) for the Sparta Sand have declined (dropped) by as much as 100 feet under Memphis since 1886 as a result of MLGW pumping, forming a large cone of depression extending into substantially all of DeSoto County, Mississippi. As a result, recorded water levels in the Sparta Sand under north DeSoto County, Mississippi have been estimated from a USGS model (Arthur and Taylor, 1990) to have declined by up to 90 feet. In a deposition on March 27, 2007 of Charles H. Pickel, a retired MLGW water manager, he confirmed that the cone of depression created by MLGW pumpage extended into northern Mississippi. This current large cone of depression only exists because of the continuous, cumulative increases in groundwater pumping in Shelby County, Tennessee, primarily in MLGW's 170+ commercial wells. Essentially, the ten significant MLGW well field cones of depression overlap forming one, large oval-shaped cone of depression centered in Memphis from which MLGW draws groundwater. **Figure 1** illustrates the area of the larger and somewhat oval-shaped cone of depression that occurs from the cumulative MLGW well field pumping. The Davis, Palmer and Lichterman well fields, which are located near the Mississippi state line, more readily withdraw groundwater out of the Sparta Sand in Mississippi.

Figure 3 is a three-dimensional illustration showing the approximate total area from which the MLGW cone of depression withdraws groundwater. The Arthur and Taylor model shows that Mississippi groundwater has been pulled out of storage and from its natural west/southwest direction of seep and drawn north into Tennessee by the MLGW cone of depression. These conditions were recognized by David Feldman from the University of Tennessee, prompting the publishing of a report titled "Water Supply Challenges Facing Tennessee: Case Study Analyses and the Need for Long-Term Planning (June 2000), David Lewis Feldman, Ph.D., and Julia O. Elmendorf, J.D." In this report the author states that, at a groundwater pumping rate of approximately 145 MGD from the MLGW cone of depression, 20-40 MGD is taken from beneath DeSoto County, Mississippi. The MLGW cone of depression can also be seen in potentiometric surface contour maps presented by Moore, 1960; Criner and Parks, 1976; and Parks, 1990. **Appendix A** contains the maps from these three separate reports.

3.0 SPARTA SAND HYDROGEOLOGY

There are a number of aquifers and confining units in the northwestern Mississippi and southwestern Tennessee area. The major aquifers are the Sparta/Memphis Sand and the Fort Pillow Sand. The Sparta Sand is a distinct geological formation and primary source of groundwater in northwest Mississippi and Shelby County, Tennessee. **Figure 4** is a generalized hydrogeologic cross section showing the Sparta Sand and lower Fort Pillow confined aquifers. .

The Sparta Sand is a thick, variable sand and sandstone formation made up of fine to very coarse sand with lenses of clay and silt (Graham and Parks, 1986). In north Mississippi, the Sparta Sand occurs at a depth of 0 to 600 feet, and varies in thickness between 200 to 900 feet. The formation is thinnest at outcrops at or near the surface in the eastern Shelby County and northwestern Fayette County, Tennessee, and in north Mississippi beginning in east Marshall County. The outcrops continue in a north and south strike along the edge of the Mississippi Embayment in both states. An outcrop is defined as the location where a laterally extensive dipping subsurface rock formation is exposed at or near land surface. **Figure 5** shows the outcrop area of the Sparta Sand. The formation descends from the outcrops, getting progressively thicker, and is thickest near the Mississippi River in Shelby County, Tennessee, and in DeSoto County, Mississippi. Within north Mississippi and along the common border with Tennessee, the Sparta Sand formation has a dominant, gentle dip from eastern outcrops to the west/southwest across north Mississippi and Tennessee to the Mississippi River.

The Sparta Sand is confined above by the Jackson Formation and the upper part of the Claiborne Group which consist primarily of clay, silt and fine sand. This serves as a confining bed retarding vertical groundwater flow between the unconfined surficial aquifer above and the Sparta Sand. Except in areas where the upper confining bed is breached, it protects the high quality of the stored water from surface pollution. The thickness of this confining bed is variable in the Tennessee and northwestern Mississippi areas, ranging from 0 to 360 feet (Graham and Parks, 1986). The Flour Island Formation is a confining bed consisting primarily of silty clay and sandy silt that underlies the Sparta Sand and separates it from the deeper Fort Pillow Sand. The Fort Pillow Sand is comprised of fine to medium-grained sand in the subsurface throughout the Memphis area and is the second most used aquifer by MLGW. The Sparta Sand formation has allowed the transmission and accumulation of high quality water stored under hydrostatic pressure over a long period time within each state's border.

The Sparta Sand is one of the principal and most productive aquifers in Shelby County, Tennessee, and northwestern Mississippi. It is reported that the aquifer provides about 95 percent of the water used for municipal and industrial water supplies in the Memphis area. Aquifer is defined as: A subsurface geologic rock formation capable of storing and transmitting usable amounts of water. This sandstone formation is saturated and stores groundwater collected over thousands of years, and very slowly transmits usable amounts of water within the formation, classifying it as an aquifer. The primary source of any new groundwater for collection and storage in the Sparta Sand is the recharge that occurs from rainfall. This groundwater recharge generally occurs east of Memphis in Tennessee, and in east Marshall County, Mississippi at the outcrop areas as shown on **Figure 5**. Within this outcrop belt, recharge occurs by infiltration of rainfall directly into the sandstone formation or by downward seepage of water from the overlying surficial aquifer. **Figure 6** is a 3-dimensional diagram showing a cross-section of the hydrogeologic formations in the Memphis and northwestern Mississippi area. This diagram shows that the formations are dipping generally from east to west and the Sparta outcrop occurs in the eastern portion of the area. As rain falls on the outcrop area of the Sparta it slowly percolates downward and then under gravity and the weight of the water accumulated above it in the formation slowly provides recharge as it seeps through the tiny pore spaces of the sandstone down gradient following the dip of the formation in a slightly west to southwesterly direction under natural conditions. The groundwater recharge is exceedingly slow seeping through the sandstone at a rate of about 1 inch per day. At this rate, groundwater naturally collected resides in the Sparta Sand for thousands of years as it gradually moves down gradient towards the Mississippi River. **Figure 7** shows the pre-development potentiometric surface under natural conditions generated from groundwater modeling that shows this generally east to west/southwest groundwater directional movement perpendicular to the contours in northwest Mississippi. **Figure 8** is a portion of a cross section from Brahana & Broshears, 2001 further illustrates the dipping of the formations generally from east to west towards the Mississippi River.

4.0 HYDROLOGIC EVALUATIONS

Groundwater conditions can be affected by a number of things that include climatic conditions, hydrogeologic characteristics and pumping from wells. For the purposes of this evaluation, pumpage from Shelby County, Tennessee wells, primarily in MLGW's well fields, has the greatest impact on Mississippi groundwater conditions. This is shown by an evaluation of available hydrologic data.

As discussed in the **BACKGROUND** section of this report, Memphis began using the Sparta Sand as its municipal water supply in 1886. There are no data to suggest that the initial usage had any impact on Mississippi groundwater. However, by the 1970s, available data show that MLGW pumpage began increasing significantly from year to year, and by the late 1990s total Shelby County pumpage had increased to a rate of approximately 200 MGD (Brahana & Broshears, 2001). Approximately 75% of the pumpage was from MLGW wells. The continual increase in groundwater withdrawals in the Memphis area has drawn out groundwater faster than recharge is possible, lowering the potentiometric surface of the aquifer and pressure within the formation, and changing the groundwater flow direction and hydraulic gradients which are represented by the cone of depression. This has resulted in a long-term decline in groundwater levels in the Sparta Sand. This groundwater level condition is observed in hydrographs from observation wells monitored by the Tennessee USGS. Hydrographs were developed from actual water-level measurements collected in the field by USGS personnel and presented in the May 2007 LBG report. These hydrographs show that water levels have declined from approximately 20 to 50 feet in these area observation wells since 1958. **Figure 9** included in this report contains two hydrographs representative of those presented previously in the LBG May 2007 report.

The USGS has also prepared groundwater elevation maps of the potentiometric surface for the Sparta Sand that shows the declining water-level conditions across the southwest Tennessee and northwest Mississippi. The potentiometric surface is the groundwater level that water in an aquifer will rise to in a tightly cased well. Potentiometric surface maps illustrate the groundwater hydraulic gradient across a given area. Potentiometric surface maps were prepared for the following years; 1960, 1970, 1980, 1988, 1990, 1995, 2000 and 2005 and are presented in the May 2007 LBG report. **Figure 10** shows the potentiometric surface for year 2000, which has a similar and representative pattern as the potentiometric surface for the other seven years. As with the hydrographs, the potentiometric surface maps are based on actual water-level measurements. Water levels in the Sparta Sand in Shelby County, Tennessee, have declined by approximately 100 feet since 1886 forming a large cone of depression. Water levels in the Sparta Sand under northern DeSoto County, Mississippi have been estimated from a USGS model developed by Arthur and Taylor, 1990, to have declined by up to 90 feet.

These potentiometric surface maps provide information regarding groundwater hydraulic gradient showing the flow direction which is always perpendicular to contours. While the natural movement of the groundwater in the Sparta Sand is east to slightly southwest, the recent potentiometric maps all show that the groundwater flow in northwest Mississippi is now drawn radially to the north toward the center of Memphis where the lowest water levels are observed in the aquifer. This large cone of depression seen on **Figure 10** has been created by the cumulative groundwater pumping (hundreds of wells) in Tennessee, from the MLGW well fields. Groundwater gradient or flow direction is discussed further in the following section on **FLOW NET METHODOLOGY**.

4.1 Flow Net Methodology

The movement of groundwater in a regional confined groundwater system is defined by a set of equipotential lines, boundary conditions, and corresponding flow lines. Equipotential lines are contour lines of the potentiometric surface elevations in an aquifer, as defined by water levels in wells open to a specific aquifer. Boundary conditions can be physical geologic features that define the extent of an aquifer, or hydraulic boundaries such as recharge and discharge boundaries. Flow lines define the direction of groundwater flow based on the configuration of the equipotential lines and boundary conditions. **Figure 7** is an example of equipotential lines (potentiometric surface) and its respective flow field for pre-development or natural conditions. A flow field or flow net is a graphical representation of the groundwater flow system consisting of a set of equipotential lines and corresponding flow lines (Freeze and Cherry, 1979). It should be noted that the flow net method of analysis is a standard application utilized by hydrologists to calculate groundwater flow volumes driven by a gradient and is a relatively simple and straight forward process.

Flow nets are constructed from potentiometric surface contour maps, such as those published by the U.S. Geological Survey (USGS) or from groundwater model-derived potentiometric surface contour maps.

These flow nets can reflect changes in the hydraulic gradient of the aquifer caused by pumping. Flow lines define the direction of groundwater from high potentiometric head to low potentiometric head using four basic rules: 1) flow lines and equipotential lines must intersect at right angles; 2) equipotential lines must meet impermeable boundaries at right angles; 3) equipotential lines must parallel constant head boundaries; and 4) if the flow net is constructed such that squares are created between two equipotential lines in one portion of the flow field, then squares must exist between these equipotential lines across the flow field (Freeze and Cherry, 1979). Rules 1 and 4 are the basis for construction of a flow net to define the amount of flow through a specified portion of a regional groundwater flow system. Calculation of flow through a section of aquifer is based on the Darcy Equation:

$$\mathbf{q = K(dh/ds)(dm)(b)}$$

where **K** is aquifer hydraulic conductivity, **dh** is the change in head between two adjacent equipotential lines, **ds** and **dm** are the dimensions of the square defined by an orthogonal set of equipotential line and flow lines (referred to as a flow tube), and **b** is the aquifer thickness. If the flow net is constructed based on a series of squares **(ds = dm)** across the area of interest, the total flow through the area of interest is calculated as:

$$\mathbf{Q = K(dh)(b)(m)}$$

where **m** is the number of flow tubes across the area of interest. **Figure 11,** that is included in this report, illustrates the flow net concept as presented by Freeze and Cheery.

Flow nets were prepared using potentiometric surface maps from the USGS for the years 1980, 1988, 1990, 1995, 2000 and 2005. In the portion of Mississippi beyond the extent of equipotential lines on the USGS map, the equipotential lines were extended manually based on configurations derived from groundwater modeling results. The flow nets were based on a series of squares using two adjacent equipotential lines located east of the major withdrawals in Shelby County by MLGW along the border with DeSoto County, Mississippi. The flow lines were then extended up gradient and down gradient from the squares by maintaining right angles at the intersections with each equipotential line. The number of flow tubes that showed groundwater flowing from Mississippi into Tennessee was then totaled for calculation of the total groundwater flow from Mississippi.

Flow nets were constructed for the years 1980, 1988, 1990, 1995, 2000 and 2005. The flow nets for these six years all show very similar groundwater flow path patterns. **Figure 12** is included in this report showing the flow net for year 2000. From the shape of the potentiometric contours in **Figure 12**, the cone of depression caused by MLGW pumping can be seen. The flow lines on the figure also show that groundwater flow direction perpendicular to the potentiometric contours is towards Memphis from Mississippi has changed for the patterns for pre-development conditions seen on **Figure 7**. Our flow net analysis indicated that flow of groundwater from Mississippi to Tennessee in the Sparta Sand was approximately 36.5 MGD in 1980, 39.8 MGD in 1988, 1990, and 1995, 43.2 MGD in 2000, and 33 MGD in 2005. The results of this analysis are supported by information reviewed from a deposition that took place on August 7, 2006 of Dr. Randall W. Gentry, a former Director of the Ground Water Institute at the University of Memphis. Of particular interest was a flow net analysis performed by Dr. Gentry in the 1999 to 2000 time frame. Dr. Gentry estimated that about 25 % to 1/3 of the pumpage occurring in the Memphis, Tennessee, area is derived from the groundwater system in Mississippi. He based his analysis on a potentiometric surface map prepared by the USGS for the 1988 period.

Groundwater modeling was utilized to assist in calculating the groundwater flow contributions from Mississippi due to changes in pumpage from Shelby County, Tennessee, and is described in the following section.

4.2 Groundwater Modeling

Groundwater flow models are tools utilized by hydrogeologists and engineers to simulate a groundwater flow system. Assuming that hydrogeologic data is available for the area of concern, the hydrogeologist or engineer will first develop a conceptual model that is a simplified framework of the hydrogeologic system and is used to develop a groundwater flow model. Next, a model code is selected, such as MODFLOW to set up the model. A model grid is created to define the horizontal and vertical dimensions of the aquifer system. Boundary conditions are assigned to define the regional flow system. Aquifer characteristics are assigned to the model grid system of nodes or cells to define the hydraulic properties of the aquifer and confining layers. Recharge (rainfall), discharge (evapotranspiration and groundwater pumpage), and in some cases, streams, are included in the model to simulate the natural hydrologic cycle. The model is then run and the results are compared to observed groundwater level data from the area being evaluated. The input data are then adjusted until an acceptable match between observed and modeled water levels are obtained. This adjustment process is referred to as model calibration. The calibrated model is then used to perform predictive simulations.

In order to conduct our analysis for calculating the flow of groundwater taken from beneath Mississippi, as a result of MLGW pumpage, it was determined that groundwater modeling was a necessary tool to utilize. After reviewing the literature, several candidate groundwater models were identified and reviewed for potential use on this project. They were all calibrated at the time of their development. Those models are identified below.

1. Hydrogeology and Ground-Water Flow in the Memphis and Fort Pillow Aquifers in the Memphis Area, Tennessee, Water-Resources Investigations Report 89-4131 by J.V. Brahana and R.E. Broshears. U.S. Geological Survey. 2001.

2. A Ground Water Flow Model of the Northern Mississippi Embayment by David Kenley of Ground Water Institute, The University of Memphis, 1993.

3. A Ground Water Flow Analysis of the Memphis Sand Aquifer in the Memphis, Tennessee Area by Jamie Outlaw of Ground Water Institute, The University of Memphis, 1994.

4.3 Groundwater Modeling Simulations

After reviewing these three models, it was decided that the USGS model by Brahana and Broshears (2001) was appropriate to use for all model simulations in this evaluation. The Brahana and Broshears (2001) model was used because it includes both the Sparta Sand and contributing aquifers in Shelby County including the Fort Pillow aquifer. Even though the "David Kenley" and "Jamie Outlaw" models were derived from Brahana and Broshears (2001) model, they were not considered since they only include the Fluvial deposits and Sparta Sand and contributing sands, but do not include the Fort Pillow aquifer. The Fort Pillow aquifer is one of the major aquifers and not simulating its heads is likely to under-predict its contribution and affect the regional groundwater budget. A detailed description of the groundwater flow model prepared by the USGS,

> ***Hydrogeology and Ground-Water Flow in the Memphis and Fort Pillow Aquifers in the Memphis Area, Tennessee, Water-Resources Investigations Report 89-4131 by J.V. Brahana and R.E. Broshears, U.S. Geological Survey, 2001,***

was presented previously in the May 2007 LBG report. Following is a brief summary description of the model.

This is a regional groundwater model constructed by Brahana and Broshears to determine changes in regional flow from pre-development time to 1980 due to changes in pumpage in Sparta/Memphis Sand and Fort Pillow aquifers. The geographic extent of the model grid area is shown in **Figure 13** included in this report. The report includes the hydrogeology of the Sparta Sand and the Fort Pillow aquifers in the Memphis, Tennessee and northwestern Mississippi area. The model grid consists of three-layers, which are, from top to bottom: a) Fluvial Deposits; b) Sparta Sand Aquifer; and c) Fort Pillow Aquifer. A brief summary of a description by Brahana and Broshears of the three aquifers (layers) is as follows:

The Brahana and Broshears model is a transient groundwater model with hydrologic data from 1886 to 1980. The model is comprised of 8 stress-periods. The model was developed using the USGS finite difference groundwater flow code, MODFLOW (McDonald and Harbaugh, 1988). The model grid has 58 rows and 44 columns, with grid spacing varying between 3200 feet to 100,000 feet in the horizontal directions (north-south and east-west). Finer grid-spacing was done within the Memphis area. The interaction between the confining layers within the model is replicated by leakance terms, using the MODFLOW VCONT array. All three layers in the model were simulated as a confined aquifer (LAYCON 0). Calibration was concentrated on stress periods from 1961 to 1980. Calibration was conducted by adjusting the global multiplier of transmissivity, vertical conductance, and storage coefficients for the Sparta/Memphis Sand and Fort Pillow aquifers.

For our analysis, water-level conditions of the Sparta Sand were of primary interest. The MODFLOW input data files were input into Groundwater Vistas (ESI, 2006). Groundwater Vistas is a pre- and post-processor and includes USGS MODFLOW code to perform numerical simulations.

Pre-development simulation was conducted by turning off the well package of MODFLOW. **Figure 14** included in this report, shows the model-computed potentiometric surface of the Sparta/Memphis Sand aquifer prior to 1886, which is considered to represent predevelopment or pre-pumping conditions. This figure shows that the pre-development groundwater flow direction for the Sparta Sand was generally from east to west/southwest toward the Mississippi River in Mississippi. This pre-development potentiometric surface map was presented by Brahana, 2001 and has been published by others who have performed hydrologic analyses in the region. Post-development modeling scenarios were initially conducted from 1924 to 1980. The post-development includes changes in hydraulic stress due to pumpage in the Sparta Sand and Fort Pillow aquifers. **Figure 15** contained in this report, shows the potentiometric surface at the end of the 1980 stress period in the Sparta/Memphis Sand aquifer. During the post-development stage, i.e., in the year 1980, the potentiometric surface in the Memphis area was significantly altered due to pumpage in the Sparta/Memphis Sand aquifer as evidenced by the shapes of the contours on the figure. The "bull's-eye" areas in the figure are indicative of significant drawdown or cones of depression. The bending of the potentiometric contours in northwest Mississippi (DeSoto County) indicates that groundwater pumpage occurring in the Memphis area is affecting groundwater conditions in DeSoto County. This same effect on groundwater levels in northwest Mississippi can be seen from work performed by others including Arthur and Taylor, 1990; Kinley, 1993; and Outlaw, 1994. **Appendix B** contains figures from each of these three reports that show water-level contour maps for the potentiometric surface of the Sparta/Memphis Sand aquifer. All of the maps show a cone of depression extending into northwest Mississippi. A comparison of **Figure 14**, pre-development potentiometric surface vs **Figure 15,** 1980 potentiometric surface, the cone of depression shows that the groundwater flow direction has been altered and groundwater is being diverted northward due to the Memphis pumpage.

Since the original Brahana and Broshears model was developed only through 1980 it was determined to update the model in order to begin evaluating more current conditions. LBG updated the Brahana and Broshears model for the period of 1983 to 1993 using pumpage data from the "David Kenley model". That updated model is described in the May 2007 LBG report.

Since the objective of this project is to calculate the flow of groundwater from Mississippi to Memphis as a result of groundwater pumping to as near the current as possible, it was decided to further update the model. This was deemed necessary since groundwater data were not readily available to prepare potentiometric surface maps. In order to further update the model, pumpage data were necessary. Pumpage data from several sources were reviewed for use in this modeling exercise. These sources included the USGS Water Use Estimates reports, MLGW production reports and pumpage estimates for various utilities in Mississippi. We also utilized population estimates and projections where necessary. The model was then further updated through 2005 and eventually through 2012 by including several additional stress periods. Potentiometric surface maps for 1995, 2000, 2005, 2006, 2010 and 2012 are shown respectively, on **Figures 16 - 21**. These maps are similar to potentiometric surface maps presented previously, which are based on actual water-level data collected by the USGS. These relatively good comparisons provide confidence in the updated model.

4.4 Groundwater Drawdown

Groundwater drawdown at the end of each modeled stress period was determined by subtracting the groundwater heads after each stress period from the pre-development groundwater heads. Drawdown in the Memphis area significantly increased with time in the Sparta Sand for the year 1980 as shown on **Figure 22**. In the Memphis area, drawdown in some places was as much as 100 feet in the Sparta Sand. This figure shows the extent of the cone of depression formed for the Sparta Sand as a result of the groundwater pumpage mostly from Memphis.

The drawdown contours in the Sparta Sand tend to be longitudinally oriented, between the Mississippi River and the aquifer outcrop in the east. Due to the higher heads of the Mississippi River (simulated in the model as a constant head in layer -1), an effective hydrologic boundary is created and preventing the drawdown cone of depression from moving out into Arkansas. The Sparta Sand outcrops to the east in Tennessee and Mississippi, and in many places it gets direct recharge from precipitation, and as a result the cone of depression is prevented from moving further out in the east. **Figures 23 through 28** contained in this report, show the cone of depression or drawdown by as much as 120 feet for the 1995, 2000, 2005, 2006, 20010 and 2012 periods, respectively, in the Sparta

Sand using the updated Brahana and Broshears model. The cone of depression on each of these drawdown maps shows the groundwater flow has been diverted from Mississippi to the Memphis area of Tennessee due to Memphis pumpage.

4.5 Groundwater Budget Analysis

A groundwater budget analysis was conducted using the updated Brahana and Broshears model which includes the time period from 1886 to 2005. The groundwater budget represents the components of inflows, outflows and changes in storage to the aquifer. Groundwater budget analysis for the Memphis area was conducted using the U.S. Geological Survey MODFLOW model (Brahana and Broshears, 2001). Once the model simulations were completed the cell-by-cell flow data for each of the zones were calculated for a specified time interval, which provides the amount of inflow and outflow such as pumping wells, constant heads, and storage out and into the county. The groundwater budget also provides amount of net flow being contributed by one county to another county due to stress in the system such as pumping wells. The net flow indicates the difference of flow from the developmental conditions to pre-development conditions (i.e., prior to any pumpage).

The focus of the budget analysis was to determine the net groundwater flow to the Shelby County, Tennessee area from DeSoto and Marshall Counties, Mississippi. **Figure 29**included in this report shows a plot of net flow of groundwater to the Shelby County area under the influence of MLGW pumpage. The contribution or diversion of groundwater to Shelby County, Tennessee from DeSoto and Marshall Counties has steadily increased with time. In 1924 the diversion from DeSoto and Marshall Counties was 4.18 MGD, whereas in 1993 the diversion was 35.57 MGD. This increased flow from DeSoto and Marshall Counties to Shelby County is attributed to an increase in pumpage from the MLGW wells. The high pumpage creates a cone of depression that stretches as far south as DeSoto County with pronounced drawdown near the political boundary between Shelby County and DeSoto County. Some of the largest well fields of Shelby County, such as Davis and Lichterman well fields operated by MLGW are very close to the state boundary between Tennessee and Mississippi causing significant drawdown and groundwater flow from DeSoto County to Shelby County, Tennessee. Moore in 1960 also presented a groundwater budget for the Memphis area. His analysis, which was based on 1960 data, shows that 25 MGD of groundwater is derived as underflow through the Sparta Sand from Mississippi. The results depicted in **Figure 29** are in the same range of values reported by Moore in 1965, Criner in 1964, Feldman in 2000, Gentry in 2000 and Arthur in 2006.

After 1993 to 2005, the contribution from DeSoto and Marshall Counties to Shelby County decreased to 33.27 MGD. This decrease can be observed on **Figure 29** and included in this report. Even though pumpage in Shelby County increased, the decrease in contribution from DeSoto and Marshall Counties likely resulted from increases in pumpage from DeSoto County, which reduces the amount of groundwater available to flow into Shelby County.

It is our opinion that based on our hydrologic evaluation and from the review of technical reports, groundwater pumpage from the MLGW has created a large cone of depression that has altered natural aquifer flow paths, and as a result is diverting and taking groundwater from beneath the state of Mississippi.

5.0 EVALUATION OF MLGW PUMPAGE ON MISSISSIPPI GROUNDWATER

It is clear from our review of a number of technical reports described previously that a large cone of depression of the potentiometric surface for the Sparta Sand has been developed as a result of groundwater pumpage from the Memphis, Tennessee. Most of this pumpage that is diverting Mississippi's groundwater is attributable to MLGW. This cone of depression extends into northern Mississippi and has altered the groundwater gradient. The groundwater gradient of the Sparta Sand has been altered from its natural generally east to west flow direction to a northerly direction. **Figures 30 and 31** are potentiometric surface maps for pre-development and 2012, respectively. Each of these maps also shows groundwater flow direction. The pre-development flow direction shown in **Figure 30** in northwestern Mississippi is generally from east to west/southwest in Mississippi with a very small flow component into Tennessee. The 2012 flow direction in **Figure 31** shows that it has been significantly diverted towards Memphis as a result of MLGW pumpage.

MLGW is by far the largest groundwater user in the area. They operate over 170 wells from more than 10 well fields for providing water supply to the City of Memphis and surrounding area. Wells in these 10 well fields withdraw groundwater from the Sparta/Memphis

Sand aquifer, which is the principal aquifer in the region. **Table 1** lists historical pumpage for the 10 well fields from 1965 through 2012. From 2006 through 2012 an apparent slight decreasing trend is observed.

It was decided that since MLGW is by far the largest groundwater user in the area, the impacts from MLGW pumpage only from the Shelby County area should be evaluated. In order to accomplish this, the Brahana and Broshears model was utilized. For this exercise, all ground-withdrawals, with the exception of those for the 10 MLGW well fields and those in northern Mississippi (primarily DeSoto County), were removed from the model set-up. The model was then rerun utilizing historical pumpage since 1965 to 2006 and then updated through 2012. The updated pumpage is shown in **Table 2**. The purpose of this modeling exercise was to determine the amount of drawdown, extent of the cone of depression and volume of groundwater diverted from northern Mississippi due to MLGW pumpage. **Appendix C** of this report contains a series of potentiometric surface and drawdown maps showing the effects of pumping every five years beginning in 1965 through 2006 and updated for select years through 2012. It is clear from the review of these maps that MLGW pumpage has caused a cone of depression that extends well into northern Mississippi. The potentiometric surface maps for 2006 and 2012 clearly show that the pre-development groundwater flow direction from generally east to west in northwestern Mississippi has been altered and is now diverted in a more northerly direction towards the MLGW pumping centers. The drawdown maps for 2006 and 2012 also clearly show that a large cone of depression has formed due to MLGW pumpage and extends well into DeSoto County Mississippi. The maps show that a great deal of DeSoto County experiences more than 10 feet of drawdown due to MLGW pumpage. In the extreme north-central part of DeSoto County, more than 20 feet of drawdown occurs as a result of MLGW pumpage.

Presented earlier in this report is information developed by LBG and others that indicates groundwater is flowing from Mississippi to the Memphis area due to large amounts of pumpage occurring in the Memphis area. The groundwater flow modeling that has been presented in this report that addresses MLGW pumpage also shows that groundwater is flowing from Mississippi to the Memphis area due to the MLGW pumpage. A groundwater budget analysis was also performed from this modeling effort to determine the amount of groundwater that is diverted from northern Mississippi to the Memphis area due to MLGW pumpage. Groundwater budget represents the components of inflows, outflows and changes in storage to the aquifer. A detailed description of budget analysis using MODFLOW was presented earlier in this report. DeSoto and Marshall Counties in Mississippi are of interest in this evaluation since they are in northern Mississippi. The total volumes for those two counties for each year from 1965 through 2006 and through 2012 are presented in **Table 3**. For example, the volume of water taken from DeSoto and Marshall Counties in 2006 is 24.1 MGD and in 2012 is 20.98. In fact, the total volume of groundwater taken from Mississippi due to MLGW pumpage since 1965 is calculated to be approximately 411.3 billion gallons.

It is interesting to observe that in **Table 3** starting in the early 1990s the volumes taken from Mississippi begin to continually decrease. The largest volume of 28.2 occurred in 1988. This decrease can also be observed in **Table 3**. Even though MLGW pumpage continued to increase from 1965 through 2006, the decrease in contribution from DeSoto and Marshall Counties likely resulted from increases in pumpage from DeSoto County, which reduced the amount of groundwater available to flow into Shelby County. As a result, the increased pumpage in DeSoto County is preventing the increased pumpage from MLGW to take some of the groundwater from the northern Mississippi area. Also, beginning in 2006 a decrease in MLGW pumpage began to occur as shown in **Table 1**. As a result of this decrease in MLGW pumpage, a further decrease in diversion from DeSoto County occurs. Based on the volumes shown in **Table 3** beginning in 2001, it appears that some stabilization of the volume of water taken from DeSoto and Marshall Counties has occurred. Therefore, it is very likely that unless groundwater withdrawal conditions in either state change radically from those that have occurred from 2001 through 2012, the volume of approximately 21 to 24 MGD being taken from Mississippi will not change in the future.

6.0 CONCLUSIONS

The primary purpose of our investigation as presented in this report is the evaluation of the effects on groundwater flows in northwestern Mississippi as a result of groundwater pumpage in the Memphis area of Tennessee, most of which is attributable to MLGW. This evaluation included the review of existing technical reports and hydrologic data from the USGS, University of Memphis GWI, MLGW and the MDEQ and the performance of calculations to determine the volume of groundwater that is coming from the aquifer beneath Mississippi due to pumping from the Memphis area, focusing on MLGW. These calculations were performed using the flow net methodology and an existing groundwater flow model developed by the USGS.

It is clear from our review of a number of technical reports described previously that a large cone of depression of the potentiometric surface for the Sparta/Memphis Sand aquifer has been developed as a result of groundwater pumpage from the Memphis, Tennessee area. Most of this pumpage that is diverting Mississippi's groundwater is attributable to MLGW. This cone of depression extends into northern Mississippi and has altered the groundwater gradient. The groundwater gradient of the Sparta Sand has been altered from its natural east to west/southwest flow direction and diverted to a northerly direction. This finding is also confirmed from our review of water-level data associated with potentiometric surface maps prepared by the USGS and from groundwater flow modeling. Observations have shown that water levels in the Sparta/Memphis Sand aquifer have declined (dropped) by as much as 100 feet since 1886 forming a large cone of depression. As part of this cone of depression, water levels under northern DeSoto County, Mississippi have been estimated from a USGS model (Arthur and Taylor, 1990) to have declined by up to 90 feet. In a deposition on March 27, 2007 of Charles H. Pickel, a retired MLGW water manager, he indicated that the cone of depression created by MLGW pumpage extended into northern Mississippi. These conditions were recognized by David Feldman from the University of Tennessee prompting the publishing of a report titled "Water Supply Challenges Facing Tennessee: Case Study Analyses and the Need for Long-Term Planning (June 2000), David Lewis Feldman, Ph.D., and Julia O. Elmendorf, J.D." In this report the author states that, at a groundwater pumping rate of approximately 145 million gallons per day (MGD) from the Memphis area a cone of depression is formed and 20-40 MGD is derived from beneath DeSoto County which is located in northwestern Mississippi. The cone of depression of the Sparta Sand can also be seen in potentiometric surface contour maps presented by Moore, 1960; Criner and Parks, 1976; and Parks, 1990.

Flow net analysis was performed utilizing several USGS potentiometric surface maps. These maps were constructed for the years 1980, 1988, 1990, 1995, and 2000. The flow net analysis indicated that flow of groundwater from Mississippi to the Memphis area in the Sparta Sand was approximately 36.5 MGD in 1980, 39.8 MGD in 1988, 1990, and 1995, 43.2 MGD in 2000, and 33 MGD in 2005.

Groundwater flow modeling was also performed to supplement the flow net analyses for calculating groundwater flow contribution or diversion from Mississippi as a result of Memphis area pumpage. The modeling exercises were performed utilizing the USGS model prepared by Brahana and Broshears (2001). Flow amounts calculated from the model for 1980 was 33.5 MGD, for 1983 was 34.5 MGD, for 1991 was 35.6 MGD, for 1995 was 32.3 MGD, for 2000 was 33.2 MGD and for 2005 was 33.3 MGD. These quantities are in the same range of values reported by Moore in 1965, Criner in 1964, Feldman in 2000, Gentry in 2000 and Arthur in 2006. From the review of **Table 4** contained in this report, which shows the pumpage amounts from DeSoto County, an increase in pumpage from DeSoto County can be observed after 1993. This corresponds with a decrease in the flow diversion from DeSoto County to Shelby County calculated from the model. As a result, the increased pumpage in DeSoto County is preventing the increased pumpage from the Memphis area to divert and take some of the groundwater from the northern Mississippi area.

Based upon the Brahana Model, our own independent flow net analysis, potentiometric surface mapping, groundwater modeling, and our review of studies by other reputable scientists and water policy analysts (as discussed herein), it is our opinion that (1) Memphis area pumpage, primarily by MLGW, has altered the natural flow path and created a cone of depression in the Sparta Sand, resulting in the diversion of Mississippi's groundwater; and (2) over the period of 1965 to 2006, an estimated 25 % to 35 % of Memphis area water supply has been taken from Mississippi.

Since MLGW is by far the largest groundwater user in the Memphis area, it was decided that impacts from their groundwater pumpage should be evaluated. This was accomplished by utilizing the Brahana and Broshears (2001) model. The model was run utilizing historical pumpage from 1965 to 2006 and updated through 2012. The modeling results show a large cone of depression extending into northern Mississippi.

Table 3 lists the volumes derived from the modeling exercise for each year beginning in 1965 through 2012 that are taken from Mississippi groundwater as a result of MLGW pumpage. The groundwater budget analysis showed that currently approximately 24 MGD in 2006 and 21 MGD in 2012 of Mississippi groundwater is being diverted towards Memphis due to MLGW pumpage. The total volume of groundwater taken from Mississippi due to MLGW pumpage since 1965 is calculated to be approximately 411.3 billion gallons.

It appears that this quantity will not change significantly in the future. Our evaluation also shows that 15 % to 22 % of MLGW's groundwater withdrawals are obtained from diversions of groundwater beneath Mississippi as shown in the table below.

Year	Percent Volume Taken	Year	Percent Volume Taken	Year	Percent Volume Taken
1965	19	1981	20	1997	16
1966	20	1982	20	1998	16
1967	20	1983	19	1999	16
1968	20	1984	19	2000	15
1969	20	1985	19	2001	15
1970	21	1986	19	2002	15
1971	21	1987	19	2003	15
1972	22	1988	19	2004	15
1973	21	1989	19	2005	15
1974	21	1990	19	2006	15

1975	20	1991	18	2007	16
1976	20	1992	18	2008	16
1977	20	1993	18	2009	15
1978	20	1994	18	2010	15
1979	20	1995	16	2011	15
1980	20	1996	16	2012	15

It is our opinion that based on our analysis and the review of technical reports produced by others, groundwater pumpage from MLGW in the Memphis area has created a large cone of depression that has altered natural aquifer flow paths, and as a result is diverting and taking groundwater from beneath the state of Mississippi at a rate of approximately 21 to 24 MGD.

7.0 REFERENCES

Arthur, J.K. and Taylor, R.E. 1990. Definition of the geohydrologic framework and preliminary simulation of ground-water flow in the Mississippi Embayment aquifer system, Gulf Coastal Plain, United States: U.S. Geological Survey Water-Resources Investigations Report 86-4364, 97 p.

Brahana, J.V. 1981. Ground Water Supply, Chapter 3 – Final Report Metropolitan Area Urban Water Resources Study: U.S. Geological Survey.

Brahana, J.V. 1982a. Digital Ground Water Model of the Memphis Sand and Equivalent Units, Tennessee, Arkansas, Mississippi: U.S. Geological Survey Open-File Report 82-99, 55 p.

Brahana, J.V., and Broshears, R.E., 2001. Hydrogeology and Ground-Water Flow in the Memphis and Fort Pillow Aquifers in the Memphis Area, Tennessee, Water-Resources Investigations Report 89-4131, 56 p.

Criner, J.H., Sun, P-C.P., and Nyman, D.J. 1964. Hydrology of the aquifer systems in the Memphis Area, Tennessee: U.S. Geological Survey Professional Paper 1779-O, 54 p.

E.M. Gushing, E.H. Boswell, and R.L. Hosman, General Geology of the Mississippi Embayment, Water Resources of the Mississippi Embayment, (1964) Department of the Interior, Geological Survey Professional Paper 448-B

Environmental Simulations Incorporated (ESI), 2006. Groundwater Vistas a pre-and post-processors.

Feldman, D. L., Ph.D., and Elmendorf, J. O., J.D., Final Report – Water Supply Challenges Facing Tennessee: Case Study Analyses and the Need for Long-Term Planning (June 2000).

Freeze, R.A., and Cherry, J.A., 1979. Groundwater: Englewood Cliffs, New Jersey, 604 p.

Graham, D.D., and Parks, W.S., 1986. Potential for leakage among principal aquifers in the Memphis area, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 85-4295, 46 p.

Hosman, R.L., Long, A.T., and Lambert, T.W., and others. 1968. Tertiary aquifers in the Mississippi embayment, *with discussions* of Quality of the water by

H.G. Jeffrey: U.S. Geological Survey Professional Paper 448-D, 29 p.

McDonald, M.G. and Harbaugh, A.W. 1988. A modular three-dimensional finite difference ground-water flow model, USGS Techniques of Water-Resources Investigations, Book 6.

Mississippi Embayment Regional Ground Water Study, EPA 600R/-10/130, 1 January 2011

Moore, 1965. Geology and hydrology of the Claiborne Group in western Tennessee: U.S. Geological Survey Water-Supply Paper 1809-F, 44 p.

Parks, W.S., and Carmichael, J.K. 1989a. Geology and ground-water resources of the Memphis Sand in western Tennessee: U.S. Geological Survey Water Resources Investigations Report 88-4182. 30 p.

T.P. Schrader, Potentiometric Surface in the Sparta-Memphis Aquifer of The Mississippi Embayment, Spring 2007, Scientific Investigations Map 3014, 2008

Wells, F.G., 1933. Ground-water resources of western Tennessee, *With a discussion of* Chemical character of the water by F.G. Wells and M.D. Foster: U.S. Geological Survey Water-Supply Paper 656, 319 p.

W. S. Parks and J. K. Carmichael, Altitude of Potentiometric Surface, FUN 1985, and Historic Water-Level Changes in the Memphis Aquifer in Western Tennessee, U.S. Geological Survey Water-Resources Investigations Report 88-4180 (1990a).

TABLES

LEGGETTE, BRASHEARS & GRAHAM, INC.

Table 1

MEMPHIS LIGHT, GAS AND WATER DIVISION
CITY OF MEMPHIS

Water Pumpage By Stations
Gallons Per Day
1965-2012

[*Fold-out Exhibit, See Next Page*]

Table 1

MEMPHIS LIGHT, GAS AND WATER DIVISION
CITY OF MEMPHIS

Water Pumpage By Stations
Gallons Per Day
1965-2012

	Sheahan	Mallory	Allen	Lichterman	McCord	Davis	Palmer	Morton	LNG	Shaw	TOTAL	Starting	Ending	Monthly	Comments (If not raw pumpage data)
Row	41	41	45	44	33	50	48	33	26	33		Bates #	Bates #	or Yearly	
Column	25	17	21	29	25	17	24	18	26	32					
1965	17,773,000	13,268,000	22,519,000	4,220,000	14,181,000						71,961,000	MLGW 66416		Yearly	Net Pumpage
1966	16,991,000	12,618,000	22,969,000	9,697,000	13,472,000						75,747,000	MLGW 66417		Yearly	Net Pumpage
1967	15,870,000	12,364,000	22,592,000	13,277,000	13,599,000						77,702,000	MLGW 66417		Yearly	Net Pumpage
1968	15,961,000	12,582,000	23,430,000	14,621,000	14,487,000						81,081,000	MLGW 66417		Yearly	Net Pumpage
1969	15,063,000	11,961,000	23,934,000	16,192,000	15,495,000						82,645,000	MLGW 66418		Yearly	Net Pumpage
1970	15,556,000	11,231,000	27,167,000	16,775,000	16,211,000	3,258,000			101,000		90,299,000	MLGW 66418		Yearly	Net Pumpage
1971	18,332,000	12,953,000	25,420,000	15,585,000	15,930,000	7,487,000			151,000		95,858,000	MLGW 66418		Yearly	Net Pumpage
1972	15,927,000	15,973,000	22,024,000	16,373,000	15,491,000	10,204,000	2,801,000		249,000		99,042,000	MLGW 66419		Yearly	Net Pumpage
1973	17,167,583	18,880,000	21,578,667	18,084,333	17,281,583	10,867,333	2,776,333	1,660,000	174,166		108,469,998	MLGW 67682	MLGW 67741	Monthly	
1974	17,579,833	20,101,500	22,193,750	18,142,667	15,353,667	10,617,083	2,944,833	2,354,083	255,750		109,543,166	MLGW 67622	MLGW 67681	Monthly	
1975	18,130,916	19,148,583	21,276,750	17,378,916	19,111,750	11,688,416	3,047,666	160,500	243,833		110,187,330	MLGW 67562	MLGW 67621	Monthly	
1976	19,007,000	20,641,000	19,947,000	18,148,000	18,721,000	11,370,000	3,158,000	3,000	260,000		111,255,000	MLGW 66420		Yearly	Net Pumpage
1977	18,564,000	22,114,000	21,680,000	18,809,000	19,986,000	13,226,000	3,360,000	5,000	268,000		118,012,000	MLGW 66420		Yearly	Net Pumpage
1978	16,055,000	20,785,000	21,316,000	20,517,000	21,086,000	13,779,000	3,545,000	34,000	361,000		117,478,000	MLGW 67562	MLGW 67848	Monthly	
1979	17,419,000	20,294,000	19,867,000	22,645,000	22,164,000	14,125,000	2,869,000	4,000	327,000		119,714,000	MLGW 67831	MLGW 67835	Monthly	
1980	20,744,000	20,953,000	21,591,000	23,151,000	20,700,000	13,262,000	3,186,000	53,000	343,000		123,983,000	MLGW 67818	MLGW 67882	Monthly	
1981	21,229,000	20,375,000	19,305,000	21,633,000	21,556,000	11,526,000	3,425,000	20,000	339,000		119,408,000	MLGW 67805	MLGW 67809	Monthly	
1982	21,465,000	17,526,000	20,508,000	22,524,000	19,124,000	11,591,000	2,850,000	5,618,000	421,000		121,627,000	MLGW 67791	MLGW 67795	Monthly	
1983	22,914,000	17,338,000	20,947,000	22,163,000	17,269,000	12,705,000	179,000	10,874,000	465,000		124,855,983	MLGW 67778	MLGW 67782	Monthly	
1984	20,743,000	18,693,000	21,102,000	21,850,000	20,772,000	12,244,000	724,000	11,091,000	460,000		127,680,984	MLGW 67765	MLGW 67769	Monthly	
1985	20,499,000	21,784,000	23,607,000	21,550,000	20,764,000	11,294,000	255,000	11,402,000	500,274	-	131,655,274	MLGW 0003		Yearly	Net Pumpage
1986	20,310,411	20,834,795	24,906,027	24,151,781	20,575,068	12,620,548	138,904	12,447,671	554,247	-	136,539,452	GWI 013666	GWI 013684	Monthly	
1987	18,876,438	20,218,082	24,590,411	24,483,562	20,714,795	12,785,753	293,425	12,953,425	530,411	-	135,446,301	GWI 013685	GWI 013722	Monthly	
1988	21,445,479	21,059,178	24,733,973	25,466,575	20,743,562	12,714,521	1,681,096	14,218,082	526,849	-	142,589,315	GWI 012946	GWI 013051	Monthly	
1989	19,761,096	19,727,397	21,925,753	24,121,370	20,559,726	11,349,589	3,776,712	13,705,753	397,260	-	135,324,658	GWI 013082	GWI 013208	Monthly	Some Net pumpage used for Nov - MLGW 00005
1990	21,005,205	19,690,959	24,137,260	23,247,945	19,839,178	10,447,671	4,101,644	12,236,712	434,247	5,867,397	141,008,219	GWI 01321	GWI 013384	Monthly	Net pumpage used for Jan - MLGW 00005
1991	20,998,082	20,714,795	21,012,603	21,771,507	18,516,438	10,135,890	5,079,178	10,465,753	393,151	10,983,562	140,070,959	GWI 012341	GWI 012487	Monthly	
1992	20,023,836	20,626,849	20,444,110	21,130,685	19,223,562	9,701,918	5,337,534	10,458,904	423,014	11,872,603	139,243,014	GWI 012490	GWI 012636	Monthly	
1993	19,548,219	20,222,192	21,248,767	21,801,644	18,483,836	9,960,000	4,808,767	12,719,726	497,534	10,325,479	139,616,164	GWI 012639	GWI 012785	Monthly	
1994	20,627,397	15,901,370	21,576,712	21,936,438	17,695,890	11,866,027	4,938,356	14,360,548	477,260	12,982,466	142,362,466	GWI 012787	GWI 012943	Monthly	
1995	20,570,137	16,029,315	22,800,548	21,915,342	17,398,082	12,569,863	4,903,562	17,106,301	529,589	14,177,260	148,000,000	GWI 011938	GWI 012085	Monthly	
1996	20,170,137	17,329,589	22,532,055	21,929,041	17,373,425	14,135,616	4,668,767	18,168,767	515,342	13,058,630	149,881,370	GWI 012087	GWI 012235	Monthly	
1997	19,556,438	15,529,315	22,114,521	21,377,534	15,968,493	14,602,466	4,284,658	16,915,068	444,384	14,880,000	145,672,877	GWI 012239	GWI 012337	Monthly	Net pumpage used for Sept-Dec - MLGW 00009
1998	21,355,068	17,229,863	22,910,137	23,288,767	15,794,795	15,442,466	4,090,411	17,976,986	419,726	17,894,795	156,403,014	GWI 011534	GWI 011631	Monthly	Net pumpage used for Jan-Apr - MLGW 00009
1999	21,441,370	18,560,548	25,246,575	23,447,397	16,404,932	12,718,356	5,067,945	18,886,027	493,425	19,609,863	161,876,438	GWI 011632	GWI 011767	Monthly	Some Net pumpage used - MLGW 00010
2000	21,641,370	17,321,096	24,287,123	22,502,466	17,129,589	13,992,603	4,998,082	19,012,329	369,315	20,854,521	162,108,493	GWI 011773	GWI 011911	Monthly	Net pumpage used for May - MLGW 00010
2001	19,443,014	17,588,767	19,972,329	19,626,575	16,318,904	17,500,548	4,785,205	17,477,260	446,301	20,248,493	153,407,397	MLGW 00011		Yearly	Net Pumpage
2002	18,140,000	17,300,000	22,000,000	18,550,000	15,550,000	19,000,000	4,525,000	18,000,000	475,000	20,983,333	154,523,333	MLGW2 03771 **CD**		Monthly	
2003	15,616,666	15,708,333	22,383,333	18,133,333	16,066,667	19,508,333	5,108,333	18,941,667	334,167	20,100,000	151,900,832	MLGW2 03771 **CD**		Monthly	
2004	15,775,000	16,075,000	21,858,333	17,700,000	16,341,667	19,641,667	5,150,000	18,741,667	400,000	22,666,667	154,350,001	MLGW2 03771 **CD**		Monthly	
2005	15,266,667	17,141,667	21,675,000	19,158,333	17,700,000	20,225,000	3,383,333	18,783,333	558,333	23,000,000	156,891,666	MLGW2 03771 **CD**		Monthly	
2006	16,658,333	16,575,000	21,358,333	19,550,000	17,458,333	20,566,667	4,166,667	18,341,667	358,333	21,200,000	156,233,333	MLGW2 03771 **CD**		Monthly	
2007	15,944,167	16,335,833	19,518,333	19,852,500	16,528,333	21,447,500	4,173,333	16,946,533	360,000	22,879,167	153,985,700			Monthly	
2008	13,724,167	12,552,075	19,653,333	17,886,667	15,801,667	19,312,500	4,002,500	17,174,167	471,667	22,777,500	143,356,242			Monthly	
2009	12,895,000	13,594,167	19,072,500	17,191,667	16,713,333	17,517,500	4,173,333	17,405,000	414,167	21,349,167	140,325,833			Monthly	
2010	14,673,333	15,620,833	19,414,167	19,205,833	18,050,833	19,156,667	3,945,833	18,084,167	555,000	22,617,500	151,324,167			Monthly	
2011	12,204,167	13,573,333	16,038,333	17,151,667	16,538,333	17,512,500	3,195,000	15,785,833	414,167	20,342,500	132,755,833			Monthly	
2012	13,055,000	14,755,833	17,163,333	18,685,833	16,694,167	19,038,333	4,275,000	17,343,333	461,667	22,120,833	143,593,333			Monthly	

Table 2 - Pumpage Amounts From Shelby and DeSoto Counties

Year	Shelby County (MGD)	DeSoto County (MGD)
2007	154.9	11.09
2008	144.3	10.69
2009	141.2	12.44
2010	152.3	14.44
2011	133.6	13.37
2012	144.4	15.31

Table 3 - Volume of Groundwater Taken from Mississippi Due to MLGW Pumpage

Years	MGD
1965	13.64
1966	15.27
1967	16.08
1968	16.86
1969	17.32
1970	19.44
1971	20.73
1972	21.98
1973	23.46
1974	23.80
1975	22.85
1976	23.01
1977	24.59
1978	24.70
1979	25.11
1980	26.26
1981	24.73
1982	25.00
1983	24.96
1984	24.95
1985	25.41
1986	26.90
1987	26.72

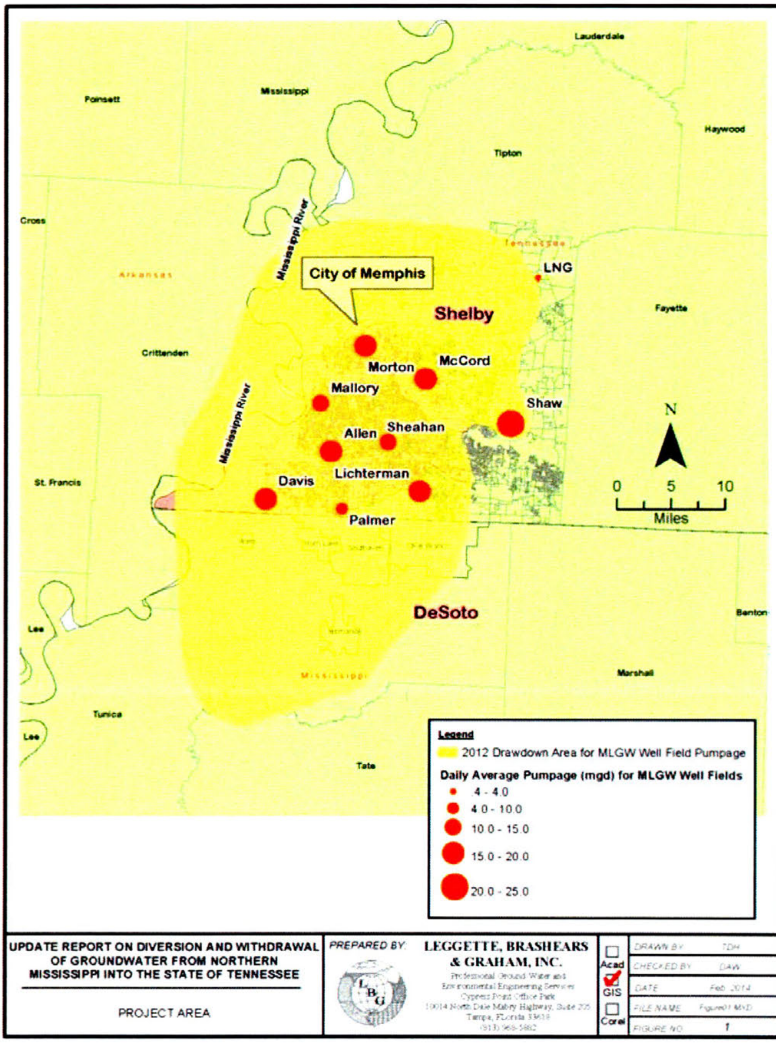
61a

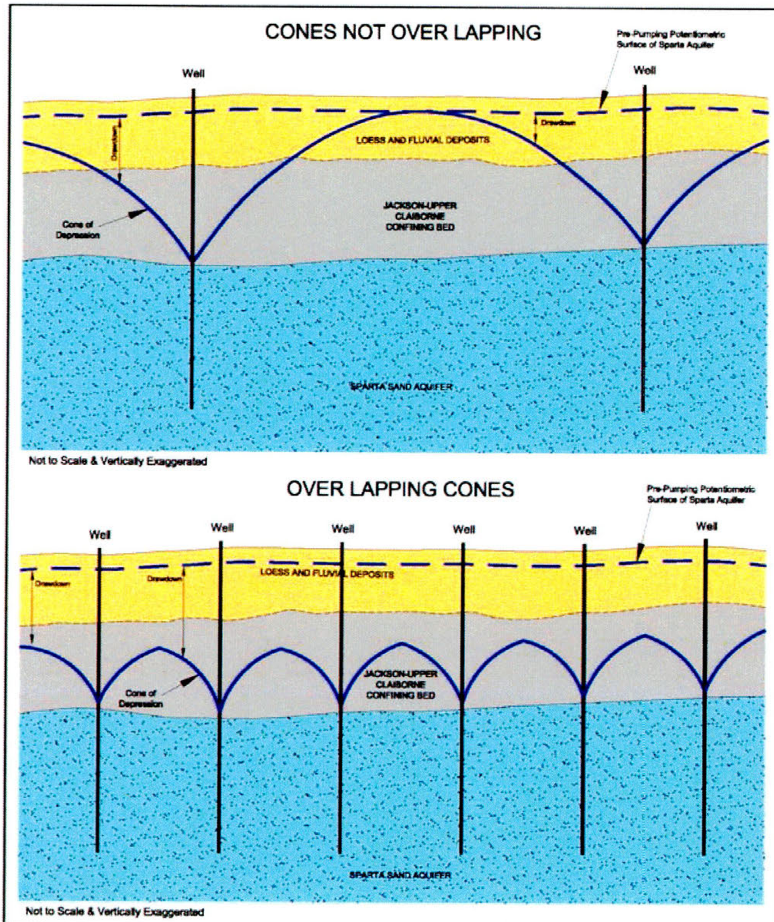
1988	28.33
1989	26.95
1990	27.26
1991	26.17
1992	25.61
1993	25.85
1994	26.39
1995	24.14
1996	24.65
1997	23.83
1998	25.53
1999	26.02
2000	25.66
2001	24.05
2002	24.33
2003	24.08
2004	23.95
2005	23.81
2006	24.29
2007	25.00
2008	22.86
2009	21.29
2010	22.59
2011	19.47
2012	20.98

Table 4 - Pumpage Amounts From DeSoto County

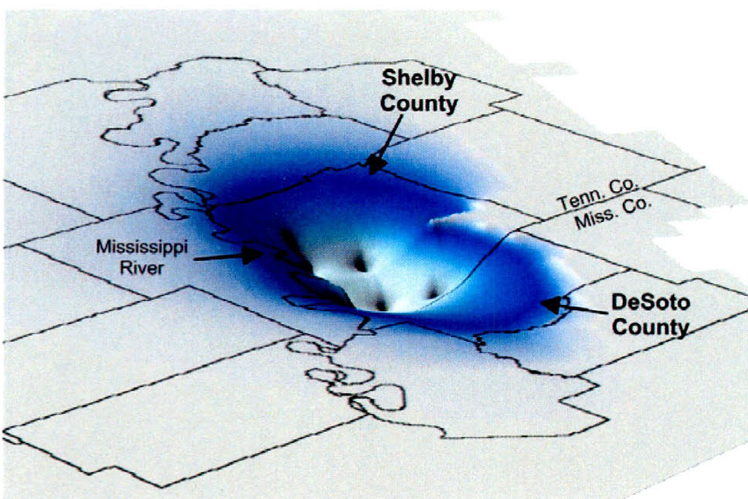
Years	DeSoto, MS-- Pumpage From Model (MGD)
1886 - 1924	0
1924 - 1941	0
1941 - 1955	0
1955 - 1960	0.497
1960 - 1965	0.898
1965 - 1970	1.23
1970 - 1975	4.18
1975 - 1980	4.18
1980 - 1983	3.6
1983 - 1991	3.6
1991 - 1993	3.6
1993 - 1995	13.05
1995 - 2000	13.40
2000 - 2005	14.00
2007	11.09
2008	10.69
2009	12.44
2010	14.44
2011	13.37
2012	15.31

FIGURES

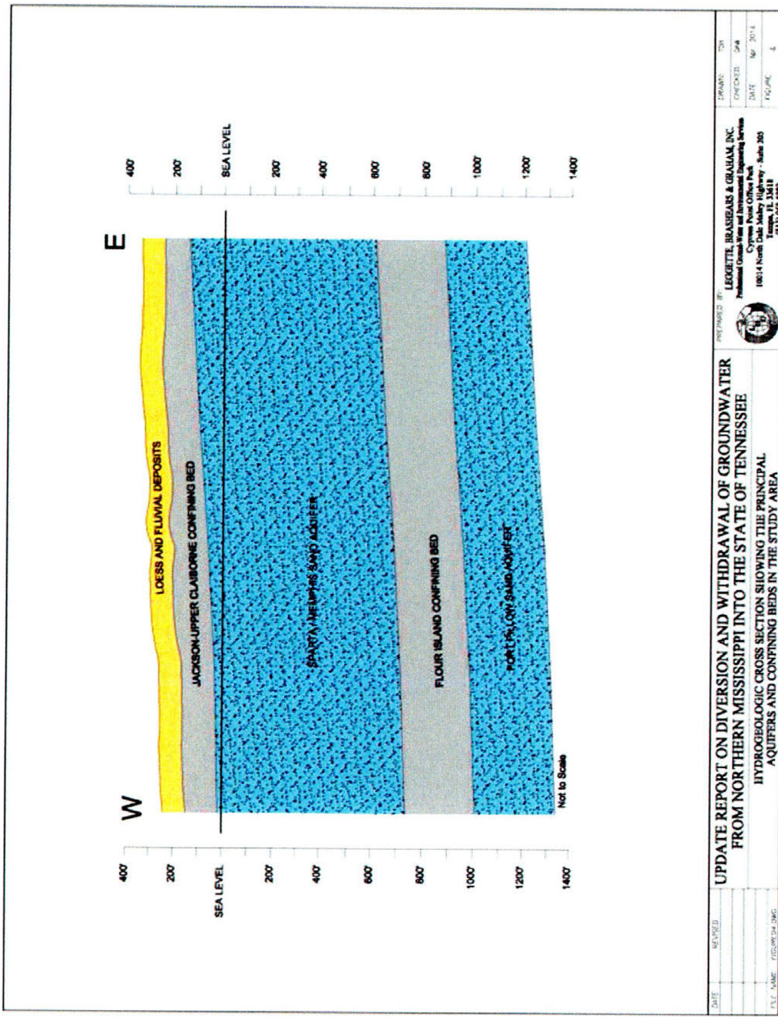

Lauderdale
Poinsett
Mississippi
Haywood
Tipton
Cross
Mississippi River
Tennessee
City of Memphis
LNG
Arkansas
Shelby
Fayette
Crittenden
Morton
McCord
Mallory
Mississippi River
Shaw
N
Allen
Sheahan
St. Francis
Davis
Lichterman
0
5
10
Miles
Palmer
DeSoto
Benton
Lee
Marshall
Mississippi
Tunica
Lee
Tate
Legend
2012 Drawdown Area for MLGW Well Field Pumpage
Daily Average Pumpage (mgd) for MLGW Well Fields
.4 - 4.0
4.0 - 10.0
10.0 - 15.0
15.0 - 20.0
20.0 - 25.0
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
PROJECT AREA
PREPARED BY:
LEGGETTE, BRASHEARS & GRAHAM, INC.
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Feb. 2014
FIGURE NO. 1

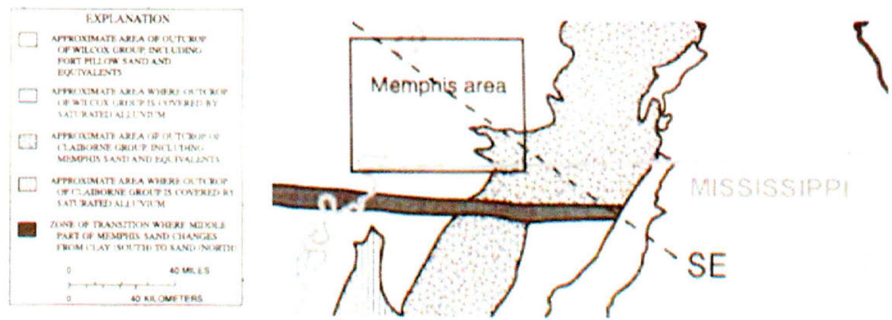


DATE	REVISED		PREPARED BY	
		UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE	LEGGETTE, BRASHEARS & GRAHAM, INC. Professional Ground-Water and Environmental Engineering Services Cypress Point Office Park 10014 North Dale Mabry Highway - Suite 205 Tampa, FL 33618 (813) 968-5882	DRAWN: TDH
				CHECKED: DAW
		HYDROGEOLOGIC CROSS SECTION SHOWING AN EXAMPLE OF CONES OF DEPRESSION		DATE: Apr 2014
FILE NAME: FIGURE02.DWG				FIGURE 2



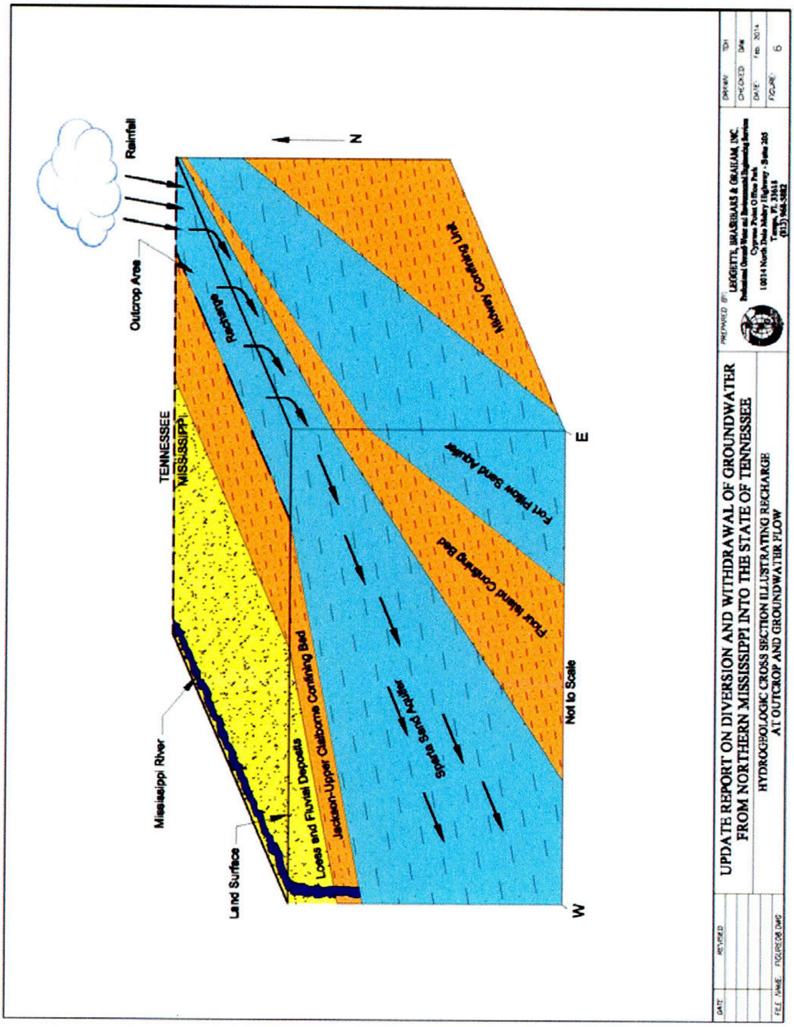
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE THREE-DIMENSIONAL ILLUSTRATION SHOWING CONE OF DEPRESSION	PREPARED BY LEGGETTE, BRASHEARS & GRAHAM, INC. Professional Ground Water and Environmental Engineering Services Cypress Point Office Park 10014 North Dale Mabry Highway, Suite 205 Tampa, Florida 33618 (813) 968-3882	Acad GIS Corel	DRAWN BY TDH CHECKED BY DAW DATE Apr 2014 FILE NAME Figure03.MXD FIGURE NO 3


E
W
400'
200'
SEA LEVEL
200'
400'
600'
800'
1000'
1200'
1400'
LOESS AND FLUVIAL DEPOSITS
JACKSON-UPPER CLAIBORNE CONFINING BED
SPARTA / MEMPHIS SAND AQUIFER
FLOUR ISLAND CONFINING BED
FORT PILLOW SAND AQUIFER
Not to Scale
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER
FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
HYDROGEOLOGIC CROSS SECTION SHOWING THE PRINCIPAL
AQUIFERS AND CONFINING BEDS IN THE STUDY AREA
PREPARED BY:
LEGGETTE, BRASHEARS & GRAHAM, INC.
Cypress Point Office Park
Tampa, FL 33618
DATE
REVISED
DRAWN:
CHECKED:
DATE
FIGURE
4



Map of the northern Mississippi Embayment (NME) showing approximate distribution of outcrop and subcrop of the Wilcox and Claiborne group sediments (From Brahana and Broshears, 2001). Dashed line shows trace of cross-section shown in Figure 3

DATE	REVISED			PREPARED BY		
			UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE	**LEGGETTE, BRASHEARS & GRAHAM, INC.** Professional Groundwater and Environmental Engineering Services, Cypress Point Office Park, 10014 North Dale Mabry Highway, Suite 205, Tampa, FLorida 33618, (813) 968-5882	DRAWN BY	TDH
					CHECKED BY	DAW
					DATE	Apr 2014
FILE NAME	FIGURE05.MXD		MAP FROM THE NORTHERN MISSISSIPPI EMBAYMENT		FIGURE NO.	5


Rainfall
Outcrop Area
Recharge
N
TENNESSEE
MISSISSIPPI
Mississippi River
Land Surface
Loess and Fluvial Deposits
Jackson-Upper Claiborne Confining Bed
Sparta Sand Aquifer
Flour Island Confining Bed
Fort Pillow Sand Aquifer
Midway Confining Unit
E
W
Not to Scale
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
HYDROGEOLOGIC CROSS SECTION ILLUSTRATING RECHARGE AT OUTCROP AND GROUNDWATER FLOW
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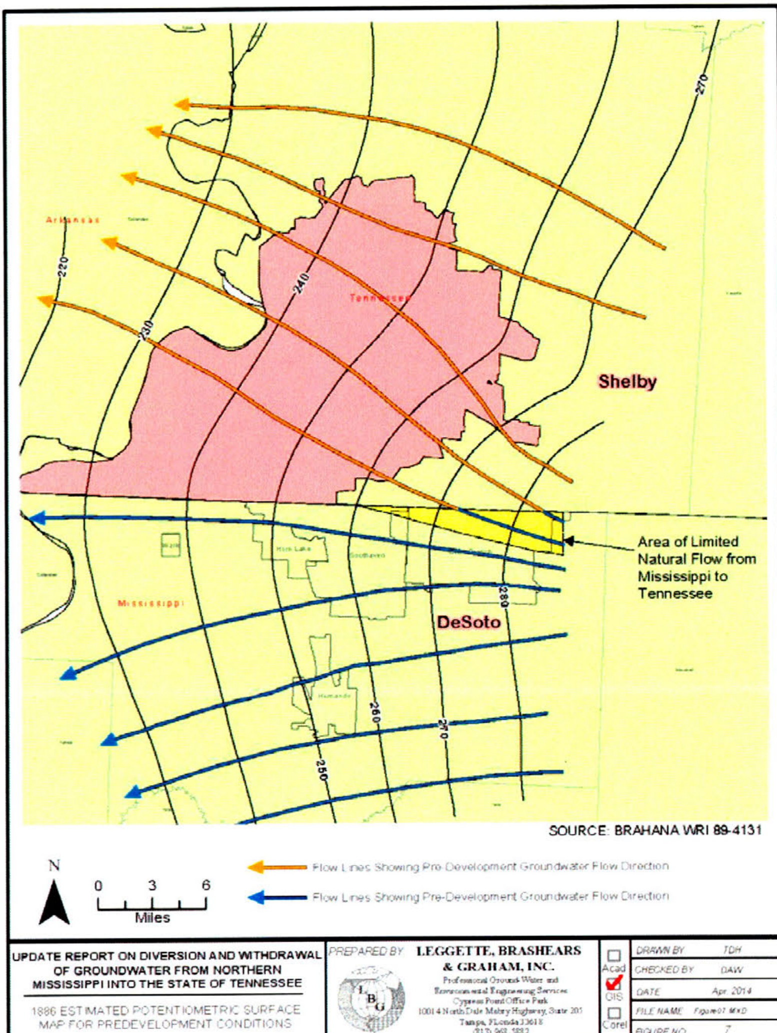
DRAWN: TDH
CHECKED: DW
DATE: Feb. 2014
FIGURE: 6
DATE
REVISED
FILE NAME: FIGURE06.DWG


Arkansas
Tennessee
Mississippi
Shelby
DeSoto
220
230
240
250
260
270
280
Area of Limited Natural Flow from Mississippi to Tennessee
SOURCE: BRAHANA WRI 89-4131
N
0 3 6
Miles
Flow Lines Showing Pre-Development Groundwater Flow Direction
Flow Lines Showing Pre-Development Groundwater Flow Direction
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
1886 ESTIMATED POTENTIOMETRIC SURFACE MAP FOR PREDEVELOPMENT CONDITIONS
PREPARED BY
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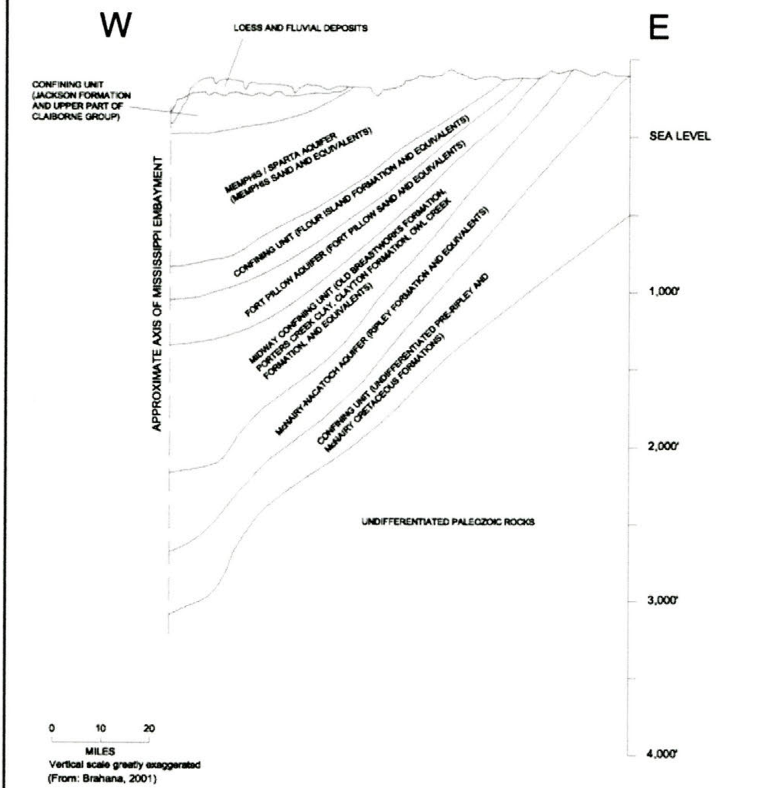
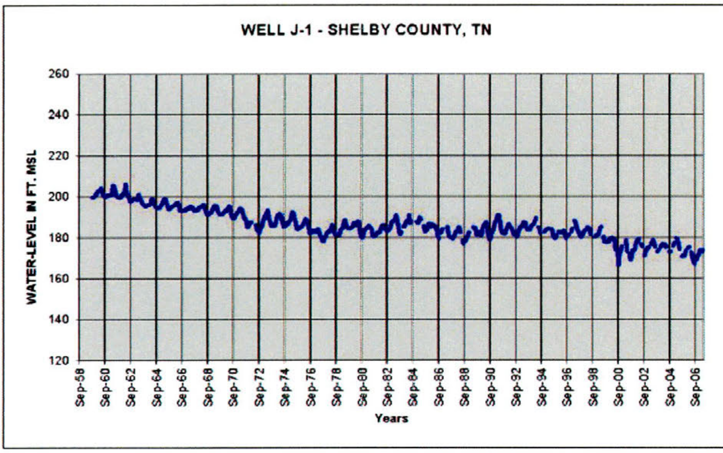
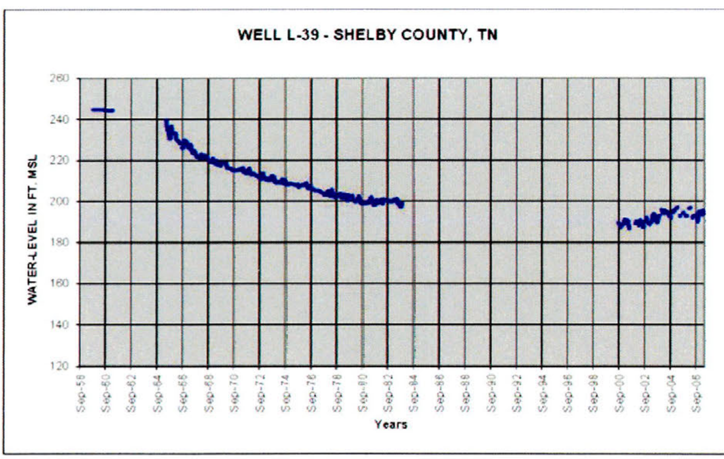
Cypress Point Office Park
Tampa, Florida 33618
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Apr. 2014
FIGURE NO 7



DATE	REVISED		PREPARED BY	
		UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE	LEGGETTE, BRASHEARS & GRAHAM, INC. Professional Ground-Water and Environmental Engineering Services Cypress Point Office Park 10014 North Dale Mabry Highway - Suite 205 Tampa, FL 33618 (813) 968-5882	DRAWN: TDH
				CHECKED: DAW
		HYDROGEOLOGIC SECTION SHOWING PRINCIPAL AQUIFERS AND CONFINING UNITS, EAST TO WEST, THROUGH THE MISSISSIPPI EMBAYMENT		DATE: Apr. 2014
FILE NAME: FIGURE08.DWG				FIGURE: 8





UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE

SPARTA / MEMPHIS SAND AQUIFER HYDROGRAPHS

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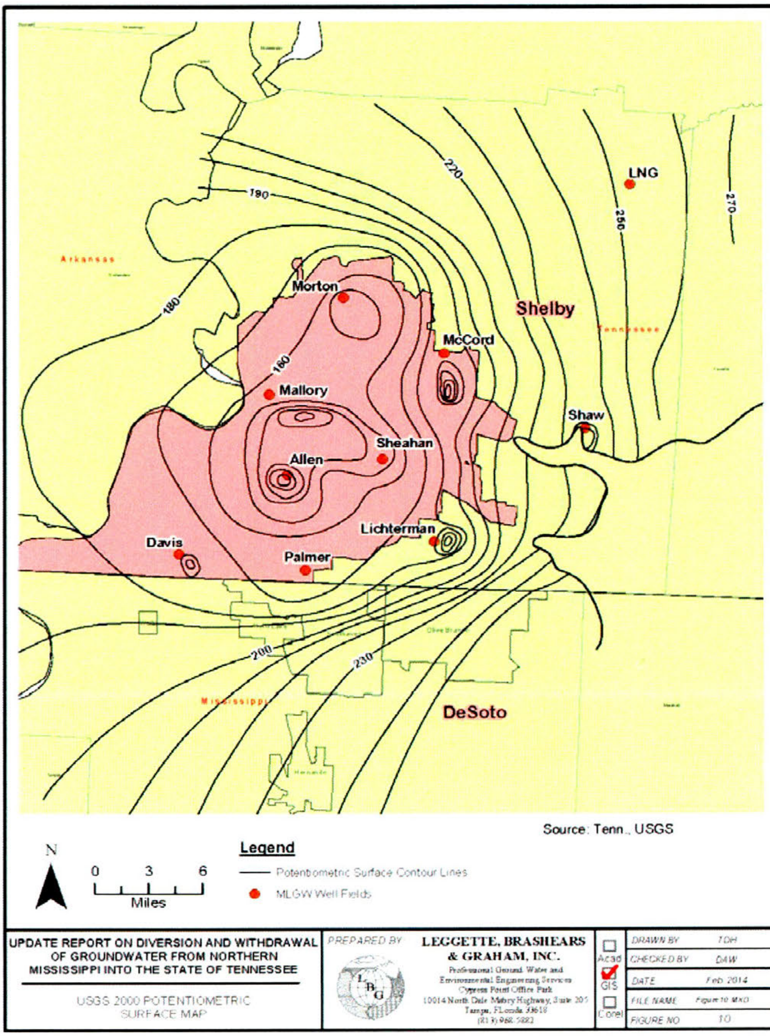
GIS	CHECKED BY	DAW
Corel ✔	DATE	Apr 2014
	FILE NAME	Figure09.xls
	FIGURE NO.	9


190
220
250
270
LNG
Arkansas
180
Morton
Shelby
Tennessee
McCord
180
Mallory
Shaw
Sheahan
Allen
Lichterman
Davis
Palmer
200
230
Mississippi
DeSoto
Source: Tenn., USGS
N
0 3 6
Miles
Legend
Potentiometric Surface Contour Lines
MLGW Well Fields
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
USGS 2000 POTENTIOMETRIC SURFACE MAP
PREPARED BY
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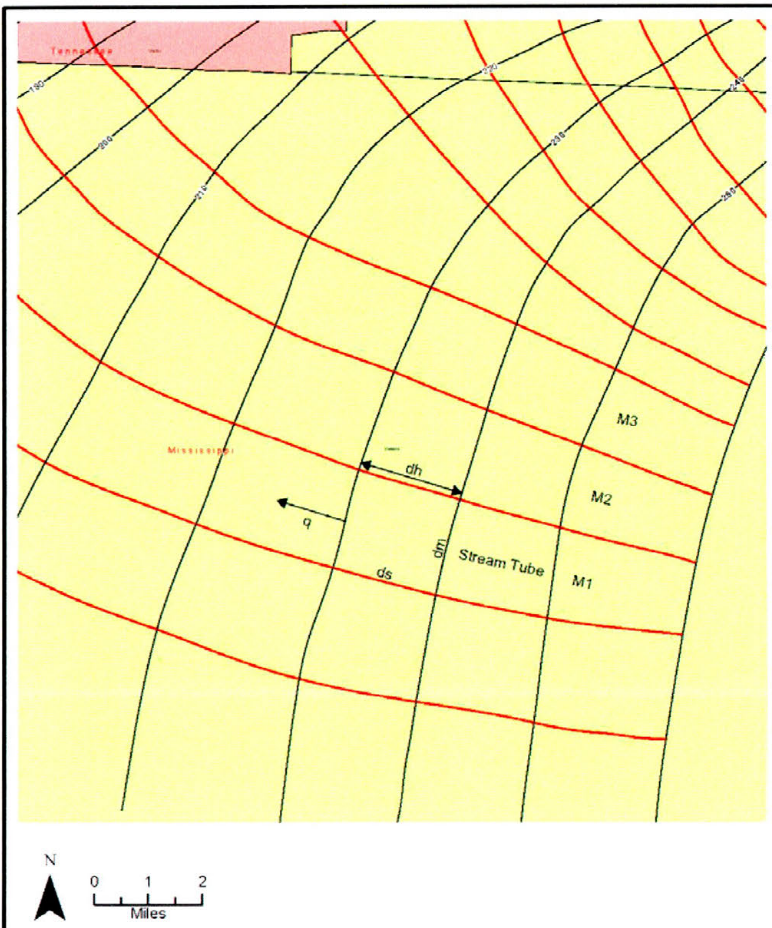
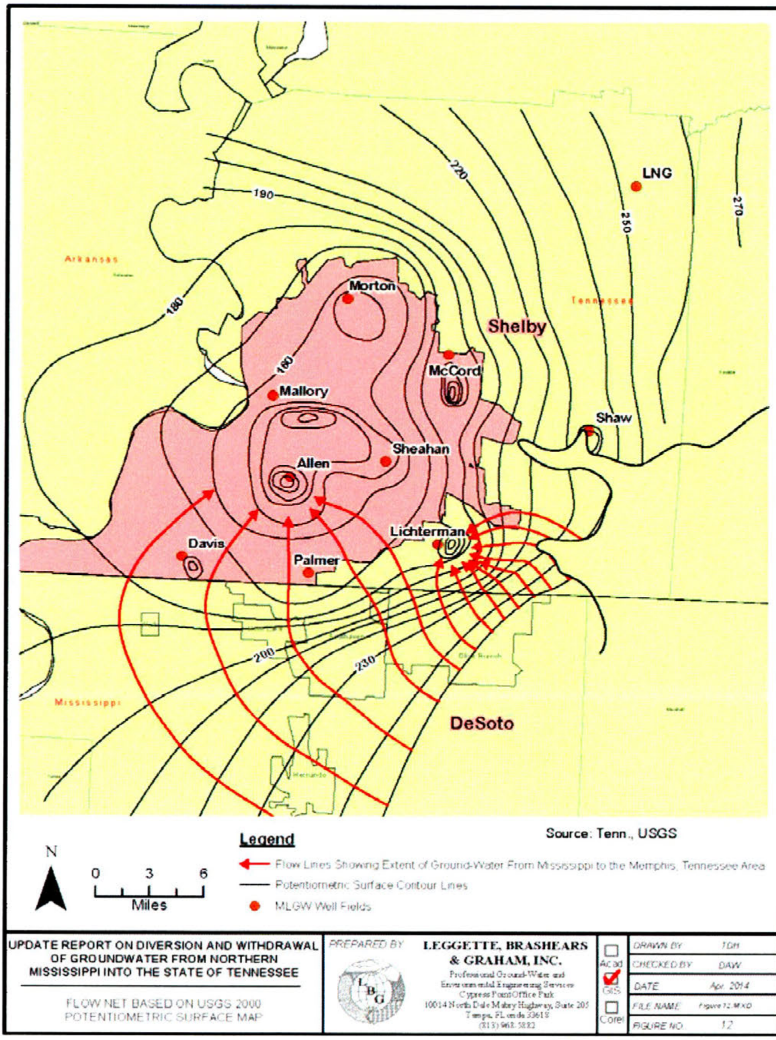
Professional Ground Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, FLorida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Feb 2014
FIGURE NO 10



UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE FLOW NET SCHEMATIC (FREEZE AND CHERRY 1979)	PREPARED BY **LEGGETTE, BRASHEARS & GRAHAM, INC.** Professional Ground-Water and Environmental Engineering Services Cypress Point Office Park 10014 North Dale Mabry Highway, Suite 205 Tampa, Florida 33618	☐ Acad ☑ GIS ☐ Corel	DRAWN BY TDH CHECKED BY DAW DATE Apr 2014 FILE NAME Figure 11.MXD FIGURE NO 11



LNG
220
250
270
190
180
160
Arkansas
Tennessee
Mississippi
Morton
Shelby
McCord
Mallory
Shaw
Sheahan
Allen
Lichterman
Davis
Palmer
200
230
DeSoto
Source: Tenn., USGS
Legend
Flow Lines Showing Extent of Ground-Water From Mississippi to the Memphis, Tennessee Area
Potentiometric Surface Contour Lines
MLGW Well Fields
N
0 3 6
Miles
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
FLOW NET BASED ON USGS 2000 POTENTIOMETRIC SURFACE MAP
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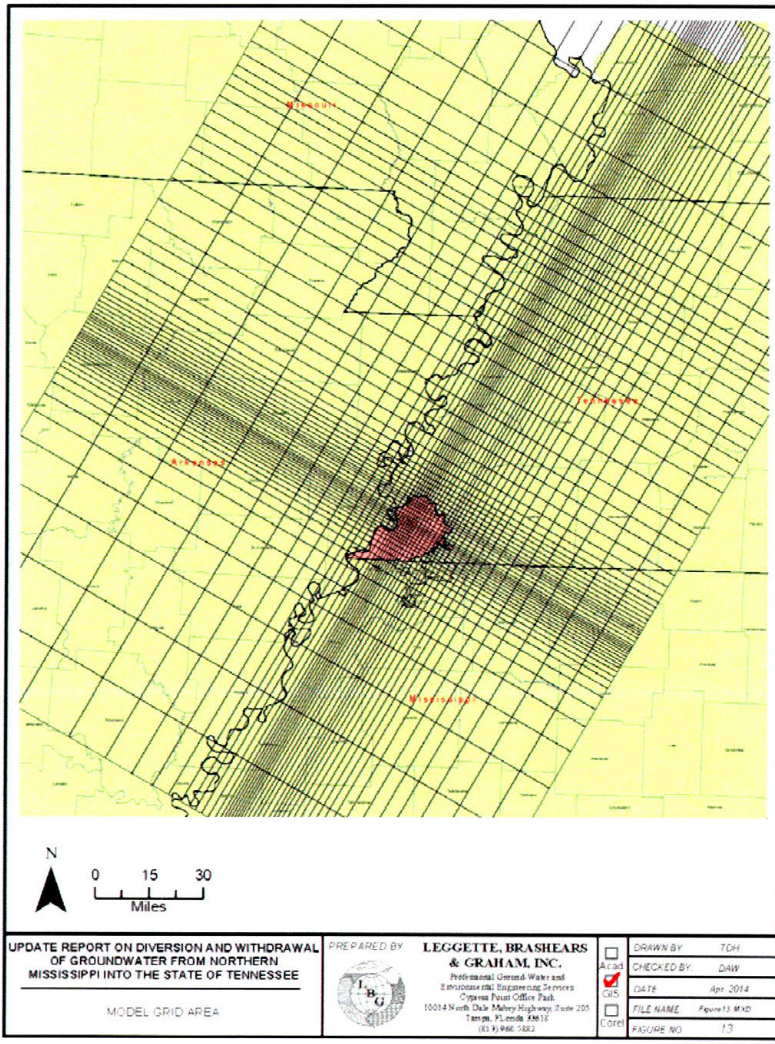
10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TGH
CHECKED BY DAW
DATE Apr. 2014
FILE NAME Figure 12.MXD
FIGURE NO. 12


Missouri
Tennessee
Arkansas
Mississippi
N
0 15 30
Miles
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
MODEL GRID AREA
PREPARED BY
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Professional Ground-Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, FLorida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TDH
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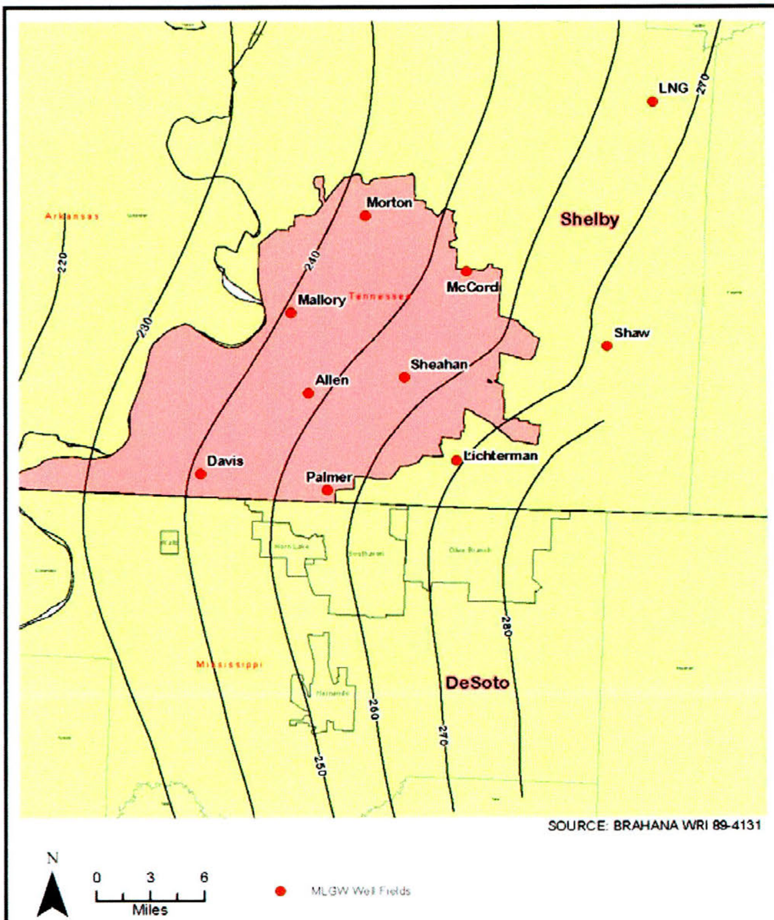
DATE Apr. 2014
FILE NAME Figure13.MXD
FIGURE NO 13



UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE

1886 ESTIMATED POTENTIOMETRIC SURFACE MAP FOR PREDEVELOPMENT CONDITIONS

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Tampa, Florida 33618
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Corel

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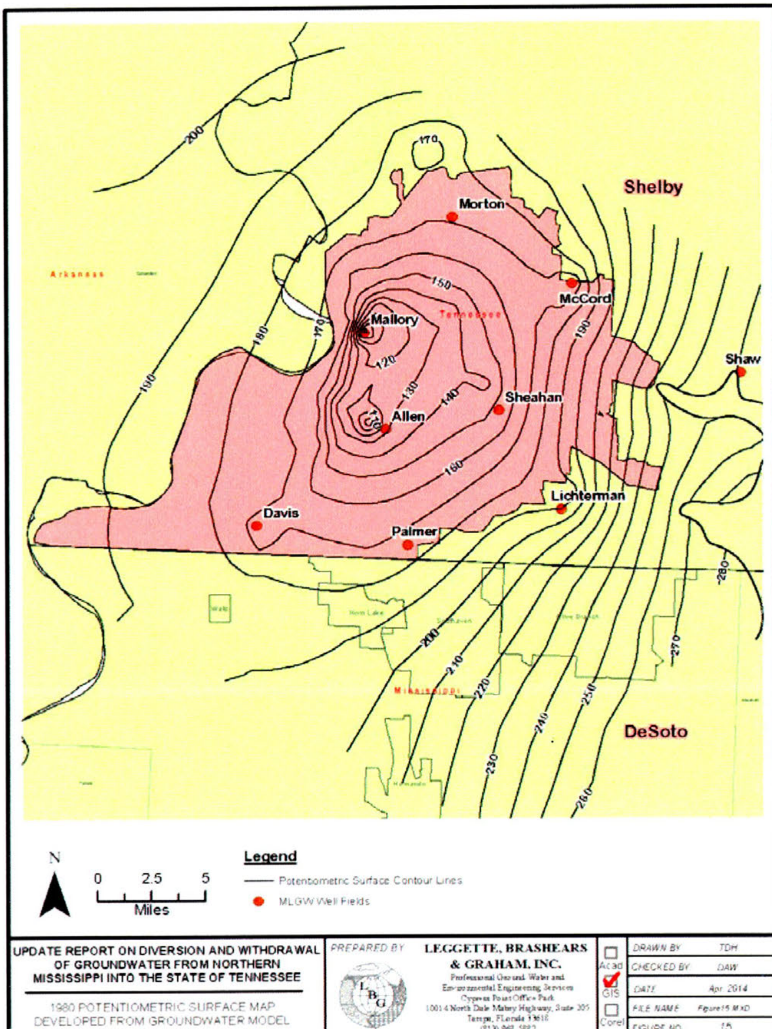
DATE	Apr. 2014
FILE NAME	Figure14.MXD
FIGURE NO	14


Shelby
Morton
McCord
Arkansas
Tennessee
Mallory
Shaw
Sheahan
Allen
Davis
Palmer
Lichterman
Mississippi
DeSoto
200
170
150
180
190
120
130
140
110
160
280
270
210
220
250
240
230
260
N
0 2.5 5
Miles
Legend
Potentiometric Surface Contour Lines
MLGW Well Fields
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
1980 POTENTIOMETRIC SURFACE MAP DEVELOPED FROM GROUNDWATER MODEL
PREPARED BY
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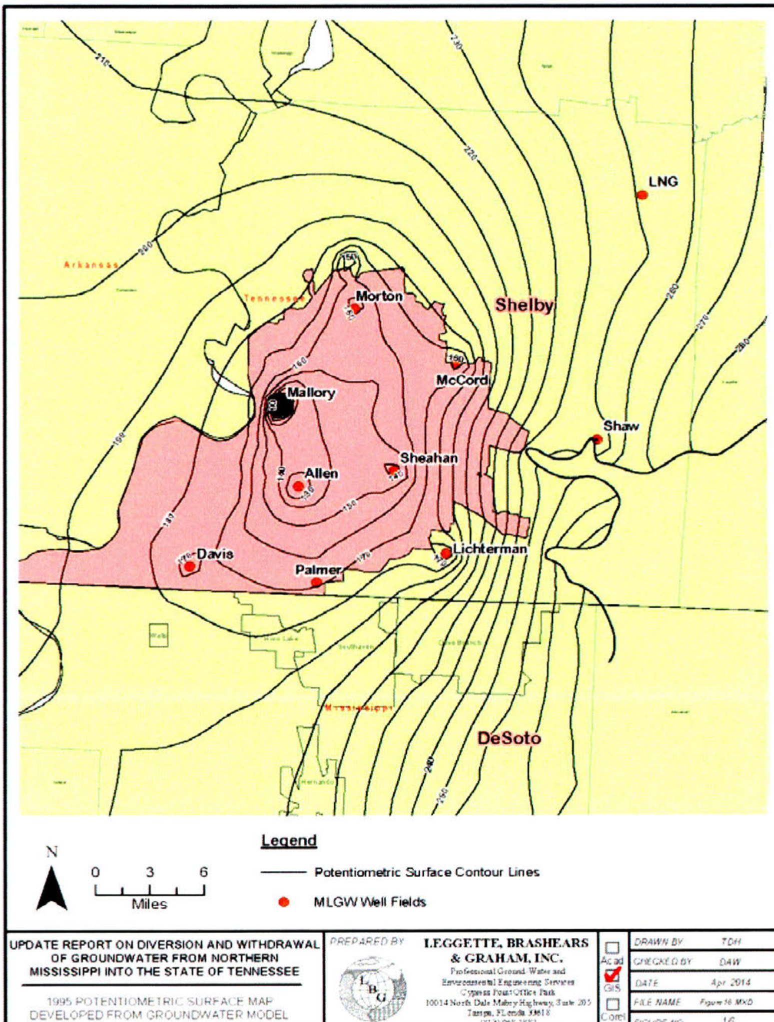
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, FLorida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Apr. 2014
FILE NAME Figure15.MXD
FIGURE NO. 15


LNG
Arkansas
Tennessee
Morton
Shelby
McCord
Mallory
Sheahan
Allen
Shaw
Davis
Palmer
Lichterman
Mississippi
DeSoto
Legend
N
0 3 6
Miles
Potentiometric Surface Contour Lines
MLGW Well Fields
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
1995 POTENTIOMETRIC SURFACE MAP DEVELOPED FROM GROUNDWATER MODEL
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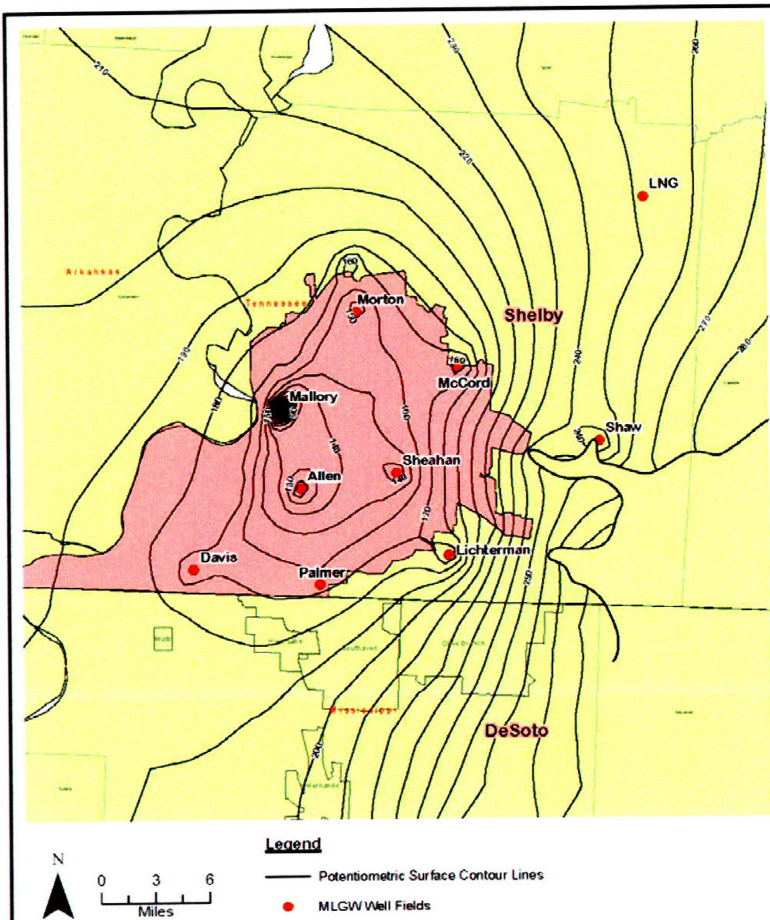
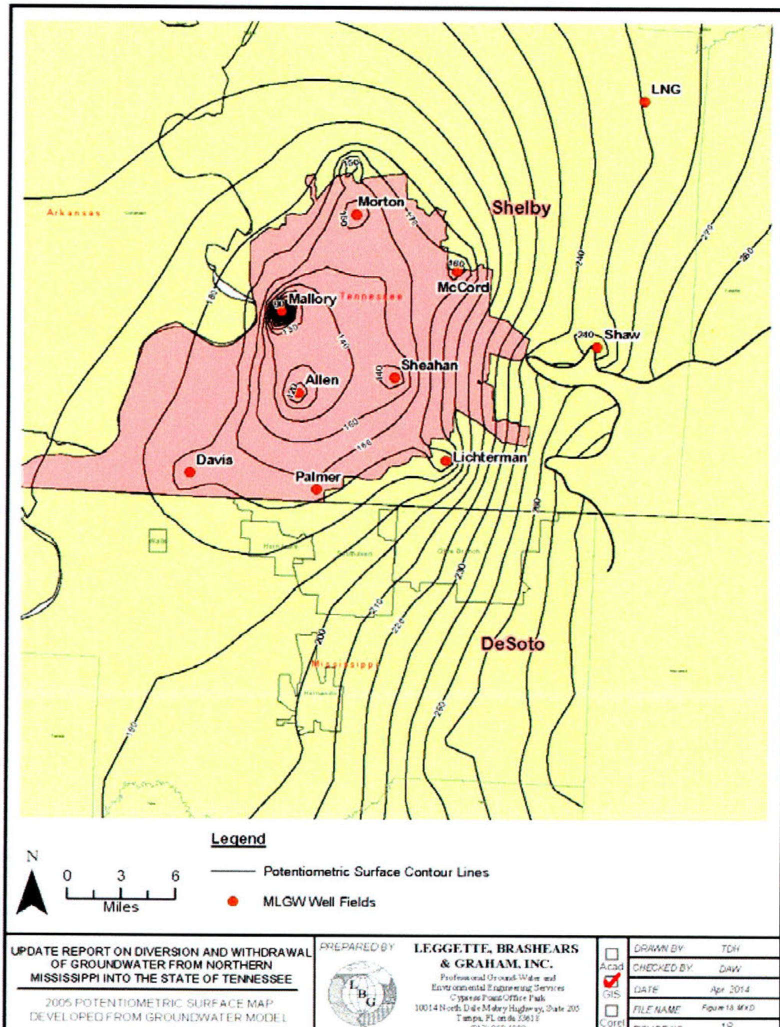
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Apr 2014
FIGURE NO 16



UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE 2000 POTENTIOMETRIC SURFACE MAP DEVELOPED FROM GOUNDWATER MODEL	PREPARED BY **LEGGETTE, BRASHEARS & GRAHAM, INC.** Professional Ground-Water and Environmental Engineering Services Cypress Point Office Park 10014 North Dale Mabry Highway, Suite 205 Tampa, FLorida 33618 (813) 968-5882	☐ Acad ☑ GIS ☐ Corel	DRAWN BY: TDH CHECKED BY: DAW DATE: Apr. 2014 FILE NAME: Figure 17.MXD FIGURE NO: 17


LNG
Shelby
Arkansas
Morton
McCord
Mallory
Tennessee
Shaw
Sheahan
Allen
Davis
Lichterman
Palmer
DeSoto
Mississippi
Legend
Potentiometric Surface Contour Lines
MLGW Well Fields
N
0 3 6
Miles
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
2005 POTENTIOMETRIC SURFACE MAP DEVELOPED FROM GROUNDWATER MODEL
PREPARED BY
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Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
(813) 968-5882
Acad
GIS
Corel
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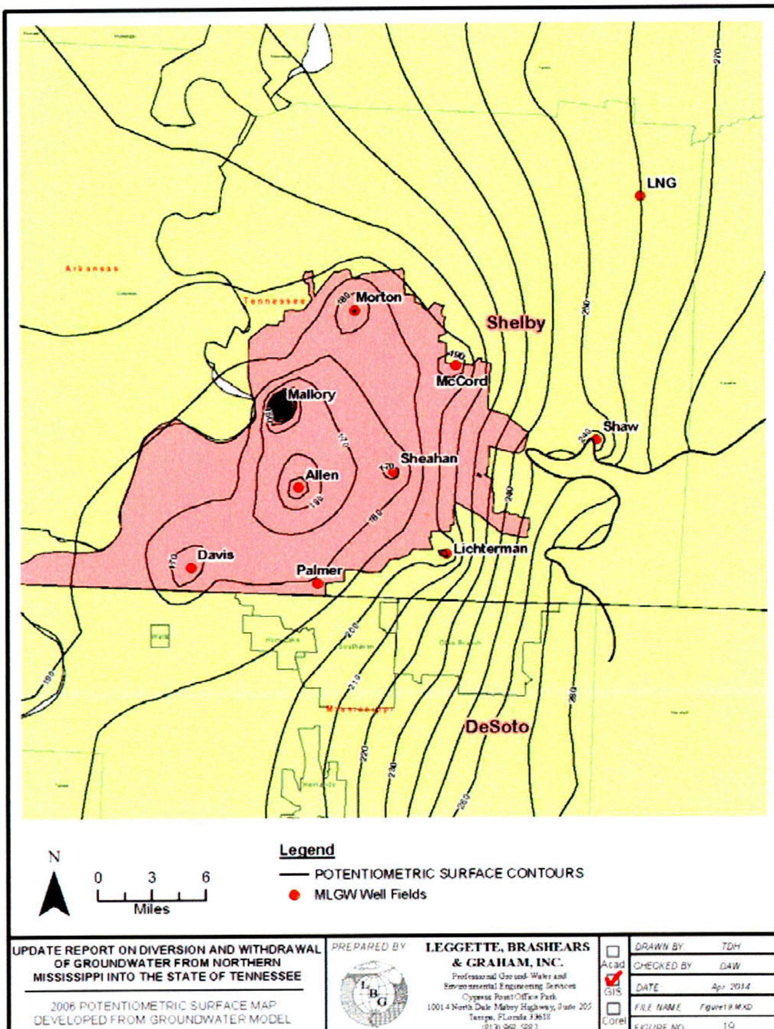
CHECKED BY DAW
DATE Apr. 2014
FILE NAME Figure 18.MXD
FIGURE NO. 18



LNG
Arkansas
Tennessee
Morton
Shelby
McCord
Mallory
Shaw
Sheahan
Allen
Lichterman
Davis
Palmer
Mississippi
DeSoto
270
250
240
230
220
210
200
190
180
170
N
0 3 6
Miles
Legend
POTENTIOMETRIC SURFACE CONTOURS
MLGW Well Fields
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
2006 POTENTIOMETRIC SURFACE MAP DEVELOPED FROM GROUNDWATER MODEL
PREPARED BY
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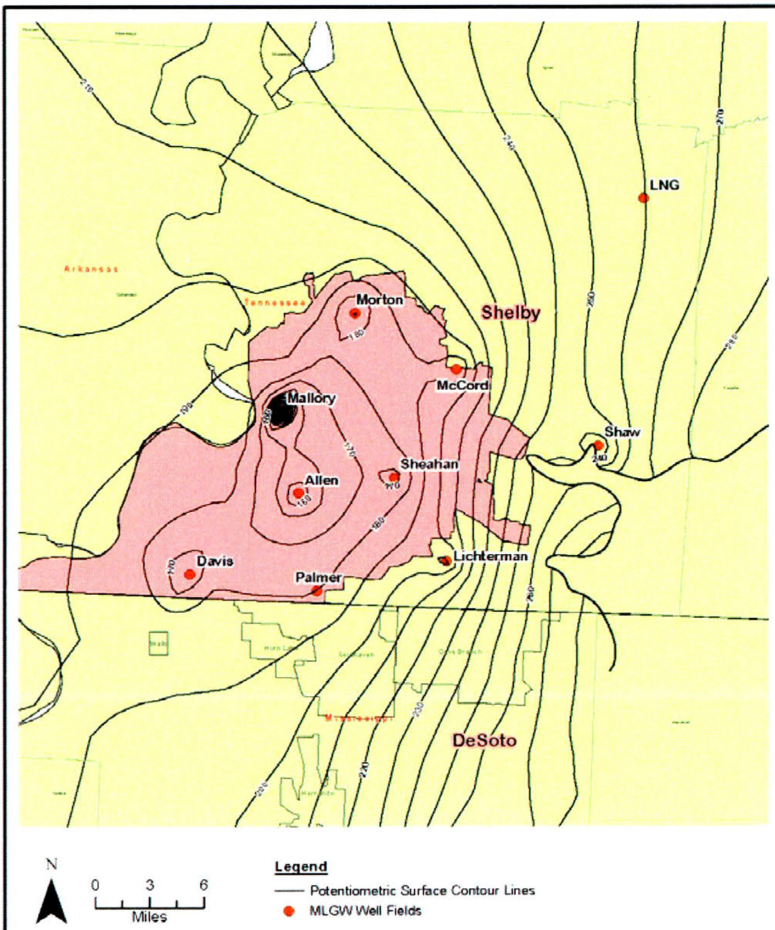
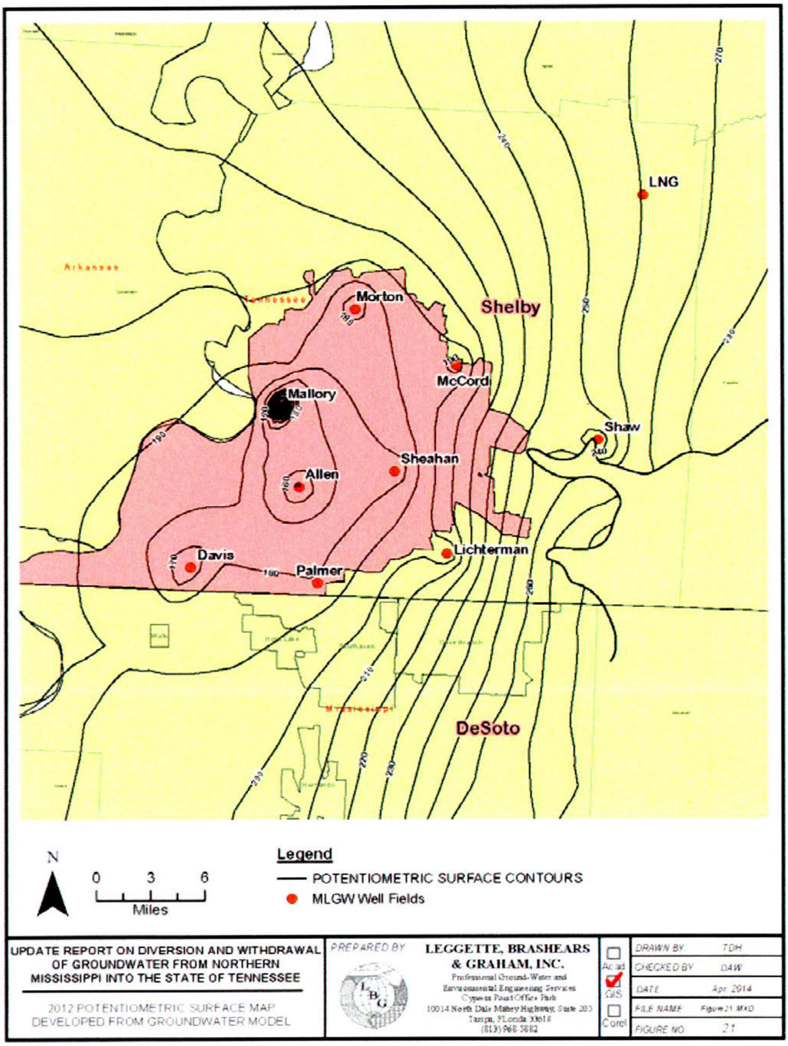
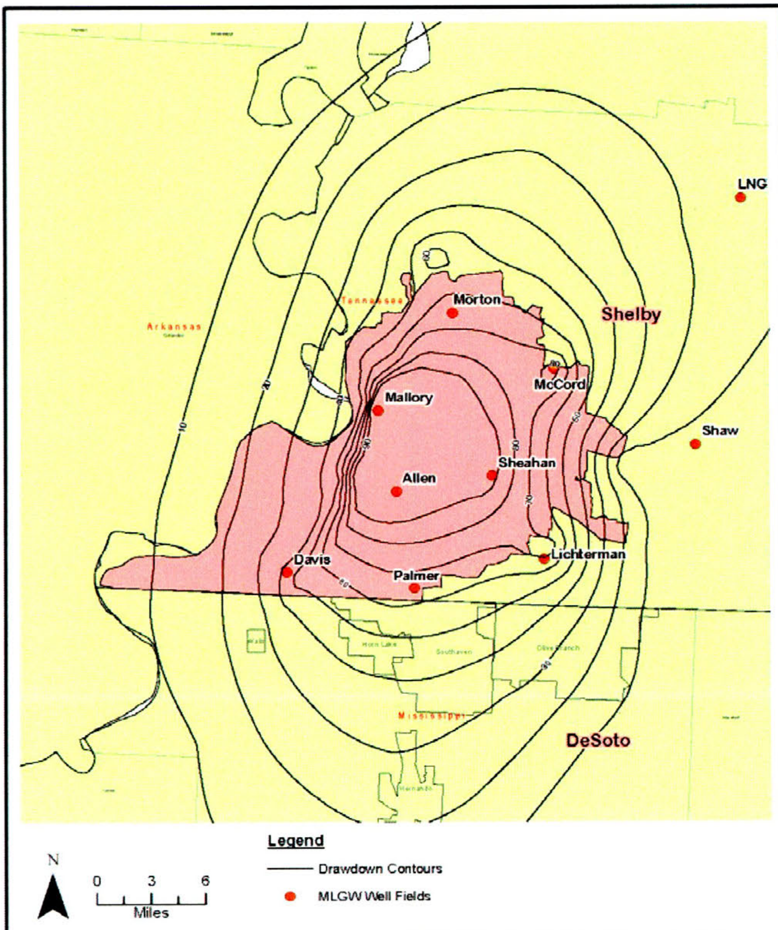
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, FLorida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Apr. 2014
FILE NAME Figure19.MXD
FIGURE NO 19



UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE 2010 POTENTIOMETRIC SURFACE MAP DEVELOPED FROM GROUNDWATER MODEL	PREPARED BY LEGGETTE, BRASHEARS & GRAHAM, INC. Professional Ground-Water and Environmental Engineering Services Cypress Point Office Park 10014 North Dale Mabry Highway, Suite 205 Tampa, Florida 33618 (813) 968-5882	Acad GIS Corel	DRAWN BY TDH CHECKED BY DAW DATE Apr 2014 FILE NAME Figure20.MXD FIGURE NO 20


LNG
Arkansas
Tennessee
Morton
Shelby
McCord
Mallory
Shaw
Sheahan
Allen
Davis
Palmer
Lichterman
Mississippi
DeSoto
N
0 3 6
Miles
Legend
POTENTIOMETRIC SURFACE CONTOURS
MLGW Well Fields
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
2012 POTENTIOMETRIC SURFACE MAP DEVELOPED FROM GROUNDWATER MODEL
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground-Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, FLorida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Apr 2014
FILE NAME Figure21.MXD
FIGURE NO 21



UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE

1980 DRAWDOWN CONTOUR MAP DEVELOPED FROM GROUNDWATER MODEL

PREPARED BY
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10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
(813) 968-5882

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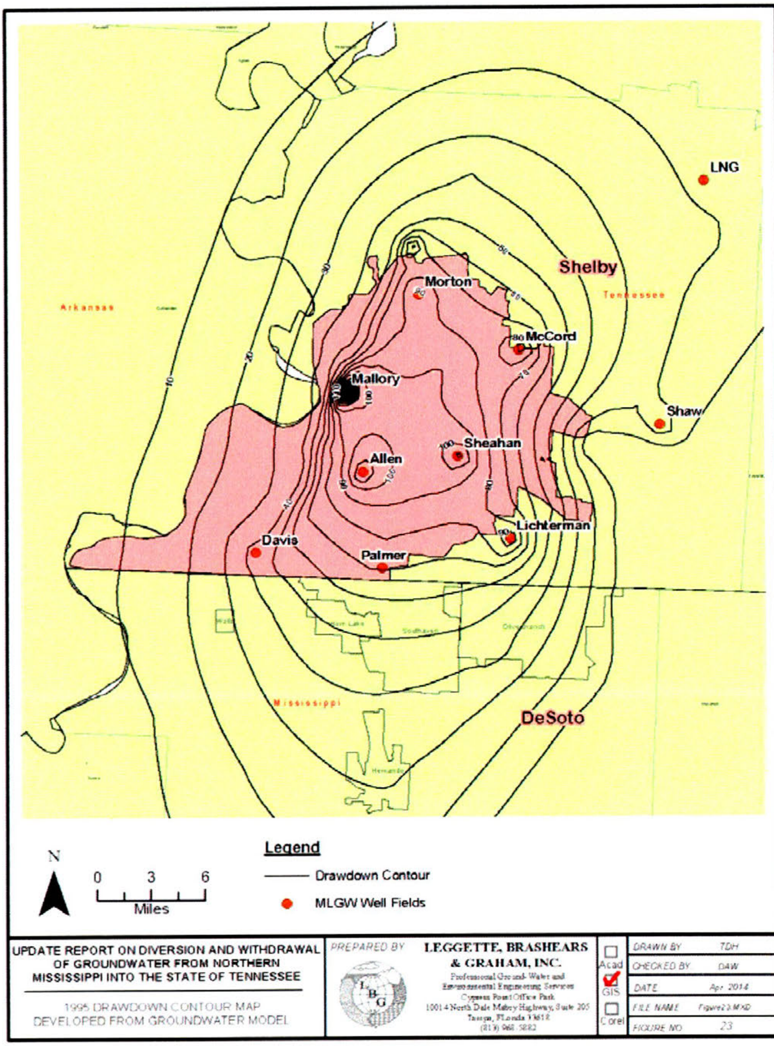
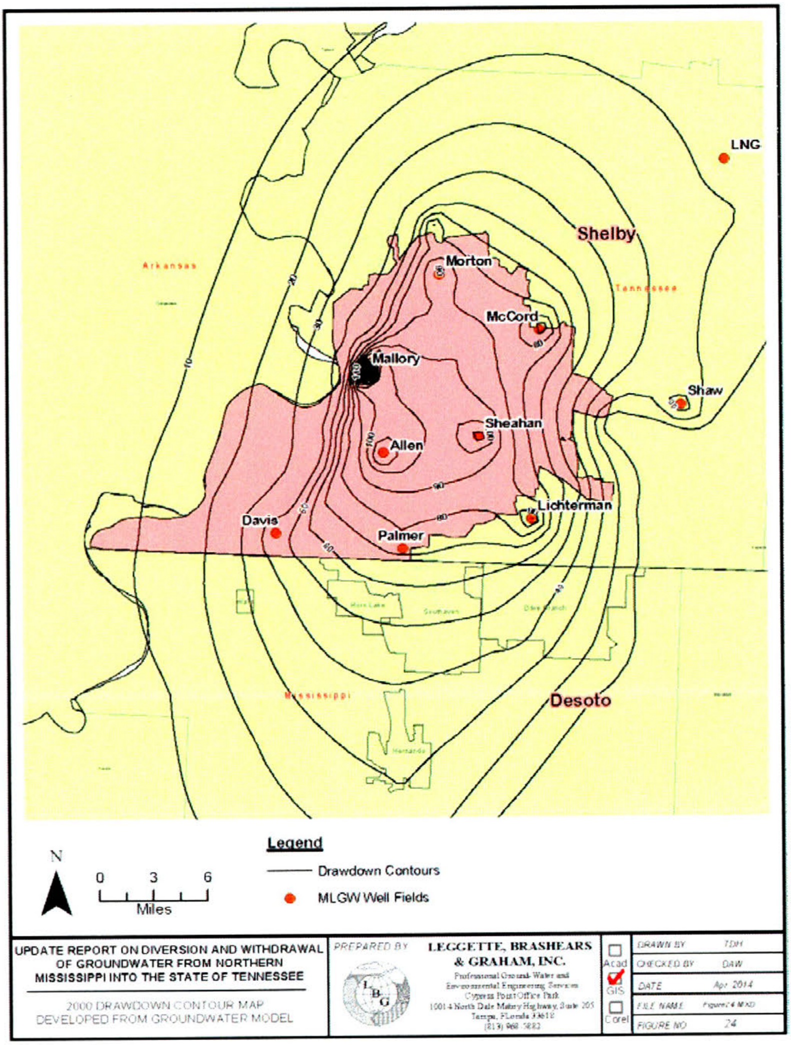
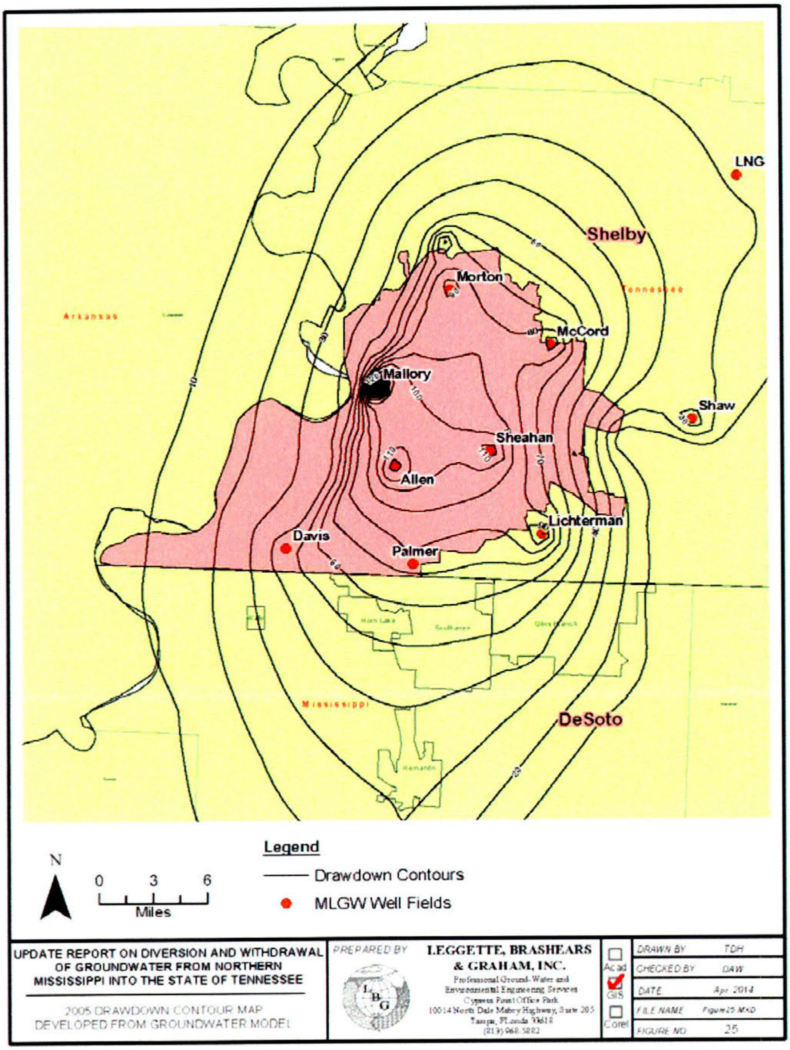
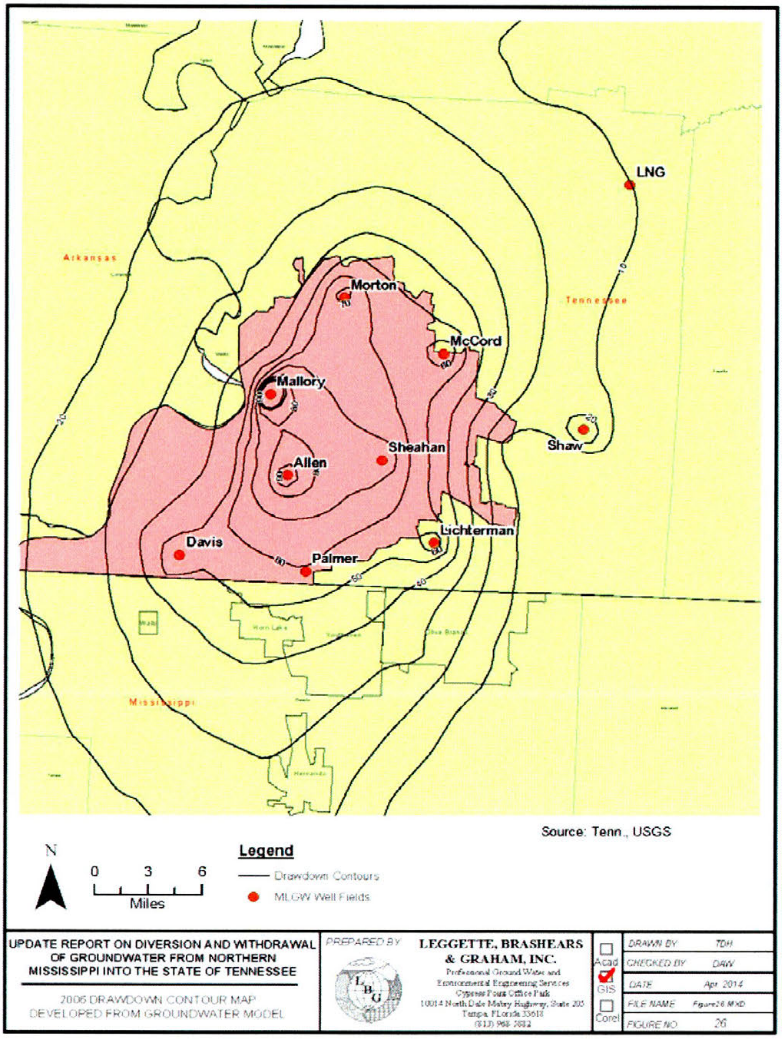
DRAWN BY:	TDH
CHECKED BY:	DAW
DATE:	Apr. 2014
FILE NAME:	Figure 22.MXD
FIGURE NO.:	22


LNG
Shelby
Tennessee
Arkansas
Morton
McCord
Mallory
Shaw
Sheahan
Allen
Lichterman
Davis
Palmer
Mississippi
DeSoto
Legend
Drawdown Contour
MLGW Well Fields
N
0 3 6
Miles
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
1995 DRAWDOWN CONTOUR MAP DEVELOPED FROM GROUNDWATER MODEL
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground-Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Apr 2014
FILE NAME Figure23.MXD
FIGURE NO. 23


LNG
Shelby
Arkansas
Tennessee
Morton
McCord
Mallory
Shaw
Sheahan
Allen
Lichterman
Davis
Palmer
Mississippi
Desoto
Legend
Drawdown Contours
MLGW Well Fields
N
0 3 6
Miles
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
2000 DRAWDOWN CONTOUR MAP DEVELOPED FROM GROUNDWATER MODEL
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground-Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Apr 2014
FIGURE NO 24



LNG
Shelby
Tennessee
Arkansas
Morton
McCord
Mallory
Shaw
Sheahan
Allen
Lichterman
Davis
Palmer
Horn Lake
Southaven
Olive Branch
Mississippi
DeSoto
Hernando
N
0 3 6
Miles
Legend
Drawdown Contours
MLGW Well Fields
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
2005 DRAWDOWN CONTOUR MAP DEVELOPED FROM GROUNDWATER MODEL
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground-Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Apr 2014
FIGURE NO 25


LNG
Arkansas
Tennessee
Morton
McCord
Mallory
Shaw
Sheahan
Allen
Lichterman
Davis
Palmer
Mississippi
Source: Tenn., USGS
N
0 3 6
Miles
Legend
Drawdown Contours
MLGW Well Fields
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
2006 DRAWDOWN CONTOUR MAP DEVELOPED FROM GROUNDWATER MODEL
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground Water and Environmental Engineering Services
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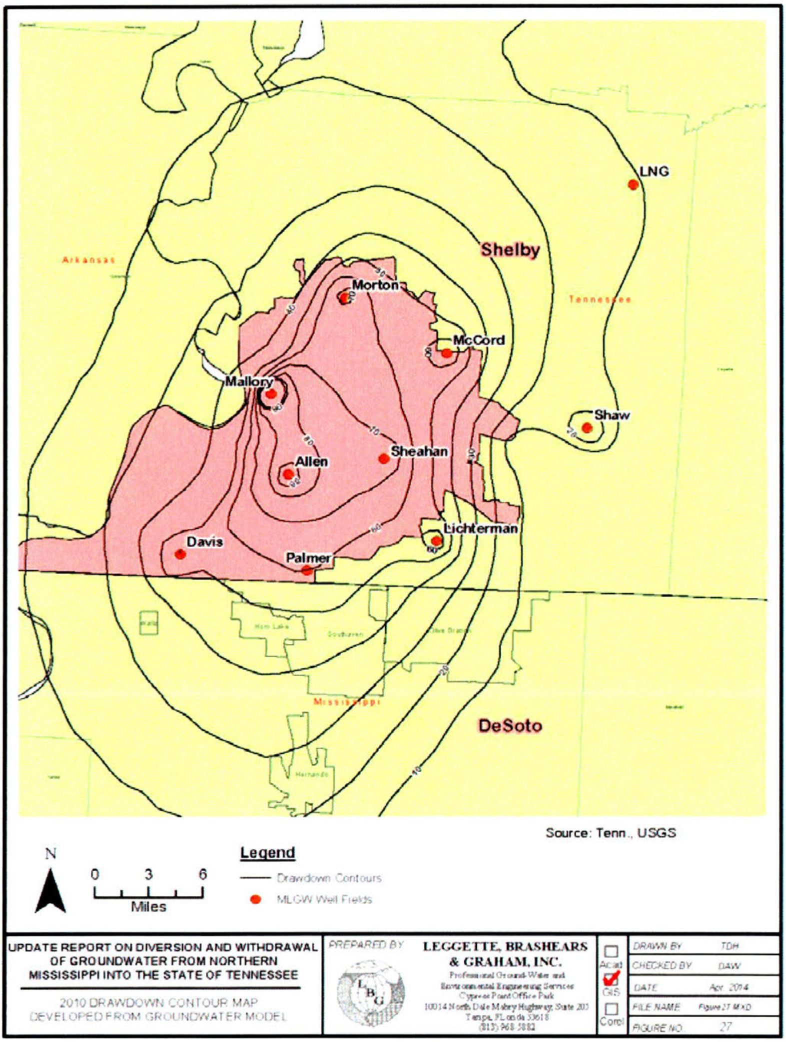
10014 North Dale Mabry Highway, Suite 205
Tampa, FLorida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Apr. 2014
FILE NAME Figure26.MXD
FIGURE NO. 26


LNG
Shelby
Arkansas
Tennessee
Morton
McCord
Mallory
Shaw
Allen
Sheahan
Lichterman
Davis
Palmer
Mississippi
DeSoto
Source: Tenn., USGS
N
0 3 6
Miles
Legend
Drawdown Contours
MLGW Well Fields
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
2010 DRAWDOWN CONTOUR MAP DEVELOPED FROM GROUNDWATER MODEL
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground-Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Apr. 2014
FILE NAME Figure27.MXD
FIGURE NO. 27

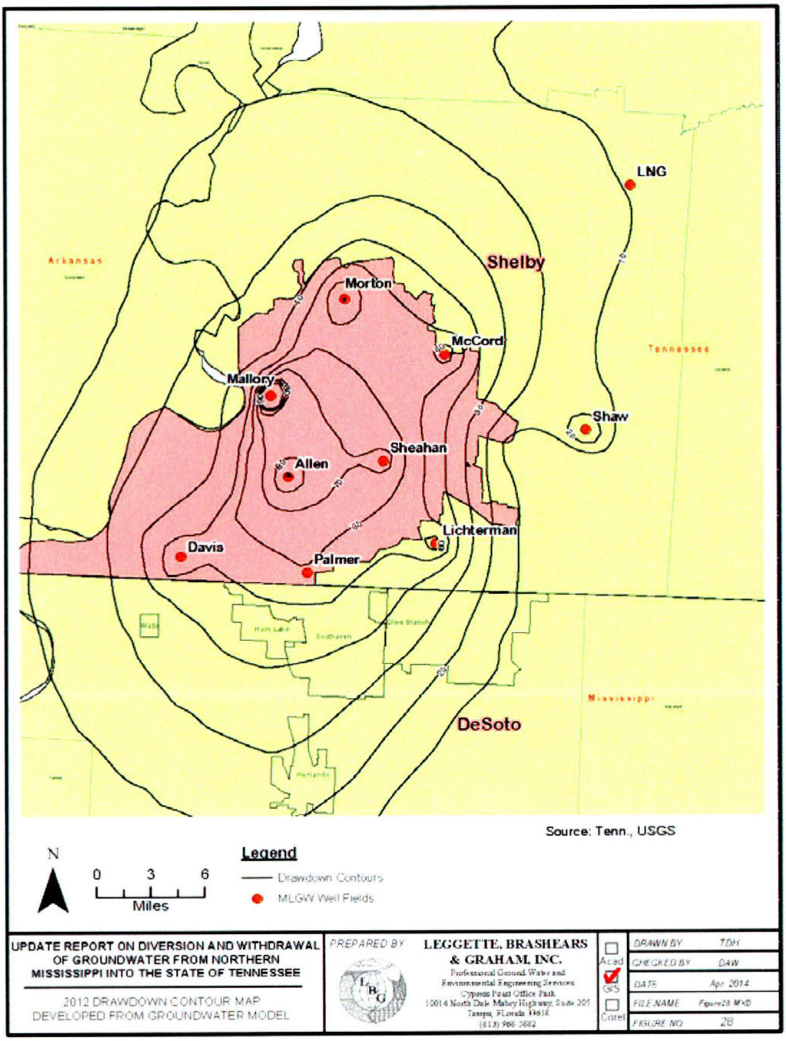
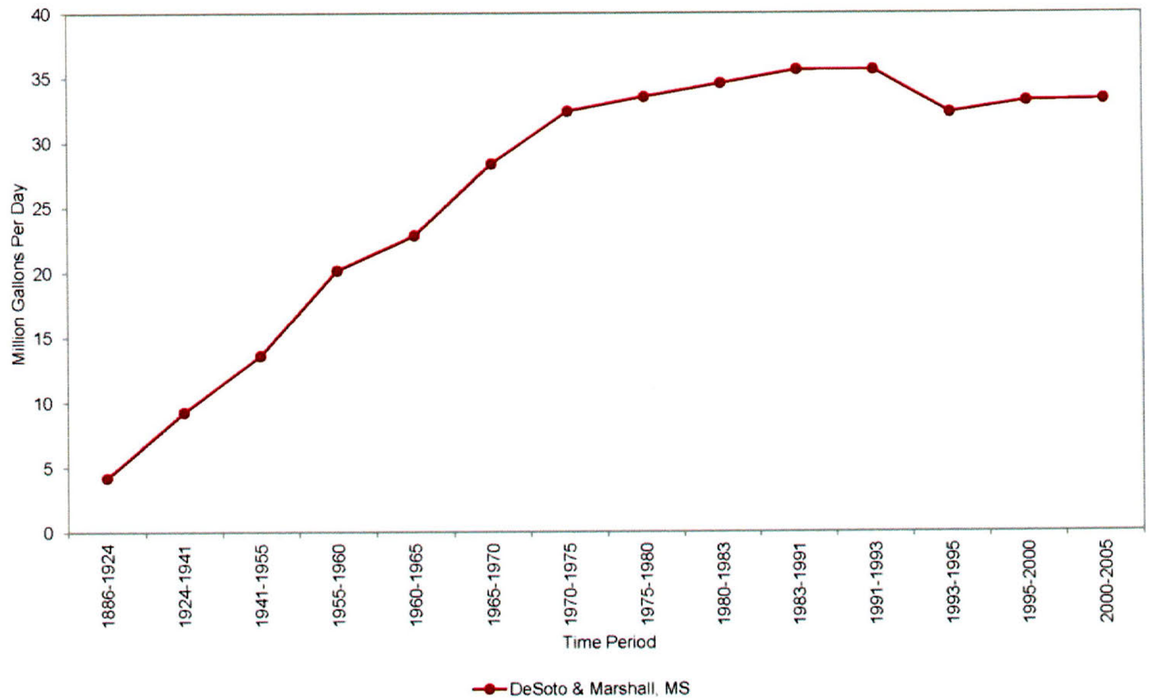
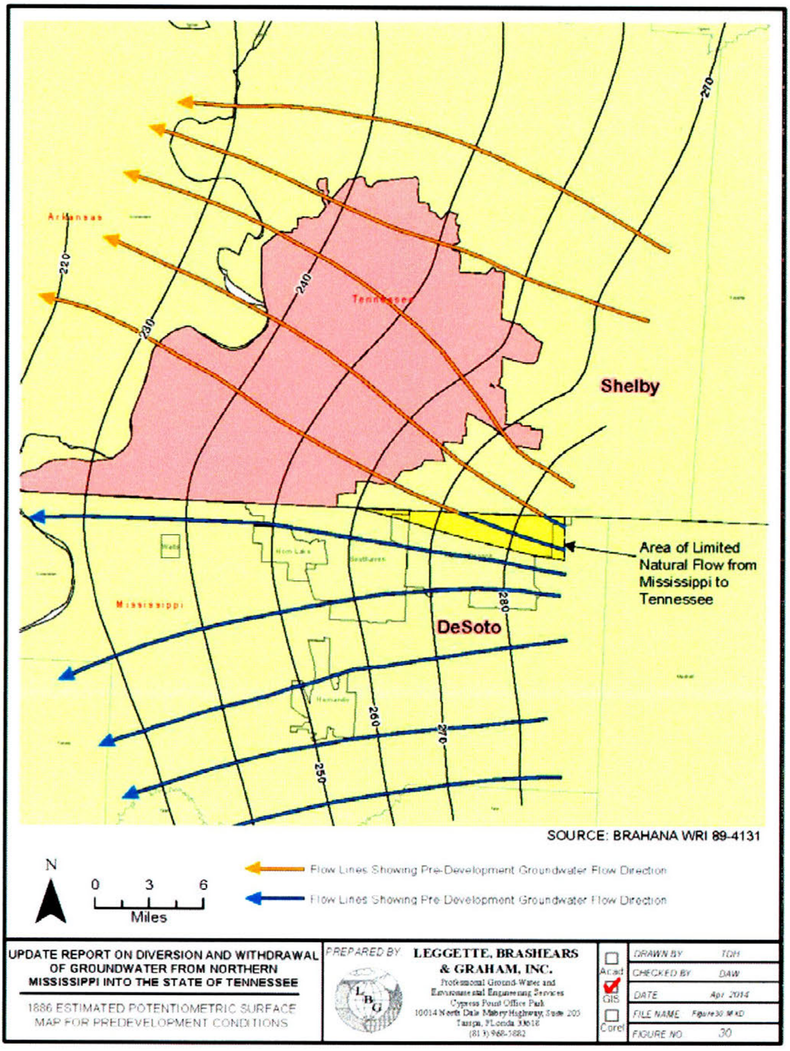

Arkansas
Shelby
LNG
Morton
McCord
Tennessee
Mallory
Shaw
Sheahan
Allen
Lichterman
Davis
Palmer
Mississippi
DeSoto
Source: Tenn., USGS
N
0 3 6
Miles
Legend
Drawdown Contours
MLGW Well Fields
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
2012 DRAWDOWN CONTOUR MAP DEVELOPED FROM GROUNDWATER MODEL
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Apr 2014
FILE NAME Figure28.MXD
FIGURE NO 28

Figure 29
Volume of Water Contributed to Shelby County, TN, From DeSoto & Marshall Counties:
Due to Pumpage (1886-2005)




220
230
240
250
260
270
280
Shelby
DeSoto
Area of Limited Natural Flow from Mississippi to Tennessee
SOURCE: BRAHANA WRI 89-4131
N
0 3 6
Miles
Flow Lines Showing Pre-Development Groundwater Flow Direction
Flow Lines Showing Pre-Development Groundwater Flow Direction
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
1886 ESTIMATED POTENTIOMETRIC SURFACE MAP FOR PREDEVELOPMENT CONDITIONS
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground-Water and Environmental Engineering Services
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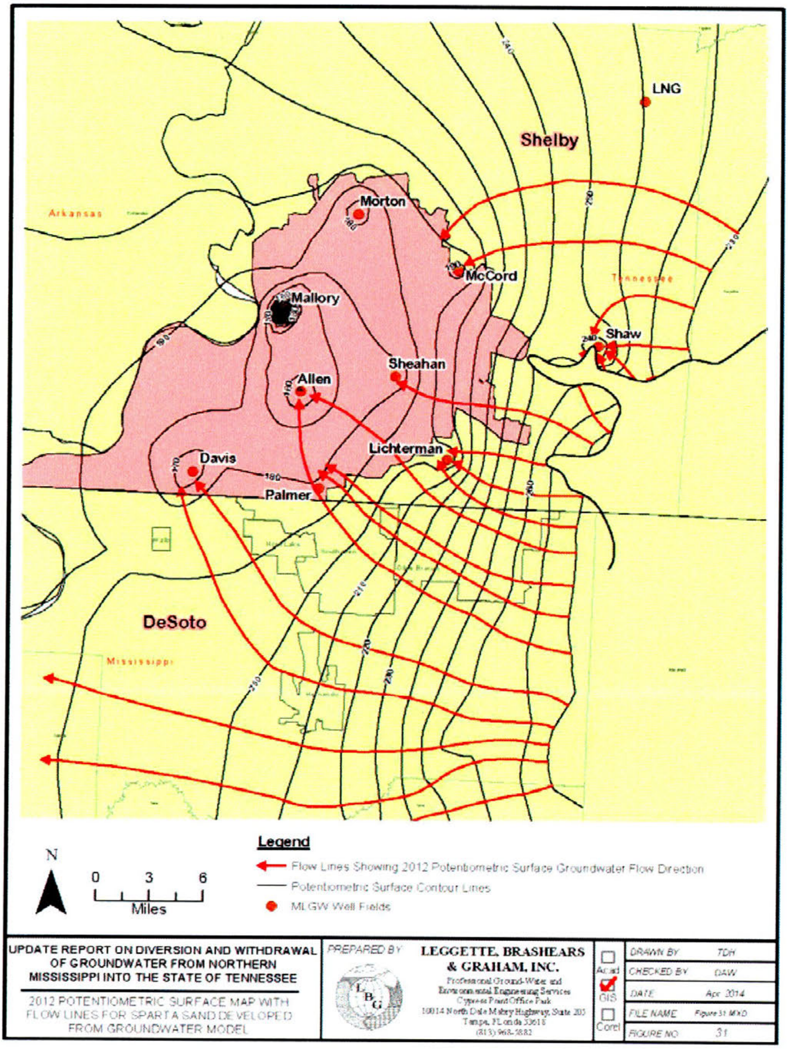
Tampa, Florida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TGH
CHECKED BY DAW
DATE Apr 2014
FILE NAME Figure30.MXD
FIGURE NO 30


LNG
Shelby
Arkansas
Morton
McCord
Tennessee
Mallory
Shaw
Sheahan
Allen
Lichterman
Davis
Palmer
DeSoto
Mississippi
N
0 3 6
Miles
Legend
Flow Lines Showing 2012 Potentiometric Surface Groundwater Flow Direction
Potentiometric Surface Contour Lines
MLGW Well Fields
UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
2012 POTENTIOMETRIC SURFACE MAP WITH FLOW LINES FOR SPARTA SAND DEVELOPED FROM GROUNDWATER MODEL
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground-Water and Environmental Engineering Services
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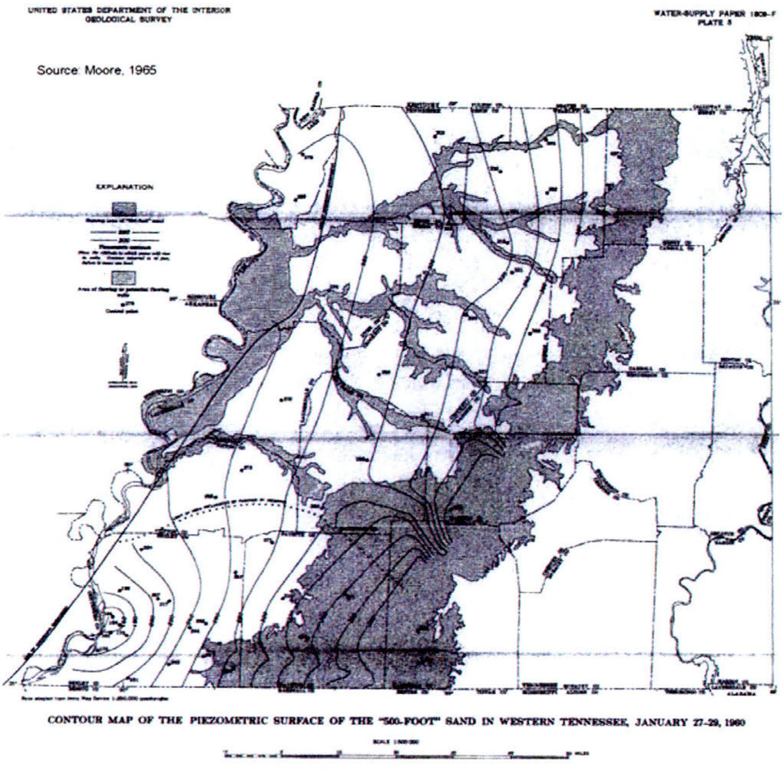
Tampa, Florida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE Apr 2014
FILE NAME Figure 31.MXD
FIGURE NO 31

APPENDIX A

Potentiometric Surface Contour Maps by Others Showing Cone of Depression

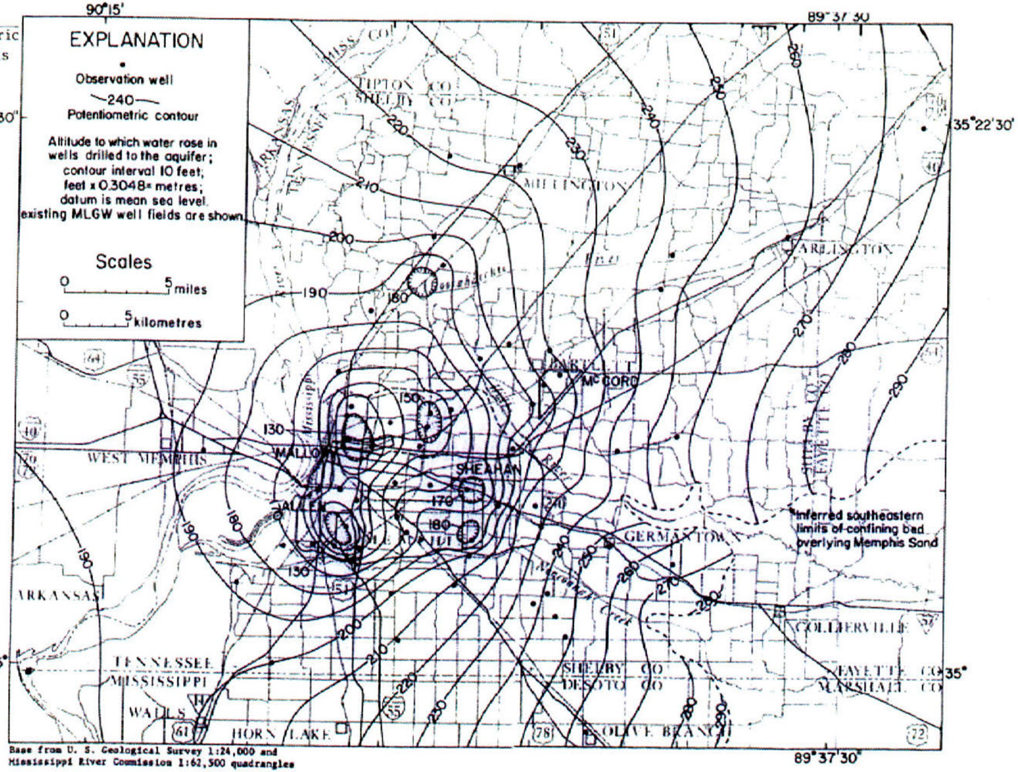
LEGGETTE, BRASHEARS & GRAHAM, INC.



CONTOUR MAP OF THE PIEZOMETRIC SURFACE OF THE "500-FOOT" SAND IN WESTERN TENNESSEE, JANUARY 27-29, 1960

Figure 5.--Potentiometric surface of the Memphis Sand in August 1960.

Source: Criner and Parks, 1976



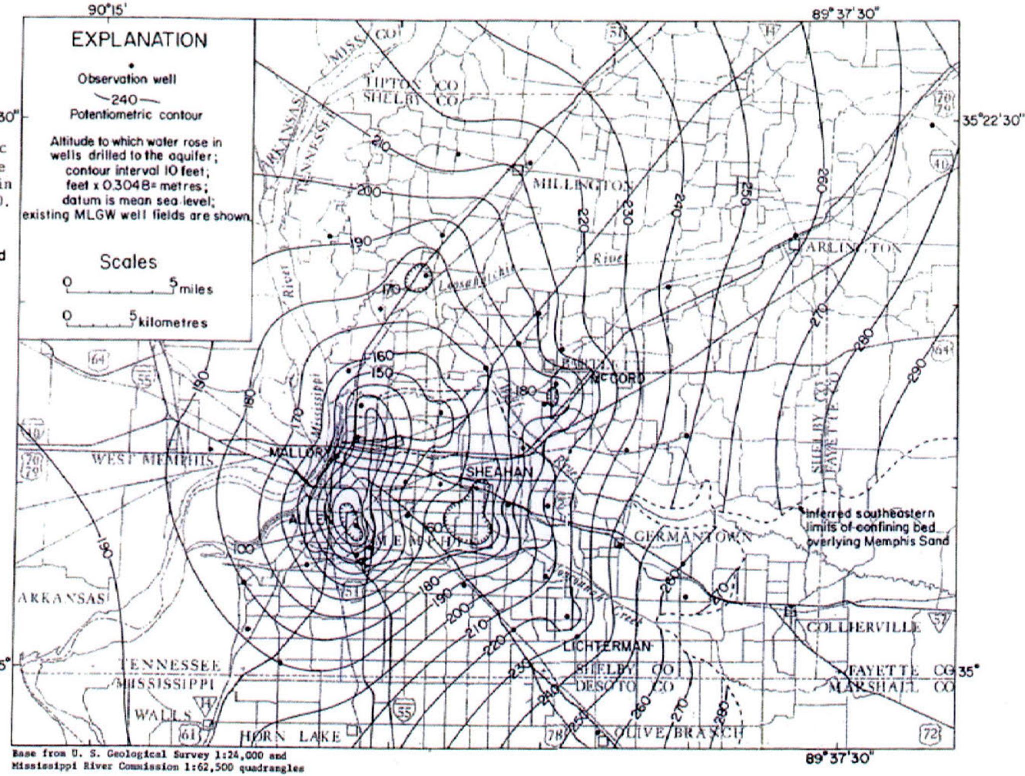
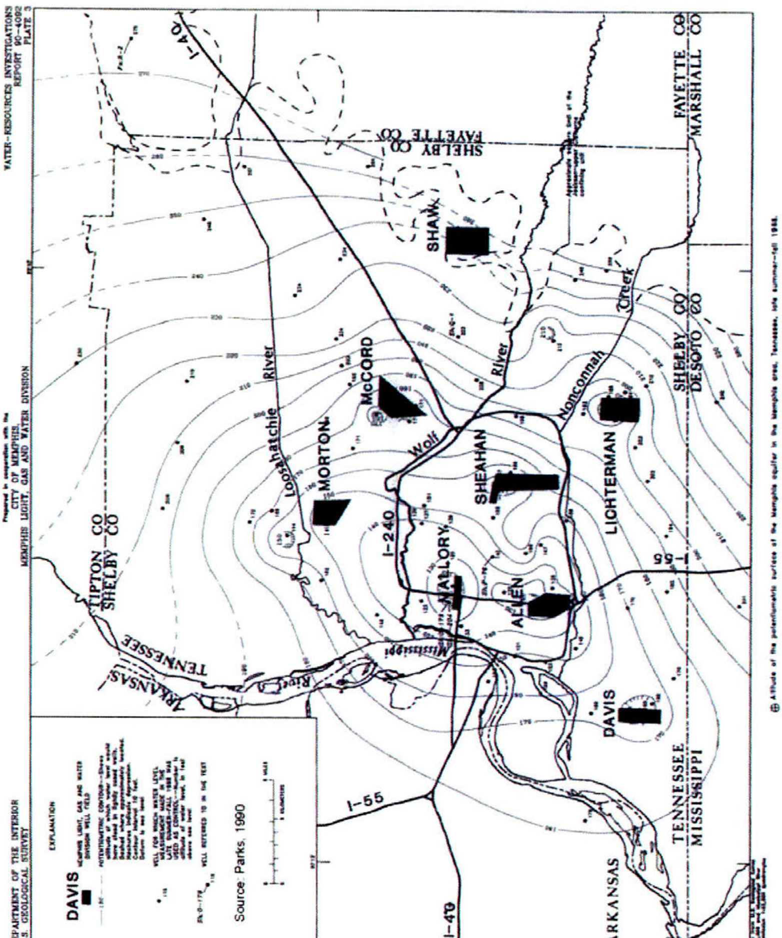


Figure 6. --Potentiometric surface of the Memphis Sand in September 1970.

Source: Criner and Parks, 1976


WATER-RESOURCES INVESTIGATIONS REPORT 90-4092 PLATE 3
DEPARTMENT OF THE INTERIOR U.S. GEOLOGICAL SURVEY
Prepared in cooperation with the CITY OF MEMPHIS, MEMPHIS LIGHT, GAS AND WATER DIVISION
EXPLANATION
DAVIS
Source: Parks, 1990
TIPTON CO
SHELBY CO
SHELBY CO
FAYETTE CO
FAYETTE CO
MARSHALL CO
SHELBY CO
DESOTO CO
TENNESSEE
MISSISSIPPI
ARKANSAS
TENNESSEE
ARKANSAS
SHAW
McCORD
MORTON
SHEAHAN
LICHTERMAN
MALLORY
ALLEN
DAVIS
Loosahatchie River
Wolf River
Nonconnah Creek
Mississippi River
I-40
I-240
I-55
I-55
I-40

APPENDIX B

Modeled Potentiometric Surface Contour Maps
by Others Showing Cone of Depression

LEGGETTE, BRASHEARS & GRAHAM, INC.

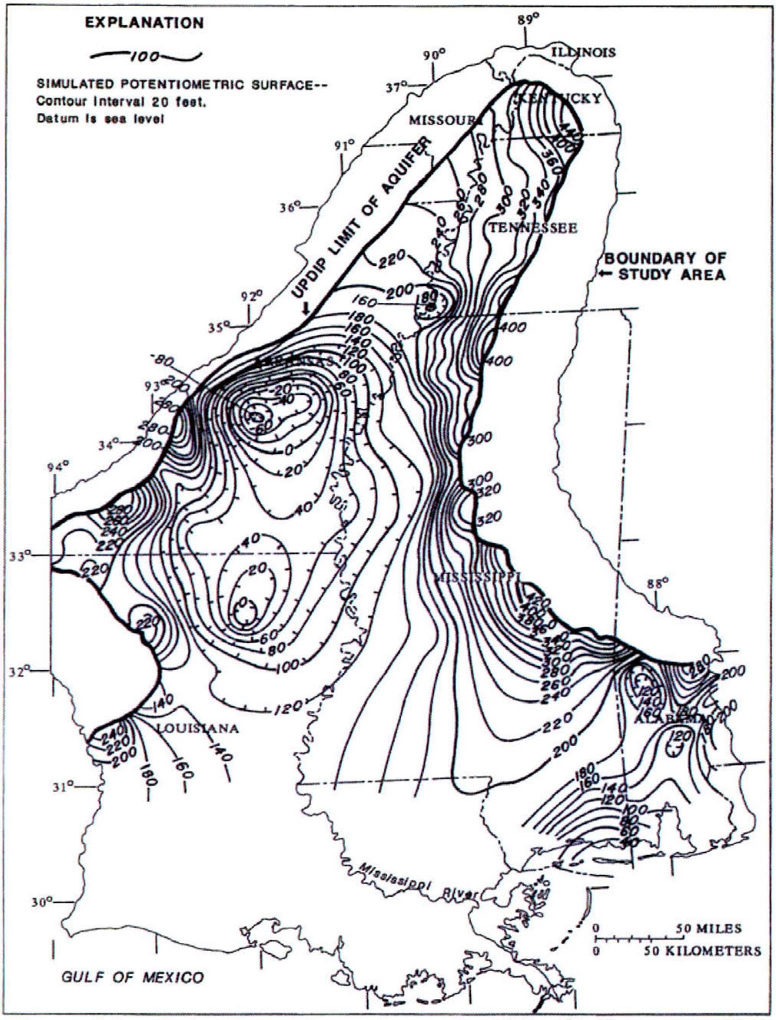


Figure 61.--Potentiometric surface of middle Claiborne aquifer using model-generated heads representing 1980 pumpage.

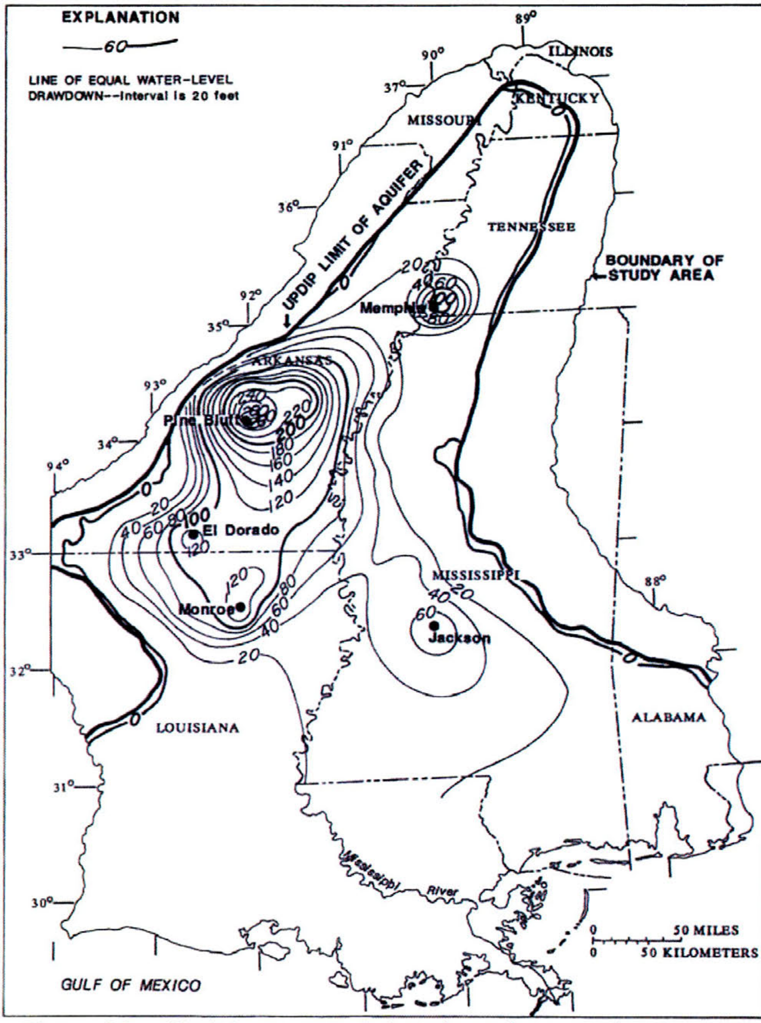
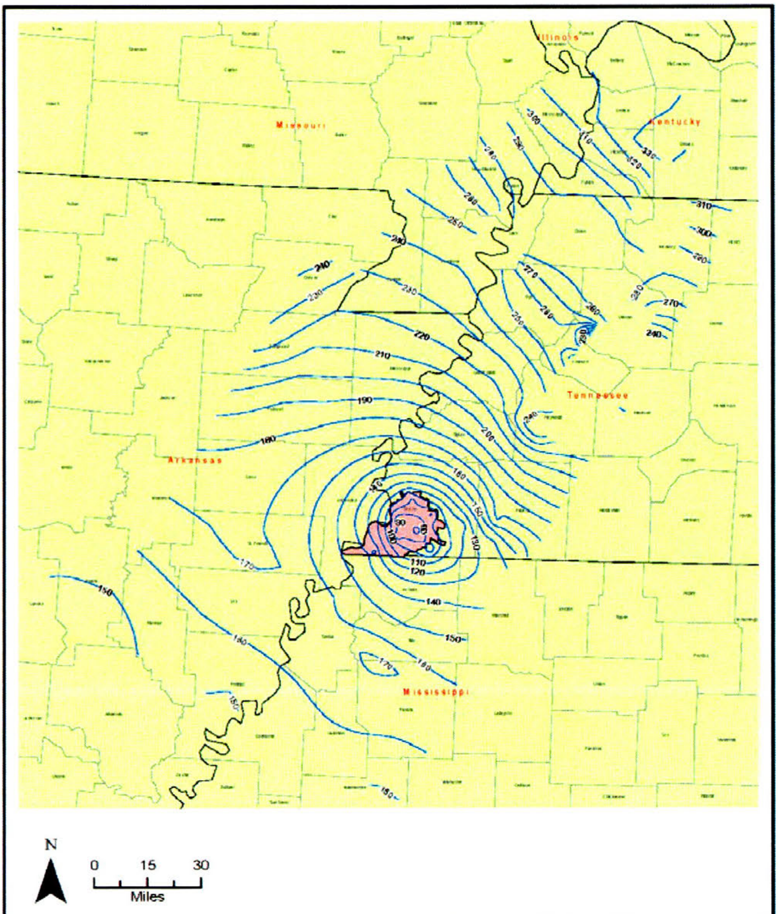


Figure 63.--Model-generated drawdown from predevelopment conditions in middle Claiborne aquifer using 1980 pumpage.



MEMPHIS, TENNESSEE

POTENTIOMETRIC MAP IN DAVID KENLEY'S MODEL FROM 1993

PREPARED BY

LEGGETTE, BRASHEARS & GRAHAM, INC.

Professional Ground-Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, FLorida 33618
(813) 968-5882

☐ Acad
☑ GIS
☐ Corel

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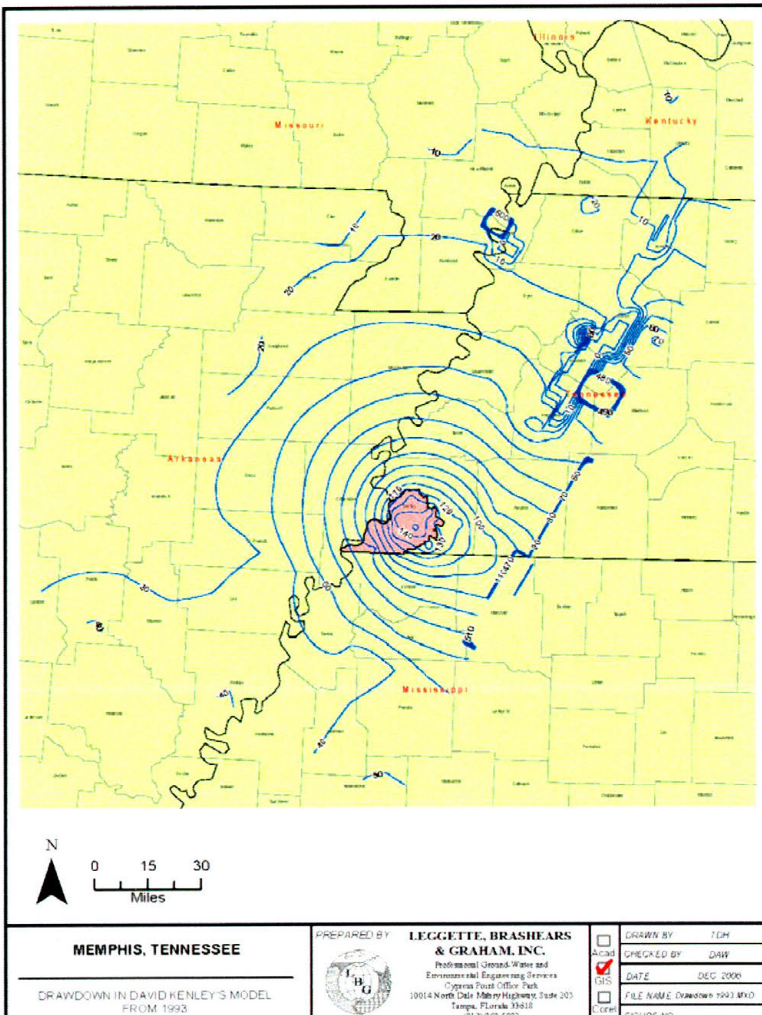
CHECKED BY	DAW
DATE	DEC 2006
FILE NAME	Pot map 1993.MXD
FIGURE NO.	


Illinois
Missouri
Kentucky
Arkansas
Tennessee
Mississippi
N
0 15 30
Miles
MEMPHIS, TENNESSEE
DRAWDOWN IN DAVID KENLEY'S MODEL FROM 1993
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground-Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE DEC 2006
FIGURE NO.

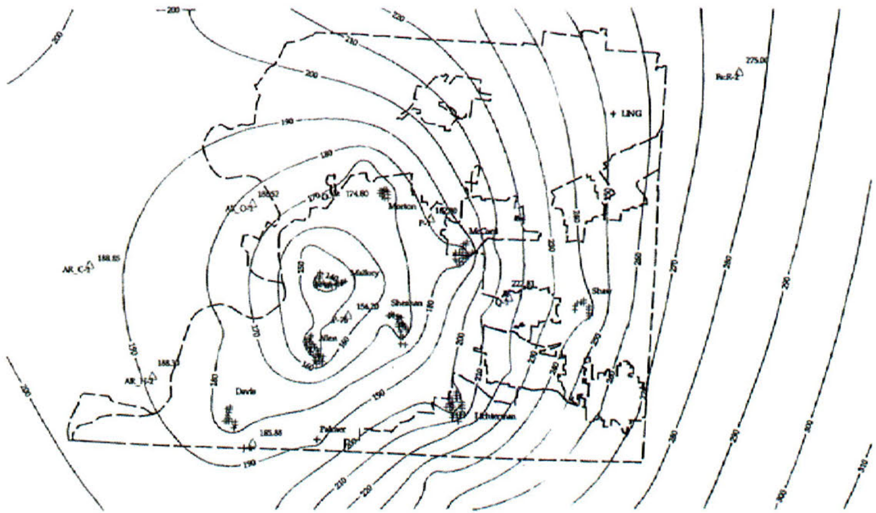


Figure 28.
Piezometric Surface of the Memphis Sand Aquifer for December, 1993

Source: Outlaw, 1993

Legend:

- Municipal/County Boundary
- Piezometric Surface of Memphis Sand Aquifer
- MLGW Production Well
- Observation Well Used in Calibration

All elevations are feet mean sea level

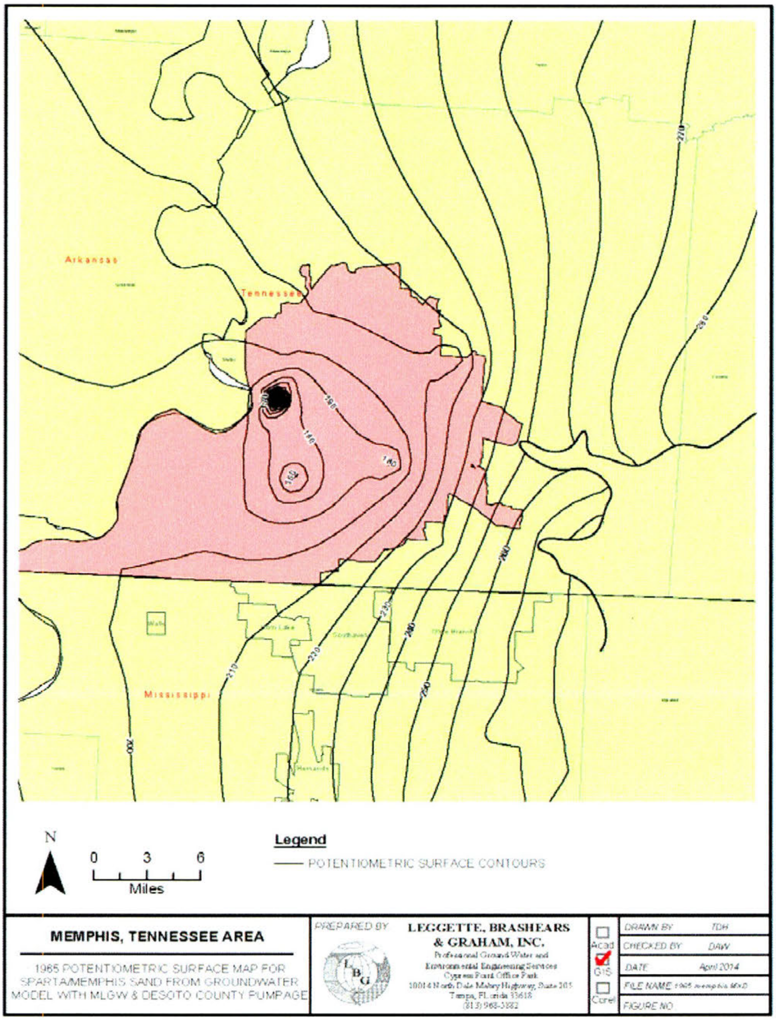
North

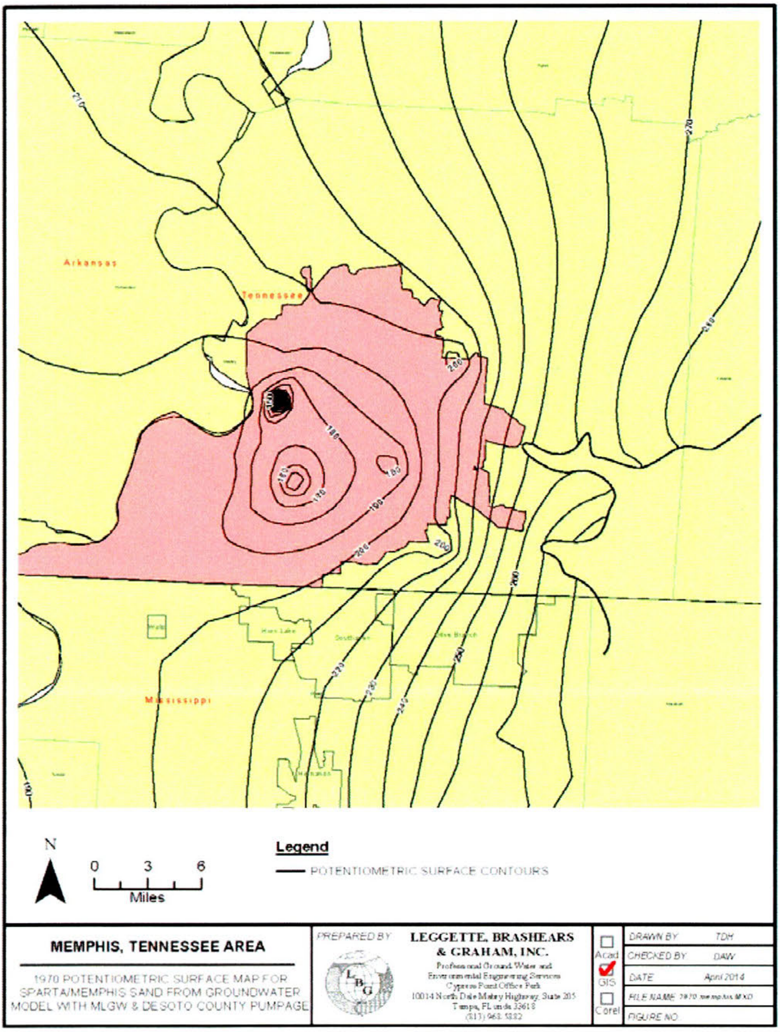
Scale: 1 in. = 30,000 ft.

APPENDIX C

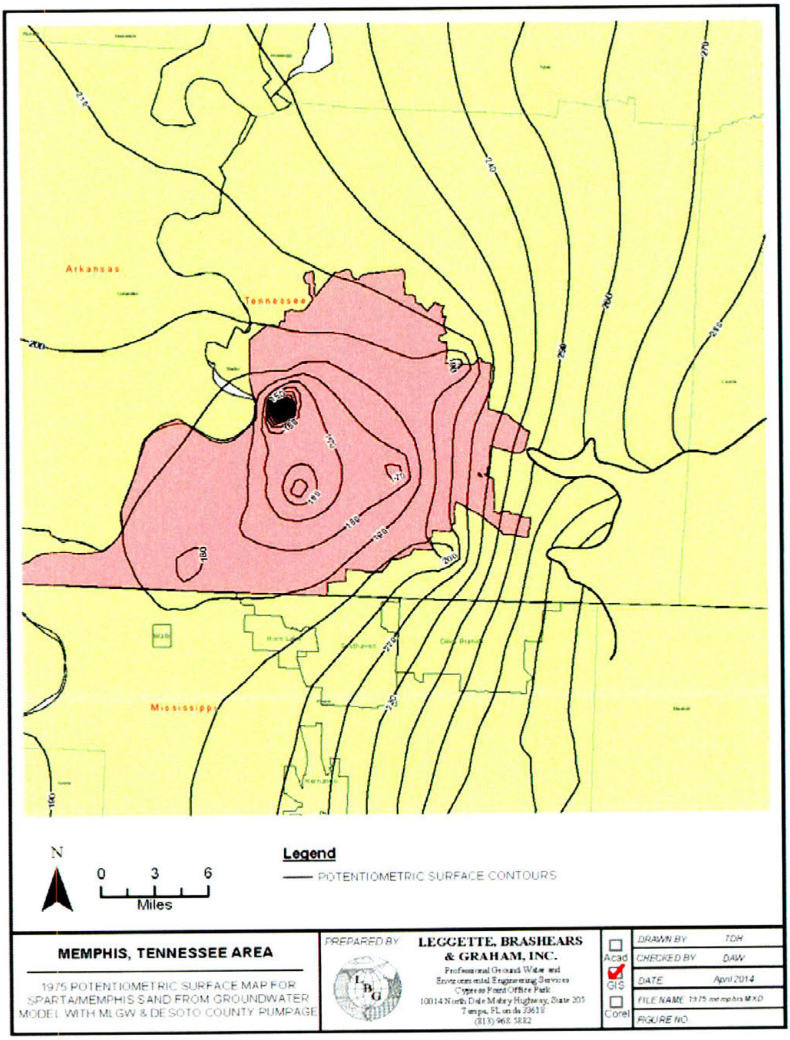
Potentiometric Surface and Drawdown Maps for Sparta/Memphis Sand from Groundwater Model with MLGW and DeSoto County Pumpage (1965-2012)

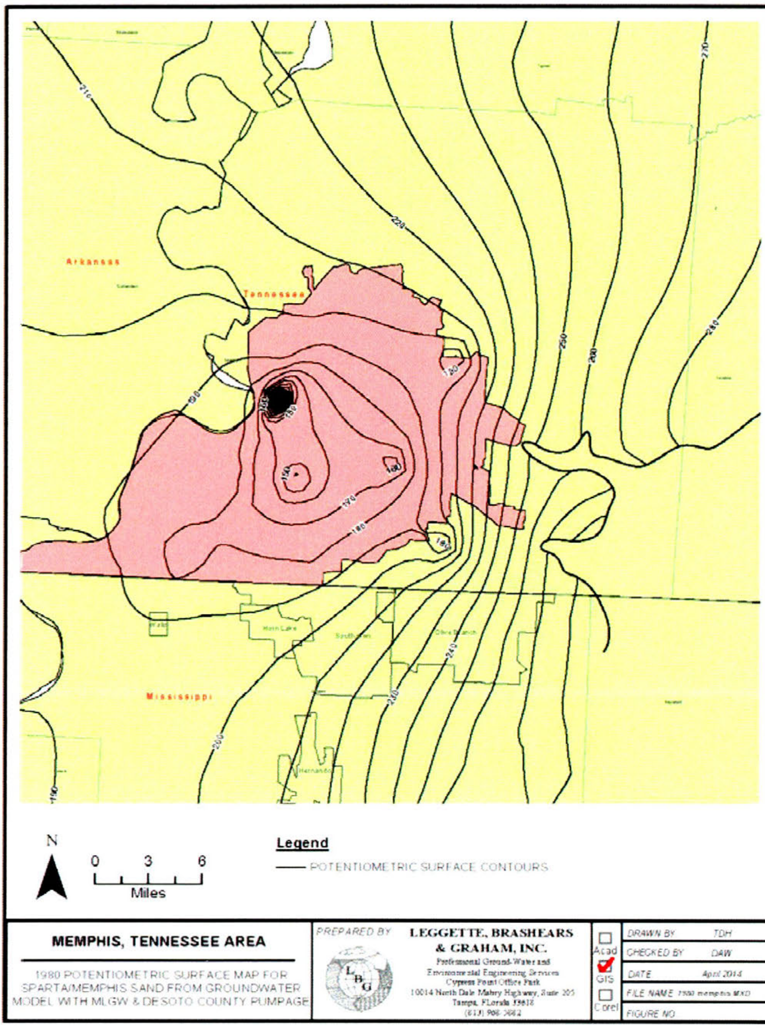
LEGGETTE, BRASHEARS & GRAHAM, INC.

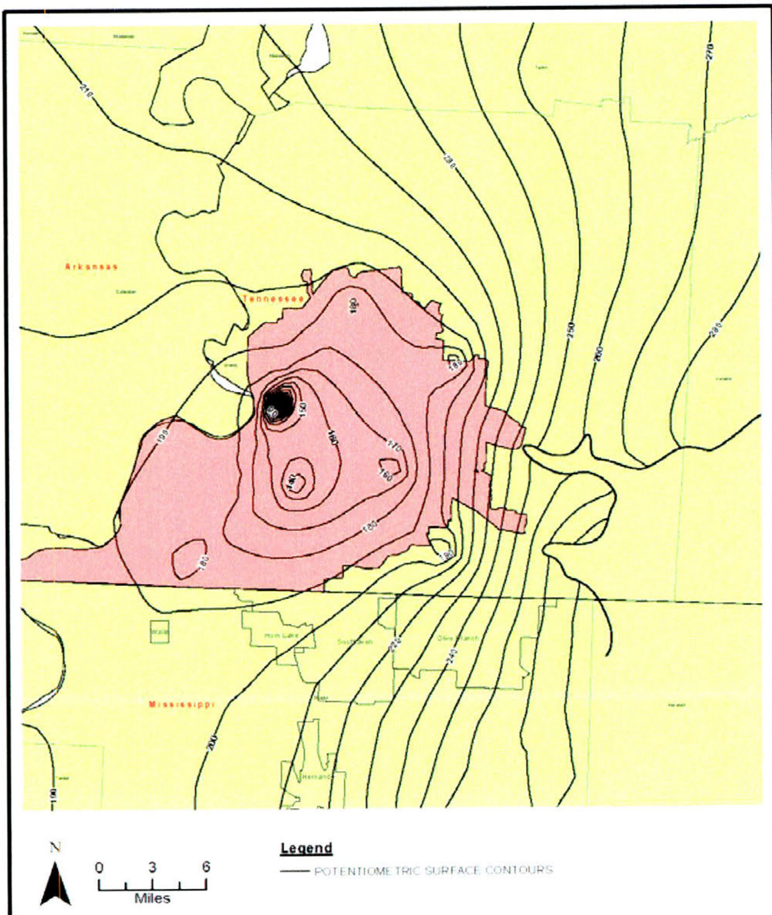

Arkansas
Tennessee
Mississippi
270
280
260
240
250
230
220
210
200
190
140
160
150
N
0
3
6
Miles
Legend
POTENTIOMETRIC SURFACE CONTOURS
MEMPHIS, TENNESSEE AREA
1965 POTENTIOMETRIC SURFACE MAP FOR SPARTA/MEMPHIS SAND FROM GROUNDWATER MODEL WITH MLGW & DESOTO COUNTY PUMPAGE
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
(813) 968-3882
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE April 2014
FILE NAME
FIGURE NO



Arkansas
Tennessee
Mississippi
210
270
260
200
180
160
170
190
220
230
240
250
N
0 3 6
Miles
Legend
POTENTIOMETRIC SURFACE CONTOURS
MEMPHIS, TENNESSEE AREA
1970 POTENTIOMETRIC SURFACE MAP FOR SPARTA/MEMPHIS SAND FROM GROUNDWATER MODEL WITH MLGW & DESOTO COUNTY PUMPAGE
PREPARED BY:
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY: TDH
CHECKED BY: DAW
DATE: April 2014
FIGURE NO.


Arkansas
Tennessee
Mississippi
200
210
240
250
260
270
N
0
3
6
Miles
Legend
POTENTIOMETRIC SURFACE CONTOURS
MEMPHIS, TENNESSEE AREA
1975 POTENTIOMETRIC SURFACE MAP FOR SPARTA/MEMPHIS SAND FROM GROUNDWATER MODEL WITH MLGW & DESOTO COUNTY PUMPAGE
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground-Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY
TDH
CHECKED BY
DAW
DATE
April 2014
FILE NAME
FIGURE NO.


Arkansas
Tennessee
Mississippi
210
220
230
240
250
260
270
280
200
190
180
170
N
0 3 6
Miles
Legend
POTENTIOMETRIC SURFACE CONTOURS
MEMPHIS, TENNESSEE AREA
1980 POTENTIOMETRIC SURFACE MAP FOR SPARTA/MEMPHIS SAND FROM GROUNDWATER MODEL WITH MLGW & DESOTO COUNTY PUMPAGE
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground-Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE April 2014
FILE NAME 1980 memphis.MXD
FIGURE NO



MEMPHIS, TENNESSEE AREA

1985 POTENTIOMETRIC SURFACE MAP FOR SPARTA/MEMPHIS SAND FROM GROUNDWATER MODEL WITH MLGW & DESOTO COUNTY PUMPAGE

PREPARED BY

LEGGETTE, BRASHEARS & GRAHAM, INC.
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Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
(813) 968-5882

DRAWN BY	TDH
CHECKED BY	DAW
DATE	April 2014
FILE NAME	1985 memphis.MXD
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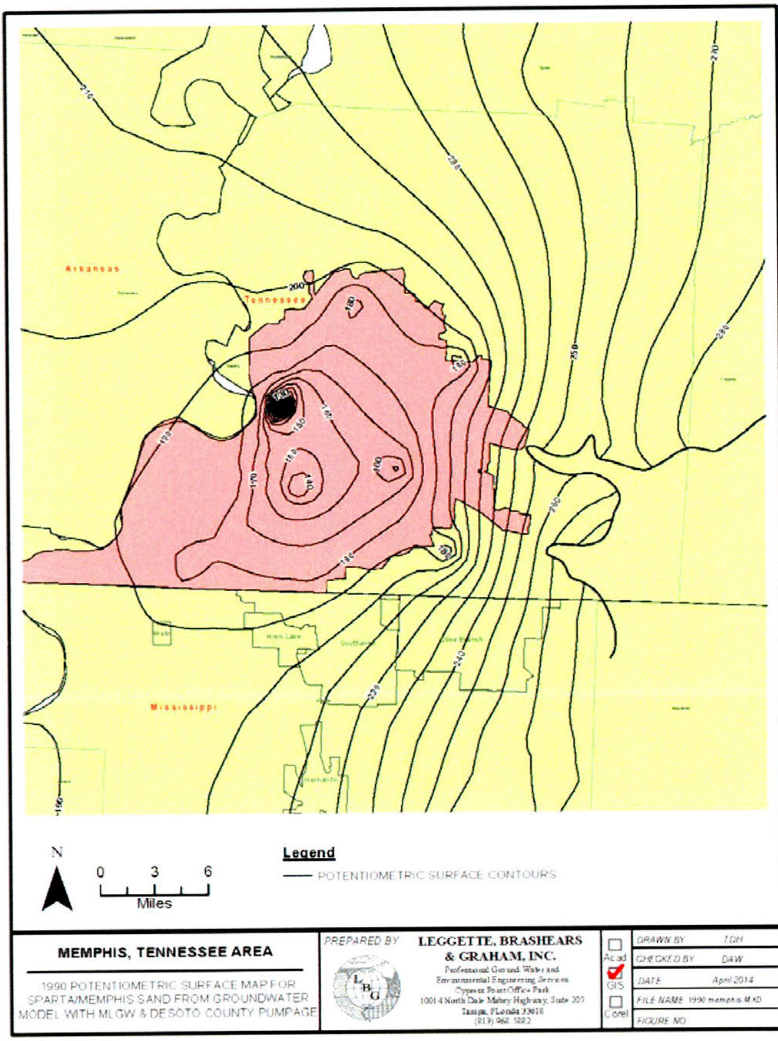
Arkansas
Tennessee
Mississippi
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200
230
270
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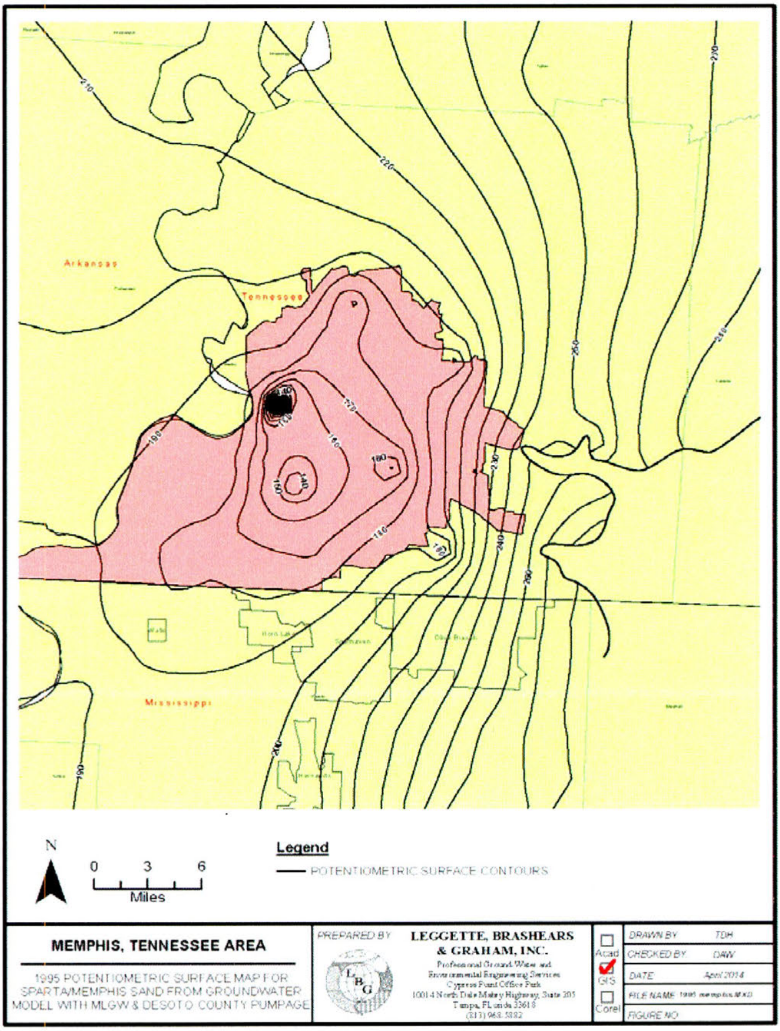
280
180
190
170
160
140
220
240
N
0 3 6
Miles
Legend
POTENTIOMETRIC SURFACE CONTOURS
MEMPHIS, TENNESSEE AREA
1990 POTENTIOMETRIC SURFACE MAP FOR SPARTA/MEMPHIS SAND FROM GROUNDWATER MODEL WITH MLGW & DESOTO COUNTY PUMPAGE
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, FLorida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TGH
CHECKED BY DAW
DATE April 2014
FIGURE NO



210
220
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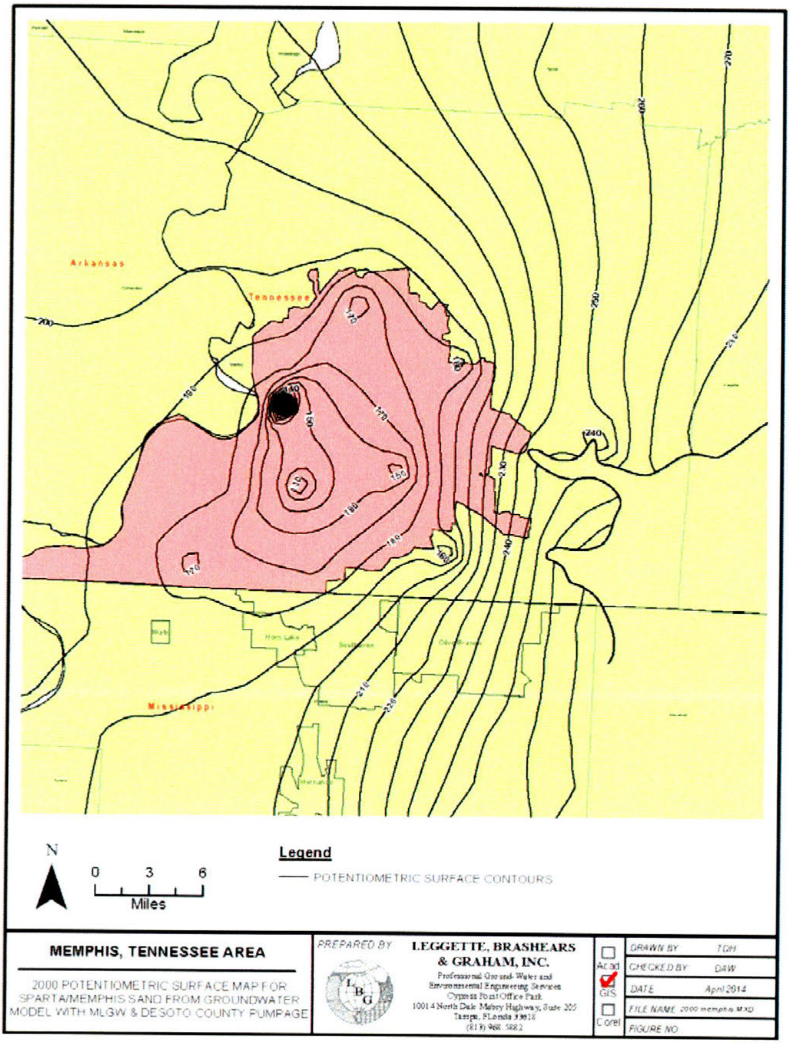
Arkansas
Tennessee
Mississippi
140
150
160
170
180
190
200
230
240
N
0 3 6
Miles
Legend
POTENTIOMETRIC SURFACE CONTOURS
MEMPHIS, TENNESSEE AREA
1995 POTENTIOMETRIC SURFACE MAP FOR SPARTA/MEMPHIS SAND FROM GROUNDWATER MODEL WITH MLGW & DESOTO COUNTY PUMPAGE
PREPARED BY
LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground-Water and Environmental Engineering Services
Cypress Point Office Park
10014 North Dale Mabry Highway, Suite 205
Tampa, Florida 33618
(813) 968-5882
Acad
GIS
Corel
DRAWN BY TDH
CHECKED BY DAW
DATE April 2014
FIGURE NO


Arkansas
Tennessee
Mississippi
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250
260
270
210
220
N
0 3 6
Miles
Legend
POTENTIOMETRIC SURFACE CONTOURS
MEMPHIS, TENNESSEE AREA
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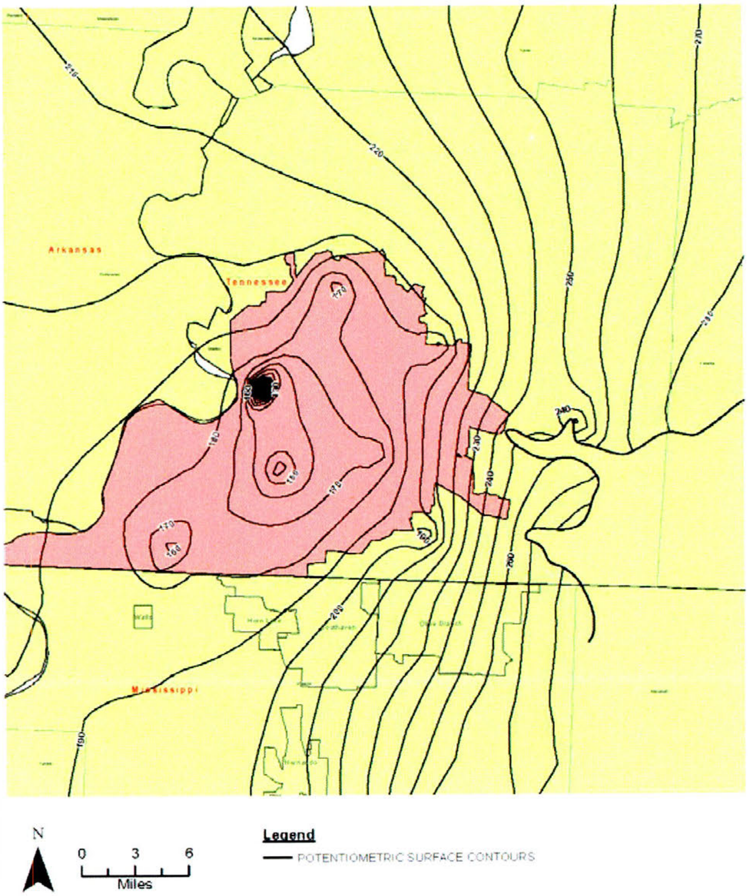

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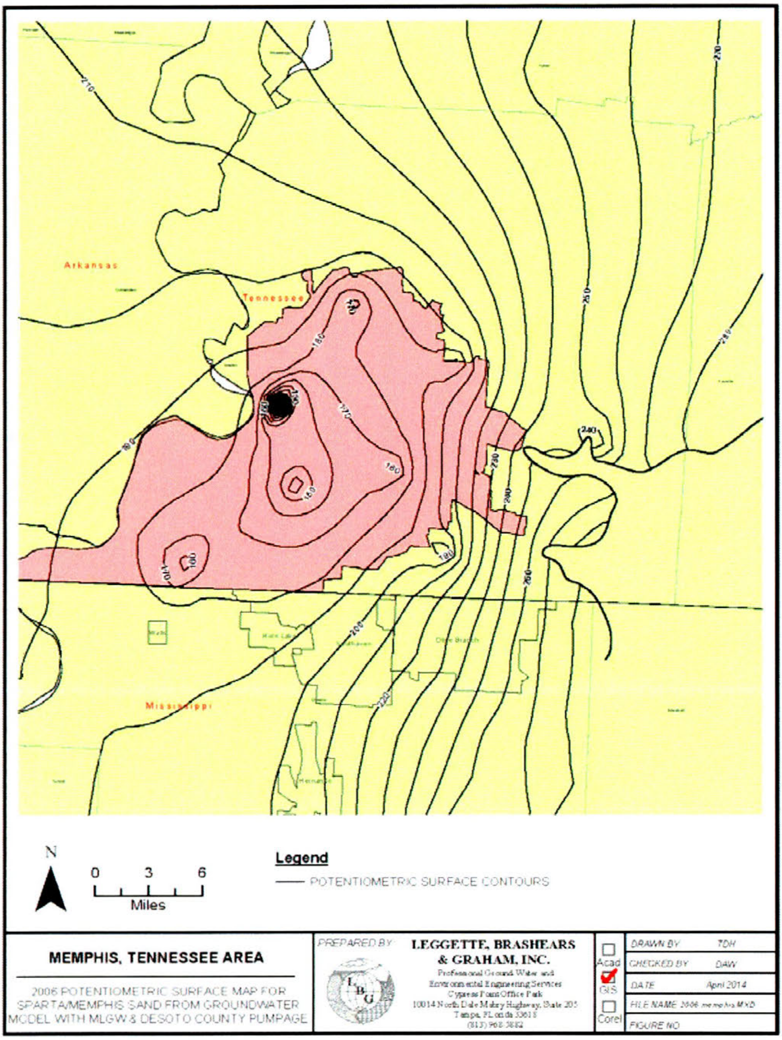
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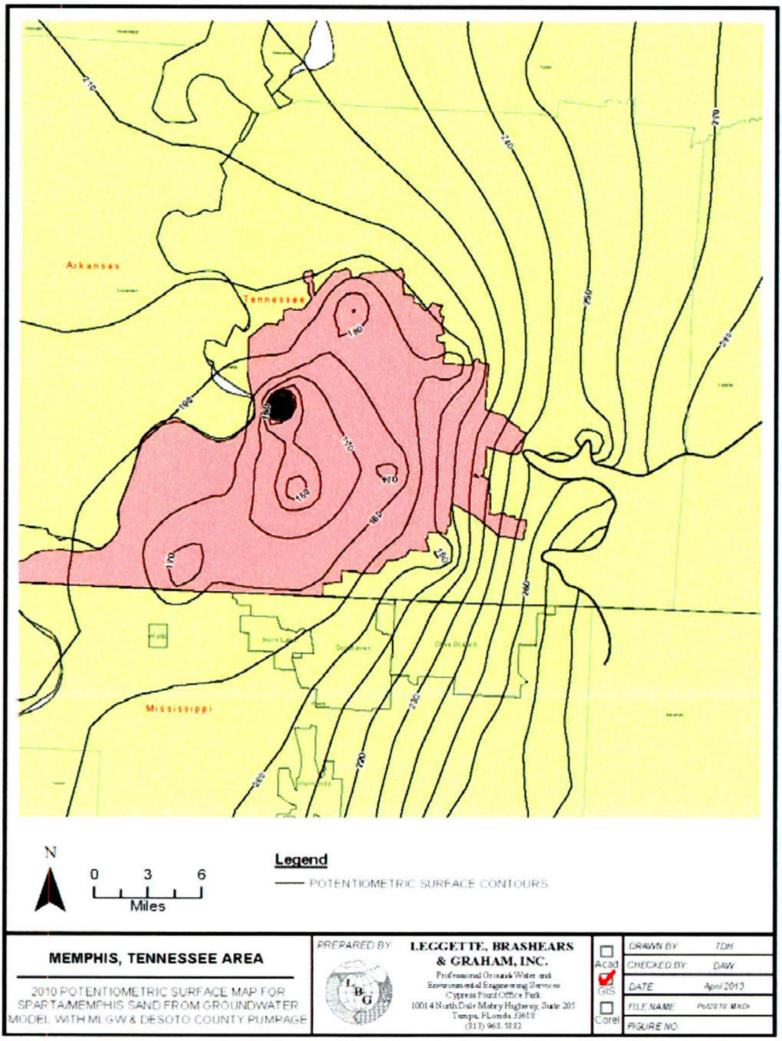
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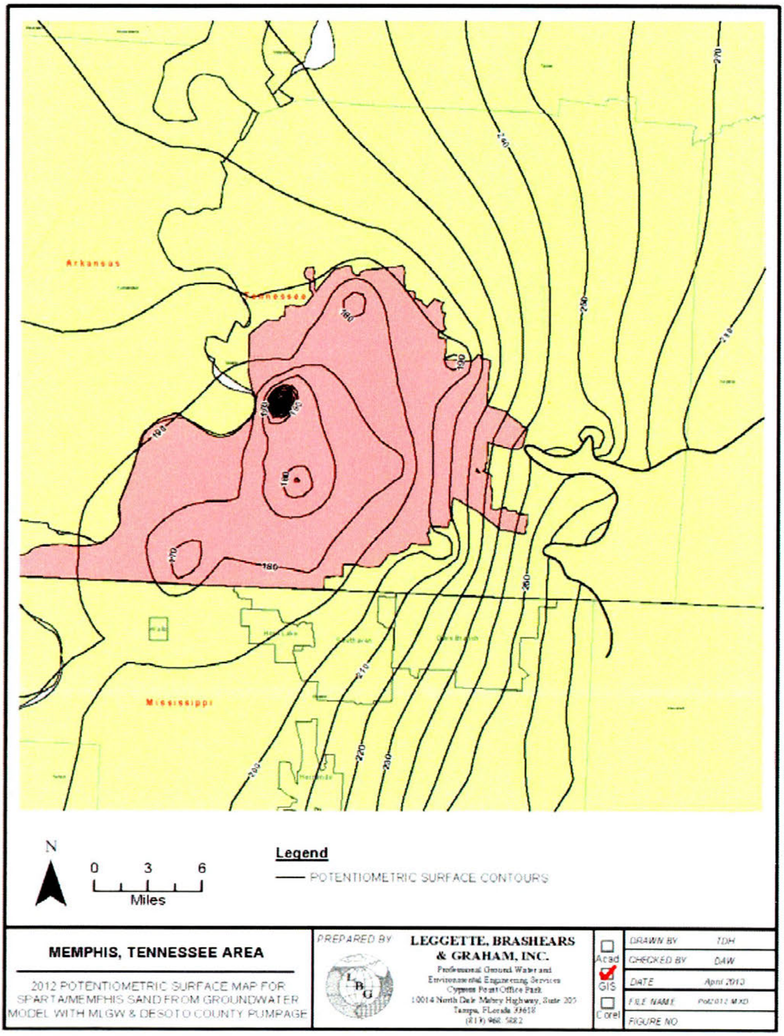
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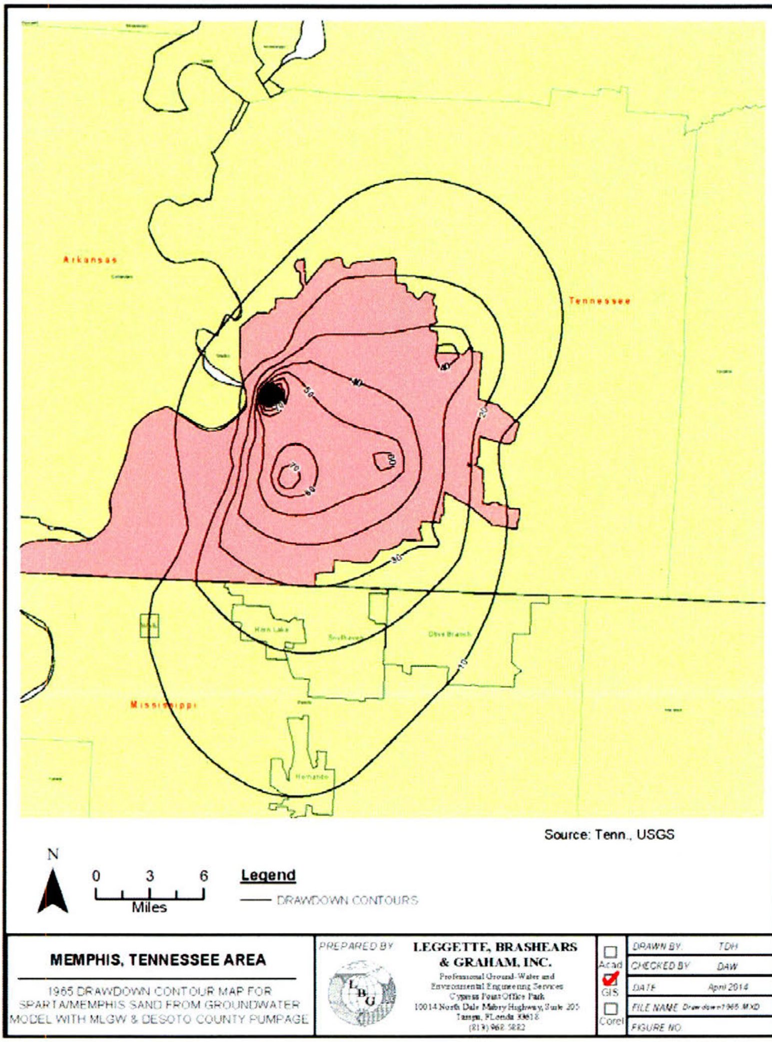
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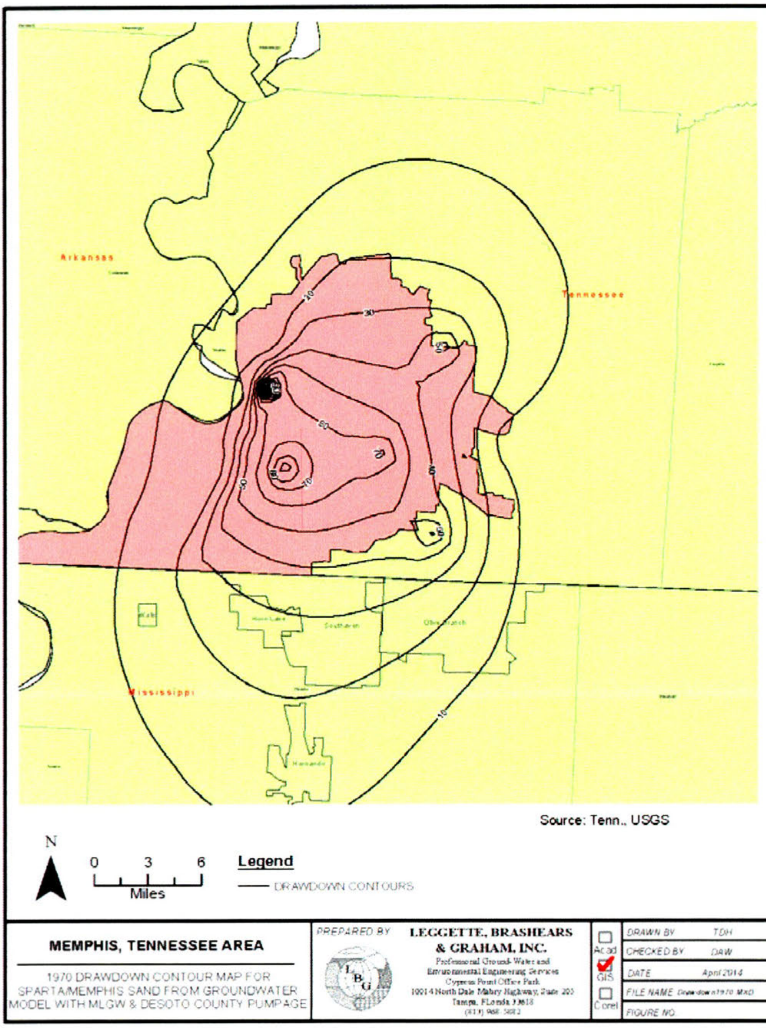
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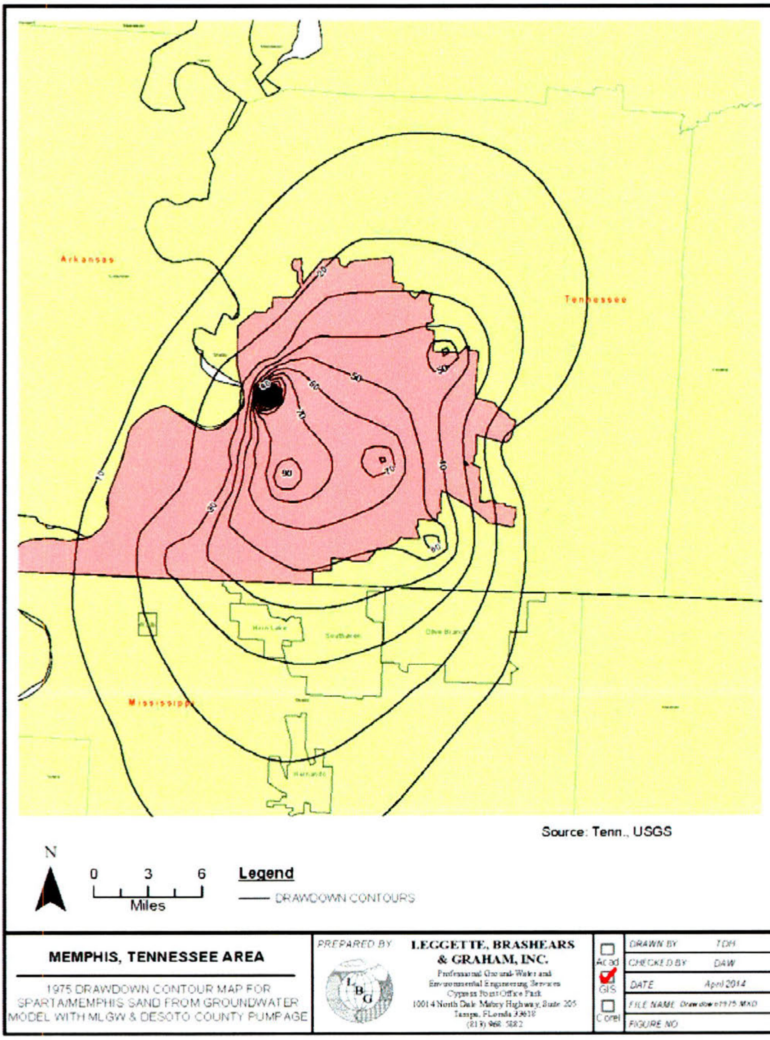
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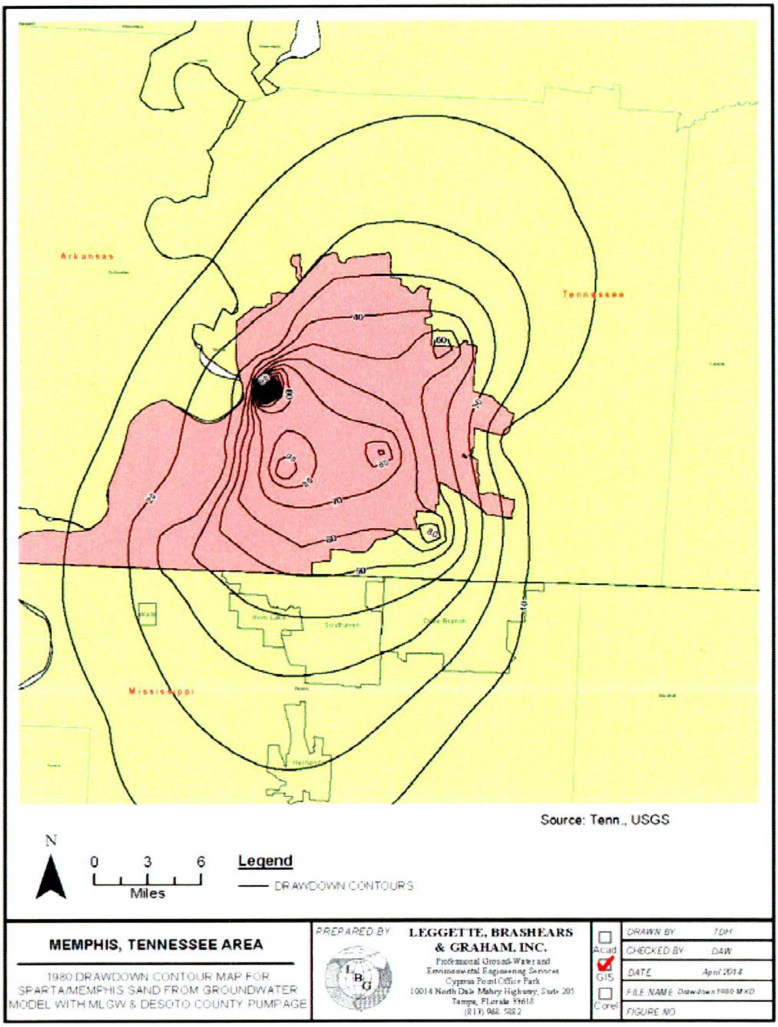
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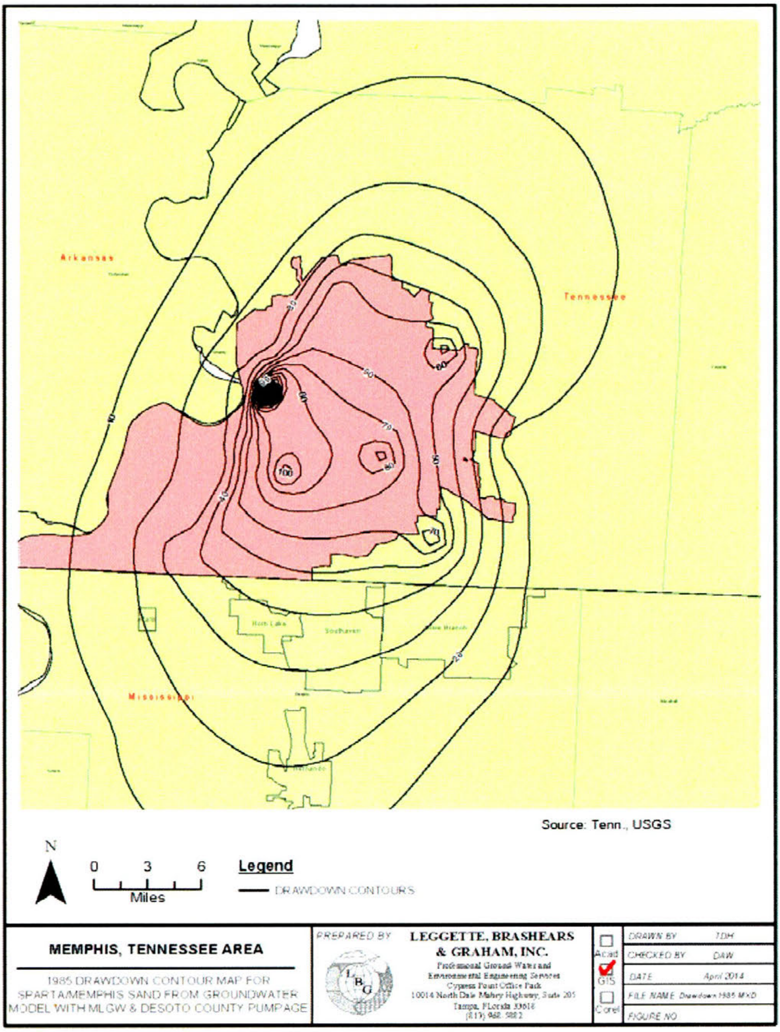
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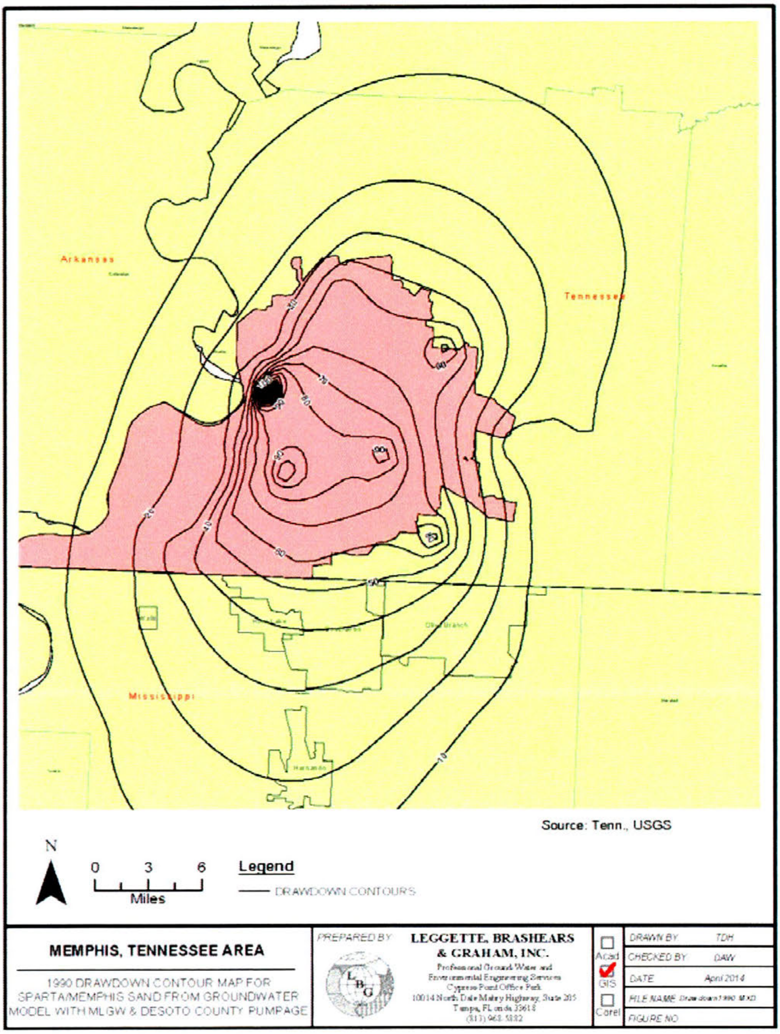
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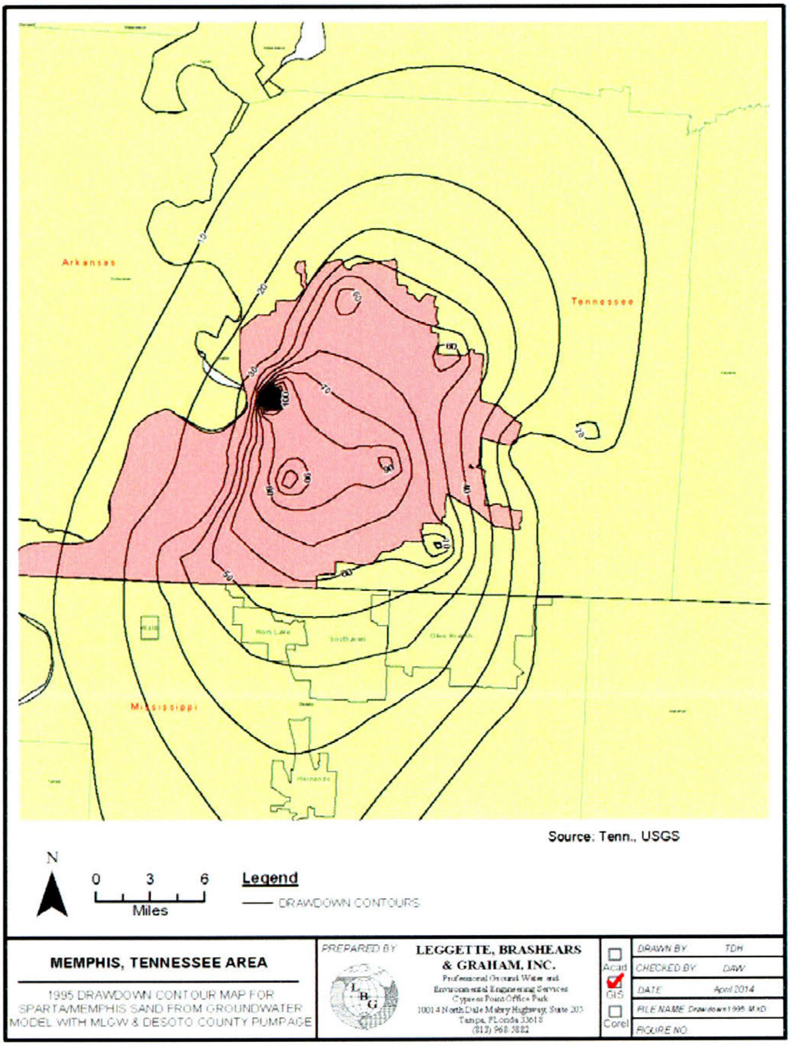

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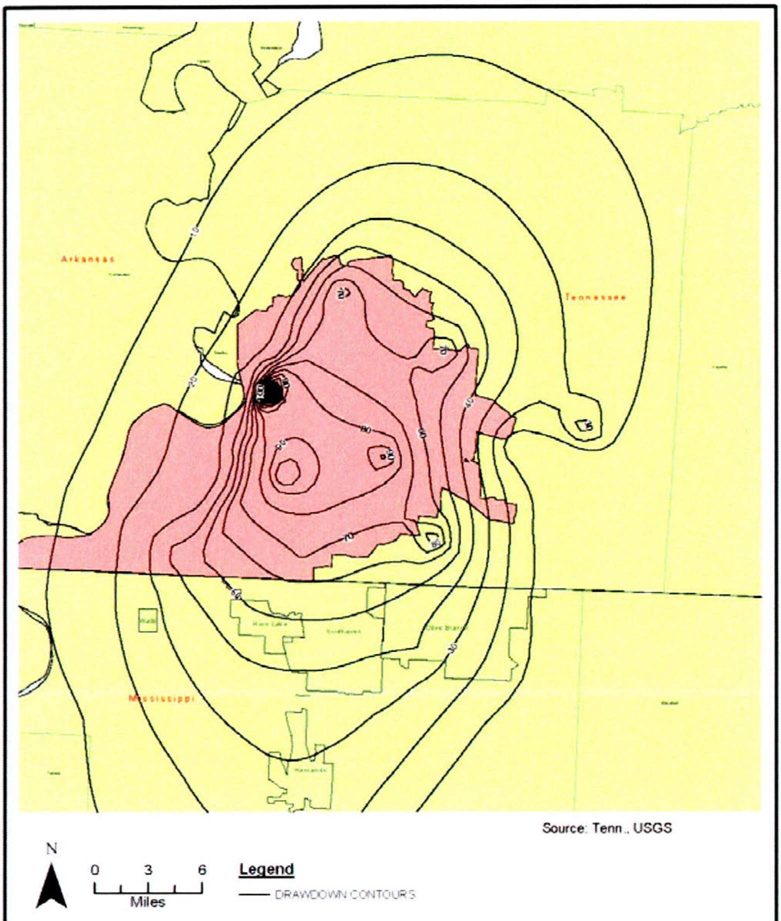

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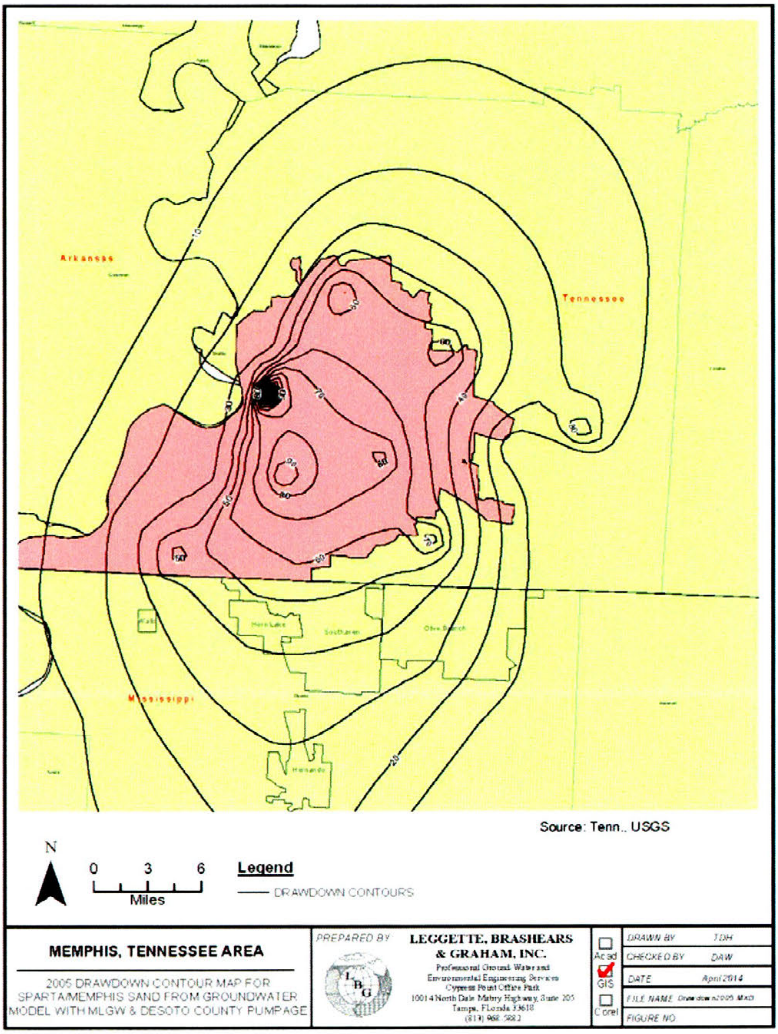
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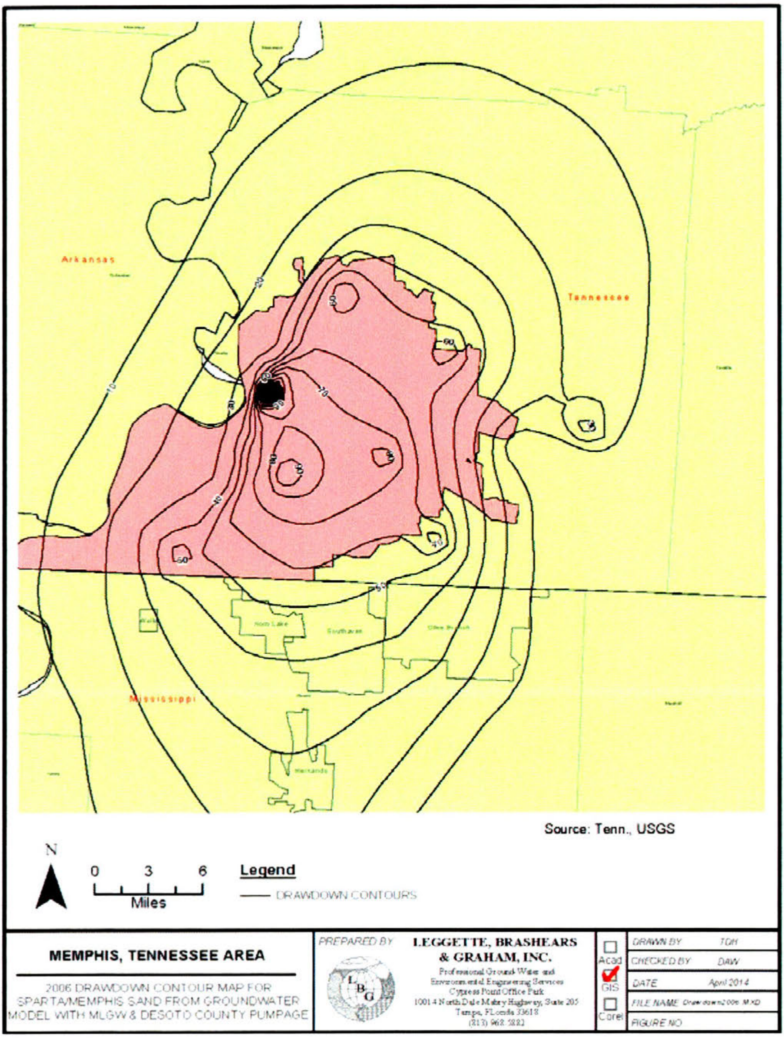
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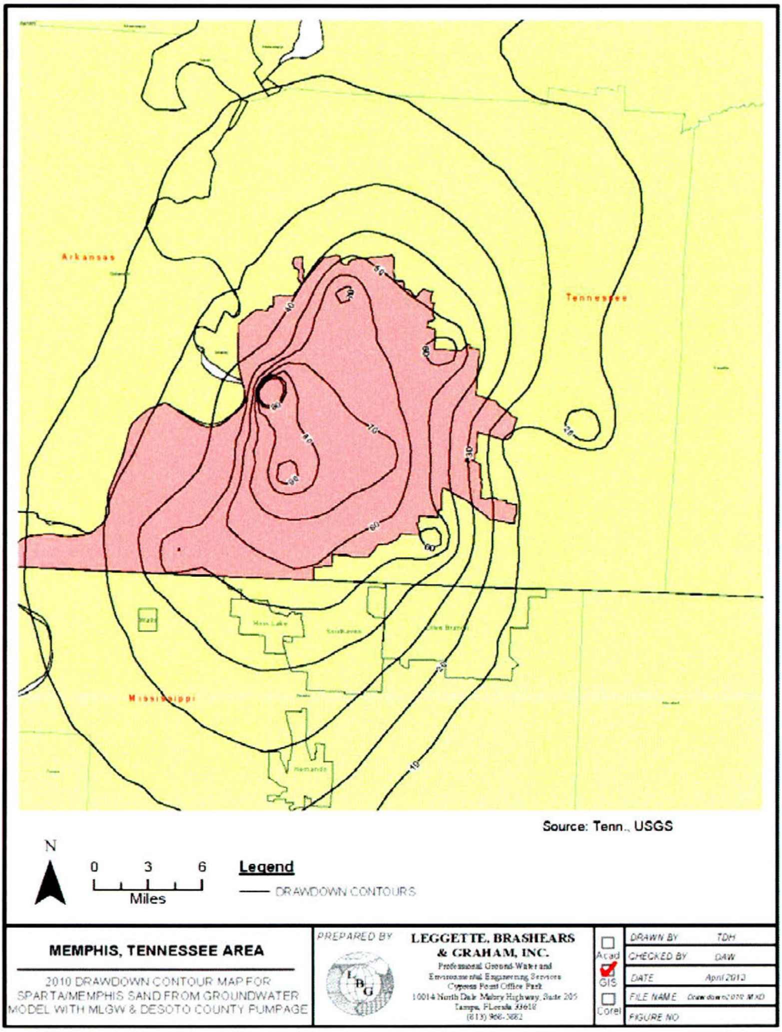
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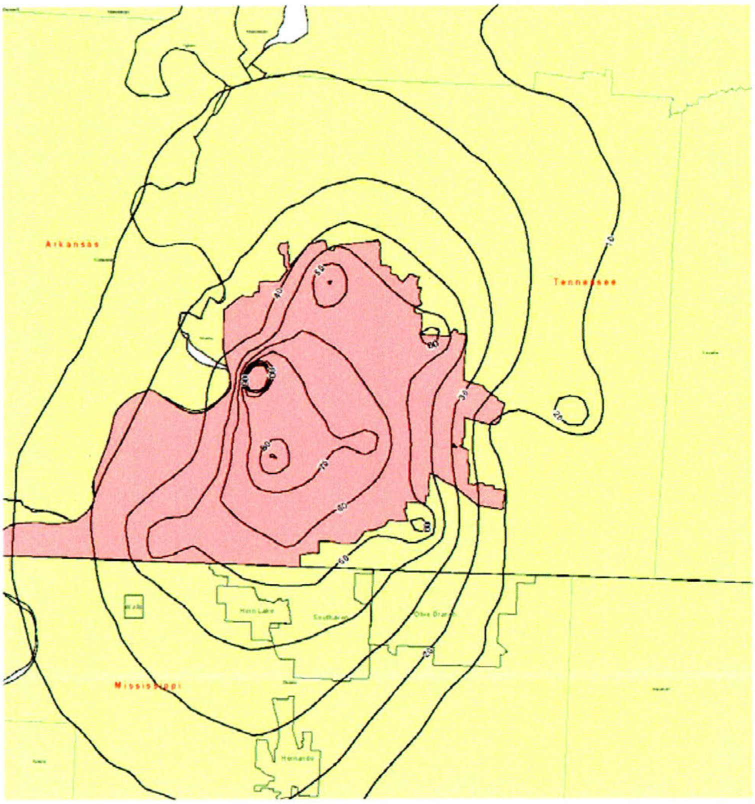

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MEMPHIS, TENNESSEE AREA

2012 DRAWDOWN CONTOUR MAP FOR SPARTA/MEMPHIS SAND FROM GROUNDWATER MODEL WITH MLGW & DESOTO COUNTY PUMPAGE

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EXHIBIT 2

FAIR VALUE OF GROUND WATER DIVERTED FROM NORTHERN MISSISSIPPI DUE TO MEMPHIS AREA WELL FIELDS

Prepared For:
Jim Hood, Attorney General of the State of Mississippi
April 28, 2014

Prepared By:
William G. Foster, Ph.D.
Foster Economic Research
1865 Mountainside Drive
Blacksburg, Virginia 24060

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April 28, 2014

Expert Report (Updated)
by
William G. Foster, Ph.D.
for
The State of Mississippi

I. Introduction

I understand that this case involves the unlawful diversion, usage, and selling of the State of Mississippi's water resources by the City of Memphis, Tennessee, and Memphis Light, Gas & Water Division (MLGW). MLGW is a combination electric, gas, and water municipal utility serving the City of Memphis and Shelby County, Tennessee.

I have been requested by the State of Mississippi to:

A.) Determine the fair value of the water resources in dispute for the period 1985 through 2012.

B.) Determine the amount owed to Mississippi, plus interest, based on the fair market value for this period.

C.) Conduct a similar study of the fair value of Mississippi water for the prospective period of 2013 through 2017.

MLGW pumps high quality water from the Sparta Sand Aquifer which underlies both northwest Mississippi and western Tennessee. MLGW's pumping is withdrawing Mississippi's ground water from the

Sparta Sand Aquifer to supplement its water distribution system.

An appropriate approach to evaluating ground water is to first quantify the amount of water involved. In this instance, it is the quantity of water diverted by MLGW. This quantification was conducted by Leggett, Brashears & Graham, Inc., as set out in their "Update Report On Diversion Of Ground Water From Northern Mississippi Due To Memphis Area Well Fields".

The second step in evaluating ground water is to determine the replacement costs for the ground water. This refers to an alternative method of providing water to MLGW's customers, such as constructing a water plant to treat water from the Mississippi River.

In lieu of using the replacement costs for ground water for valuation purposes, one can determine the compensation value of the diverted water. The replacement cost obviously sets a ceiling on this value. This would be the fair value of the resource that would be paid to the injured party in a dispute. This study analyzes the fair value of the Mississippi water diverted by the City of Memphis.

I am the President of Foster Economic Research. I have been an independent economic consultant in the natural resource field for more than 43 years, specializing in market analysis. I hold a Ph.D. in economics from The George Washington University. A copy of my resume is in Exhibit I of this report.

I am being compensated for the preparation of this report at a rate of $275 per hour.

I reserve the right to revise this report as necessary to reflect new facts that may become available. Exhibit II is a list of documents that I relied on in order to form my opinion. Exhibit III contains schedules that support this report.

II. Executive Summary

I have been requested by the State of Mississippi to determine a fair value of the water resources in dispute between Mississippi and MLGW for the period 1985 through 2012, and prospectively through 2017.

The value of the water can be estimated using a fair market value determination. Had MLGW negotiated a wholesale purchase contract to buy the water from Mississippi, the two parties would have considered a number of factors, including: market demand, quality and location of the water, alternative sources of supply, cost of production, value to consumers, and comparable water rates. These factors that would have been considered in the negotiations would determine the fair market value.

The negotiated price would be lower than the alternative replacement cost of the water. In the present case, the alternative supply for MLGW would be water from the Mississippi River, and that would require a water treatment plant. I found that the cost of this plant would be higher than the assumptive negotiated price.

The amount owed to Mississippi is the market price multiplied by the volumes diverted by MLGW's wells, plus interest. Two market prices were estimated: one based upon MLGW's wholesale contract rates, and the other based upon MLGW's wholesale contract rates minus production costs.

The table below summarizes the 1985 through 2012 period.

Table 1: Summary of Damages 1985-2012

	High Case	Low Case
Principal	$248,759,000	$197,730,000
Interest @ 8%	$536,775,000	$418,251,000
Total	$785,534,000	$615,981,000

Prospectively through 2017, MLGW owes Mississippi $43 million to $57 million, on a present value basis.

III. Fair Market Approach

My approach in determining the fair value of Mississippi's ground water is a market value determination. MLGW could have approached Mississippi in order to contract for the purchase of water from Mississippi's portion of the Sparta Sand Aquifer. Instead, MLGW continued to pump Mississippi ground water into its water distribution system. Mississippi should have been compensated for its water by means of a wholesale purchase contract. The market value of a wholesale water contract is the price that a buyer and a seller negotiate at a given time. The amount owed to Mississippi is the price multiplied by the volumes diverted by MLGW.

In negotiating such a contract, a number of factors should be considered, including: market demand, quality and location of the water, alternative sources of supply, cost of production, value to consumers, and comparable water rates. These factors will be discussed in turn.

IV. Market Factors (1985-2012)

A.) Market Demand

In 1985, MLGW used approximately 54.3 million cubic feet (c.f.) of water. The system showed major growth over the previous twenty years as a result of population growth and new industry. The following table shows MLGW's water usage over the period 1965-1985.

Table 2: MLGW Water Usage 1965-1985

Millions of c. f.

Year	Res.	Com.	Free Met.	Other	Total
1965	13.0	14.6	1.3	.1	29.0
1970	16.0	19.0	1.5	.4	36.9
1975	20.3	22.0	1.0	1.1	44.4
1980	24.1	25.1	1.3	.8	51.3
1985	25.1	25.2	2.4	1.6	54.3
Gr. Rate	3.3%	2.8%	3.1%	----	3.2%

Source: MLGW Annual Reports

Between 1965 and 1985, water demand on MLGW's system grew in excess of 3 percent per year. From 1975-1985 water demand grew at 2 percent per year. MLGW's *1985 Annual Report* discusses the growth in the city of Memphis, and the importance of the quality of water drawn from the Sparta Sand Aquifer in attracting new industries to the area.

Memphis water is one of the city's key selling points when industries are contemplating locating in the city. Many industries that require a highly pure and abundant source of water for their products, such as brewing, bottling, or cosmetic manufacturing, find Memphis' water ideal. Our water is of excellent quality, contains no organic matter or harmful bacteria and has no odor or taste. As a result, industries find little need for extensive filtering and purification systems that would be required in other major cities.

...Memphis and Shelby County's water supply comes from an area 500 feet below the city which is called the Memphis Aquifer. Our water is pumped from 143 artesian wells at nine water stations owned by MLGW.

...Even though Memphis and Shelby County is growing every day in population, MLGW will be able to accomodate [sic] *future water needs of the city. While water shortages may affect the growth of cities in the future, Memphis can progress with an abundant water supply.*

(Memphis Light, Gas and Water Division 1985 Annual Report, p. 13)

MLGW expected water consumption to continue to grow on its system. According to the Utility's 1985 Water System Master Plan, residential/commercial consumption was expected to increase by over two percent per year.

Water demand continued to grow after 1985, and MLGW continued to pump water from the Sparta Sand

Aquifer within Mississippi to meet MLGW requirements. Between 1985 and 2006, water usage on MLGW's system grew by 1.1 percent per year. According to MLGW's *2006 Master Plan Report*, water demand was expected to continue to grow by about 1 percent per year over the next decade. However, the demand for water did not meet this projection. Demand actually declined as a result of a downturn in the area's economic conditions, and MLGW's newly implemented conservation programs.

B.) Quality And Location Of The Water

In a wholesale water agreement, the quality and location of the water are primary considerations.

The water from the Sparta Sand Aquifer is superior in quality, as attested to by the above quoted MLGW Annual Report. In fact, in the 1986 Annual Report, MLGW boasted about the water quality in Memphis, saying:

> *The secret's out on Memphis' water... the American Water Works Association (AWWA)... voted Memphis' drinking water the best in the United States.*
>
> *...There are virtually no traces of heavy metals such as lead, mercury, and arsenic, and the water has no traces of man-made compounds such as pesticides or solvents. The reason? Memphis "artesian" water is naturally filtered by the Sand and gravel through which it is pumped, meaning that it arrives at the purification and pumping facilities in a remarkably clean form. Since it is well water, it is never exposed to the "surface impurities" which are common problems*

where surface water supplies, such as lakes or rivers, are used.

(Memphis Light, Gas and Water Division 1986 Annual Report, p. 6)

There has been no deterioration in the quality of the water from the Sparta Sand Aquifer in the intervening years. In 2012, The President and CEO of MLGW, Jerry R. Collins, Jr., stated: *"Everyone knows Memphis has the best water in the world."* (MLGW News Release, June 18, 2012)

The location of the Sparta Sand Aquifer is also of benefit to MLGW. The proximity of the water to Memphis and Shelby County allows MLGW to locate their well fields close to the growth centers, which keeps the cost of the distribution at a low level.

In 2011, MLGW discovered an additional value to the location of this water supply. The Mississippi River floods that occurred in April and May of 2011 were the largest and most damaging on record. The areas that were hit the hardest included parts of Tennessee and Mississippi. *(FloodSmart.gov)* During this flood period, MLGW reported: *"The MLGW water supply is safe and no issues are expected due to the flooding....MLGW does not use surface water to supply its customers – it uses ground water from the Memphis aquifer, which is located hundreds of feet below the surface."* (MLGW News Release, June 3, 2011)

C.) Alternative Sources of Supply

Another consideration in negotiating a wholesale water contract is what other sources of water are available, and the cost of each. A rational buyer would consider the alternatives and eliminate those that are too expensive. In this case, the buyer (MLGW) would not be willing to pay Mississippi more than the cost of alternative water supplies. There are two possible alternative sources of water in this case: Mississippi River water and new wells in the northeast portion of the MLGW service territory farther away from Mississippi.

The Mississippi River as a source has many disadvantages. The water is much lower in quality due to pollutants (e.g., agricultural runoff) and sediment. In fact, the Environmental Protection Agency (EPA) reports that the Mississippi River is the most polluted river in the United States, containing more direct toxic discharge than any other river. *(Source: EPA Website)*

In order to use water from the river, MLGW would have to make major capital investments. These would include: pumping stations, treatment plants, and transmission facilities to tie into the existing infrastructure. MLGW's Spring 2005 Water Scanner Team Report (Water Rights section) lists four disadvantages to using water from a surface water plant: increased cost, taste and odor complaints, infrastructure issues, and increased regulations from the state. In a 2003 Water World article, Dr. Jerry Anderson, the Director of the University of Memphis, Memphis Ground Water Institute compared the cost of Sparta Sand water to that of Mississippi River water:

> *Water from these sands costs $15 per 10,000 gallons per month delivered to residential customers, less than half of the cost in many parts of the country and only a third as much as in areas where the water has to be highly treated.*

If Memphis drew its water from the Mississippi River rather than from artesian wells, the cost would easily be three times more than it is.

(Memphis water termed "sweetest in the world", Water World November 1, 2003)

In 2007, The Mississippi Engineering Group conducted a study to estimate the cost of using Mississippi River water as an alternative source of supply for MLGW. The cost estimate is as follows:

1) Total capital investment, including a water treatment plant, an intake station, and transmission mains, would be $607 million (in 2006 dollars).

2) Incremental operating and maintenance production costs would be $23.1 million per year (in 2006 dollars) .

3) The plant capacity would be 165 MGD, with an output of 120 MGD.

If MLGW had to invest $607 million in a Mississippi River treatment plant, the annual carrying cost including interest and depreciation would be approximately $61 million per year. This annual cost plus the incremental operating and maintenance production costs of $23.1 million, equals $84 million per year. This annual amount plus MLGW's cost of service would result in water rates that would be almost double the current level putting it on par with many other cities' water cost.

The above costs are in 2006 dollars. Construction costs and operating and maintenance production costs were lower in 1985 than they are today. Interest rates were higher, therefore carrying charges were higher. I have estimated MLGW's 1985 capital investment in a Mississippi River treatment plant based on "The Handy-Whitman Index of Public Utility Construction Costs (Cost Of Trends Water Utility Construction in the South Central Region). The 1985 investment would have been $358 million, and the annual carrying charge plus depreciation would have been $46 million. The incremental operating and maintenance production costs would have been $11 million, based on MLGW cost trends. The total cost in 1985 would have been $58 million, making this option very costly. This cost would not establish a ceiling price between a buyer and seller for Sparta Sand water for it was far higher than any reasonable negotiated price. Schedule 1 of Exhibit III sets out these calculations.

The other alternative is drilling wells in the northeast portion of the MLGW service territory. This alternative also has disadvantages, including capital investments in wells, treatment facilities, and transmission facilities to tie into the existing infrastructure. If MLGW chose to drill wells in the northeast portion of their service territory, they would have two options. First, they could drill into the Sparta Sand Aquifer to 500 feet, as they do in the southern part of the service territory. Second, they could drill into the Fort Pillow Sand Aquifer to a depth of 1400 feet. In either case, there is some question as to whether the new wells would also pull from the State of Mississippi's water resources which would need to be resolved.

D.) Cost of Production

MLGW has production costs associated with using water from the Sparta Sand Aquifer. These expenses include electric power for pumping, and other operating and maintenance expenses. These production costs have increased since 1985, as shown in the following table.

Table 3: MLGW's Production Costs

Year	$/Th. Gals.
1985	0.1418
1990	0.1646
1995	0.1663
2000	0.1800
2005	0.2248
2010	0.3087
2012	0.3538

Source: Schedule 2 of Exhibit III

In negotiating a contract, parties could argue whether the production costs should be deducted. The deductibility of these costs depends upon the negotiating strength of the parties. I have developed two cases in this report: one with production costs removed and one with them included. (See below.)

E.) Value to MLGW's Customers

Economists determine the value of a commodity by estimating the customer's "willingness to pay". Dr. William W. Wade conducted a study to determine the value of MLGW's water to its customers. Dr. Wade considered two possible cases: a high elasticity case and a low elasticity case. He found that in 1985, the value to customers ranged from $0.45 to $0.70 per thousand gallons. This value increased to a range of $0.61 to $0.90 per thousand gallons by 2005. One can assume that, had they been paying Mississippi over the period 1985 to the present, the price per thousand gallons would have been within the ranges estimated by Dr. Wade. *(See "Valuation of Mississippi-Owned Groundwater Used in MLGW Service Area," expert report of William W. Wade, Ph. D.)*

F.) Comparable Retail Water Rates

From 1985 to date, MLGW's retail customers have benefited from the availability and low cost of water from the Sparta Sand Aquifer. In 2003 for example, MLGW states in it Annual Report:

> *The reliability and low cost of our utility service... led to more than $1.38 billion in new and expanding business investments during 2003 and created almost 8,000 new jobs in our area.*
>
> *... Some new businesses say a major influence in their relocation or expansion in Memphis is the reliability and low cost of MLGW services and the abundant availability of naturally pure water in the area.*

(Memphis Light, Gas and Water Division 2003 Annual Report, p. 9)

MLGW's rates are some of the lowest in the country. While they have increased over time, they still remain lower than those of "peer cities". The table below shows the trend in MLGW's residential rates and the average monthly bill for customers over the period May 1985 to January 2013.

Table 4: Trend in MLGW's Residential Water Rate (RS W-1)

Effective Date of Rate Change	$/Ccf	$/Th. Gal.	$/Month (1500 cf/mo.)
May 2, 1985	$0.5250	$0.70	$7.88
Sept. 1, 1986	$0.5618	$0.75	$8.43
March 1, 1988	$0.6011	$0.80	$9.02
Jan. 2, 1990	$0.6582	$0.88	$9.87
April 1, 1991	$0.7076	$0.95	$10.61
Jan. 1, 1993	$0.7832	$1.05	$11.75
Jan. 6, 1995	$0.9007	$1.20	$13.51
Dec. 30, 2003	$1.1406	$1.52	$17.11
June 26, 2008	$1.3100	$1.75	$19.65
Jan. 3, 2011	$1.3760	$1.84	$20.64
Jan. 2, 2013	$1.4740	$1.97	$22.11

Today a MGLW residential customer pays about $22.11 per month for water. This is far less than customers in peer cities would pay. I have collected rate information for peer cities during four years: 1998, 2001, 2007 and 2013. In every instance, MLGW's average water bill is less than those of the other cities. (See Schedules 3, 4, 5, and 6 in Exhibit III.) For example, in 2013, while MLGW's customers were paying on average $22.11, the average for customers in peer cities was $39.92, which is 81 percent higher.

G.) Wholesale Rates

One way to establish a fair market value for a commodity is to examine comparable wholesale rates. (Water sold on the wholesale market is water that, by contract, can be resold by the initial purchaser.) In this case, one can look to the wholesale prices that MLGW has charged over time for water from the Sparta Sand Aquifer. This resale rate represents the value that MLGW assigned to the water on the wholesale market.

The following table shows the trend in MLGW's wholesale market rates from 1985 to 2013.

Table 5: MLGW's Wholesale Market Rates (W-9)

Effect. Date	$/Ccf	$/Th. Gals.
05/02/85	$0.4100	$0.548
09/01/86	$0.4390	$0.587
03/01/88	$0.4697	$0.628
01/02/90	$0.5143	$0.688
04/01/91	$0.5529	$0.739
01/01/93	$0.6171	$0.825
01/06/95	$0.7158	$0.957
12/30/03	$0.9881	$1.321
06/26/08*	$1.1440*	$1.529*
11/03/11*	$1.2010*	$1.606*
01/02/13	$1.2850	$1.718

**Data for these years were estimated.*

The table above shows MLGW's wholesale market rates since 1985. These W-9 rates represent constant year round service. MLGW also has negotiated sales contracts based upon these rates. However, the negotiated rates vary by time of day and season.

The average annual resale prices for the period 2010 through 2012 are shown on Schedule 8 of Exhibit III. Over this period, the weighted average of all these annual resale prices is $1.266 per thousand gallons. This resale price is $0.34 below the W-9 charges.

MLGW's wholesale customers include the Mississippi municipalities of Arlington, Bartlett, Collierville, Germantown, Lakeland, Millington and Olive Branch. This shows that MLGW is actually selling water diverted from the Sparta Sand Aquifer back to municipalities in the State of Mississippi for a profit. For example, in 2001 MLGW contracted with the City of Olive Branch, Mississippi at a price that ranges from 75% to 125% of the W-9 wholesale price, depending upon the time of day and season the water is purchased.

V. Fair Market Value/Damages

In my opinion, a fair market value is a rate between MLGW's wholesale rate and the wholesale rate minus production costs. I have developed two damage cases, a high price case (wholesale rates) and a low price case (the wholesale rates minus production costs). The damages are the prices times the volume of the water diverted by MLGW over the period 1985 to 2012, and prospectively to 2017.

In this report I have relied upon the updated report of Legette, Brashears & Graham for the volumes of the water diverted from Mississippi by MLGW. Schedule 7 of Exhibit III shows the volume of Mississippi's water that has been diverted by MLGW from 1985 through

2012. It is estimated that in 1985, MLGW took 9,274.6 million gallons. Since that time the volumes have fluctuated. For example, in 2012 the amount of water diverted was 7,678.7 million gallons. MLGW projects that pumpage will be constant over the next five years.

I have applied the fair market value to these volumes to calculate the amount owed to Mississippi by MLGW. Schedules 9 and 10 of Exhibit III show the amount due under the high case and the low case. Schedules 11 and 12 show the calculation of the interest related to the high and low damage cases. Interest is applied at 8 percent compounded annually.

The table below summarizes the damages due to Mississippi plus interest over the period 1985 to 2012.

Table 6: Summary of Damages 1985-2012

	High Case	Low Case
Principal	$248,759,000	$197,730,000
Interest @ 8%	$536,775,000	$418,251,000
Total	$785,534,000	$615,981,000

VI. Prospective Damages (2013-2017)

I have calculated prospective damages for the period 2013 through 2017. This estimate is based on the same methodology that was used above. The present value calculations assume that the total payment will be made in 2014, therefore the principal was discounted by eight percent. The prospective MLGW pumpage was held constant at the 2012 level, consistent with MLGW's 2012 Strategic Plan. This plan also recognized the continuing load migration to the east, and the continuing reliance upon the Sparta Sand

Aquifer. Schedule 13 of Exhibit III shows the prospective damages. The table below summarizes the prospective damages.

Table 7: Summary of Prospective Damages 2013-2017

	High Case	Low Case
Principal	$ 65,960,000	$ 49,443,000
Pres. Value @ 8%	$ 56,937,000	$ 42,817,000

Exhibit I

Foster Economic Research
William G. Foster, Ph.D., President
1865 Mountainside Drive Blacksburg, Virginia 24060 Telephone: (540) 230-7277

Profession:	Energy Economist
Years of Experience:	43
Education:	Ph.D. in Economics, George Washington University (1982) Master of Arts, George Washington University (1975) Bachelors of Science, the University of Maryland (1970)

Key Qualifications:

Over the past 41 years, Dr. Foster has specialized in energy, natural resources and public utility economics. Dr. Foster spent most of his professional career with Foster Associates Inc., a firm that he joined in 1970. In 2006, he established Foster Economic Research.

Dr. Foster has provided consulting services addressing a wide range of regional, national and international energy-related issues and problems, with a particular focus in natural gas, petroleum, coal and electricity. He has prepared studies on such subjects as: demand and supply analysis, forecasts of supply and demand, project feasibility, regulatory analysis, market valuation, storage and transportation arrangements, royalty and taxes impacts, inter-fuel competition, sale/purchase contracting practices. He has developed energy demand and supply planning models, both for in-house use and for use by clients.

Public utility assignments have included issues such as cost of service and rate design, revenue requirements, supply/conservation, supply planning, load and rate forecasts, and the assessment of regulatory environment including restructuring, project feasibility, prudent reviews and audits. These assignments have been in the electric, natural gas and water/sewer industries.

Dr. Foster has conducted studies on antitrust issues within the petroleum and natural gas industries. These studies include the analysis of market shares, barriers to entry, degrees and measurements of competition, market definitions, vertical integration, regulation, impacts of mergers and damage estimates.

Expert Testimony:

Dr. Foster has presented testimony and evidence before many U.S. and Canadian regulatory agencies, courts of law, and private arbitration proceedings. Testimony before regulatory agencies has been in the areas of load forecasts, supply, demand and price forecasts related to specific geographic markets, rate designs, and supply planning and prudent reviews. The regulatory agencies include the U.S. Federal Energy Regulatory Commission, U.S. Economic Regulatory Administration, California Public Utilities Commission, the Kansas Corporation Commission, the Ohio Public Utilities Commission, Georgia Public Service Commission, Massachusetts Department of Public Utilities, Maryland Public Service Commission, D.C. Public Service Commission, State of New York

Board on Electric Generation Siting and the Environment, Special Natural Gas Export Commission of British Columbia, Public Utilities Board of Alberta, the National Energy Board of Canada, the Ontario Energy Board, the Regie du Gaz du Naturel du Quebec, and the Public Utilities Board of New Brunswick.

Expert testimony before courts of law has related to purchase/sales contract interpretation, price redetermination, and outlook of energy markets. Dr. Foster's evidence before arbitration panels has related to fair market value of various energy commodities.

Published Reports:

Dr. Foster has been the editor of the Foster Bulletin on Deregulated Gas, its Producer Supplement; U.S. Interstate Natural Gas Information Service and the Gas Transport Report.

In addition, Dr. Foster has directed or participated in a number of published studies, as listed below:

- Competitive Profile of Natural Gas Services, a multi-client study (1997, 2001 and 2005)
- Financial Reports: 28 Major Interstate Natural Gas Pipelines, a multi-sponsored service (1998-2006)
- Gulf of Mexico - Natural Gas Resources and Pipeline Infrastructure, prepared for the INGAA Foundation (January 1996 & 2002)
- Analysis of LDC Peak Day Planning, prepared for the American Gas Association (December 1995)

- <u>Published Price Indices as the Basis of Federal Royalty Payments</u>, prepared for Natural Gas Supply Association (December 1995)
- <u>Profile of Underground Natural Gas Storage Facilities and Market Hubs</u> prepared for INGAA Foundation (June 1995)
- <u>Restructuring/Risk Shifting Within the Natural Gas Industry</u>, presented at the Financial Research Institute Symposium, "Investment Policies During Periods of Increasing Competition and Risk" (March 1994)
- <u>Tracking Interstate Natural Gas Pipeline Restructuring Proposals</u>, a multi-sponsored monitoring service (1992-1994)
- <u>Profile of Intrastate Gas Pipelines</u>, prepared for INGAA Foundation (June 1993)
- <u>Profile of Natural Gas Gathering in the U.S.</u>, prepared for INGAA Foundation (June 1993)
- <u>Incentive Regulation: An Alternative to Assessing LDC Performance</u>, presented at the Natural Gas Conference, Chicago, Illinois, sponsored by the Center for Regulatory Studies (May 1993)
- <u>Competition in the Natural Gas Industry</u>, presented at the Natural Gas Conference, Chicago, Illinois, sponsored by the Center for Regulatory Studies (October 1991)
- <u>Deregulation of Natural Gas Sales to Large Volume Industrial Users</u>, prepared for the American Gas Association (1987)

- Canadian Gas Imports: Impact of Competitive Pricing on Demand, prepared for the American Gas Association (1986)
- "Market-Oriented Sales and Transportation Rates of Natural Gas Distributors," prepared for IAEE 1986 North American Conference Proceedings
- Analysis of High Cost Gas Purchases by Contract Termination Date, prepared for the American Gas Association (1985)
- Block Billing Under RM85-1, Not to the Root of the Problem, presented at Conference on Take-or-Pay Price Redetermination and Crucial Contract Litigation Issues (1985)
- Analysis of the Take or Pay Problem, prepared for the Natural Gas Supply Association (1984)
- "New Dimensions in Marketing Natural Gas: New Marketing Strategies and Impediments to Them," published by IAEE in Proceedings: Northern American Energy Conference (1984)
- Trend in Natural Gas Purchases by NGPA Category, prepared for the American Gas Association (1983)
- "Marketing Canadian Natural Gas in the U.S.," published by IAEE in Proceedings: Fifth Annual North American Meeting (1983)
- "Survey of Oil and Gas Supply/Demand Forecasts," published by the Electric Power Research Institute, Proceedings: Fuel Supply Seminars (1983)

- <u>Economic Impact of Pipeline Ownership by Major Integrated Oil Companies</u>, published dissertation (1982)
- <u>Fuel and Energy Price Forecasts</u>, prepared for the Electric Power Research Institute (1977)
- <u>Energy Prices 1960-1973</u>, prepared for the Ford Foundation (1974)

Court Cases Since 1998:

I. Conoco Pipeline v. TransMontaigne Pipeline Inc.,Western District Court of Missouri, Southwestern Division – Case No. 97-5085-CV-SW-1 (1998)

II. Cure Land, LLC, et al. v. WBI et al, District Court, City and County of Denver, Colorado – Case No. 99CV-3631 (2000)

III. Kinder Morgan v. Cities of Alliance Nebraska et al, Docket CI00 1309, 1310, 1311 and 1312 Consolidated District Court, Lancaster County, Nebraska (2000)

IV. The John R. Behremann Revocable Trust, District Court, Denver, Colorado – Case No. 00-CV-5704 (2001)

V. The Long Trust v. Amoco Production Co. and Enserch Corp., District Court, Rusk County, Texas – No. 92-403 (2003)

VI. Sequent Energy Management L.P., et al v. National Union Fire Insurance Company of Pittsburgh, Pennsylvania (U.S. District Court, Southern District Texas, Houston, Case No. 02 4226 (2004)

VII. Jack Holman et al. v. Patina Oil & Gas Corp. District Court, Weld County, Colorado, Case No. 03 CV 9 (2004)

VIII Bolack Minerals Company v. Burlington Resources Oil & Gas Company, et al. In the Eleventh Judicial District, County of San Juan, New Mexico, CV No. 97-96-1 (2006)

IX. State of Mississippi et al. v. Memphis Light, Gas & Water Division. U.S. District Court, Northern District of Mississippi Delta Division (Civil Action No. 2:05CV32-D-B (2006)

X. Bernard H. Anderson et al. v. Merit Energy Company, U. S. District Court, Colorado, Case No. 07-cv-00916-LTB-BNB (2008)

XI. GEOMET, INC. et al. v. CNX Gas Company LLC, Circuit Court for the County of County Tazewell, Commonwealth of Virginia, Case No. CL07000065 (2008)

XII. Mleynek, et el. v. K.P. Kauffman Company, Inc. District Court for the City and Count of Denver, Colorado, Case No. 2007 CV 3268 (2009)

XIII. Yukon Pocahontas Coal Company , et al. v. Consolidation Coal Company, et al., Circuit Court for the Count of Buchanan, Case No. CL04-91 (2010)

XIV. Gene R. Eatinger et al v. BP America Production Company, U.S. District Court For the District

Court of Kansas, Case No. 07-1266-JTM_KMH (2012)

XV. Wallace B. Roderick et al. v. Kansas Natural Gas et al., District Court of Kearny County, Kansas, Case No. 09-CV-14 (2012)

XVI. Jimmie Hershey et el. v. EXXONMOBIL OIL CORP. ,U.S. District Court, Kansas. Case No. 07-1300-JTM-KMH (2012)

XVII. Freebird, Inc. et al. v. Merit Energy Company, U.S. District Court For the District of Kansas, Civil Action No. 101154-KHV-JPO (2012)

Exhibit II

Documents Reviewed and Relied Upon

1. Memphis Light, Gas & Water Division Annual Reports

2. Memphis Light, Gas & Water Division Water Service Rate Schedules

3. "Ground Water Supply" by J.V. Brahana, prepared by USGS for the U.S. Army Corps of Engineers (July 1981)

4. Memphis Light, Gas & Water Division Scanner Team Reports

5. Memphis Light, Gas & Water Division Master Plan Reports for the Water System

6. Residential Water Rates for Peer Cities' Water Systems

7. Memphis Light, Gas & Water Division's wholesales water contracts

   a. City of Germantown, August 22,1988 (No.9797)
   b. City of Olive Branch, March 26, 2001 (No. 10736)
   c. City of Collierville, February 1, 2002
   d. City of Millington, October 16, 2003 (No. 10957)
   e. City of Bartlett, July 1, 2003 (No. 10940, replacing 1962 contract No. 5560 and 1998 Contract No. 10521)

8. Memphis Light, Gas & Water Division Strategic Plans

9. "Revisions and Additions to Valuation of Mississippi Groundwater Used in MLGW Service Area," Expert Report of William W. Wade, 2007

10. "Liquid Assets" by Ward Archer, Jr. *Memphis* Magazine, March 2005

11. "Memphis Water Termed 'Sweetest in the World.'" *Water World*, March 1, 2003

12. MLGW's Financial Reports (December)

13. "Updated Report on Diversion of Ground Water from Northern Mississippi Due to Memphis Area Well Fields," by Leggette, Brashears Graham, Inc.

14. "Evaluation For Alternative Ground-Water Supply", prepared by Leggette, Brashears & Graham, Inc.

15. "Opinion of Probable Capital Cost and Production Operation and Maintenance Cost for the Conceptual Modifications to the MLWG Water System," prepared by Mississippi Engineering Group (2007)

16. Residential Water Rate for areas in DeSoto County, Mississippi

17. Moody's Municipal Bond Yields

18. "The Handy-Whitman Index of Public Construction Costs"

Exhibit III

Schedules

List of Schedules Exhibit III

Schedule 12
Interest Calculation-High Case

Schedule 13
Market Value of Mississippi Water (2013-2017)

Schedule 1

Mississippi River Treatment Plant Cost

$ Th.

	1985	2006	2012
Capital Cost	$ 357,545	$ 606,626	$ 755,553
Interest Rate	10%	7%	5%
Carrying Charge	$ 35,755	$ 42,464	$ 37,778
Depr. At 3%	$ 10,726	$ 18,199	$ 22,667
Inc. O&M	$ 11,377	$ 23,100	$ 29,792
Total An. Cost (TH.$)	$ 57,858	$ 83,763	$ 90,236
Pumpage Vol (Th gal.)	48,054,175	57,023,950	52,553,940
Cost per Th. Gal	$ 1.20	$ 1.47	$ 1.72
H.W. Index 100=1997 Water SC Region	229	388.5	483.5

2006=100	0.5894	100	1.2455
Inc Index IPP	0.4925	100	1.2897

Schedule 2

Year	Production Cost	Pumpage MGD	Pumpage MG	Production Cost $/TH. Gal
1985	$6,812,118	131.66	48054.18	$0.1418
1986	$7,507,404	136.54	49836.90	$0.1506
1987	$7,520,628	135.45	49437.90	$0.1521
1988	$8,223,622	142.59	52187.69	$0.1576
1989	$7,877,066	135.32	49393.50	$0.1595
1990	$8,470,437	141.01	51468.00	$0.1646
1991	$8,327,496	140.07	51125.90	$0.1629
1992	$9,160,461	139.24	50962.94	$0.1797
1993	$8,119,059	139.62	50959.90	$0.1593
1994	$8,895,402	142.36	51962.30	$0.1712
1995	$8,985,245	148.00	54020.00	$0.1663
1996	$8,537,126	149.88	54856.58	$0.1556
1997	$8,858,325	145.67	53170.60	$0.1666
1998	$9,978,846	156.40	57087.10	$0.1748
1999	$10,474,128	161.88	59084.90	$0.1773
2000	$10,677,807	162.11	59331.71	$0.1800
2001	$10,820,730	153.41	55993.70	$0.1932
2002	$10,692,864	154.52	56401.02	$0.1896
2003	$11,110,246	151.90	55443.80	$0.2004
2004	$11,914,363	154.35	56492.10	$0.2109
2005	$12,874,474	156.89	57265.46	$0.2248
2006	$13,974,000	156.23	57025.17	$0.2450
2007	$14,522,000	153.99	56206.35	$0.2584

2008	$15,817,000	143.36	52469.76	$0.3014
2009	$16,215,000	140.33	51220.45	$0.3166
2010	$17,050,000	151.32	55231.80	$0.3087
2011	$16,791,000	132.76	48457.40	$0.3465
2012	$18,596,000	143.59	52553.94	$0.3538

Source:Production Cost: 1985-2005-MLGW' Financial Reports (Dec.)

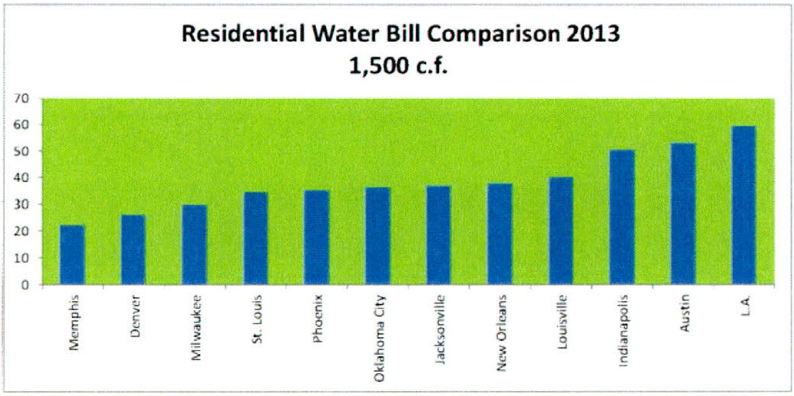
Post 2005-Annual Reports.

Pumpage data-Leggette, Brashears & Graham

Schedule 3

Residential Water Bill Comparison 2013
(1,500 c.f.)

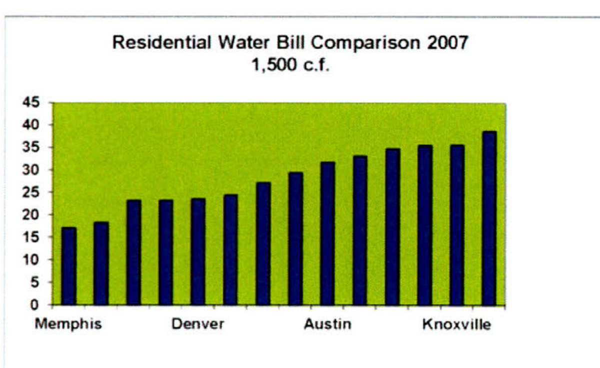
Memphis	$	22.11
Denver	$	25.95
Milwaukee	$	29.88
St. Louis	$	34.56
Phoenix	$	35.03
Oklahoma City	$	36.12
Jacksonville	$	36.98
New Orleans	$	37.67
Louisville	$	40.06
Indianapolis	$	50.42
Austin	$	52.98
L.A.	$	59.45



Schedule 4

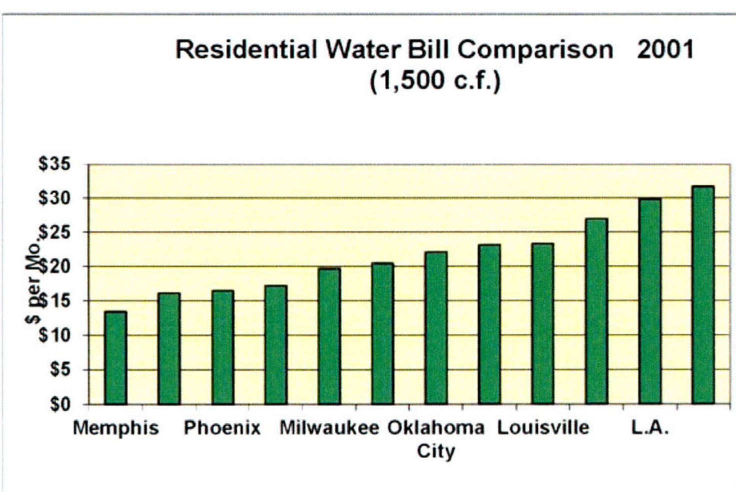
Residential Water Bill Comparison 2007
(1,500 c.f.)

Memphis	$17.11
Jacksonville	$18.34
St. Louis	$23.22
Milwaukee	$23.28
Denver	$23.55
Louisville	$24.41
Oklahoma City	$27.15
New Orleans	$29.42
Austin	$31.73
Phoenix	$33.07
El Paso	$34.71
Indianapolis	$35.51
Knoxville	$35.53
L.A.	$38.58

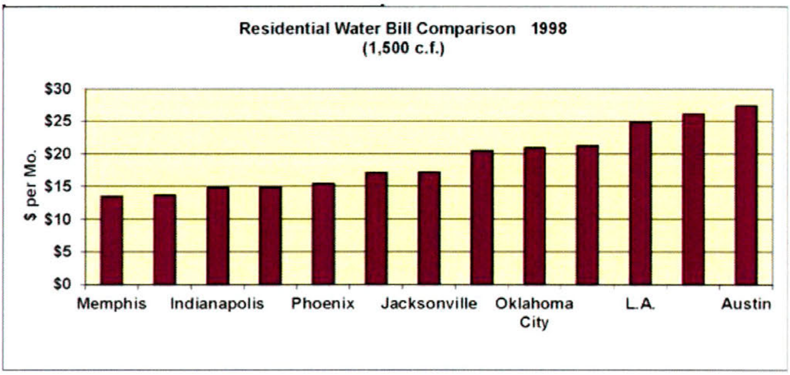


Schedule 5

Residential Water Bill Comparison 2001	
Memphis	$13.51
El Paso	$16.11
Phoenix	$16.48
Jacksonville	$17.15
Milwaukee	$19.72
St. Louis	$20.47
Oklahoma City	$22.12
Austin	$23.13
Louisville	$23.32
Indianapolis	$27.05
L.A.	$29.88
Knoxville	$31.70



Schedule 6	
Res. Water Bill Comparison 1998	
	(1,500 c.f.)
Memphis	$13.51
El Paso	$13.69
Indianapolis	$14.79
Denver	$14.93
Phoenix	$15.45
Milwaukee	$17.13
Jacksonville	$17.15
St. Louis	$20.47
Oklahoma City	$20.91
Louisville	$21.26
L.A.	$24.87
New Orleans	$26.17
Austin	$27.36



Schedule 7

MLGW's Diversion OF MISSISSIPPI WATER (1985-2012)

	MLGW's Pumpage	Takes From Mississippi		Percentage of MLGW's Water From Mississippi
	MGD	MGD	MG	
1985	131.66	25.41	9,274.65	19.30%
1986	136.54	26.90	9,818.50	19.70%
1987	135.45	26.72	9,752.80	19.73%
1988	142.59	28.33	10,368.78	19.87%
1989	135.32	26.95	9,836.75	19.92%
1990	141.01	27.26	9,949.90	19.33%
1991	140.07	26.17	9,552.05	18.68%
1992	139.24	25.61	9,373.26	18.39%
1993	139.62	25.85	9,435.25	18.52%
1994	142.36	26.39	9,632.35	18.54%
1995	148.00	24.14	8,811.10	16.31%
1996	149.88	24.65	9,021.90	16.45%
1997	145.67	23.83	8,697.95	16.36%
1998	156.40	25.53	9,318.45	16.32%
1999	161.88	26.02	9,497.30	16.07%
2000	162.11	25.66	9,391.56	15.83%
2001	153.41	24.05	8,778.25	15.68%
2002	154.52	24.33	8,880.45	15.75%
2003	151.90	24.08	8,789.20	15.85%

2004	154.35	23.95	8,765.70	15.52%
2005	156.89	23.81	8,690.65	15.18%
2006	156.23	24.29	8,865.85	15.55%
2007	153.99	25.00	9,125.00	16.23%
2008	143.36	22.86	8,366.76	15.95%
2009	140.33	21.29	7,770.85	15.17%
2010	151.32	22.59	8,245.35	14.93%
2011	132.76	19.47	7,106.55	14.67%
2012	143.59	20.98	7,678.68	14.61%

Schedule 8

Average MLGW Resale Revenues

	2010	**2011**	**2012**	**Total**
Revenues	$374,808	$ 413,589	$369,835	$ 1,158,232
Sales (CCF)	377,513	405,808	439,517	1,222,838
Rev/CCF	$ 0.993	$ 1.019	$ 0.841	$ 0.947
Rev/Th. gal	$ 1.327	$ 1.363	$ 1.125	$ 1.266

Schedule 9

Mississsippi Water Value Based on Market Approach

High Case

Year	MS. Water Taken by MLGW (MG)	Fair Market Value $/Th. Gal.	Amount Owed MS as Damages $ Th.
1985	9,274.7	$0.548	$5,083
1986	9,818.5	$0.548	$5,381
1987	9,752.8	$0.587	$5,725
1988	10,368.8	$0.628	$6,512
1989	9,836.8	$0.628	$6,177
1990	9,949.9	$0.688	$6,846
1991	9,552.1	$0.688	$6,572
1992	9,373.3	$0.739	$6,927
1993	9,435.3	$0.825	$7,784
1994	9,632.4	$0.825	$7,947
1995	8,811.1	$0.957	$8,432
1996	9,021.9	$0.957	$8,634
1997	8,698.0	$0.957	$8,324
1998	9,318.5	$0.957	$8,918
1999	9,497.3	$0.957	$9,089
2000	9,391.6	$0.957	$8,988
2001	8,778.3	$0.957	$8,401
2002	8,880.5	$0.957	$8,499
2003	8,789.2	$0.957	$8,411

2004	8,765.7	$1.321	$11,579
2005	8,690.7	$1.321	$11,480
2006	8,865.9	$1.321	$11,712
2007	9,125.0	$1.321	$12,054
2008	8,366.8	$1.321	$11,052
2009	7,770.9	$1.529	$11,882
2010	8,245.4	$1.529	$12,607
2011	7,106.6	$1.606	$11,413
2012	7,678.7	$1.606	$12,332
Total	252,795.8		$248,759

Schedule 10

Mississsippi Water Value Based on Market Approach

Low Case

Year	MS. Water Taken by MLGW (MG)	High Market Value' $/Th. Gal.	Pro-duction Cost $/Th. Gal.	Fair Market Value $/Th. Gal.	Amount Owed MS as Damages $ Th.
1985	9,274.7	$0.548	$0.142	$0.406	$3,768
1986	9,818.5	$0.548	$0.151	$0.398	$3,908
1987	9,752.8	$0.587	$0.152	$0.435	$4,241
1988	10,368.8	$0.628	$0.158	$0.470	$4,873
1989	9,836.8	$0.628	$0.159	$0.469	$4,609
1990	9,949.9	$0.688	$0.165	$0.523	$5,208
1991	9,552.1	$0.688	$0.163	$0.525	$5,016
1992	9,373.3	$0.739	$0.180	$0.559	$5,237
1993	9,435.3	$0.825	$0.159	$0.666	$6,281
1994	9,632.4	$0.825	$0.171	$0.654	$6,298
1995	8,811.1	$0.957	$0.166	$0.791	$6,967
1996	9,021.9	$0.957	$0.156	$0.801	$7,226
1997	8,698.0	$0.957	$0.167	$0.790	$6,875
1998	9,318.5	$0.957	$0.175	$0.782	$7,289
1999	9,497.3	$0.957	$0.177	$0.780	$7,405
2000	9,391.6	$0.957	$0.180	$0.777	$7,293
2001	8,778.3	$0.957	$0.193	$0.764	$6,704

2002	8,880.5	$0.957	$0.190	$0.767	$6,815
2003	8,789.2	$0.957	$0.200	$0.757	$6,650
2004	8,765.7	$1.321	$0.211	$1.110	$9,726
2005	8,690.7	$1.321	$0.225	$1.096	$9,527
2006	8,865.9	$1.321	$0.245	$1.076	$9,539
2007	9,125.0	$1.321	$0.258	$1.063	$9,697
2008	8,366.8	$1.321	$0.301	$1.020	$8,530
2009	7,770.9	$1.529	$0.317	$1.212	$9,422
2010	8,245.4	$1.529	$0.309	$1.220	$10,062
2011	7,106.6	$1.606	$0.347	$1.259	$8,951
2012	7,678.7	$1.606	$0.354	$1.252	$9,615
Total	252,795.8				$197,730

Schedule 11

Interest Calculation-High Case

[*Fold-out Exhibit, See Next Page*]

Interest Calculation-High Case Schedule 11 Sheet 1 of 3 — Schedule 11 Sheet 2 of 3 — Schedule 11 Sheet 3 of 3

		Principal Thousands $	1985 $5,083	1986 $5,381	1987 $5,725	1988 $6,512	1989 $6,177	1990 $6,846	1991 $6,572	1992 $6,927	1993 $7,784	1994 $7,947	1995 $8,432	1996 $8,634	1997 $8,324	1998 $8,918	1999 $9,089
1986	0.08		$ 407														
1987	0.08		$ 439	$ 430													
1988	0.08		$ 474	$ 465	$ 458												
1989	0.08		$ 512	$ 502	$ 495	$ 521											
1990	0.08		$ 553	$ 542	$ 534	$ 563	$ 494										
1991	0.08		$ 597	$ 586	$ 577	$ 608	$ 534	$ 548									
1992	0.08		$ 645	$ 632	$ 623	$ 656	$ 576	$ 591	$ 526								
1993	0.08		$ 697	$ 683	$ 673	$ 709	$ 623	$ 639	$ 568	$ 554							
1994	0.08		$ 753	$ 738	$ 727	$ 765	$ 672	$ 690	$ 613	$ 598	$ 623						
1995	0.08		$ 813	$ 797	$ 785	$ 827	$ 726	$ 745	$ 662	$ 646	$ 673	$ 636					
1996	0.08		$ 878	$ 860	$ 848	$ 893	$ 784	$ 805	$ 715	$ 698	$ 726	$ 687	$ 675				
1997	0.08		$ 948	$ 929	$ 916	$ 964	$ 847	$ 869	$ 772	$ 754	$ 784	$ 742	$ 729	$ 691			
1998	0.08		$ 1,024	$ 1,004	$ 989	$ 1,041	$ 915	$ 939	$ 834	$ 814	$ 847	$ 801	$ 787	$ 746	$ 666		
1999	0.08		$ 1,106	$ 1,084	$ 1,068	$ 1,125	$ 988	$ 1,014	$ 901	$ 879	$ 915	$ 865	$ 850	$ 806	$ 719	$ 713	
2000	0.08		$ 1,194	$ 1,171	$ 1,153	$ 1,215	$ 1,067	$ 1,095	$ 973	$ 950	$ 988	$ 934	$ 918	$ 870	$ 777	$ 770	$ 727
2001	0.08		$ 1,290	$ 1,264	$ 1,246	$ 1,312	$ 1,152	$ 1,182	$ 1,051	$ 1,026	$ 1,067	$ 1,009	$ 991	$ 940	$ 839	$ 832	$ 785
2002	0.08		$ 1,393	$ 1,365	$ 1,345	$ 1,417	$ 1,244	$ 1,277	$ 1,135	$ 1,108	$ 1,153	$ 1,090	$ 1,070	$ 1,015	$ 906	$ 899	$ 848
2003	0.08		$ 1,504	$ 1,475	$ 1,453	$ 1,530	$ 1,344	$ 1,379	$ 1,226	$ 1,196	$ 1,245	$ 1,177	$ 1,156	$ 1,096	$ 978	$ 971	$ 916
2004	0.08		$ 1,625	$ 1,593	$ 1,569	$ 1,652	$ 1,452	$ 1,489	$ 1,324	$ 1,292	$ 1,344	$ 1,271	$ 1,249	$ 1,184	$ 1,057	$ 1,048	$ 989
2005	0.08		$ 1,755	$ 1,720	$ 1,695	$ 1,785	$ 1,568	$ 1,609	$ 1,430	$ 1,395	$ 1,452	$ 1,373	$ 1,348	$ 1,278	$ 1,141	$ 1,132	$ 1,068
2006	0.08		$ 1,895	$ 1,858	$ 1,830	$ 1,927	$ 1,693	$ 1,737	$ 1,544	$ 1,507	$ 1,568	$ 1,482	$ 1,456	$ 1,381	$ 1,233	$ 1,223	$ 1,154
2007	0.08		$ 2,047	$ 2,006	$ 1,977	$ 2,082	$ 1,829	$ 1,876	$ 1,668	$ 1,628	$ 1,694	$ 1,601	$ 1,573	$ 1,491	$ 1,331	$ 1,320	$ 1,246
2008	0.08		$ 2,211	$ 2,167	$ 2,135	$ 2,248	$ 1,975	$ 2,026	$ 1,801	$ 1,758	$ 1,829	$ 1,729	$ 1,699	$ 1,611	$ 1,438	$ 1,426	$ 1,346
2009	0.08		$ 2,387	$ 2,340	$ 2,305	$ 2,428	$ 2,133	$ 2,188	$ 1,945	$ 1,898	$ 1,975	$ 1,867	$ 1,835	$ 1,739	$ 1,553	$ 1,540	$ 1,454
2010	0.08		$ 2,578	$ 2,527	$ 2,490	$ 2,622	$ 2,303	$ 2,363	$ 2,101	$ 2,050	$ 2,133	$ 2,017	$ 1,981	$ 1,878	$ 1,677	$ 1,663	$ 1,570
2011	0.08		$ 2,785	$ 2,730	$ 2,689	$ 2,832	$ 2,488	$ 2,553	$ 2,269	$ 2,214	$ 2,304	$ 2,178	$ 2,140	$ 2,029	$ 1,811	$ 1,797	$ 1,695
2012	0.08		$ 3,007	$ 2,948	$ 2,904	$ 3,059	$ 2,687	$ 2,757	$ 2,450	$ 2,392	$ 2,488	$ 2,352	$ 2,311	$ 2,191	$ 1,956	$ 1,940	$ 1,831
2013	0.08		$ 3,248	$ 3,184	$ 3,137	$ 3,303	$ 2,902	$ 2,977	$ 2,647	$ 2,583	$ 2,688	$ 2,540	$ 2,496	$ 2,366	$ 2,112	$ 2,095	$ 1,977
Principal		$ 248,759	$ 5,083	$ 5,381	$ 5,725	$ 6,512	$ 6,177	$ 6,846	$ 6,572	$ 6,927	$ 7,784	$ 7,947	$ 8,432	$ 8,634	$ 8,324	$ 8,918	$ 9,089
Interest		$ 636,776	$ 38,765	$ 37,600	$ 36,618	$ 38,083	$ 32,995	$ 33,348	$ 29,156	$ 27,842	$ 28,497	$ 26,349	$ 25,263	$ 23,312	$ 20,193	$ 18,371	$ 17,607
Total		$ 785,534	$ 43,847	$ 42,980	$ 42,343	$ 44,594	$ 39,173	$ 40,193	$ 35,728	$ 34,869	$ 36,281	$ 34,296	$ 33,695	$ 31,946	$ 28,517	$ 28,289	$ 26,696

	2000 $8,988	2001 $8,401	2002 $8,499	2003 $8,411	2004 $11,579	2005 $11,480	2006 $11,712	2007 $ 12,054	2008 $ 11,052	2009 $ 11,882	2010 $ 12,607	2011 $ 11,413	2012 $ 12,332	2013 $ -
2001	$ 719													
2002	$ 777	$ 672												
2003	$ 839	$ 726	$ 680											
2004	$ 906	$ 784	$ 734	$ 673										
2005	$ 978	$ 847	$ 793	$ 727	$ 926									
2006	$ 1,056	$ 914	$ 856	$ 785	$ 1,000	$ 918								
2007	$ 1,141	$ 987	$ 925	$ 848	$ 1,081	$ 992	$ 937							
2008	$ 1,232	$ 1,066	$ 999	$ 915	$ 1,167	$ 1,071	$ 1,012	$ 964						
2009	$ 1,331	$ 1,152	$ 1,079	$ 989	$ 1,260	$ 1,157	$ 1,093	$ 1,041	$ 884					
2010	$ 1,437	$ 1,244	$ 1,165	$ 1,068	$ 1,361	$ 1,250	$ 1,180	$ 1,125	$ 955	$ 951				
2011	$ 1,552	$ 1,343	$ 1,258	$ 1,153	$ 1,470	$ 1,349	$ 1,275	$ 1,215	$ 1,031	$ 1,027	$ 1,009			
2012	$ 1,676	$ 1,451	$ 1,359	$ 1,245	$ 1,588	$ 1,457	$ 1,377	$ 1,312	$ 1,114	$ 1,109	$ 1,089	$ 913		
2013	$ 1,811	$ 1,567	$ 1,468	$ 1,345	$ 1,715	$ 1,574	$ 1,487	$ 1,417	$ 1,203	$ 1,197	$ 1,176	$ 986	$ 987	
Principal	$ 8,988	$ 8,401	$ 8,499	$ 8,411	$ 11,579	$ 11,480	$ 11,712	$ 12,054	$ 11,052	$ 11,882	$ 12,607	$ 11,413	$ 12,332	$ -
Interest	$ 15,456	$ 12,754	$ 11,317	$ 8,748	$ 11,568	$ 9,769	$ 8,360	$ 7,074	$ 5,187	$ 4,283	$ 3,274	$ 1,899	$ 887	$ -
Total	$ 24,443	$ 21,155	$ 19,816	$ 18,159	$ 23,147	$ 21,249	$ 20,072	$ 19,128	$ 16,240	$ 16,165	$ 15,881	$ 13,312	$ 13,319	$ -

Schedule 12

Interest Calculation-Low Case

[*Fold-out Exhibit, See Next Page*]

Interest Calculation-Low case

Schedule 12 Sheet 1 of 3

		Principal	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
		Thousand $	$3,768	$3,908	$4,241	$4,873	$4,609	$5,208	$5,016	$5,237	$6,281	$6,298
1986	0.08		$ 301									
1987	0.08		$ 326	$ 313								
1988	0.08		$ 352	$ 338	$ 339							
1989	0.08		$ 380	$ 365	$ 366	$ 390						
1990	0.08		$ 410	$ 394	$ 396	$ 421	$ 369					
1991	0.08		$ 443	$ 425	$ 427	$ 455	$ 398	$ 417				
1992	0.08		$ 478	$ 459	$ 462	$ 491	$ 430	$ 450	$ 401			
1993	0.08		$ 517	$ 496	$ 499	$ 530	$ 464	$ 486	$ 433	$ 419		
1994	0.08		$ 558	$ 536	$ 538	$ 573	$ 502	$ 525	$ 468	$ 453	$ 502	
1995	0.08		$ 603	$ 579	$ 582	$ 619	$ 542	$ 567	$ 505	$ 489	$ 543	$ 504
1996	0.08		$ 651	$ 625	$ 628	$ 668	$ 585	$ 612	$ 546	$ 528	$ 586	$ 544
1997	0.08		$ 703	$ 675	$ 678	$ 722	$ 632	$ 661	$ 590	$ 570	$ 633	$ 588
1998	0.08		$ 759	$ 729	$ 733	$ 779	$ 682	$ 714	$ 637	$ 616	$ 684	$ 635
1999	0.08		$ 820	$ 787	$ 791	$ 842	$ 737	$ 771	$ 688	$ 665	$ 738	$ 685
2000	0.08		$ 885	$ 850	$ 854	$ 909	$ 796	$ 833	$ 743	$ 718	$ 797	$ 740
2001	0.08		$ 956	$ 918	$ 923	$ 982	$ 860	$ 899	$ 802	$ 776	$ 861	$ 799
2002	0.08		$ 1,033	$ 992	$ 997	$ 1,060	$ 928	$ 971	$ 866	$ 838	$ 930	$ 863
2003	0.08		$ 1,115	$ 1,071	$ 1,076	$ 1,145	$ 1,003	$ 1,049	$ 936	$ 905	$ 1,004	$ 933
2004	0.08		$ 1,204	$ 1,157	$ 1,162	$ 1,237	$ 1,083	$ 1,133	$ 1,010	$ 977	$ 1,085	$ 1,007
2005	0.08		$ 1,301	$ 1,249	$ 1,255	$ 1,336	$ 1,170	$ 1,224	$ 1,091	$ 1,055	$ 1,172	$ 1,088
2006	0.08		$ 1,405	$ 1,349	$ 1,356	$ 1,442	$ 1,263	$ 1,322	$ 1,179	$ 1,140	$ 1,265	$ 1,175
2007	0.08		$ 1,517	$ 1,457	$ 1,464	$ 1,558	$ 1,364	$ 1,427	$ 1,273	$ 1,231	$ 1,367	$ 1,269
2008	0.08		$ 1,639	$ 1,574	$ 1,581	$ 1,683	$ 1,473	$ 1,542	$ 1,375	$ 1,329	$ 1,476	$ 1,370
2009	0.08		$ 1,770	$ 1,700	$ 1,708	$ 1,817	$ 1,591	$ 1,665	$ 1,485	$ 1,435	$ 1,594	$ 1,480
2010	0.08		$ 1,911	$ 1,836	$ 1,845	$ 1,962	$ 1,718	$ 1,798	$ 1,604	$ 1,550	$ 1,721	$ 1,598
2011	0.08		$ 2,064	$ 1,982	$ 1,992	$ 2,119	$ 1,856	$ 1,942	$ 1,732	$ 1,674	$ 1,859	$ 1,726
2012	0.08		$ 2,229	$ 2,141	$ 2,152	$ 2,289	$ 2,004	$ 2,097	$ 1,870	$ 1,808	$ 2,008	$ 1,864
2013	0.08		$ 2,408	$ 2,312	$ 2,324	$ 2,472	$ 2,165	$ 2,265	$ 2,020	$ 1,953	$ 2,168	$ 2,013
Principal		$ 197,730	$ 3,768	$ 3,908	$ 4,241	$ 4,873	$ 4,609	$ 5,208	$ 5,016	$ 5,237	$ 6,281	$ 6,298
Interest		$ 418,251	$ 28,737	$ 27,308	$ 27,129	$ 28,501	$ 24,616	$ 25,371	$ 22,253	$ 21,127	$ 22,994	$ 20,881
Total		$ 615,981	$ 32,505	$ 31,215	$ 31,370	$ 33,374	$ 29,225	$ 30,579	$ 27,269	$ 26,364	$ 29,275	$ 27,179

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	1995	1996	1997	1998	1999	2000	2001	2002	2003
	$6,967	$7,226	$6,875	$7,289	$7,405	$7,293	$6,704	$6,815	$6,650
1996	$ 557								
1997	$ 602	$ 578							
1998	$ 650	$ 624	$ 550						
1999	$ 702	$ 674	$ 594	$ 583					
2000	$ 758	$ 728	$ 642	$ 630	$ 592				
2001	$ 819	$ 786	$ 693	$ 680	$ 640	$ 583			
2002	$ 884	$ 849	$ 748	$ 735	$ 691	$ 630	$ 536		
2003	$ 955	$ 917	$ 808	$ 793	$ 746	$ 681	$ 579	$ 545	
2004	$ 1,032	$ 991	$ 873	$ 857	$ 806	$ 735	$ 626	$ 589	$ 532
2005	$ 1,114	$ 1,070	$ 943	$ 925	$ 870	$ 794	$ 676	$ 636	$ 575
2006	$ 1,203	$ 1,156	$ 1,018	$ 999	$ 940	$ 857	$ 730	$ 687	$ 621
2007	$ 1,299	$ 1,248	$ 1,099	$ 1,079	$ 1,015	$ 926	$ 788	$ 742	$ 670
2008	$ 1,403	$ 1,348	$ 1,187	$ 1,166	$ 1,097	$ 1,000	$ 851	$ 801	$ 724
2009	$ 1,516	$ 1,456	$ 1,282	$ 1,259	$ 1,184	$ 1,080	$ 919	$ 865	$ 782
2010	$ 1,637	$ 1,572	$ 1,385	$ 1,360	$ 1,279	$ 1,166	$ 993	$ 934	$ 844
2011	$ 1,768	$ 1,698	$ 1,496	$ 1,468	$ 1,381	$ 1,260	$ 1,072	$ 1,009	$ 912
2012	$ 1,909	$ 1,834	$ 1,615	$ 1,586	$ 1,492	$ 1,360	$ 1,158	$ 1,090	$ 985
2013	$ 2,062	$ 1,980	$ 1,745	$ 1,713	$ 1,611	$ 1,469	$ 1,251	$ 1,177	$ 1,063
Principal	$ 6,967	$ 7,226	$ 6,875	$ 7,289	$ 7,405	$ 7,293	$ 6,704	$ 6,815	$ 6,650
Interest	$ 20,872	$ 19,511	$ 16,678	$ 15,833	$ 14,346	$ 12,541	$ 10,178	$ 9,075	$ 7,707
Total	$ 27,839	$ 26,737	$ 23,553	$ 23,122	$ 21,751	$ 19,834	$ 16,883	$ 15,890	$ 14,357

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	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	$9,726	$9,527	$9,539	$ 9,697	$ 8,530	$ 9,422	$ 10,062	$ 8,951	$ 9,615	$ -
2005	$ 778									
2006	$ 840	$ 762								
2007	$ 908	$ 823	$ 763							
2008	$ 980	$ 889	$ 824	$ 776						
2009	$ 1,059	$ 960	$ 890	$ 838	$ 682					
2010	$ 1,143	$ 1,037	$ 961	$ 905	$ 737	$ 754				
2011	$ 1,235	$ 1,120	$ 1,038	$ 977	$ 796	$ 814	$ 805			
2012	$ 1,333	$ 1,209	$ 1,121	$ 1,055	$ 860	$ 879	$ 869	$ 716		
2013	$ 1,440	$ 1,306	$ 1,211	$ 1,140	$ 928	$ 949	$ 939	$ 773	$ 769	
Principal	$ 9,726	$ 9,527	$ 9,539	$ 9,697	$ 8,530	$ 9,422	$ 10,062	$ 8,951	$ 9,615	$ -
Interest	$ 9,716	$ 8,106	$ 6,809	$ 5,691	$ 4,004	$ 3,396	$ 2,613	$ 1,489	$ 769	$ -
Total	$ 19,442	$ 17,633	$ 16,349	$ 15,387	$ 12,534	$ 12,818	$ 12,675	$ 10,440	$ 10,384	$ -

Schedule 13

Market Value of Mississippi Water (2013-2017)

	Volume MG	Value $/Th. Gal.	Annual Value $ Th.	Discount Factor at 8%	Present Value at 8%
High Case					
2013	7678.7	$1.718	$13,192	1	$13,192.01
2014	7678.7	$1.718	$13,192	0.926	$12,215.80
2015	7678.7	$1.718	$13,192	0.857	$11,305.55
2016	7678.7	$1.718	$13,192	0.794	$10,474.45
2017	7678.7	$1.718	$13,192	0.739	$9,748.89
Total			$65,960		$56,937
Low Case					
2013	7678.7	$ 1.341	$10,297	1	$10,297.14
2014	7678.7	$ 1.316	$10,105	0.926	$9,357.39
2015	7678.7	$ 1.289	$9,898	0.857	$8,482.45
2016	7678.7	$ 1.262	$9,691	0.794	$7,694.27
2017	7678.7	$ 1.231	$9,452	0.739	$6,985.38
Total			$49,443		$42,817

EXHIBIT 3

IN THE UNITED STATES DISTRICT COURT FOR THE NORTHERN DISTRICT OF MISSISSIPPI DELTA DIVISION

CIVIL ACTION NO. 2:05CV32-D-B

[Dated August 31, 2007]

JIM HOOD, Attorney General, *ex rel.*, THE STATE OF MISSISSIPPI, Acting for Itself and *Parens Patriae* for and on behalf of the People of the State of Mississippi

PLAINTIFF

vs.

THE CITY OF MEMPHIS, TENNESSEE, AND MEMPHIS LIGHT, GAS & WATER DIVISION

DEFENDANTS

AFFIDAVIT OF CHARLES T. BRANCH

STATE OF MISSISSIPPI)
) ss.
COUNTY OF Holmes)

I, Charles T. Branch, being first duly sworn, do hereby swear and affirm under oath the following:

1. My name is Charles T. Branch. I am over twenty-one (21) years of age and I am competent to

make this Affidavit. This Affidavit is based on my personal knowledge.

2. I was formerly the Director of the Office of Land and Water Resources ("OLWR") of the Mississippi Department of Environmental Quality ("MDEQ"), and predecessor agencies, from September 1979 until my retirement in June 2002. In my capacity as Director of OLWR, I was the Chief Administrator of that office charged with management, use and allocation of surface and groundwater resources of the State of Mississippi.

3. I am a Mississippi native, born in Attala County, Mississippi, on January 20, 1944. I was educated in the Town of Goodman, Holmes County, Mississippi. I attended Holmes County Community College for a period of two years and then matriculated to Mississippi State University where I graduated with a B.S. in Civil Engineering in January 1967. Later, in August 1969, I obtained a Master's Degree in Environmental Engineering at Mississippi State University. I went to work for International Paper Company in Mobile, Alabama in September 1969 as a Senior Design Engineer for wastewater control systems. I remained with International Paper Company until January of 1972, at which time I became employed with the United States Environmental Protection Agency in Atlanta, Georgia, Region IV, in the Enforcement Division. I was the Permit Coordinator for four states -- North Carolina, South Carolina, Tennessee, and Kentucky.

4. In March of 1974, I entered into a contractual arrangement with the Mississippi Air and Water Pollution Control Commission when the State of

Mississippi was granted primacy to issue NPDES permits under the Clean Water Act. I remained in federal service with the EPA until March of 1976. In July 1976, I became employed exclusively with the Mississippi Air and Water Pollution Control Commission as a Senior Engineer. In the summer of 1978, I became the Chief of the Water Division of the Commission, and in September 1979, I became Director of the OLWR.

5. As Director of the OLWR for the MDEQ, and its predecessor agencies, I was in a position to formulate and enforce the policies of the State of Mississippi relative to the management and control of both surface and groundwater resources of the State. It was the policy of the State of Mississippi and the MDEQ that the State owned all of the surface water and groundwater resources within its territorial boundaries. It was this policy of state-ownership of surface and ground waters that provided the basic authority pursuant to which Mississippi, through MDEQ, controlled and regulated the water resources of the State.

6. During my tenure as Director of the OLWR of the MDEQ, Mississippi had three separate water quantity and quality permitting and enforcement statutes, each of which declared the basic policy of the State regarding Mississippi's ownership of its water resources.

7. In 1956, Mississippi became the first state east of the Mississippi River to adopt an appropriation system for the permitting and management of surface water. The legislative enactment, codified in MISS.

CODE ANN. §5956-01, contains a declaration confirming the policy of state-ownership, which states:

> Water occurring in any water course, lake or other natural water body of the State, is hereby declared to be among the basic resources of this state and subject to appropriation in accordance with the provisions of this Act, and the control and development and use of water for all beneficial purposes shall be in the State, which, in the exercise of its police powers, shall take such measures as shall effectuate full utilization and protection of the water resources of Mississippi.

A copy of the declaration of policy regarding the 1956 surface water permitting act is attached as Exhibit "1" to my Affidavit.

8. In July 1976, Mississippi enacted statutory provisions to provide for the creation of capacity use areas in relation to Mississippi's groundwater resources. The legislative declaration for that statutory scheme was codified in §51-4-1, which states:

> It is hereby declared that the general welfare and public interest of the state require that the water resources of the state be put to beneficial use to the fullest extent to which they are capable, subject to reasonable regulation in order to conserve those resources and to provide and maintain conditions which are conducive to the development and use of water resources. Groundwaters are hereby declared to be among the basic resources of this state and the control, development and use of water for all beneficial

> purposes shall be in the state, which in the exercise of its police powers shall take such measures as shall effectuate full utilization and protection of the groundwaters of Mississippi.

A copy of the legislative declaration of the groundwater capacity use act is attached as Exhibit "2" to my Affidavit.

9. In 1985, the Mississippi legislature enacted a statutory permitting regime relating to both surface water and groundwaters within the territorial boundaries of the State of Mississippi. With that act, Mississippi adopted a modern conjunctive water rights doctrine which reaffirmed that both surface water and ground water are owned by and property of the State of Mississippi. The legislative declaration of State policy in this regard is set forth in MISS. CODE ANN. §51-3-1 (1985 & Supp. 2006), which provides:

> All water, whether occurring on the surface of the ground or underneath the surface of the ground, is hereby declared to be among the basic resources of this state and therefore belong to the people of this state, and is subject to regulation in accordance with the provisions of this chapter. The control and development and use of water for all beneficial purposes shall be in the state, which, in the exercise of its police powers, shall take such measures to effectively and efficiently manage, protect and utilize the water resources of Mississippi.

A copy of the legislative declaration of policy for surface water and groundwater is attached as Exhibit "3" to my Affidavit.

10. Based on my personal knowledge and experience, and as a result of my work as Director of the OLWR of the MDEQ, I am personally familiar with and was directly involved in the implementation and enforcement of the policies of the State of Mississippi relative to surface water and groundwater resources. The policies governing the activities and enforcement powers of the OLWR are premised upon state-ownership of all water resources within the borders of the State of Mississippi. Mississippi has owned the waters within its borders since the time of statehood. As Mississippi's population grew, it became more important to manage and control through permitting and other enforcement powers the allocation and use of surface water and groundwater within the State. The statutes described in my Affidavit were based upon and express the policy of the State of Mississippi regarding its ownership of the waters of the State and the State's power, through its responsible agency, the MDEQ, to control, manage and protect the waters belonging to the State.

11. In the early 1990's, I personally became aware of the fact that pumpage by Memphis Light, Gas & Water Division of the City of Memphis created a cone of depression underlying Memphis that extended across the Mississippi-Tennessee border into Desoto County, Mississippi. As a result, Memphis' well fields were capturing substantial quantities of Mississippi's ground water due to pumping by Memphis Light, Gas & Water. In fact, during my tenure at the OLWR, it was determined that the City of Memphis was the user of groundwater for municipal purposes in the State of Mississippi. I was personally aware of the fact that Memphis Light, Gas & Water's pumping centers were

capturing substantial volumes of Mississippi's ground water. In 1994-95, my office attempted to convince Memphis Light, Gas & Water to cooperate in a jointly-funded research project in conjunction with the United States Geological Survey to perform a hydrologic assessment of the tertiary aquifers in northwestern Mississippi and adjacent Tennessee. The OLWR was concerned with both groundwater quantity and quality issues, particularly the diversion and withdrawal of Mississippi's groundwater into the Memphis area as a result of pumping by Memphis Light, Gas & Water. Based on my direct involvement in the attempts to coordinate and implement the joint study, I became aware that Memphis was not concerned with the water quantity issues that Mississippi wanted to address, and the joint project was never taken beyond a purely conceptual phase.

I declare under penalty of perjury that the foregoing is true and correct.

Executed, this 31st day of August, 2007.

/s/Charles T. Branch
CHARLES T. BRANCH

Subscribed and sworn to before me this 31st day of August, 2007, by CHARLES T. BRANCH.

MY COMMISSION EXPIRES: /s/Lisa Lester
[SEAL] NOTARY PUBLIC

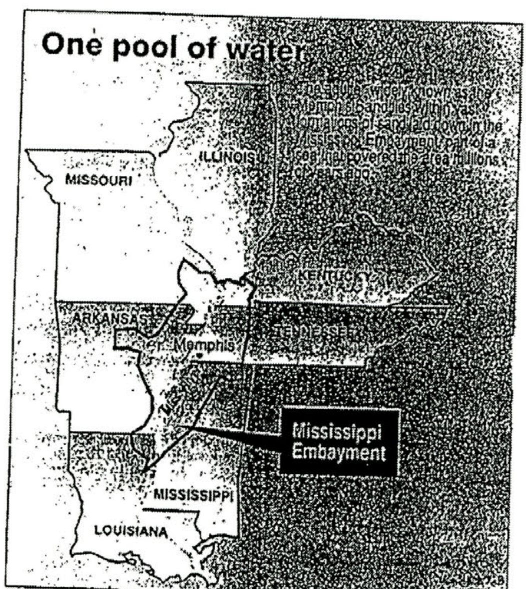
EXHIBIT 4

THE COMMERCIAL APPEAL

159th Year, No. 320, 4 Sections Memphis, Tennessee, Monday, November 16, 1998 FINAL 50¢

Memphis taps into DeSoto County's well levels

By Tom Charlier
The Commercial Appeal



By Deborah D. Young

In getting their public water supplies, Memphis and neighboring communities in Mississippi are like a group of people drinking out of the same glass at a soda fountain.

Only Memphis has the bigger straw.

In fact, though its wells lie entirely in Tennessee, the Bluff City is the largest user of Mississippi's ground water, according to that state's regulators. Memphis each day sucks 20 million to 40 million gallons from under the feet of its neighbors in DeSoto County, where wells already are straining to meet demand from rapid growth.

At a time when conflicts over surface water are escalating across other parts of Tennessee and the Southeast, the Memphis-area withdrawals show that ground water, too, can become an interstate issue.

"It's all the same pool of water," said John W. Smith, former director of the Ground Water Institute at the University of Memphis.

With that in mind, many regulators and researchers are calling for a more regional look at the aquifer system supplying the Memphis area. It's an indication that the deep, rich beds of saturated sands on which the area depends are perhaps more complex, interconnected and vulnerable than previously thought.

The issue of the cross-state withdrawals has taken on new significance in the wake of a recent meeting in which Mississippi regulators warned DeSoto County officials about the potential consequences of declining water levels.

Charles Branch, head of the office of land and water resources with the Mississippi Department of Environmental Quality, said his agency has turned more of its attention to the DeSoto County ground water issue in recent years.

"There's a lot of concern about the cumulative use in the Memphis area," Branch said.

"They (the city) are the largest user of ground water from the state of Mississippi. Significant volumes are flowing from DeSoto County northward into their pumping centers."

DeSoto County is hardly the only part of Mississippi dependent on ground water.

According to the U.S. Geological Survey, Mississippians use some 3.3 billion gallons of water a day, with 80 percent, or 2.6 billion gallons, coming from underground sources. Much of that water is used for irrigating crops or in catfish-farming operations, which soak up 400 million gallons a day.

In DeSoto County, soaring demands for water have been driven mostly by rapid development in Memphis suburbs. As in Memphis, public water is drawn from an aquifer widely known as the Memphis Sand.

Mississippi officials acknowledge that DeSoto's growth is responsible for much of the decline. And they say the well levels don't necessarily portend disaster.

DeSoto County well water levels have been declining at rates of a foot or more a year, though similar drops have been recorded in some Memphis Light, Gas & Water Division well fields.

Mississippi officials acknowledge that DeSoto's growth is responsible for much of the decline. And they say the well levels don't necessarily portend disaster.

But with Memphis siphoning away tens of millions of gallons daily, a comprehensive study is needed to ensure that all users will have enough water in the future, Branch said.

He urges the development of a three-dimensional computer model showing how water flows within the aquifer and how growth and increased pumping could affect it.

The aquifer is among the sand formations laid down across the bottom of the Mississippi Embayment, part of a sea that covered the area 60 million years ago. The embayment stretches from southeastern Missouri to Louisiana and from central Arkansas to near the Tennessee River.

In the Memphis area, the layer of saturated sands comprising the aquifer is up to 900 feet thick and lies 500 or so feet below ground. Further south, the Memphis Sand splits into what is known as the Sparta Sand, an aquifer that extends across North Mississippi and even dips under the Mississippi River into Arkansas.

"The formation we call the Memphis Sand occurs throughout the Mississippi Embayment," said Mike Bradley, assistant district chief for the USGS in Nashville.

In West Tennessee and North Mississippi, the natural flow of water in the aquifer is to the west and southwest, said Kerry Arthur, hydrologist and civil engineer with the USGS in Pearl, Miss. But the heavy pumping of municipal wells in Memphis, he said, has diverted that flow, creating "cones of depression" that pull water from the south.

Three of the well fields serving LG&W's 10 water-pumping stations extend to within 2½ miles of the Mississippi line.

Arthur said preliminary analyses suggest that as much as 20 percent to 30 percent of the water pumped by LG&W could be coming from Mississippi. The Memphis utility pumps about 145 million gallons daily.

Smith, who, as institute director, led studies on behalf of LG&W, said there's no dispute that some of that water comes from Mississippi.

"As we've increased our pumping rates, we've forced more water to come north from Mississippi into Shelby County," Smith said.

But while the aquifer crosses state lines, studies of it generally have not.

"As a regional resource, the Memphis Sand in Tennessee has been studied since the 1920s," said Bradley.

Interstate studies haven't been as common in the water-rich East as they are in the West, where "they divide up almost every raindrop," Bradley said.

More recently, studies have centered on Shelby County and concerns about contamination. The worries helped inspire the formation a decade ago of the city-county Groundwater Quality Control Board, a group charged with protecting aquifers.

Representatives of the board said they welcome more regional involvement in overseeing the aquifer.

"If you're trying to protect a resource that has as its boundaries a multistate area, then you need the cooperation to protect all that resource," said Carter Gray, technical secretary for the board.

Gray said cooperation across state lines also could help identify contamination threats to the aquifer, such as polluting industries, that might plan on locating in DeSoto or neighboring counties.

Smith said the involvement of Mississippi officials in monitoring the aquifer could bring about better water management in DeSoto County.

"DeSoto County doesn't have an (LG&W). They have 10 to 20 individual water utilities," Smith said.

It's important, Branch said, for all the groups having a stake in the aquifer to participate in efforts to protect it.

"Whatever happens in one area affects people in another" he said. "We need to have a more in-depth understanding of how this system works."

It's obvious, Branch said, that pumping ever more water from the ground eventually could cause shortages.

"There will come a time that you'll have more pronounced effects on these water levels, not just in DeSoto County, but in Shelby County."

EXHIBIT 5

FINAL REPORT

WATER SUPPLY CHALLENGES FACING TENNESSEE: CASE STUDY ANALYSES AND THE NEED FOR LONG-TERM PLANNING

by

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Senior Research Scientist,
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The University of Tennessee-Knoxville

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June, 2000

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[p.54] evaluated at the *lowest* flow, not at times of abundant flow. In past drought years, navigation on the Mississippi has been halted because there was insufficient water in the river to float barges. A large diversion from the Mississippi basin to Georgia which would return directly to the Gulf of Mexico would make such disruption more likely. Moreover, the costs of such a project would not be limited to construction of a pipeline and pumping works. Such a large-scale diversion might be considered a taking, post-*Lucas*,[19] and require compensation to affected downstream riparians. Alabama, because of existing conflict over the waters of the Chattahoochee and the Alabama-Coosa, might be uncertain about the advisability of diverting the Tennessee River. However, it appears certain that Mississippi, Kentucky and other states benefiting from navigation on the Mississippi would oppose such an action by Congress.

5.3.4 Summation - Diverting Tennessee River Water to Georgia

Tennessee-American has riparian rights to withdraw and use water from the Tennessee River but those rights are limited by the equal rights of downstream riparians. The company has no right to withdraw a large amount of water from the river for sale completely out of the Tennessee River basin if any downstream riparians object. The State of Tennessee holds the waters of the state in trust for the people of the state. Even absent specific statutory requirements that a permit be issued before water is withdrawn, the state can act to prevent withdrawals that may damage aquatic environments or existing uses of the river. Moreover, although the headwaters of several Tennessee tributaries rise in Georgia, Georgia is not a riparian to the Tennessee River. Courts are unlikely to apportion water to a state that is not a riparian.

5.4 West Tennessee, Northern Mississippi, and the Memphis Sand Aquifer - Background

Memphis is one of the largest cities in the world to rely solely on groundwater wells for its water supply.[20] The city's water is provided by a publicly-owned municipal utility, Memphis Light, Gas, and Water (MLGW). MLGW's wells tap into the Memphis Sand Aquifer and the Fort Pillow Sand Aquifer. The former aquifer is an underground reservoir that underlies nearly 7400 mi^2 in West Tennessee, an appreciable extent of Northern Mississippi, a small section of Southwestern Kentucky, and a portion of Eastern Arkansas (see Figure 5.3). Memphis is currently the largest user of the aquifer. However, DeSoto County, Mississippi - an area experiencing rapid economic and population growth, in part due to the "suburbanization" of Memphis - views the aquifer as a potential source of future water supply. According to one estimate, twenty to forty Mgal/d of the City of Memphis groundwater withdrawn from the Memphis Sand Aquifer is thought to come from beneath DeSoto county.[21] Consequently, demands have been increasing to pursue a more integrated, regional, interstate approach to management of the aquifer.

The aquifer, consisting of a 400 - 900 ft. thick layer of very fine to very coarse sand interlaced with beds of clay and silt, has long provided moderate to large volumes of water for public and industrial use in Tennessee and smaller quantities to domestic, farm, municipal, and industrial users in southwestern Kentucky and northwestern Mississippi. Public and industrial wells in the aquifer range from 80 - 922 feet deep and yield from 10 - 2300 gallons per minute.[22] Withdrawals from the aquifer have been steadily growing in recent years. For example, in 1983, withdrawals averaged 227 Mgal/d - 183 Mgal/d of which were in the Memphis-Shelby County metro area. In 1995, groundwater withdrawals in Shelby County alone totaled 208 Mgal/d.[23] In addition to growing aquifer use, however, there are four major policy challenges facing its management which underscore the complexity of this issue and its policy challenges:

Memphis Sand Aquifer recharge occurs along a broad outcrop belt that stretches across

[p.55] ***West Tennessee.*** Its source is precipitation falling above the outcrop, combined with downward infiltration from overlying fluvial deposits and alluvium. Water moves westward down the dip of the aquifer and toward the major streams draining the area. In recent years, scientists have learned that the recharge area begins just inside southeast Shelby County - where high levels of development are occurring.[24] Thus, balancing local growth against the need to protect the recharge area remains a major challenge which has sparked local efforts (e.g., Collierville, Germantown) to require ‘open space’ and to place limits on development so as to permit natural 'ponding' of standing water and aquifer recharge.

As a result of long-term pumping (begun in 1886), a cone of depression has developed in the Memphis area. However, it is unclear what long-term effects this may have. Data from observation wells shows that the water level in Shelby county declined nearly 77 ft. between 1928-1985, an average rate of decline of 1.3 ft/yr. Water levels also are declining in areas away from a "cone" at the center of the aquifer in Memphis., and smaller cones are found around major well field in the city of Memphis. In DeSoto County, Mississippi, for example, declines of one foot or more a year have been reported due to the effects of local pumping, as well as pumping in Memphis.[25] It has not been determined if any "overdrafting" has occurred; i.e., that water levels could not return to normal if pumping ceased. Nor has it been proven that there has been a significant decline in water levels in Mississippi or a measurable effect on well yields in northern Mississippi.

The Memphis Sand Aquifer is susceptible to contamination. Trace constituents of arsenic, barium, cadmium, chromium, copper, lead, mercury, strontium, and zinc - in very small concentrations - have been found in the aquifer. While well below EPA's maximum allowable concentrations for drinking water supplies, their discovery is a cause for concern because the aquifer system constitutes the principal potable water supply source for Memphis and outlying areas. Moreover, it had previously been thought that the aquifer was overlain by a thick, impermeable clay layer protecting it from contamination. Officials now realize the potential for contamination in the vicinity of waste disposal sites, and contaminants are known to be present in water-table aquifers in the Memphis area at several abandoned dump sites.[26]

Mississippi is concerned with declining water levels in the aquifer. Currently, that state derives 80% (2.6 out of a total of 3.3 BGD) of its daily potable water supply from underground sources. Calls for a comprehensive study of groundwater use, groundwater movement between the two states, and the causes of groundwater level declines have been growing, particularly among Mississippi officials. Uncertainty still surrounds the movement of groundwater beneath the two states. It is possible that parties in *either* Tennessee or Mississippi could be impairing the rights of users in the other state if they pump in high quantities. Local experts concur that any multi-jurisdictional approach to managing groundwater will require consensus among many stakeholders. At least one study has attempted to gauge stakeholder attitudes regarding these issues and has concluded that stakeholders in each state perceive a potential threat to its groundwater from users in the other state. In addition, a collaborative study involving several institutions has begun, with involvement by USGS and the Groundwater Institute of the University of Memphis.[27] Mississippi's Department of Environmental Quality is also expected to become a study participant.

The Memphis Sand Aquifer currently faces three interrelated challenges. First, an increase in the current rate of water withdrawal in and around Memphis could have various "recharge" effects. It might serve to continue to lower the water table. On the other hand, it might actually accelerate [p.56] groundwater recharge by downward leakage from the near surface water tables - so called alluvium and fluvial deposits. This, too, is problematic because the quality of the groundwater varies between different aquifers and even within the same aquifer.[28] Second, as DeSoto County and other areas of northwestern Mississippi continue to grow, competition over available groundwater, and debate over who properly "owns" it, also will grow. Finally, increased water withdrawal as well as improperly managed patterns of land use development may threaten both the recharge of the aquifer and its possible contamination.

5.5 Relevant Legal Principles Regarding the Memphis Sand Aquifer - Overview

MLGW, as the name suggests, supplies electric power and natural gas, as well as water to the population of the City of Memphis and surrounding suburbs. In 1998, MLGW's maximum pumpage to its distribution system was 227.4 Mgal/d, while its minimum pumpage was 118.9 Mgal/day. Daily averages from increased from 140.6 Mgal/d in 1994 to 153.4 Mgal/d in 1998. Most of this water is withdrawn from wells in the Memphis Sand Aquifer, a portion of which underlies the city. MLGW has 10 water pumping stations in Shelby County drawing water from more than 170 wells. MLGW advertises that the aquifer beneath the city has "an abundant supply of high quality water that could accommodate the daily needs of a city several times the size of Memphis."[29]

The common law of groundwater in Tennessee has not been the subject of much litigation. The general view of legal scholars is that Tennessee holds that landowners overlying an aquifer have rights to pump water from the aquifer that are correlative to the rights of other landowners whose land overlies the aquifer. It has been stated that "correlative rights are simply surface riparian law applied to groundwater."[30] While some may disagree with this view, the appellate court in Tennessee has rejected the absolute dominion rule which allows a surface owner to pump any amount of water from an aquifer regardless of the damage it does to the rights of other landowners overlying the same aquifer.[31] The court concluded that overlying landowners are restricted to a reasonable exercise of their mutual rights in the common source.

MLGW has rights to pump water from the Memphis Sand Aquifer by virtue of the company's ownership of land overlying the aquifer. Under Tennessee law, it is unclear whether MLGW can legally use water from the aquifer to supply water to residents of the city who live on land not overlying the aquifer, if there are any such residents. Under common law, water pumped from an aquifer can only be used on land overlying the aquifer that is owned by the pumper. This is a situation where the common law has not yet caught up with the contemporary reality of large scale pumping for use off-site. However, because MLGW has been pumping water from this aquifer for a considerable period of time, thus far without legal action taken against it, it is unlikely that Tennessee courts would enjoin the company from continuing to pump water and selling it off-site. Whether the amount that is currently being pumped would be allowed by the courts, if there is a complaint by another landowner, is another matter.

If MLGW has been pumping water from the aquifer so as to diminish the flow and pressure to others wells for a period sufficient to allow the company to acquire rights to the water through *prescription* (probably 20 years), then the company may have acquired rights to this water. However, MLGW must have been pumping during that period with the knowledge that, in fact, it had no right to do so. Some scholars are of the opinion, based on California cases, that for prescriptive rights to groundwater to be obtained, the loss of pressure and flow must have existed for the entire prescriptive period.[32]

[p.57] **5.5.1 Tennessee-Mississippi Liability Problems**

Whether or not MLGW has acquired prescriptive rights to more than its share of the water from the Memphis Sand Aquifer, MLGW - *or any other user of the aquifer* - could potentially be held liable for damages to the ability of other landowners to pump water from the aquifer. Such parties could also be held liable for creating a public nuisance by creating conditions leading to the contamination of the aquifer.

If MLGW pumping has damaged the ability of landowners in Mississippi to pump water for their own land, MLGW may be subject to a suit for damages or an injunction brought by the Mississippi landowners in either Tennessee or Mississippi state court. While the pumping is being done in Tennessee, the damage is occurring in Mississippi. Likewise, the same scenario would hold true in reverse if *Mississippi users impaired* Tennessee users' rights - that is, their courts would have to uphold Tennessee users' rights, as determined by a court of law.

Under Tennessee law, incomplete as the record is, if the volume that MLGW is pumping is unreasonably high, much more than their share of the water from the aquifer, their actions are illegal if another overlying user complains. The courts in Tennessee may only grant damages and not an injunction, however, because the pumping is for municipal purposes

Landowners in Mississippi could bring suit in Mississippi state court if a Tennessee user has damaged the landowners' ability to pump water on their land in Mississippi. The landowners would have to acquire jurisdiction. If such a suit were brought and a judgment favorable to the plaintiffs were rendered in Mississippi, the courts in Tennessee would be required to enforce the judgment under the constitutional requirement of "full faith and credit." If such a suit were brought upon MLGW, the risk is that courts in Mississippi may not have the same concern for maintaining the City of Memphis' access to groundwater, and may direct that MLGW find another source (e.g., the Mississippi River, whose waters are much less pure - see Chapter 6). In any case, should it be determined that MLGW's pumping is excessive, it would probably be illegal under Mississippi law. Mississippi law, which is a regulated riparian system, allows groundwater pumping only by permit for specified amounts.

Because the Memphis Sand aquifer underlies land in several states, it is entirely possible that this dispute could also lead to a suit for apportionment of the waters of the aquifer. MLGW may be vulnerable to suit by the State of Mississippi, acting in the interests of its citizens, to prevent continued pumping of the aquifer in excess of a reasonable amount. The State of Tennessee could be joined in the suit, in its role as trustee for the waters of the state. Such a suit would likely originate in the U.S. Supreme Court as an equitable apportionment suit. The Supreme Court has never apportioned the water in an underground aquifer. The Court has apportioned anadromous fish migrating in interstate waters, however. Thus, its powers to apportion resources are not limited to surface watercourses. Because the State of Mississippi and the overlying landowners in that state clearly have rights to the water in the Mississippi portion of the aquifer, and because actions by an entity in another state are affecting those rights, it is highly likely that the Court would hear the case. Again, the outcome might be unfavorable to MLGW and Memphis water users because there is another source, the Mississippi River, and MLGW's current use of the aquifer is not legal or equitable under the laws of either state, nor, probably, under the federal common law used by the Court in making an apportionment.

5.5.2 Legal and Political Options for Resolving Potential Aquifer Disputes

[p.58] Rather than allowing the current situation to continue and possible lawsuits to be filed, a far better approach would be for the States of Tennessee and Mississippi to work with MLGW and other aquifer users to lower reliance on the Memphis Sand Aquifer, increase recharge and protect existing recharge areas and the aquifer as a whole, and to continue their efforts in working together to better understand the flow dynamics of the aquifer. The State of Tennessee and the State of Mississippi could work together toward an agreement or even an interstate compact to apportion the aquifer and seek ways to protect it from pollution and overdraft. Because most interstate compacts must be ratified by Congress and signed by the President, they appear may to be daunting endeavors. However, there is no reason that the states cannot work together to find solutions to any over-pumping problems that may exist. It is reasonable to assume that Mississippi would have an interest in such a joint solution because a lawsuit that charges no present damages but, rather, claims that future development opportunities are being lost will not succeed. Lost opportunities cannot be recovered under riparian law. Even Mississippi, which requires permits for water withdrawals and so is no longer strictly a common law state, would not likely allow recovery for lost opportunity.

5.5.3 Summation - Avoiding Memphis Sand Aquifer Disputes

Under common law, MLGW could be held liable if it is shown that it is pumping in quantities that impair the rights of others whose land overlies the aquifer. Some Mississippi landowners have complained that pumping for Memphis' use is damaging their ability to use the aquifer. If it is shown that the utility has made no effort to fix the problem, it could be held liable. A lawsuit against MLGW or other Tennessee water users for damages to the rights of Mississippi water users could be brought in court in Mississippi. Although the damage was caused by a Tennessee entity, it occurred in Mississippi. Any judgments rendered by the courts in Mississippi would probably have to be accepted by Tennessee *and vice versa.* Under the Full Faith and Credit clause of the U. S. Constitution, Tennessee must enforce a judgment for damages rendered by the courts of another state. Thus, it might be appropriate for Tennessee to act to restrain the pumping by MLGW and to encourage the city to conserve water. If the state does not act, the issue may be taken to court, either by individuals claiming damage to their rights in Mississippi or by a suit in the Supreme Court against Tennessee brought by Mississippi acting for its citizens. As noted earlier, the same scenario would hold true in reverse. If Mississippi users impaired Tennessee users' rights, their courts would have to uphold Tennessee users' rights.

Endnotes to Chapter 5

(1) See, for example, Gregg, 1996; Jaffe, 1996; H. J. Res. 91, 1997; Graham, 1999; Seabrook, 1999; Arrandale, 1
(2) See: Michael Pare, 1998. "Atlanta Says Doesn't Need City's Water," *Chattanooga Free Press*, December 9
(3) Robert T. Dunphy, 1997. *Moving Beyond Gridlock*. Washington, D.C.; Urban Land Institute, p. 67.
(4) Tom Arrandale, 1999. "The Eastern Water Wars," *Governing* (August): 30-34; and Michael Pare, 1998. "Wate Regional Commission - unpublished report.
(5) Flessner, 1999; Gilbert, 1999a; McAllister, 1999; Walton and Pare, 1999).
(6) Michael Pare, 1998. "Water Company Eyes Role," *Chattanooga Free Press*, July 21: B-1; and "TAWC Boosts Partnership Idea to Chamber," *Chattanooga Times and Free Press*, May 12, 1999; "City Officials Dismiss Water Poll," *Chattanooga Times and Free Press*, May 29, 1999; Judy Walton, "Court Case Crucial to Water Company Takeover," *Chattanooga Times and*

Free Press, August 13, 1999; and Judy Walton, "Water Company, City Spar in Court," *Chattanooga Times and Free Press*, August 14, 1999.
(7) Kathy Gilbert (1999). "City Drops Water War," *Chattanooga Times and Free Press*, October 26: A-1; also, for a de Unpublished manuscript, Misty Smith Kelley, Attorney-at-Law.
(8) "Summary of the Resolution of the City of Chattanooga's Efforts to Acquire Tennessee-American Water Comp
[p.59] (9) For details, see Kathy Gilbert (1999). "City Drops Water War," *Chattanooga Times and Free Press*, October 26:
(10) Source: www.tawc.com, J. Frances Alexander, Director of Communications, (423)755-7606
(11) See the TVA Act (1933).
(12) This is not to suggest that Tennessee still subscribes to the "natural flow" theory of water law. Expanding definitions of "reasonable use" and increasing reliance on municipal water systems have made t
(13) Tenn. Code Ann. § 69-8-105.
(14) *Id.*
(15) Tenn. Code Ann. § 69-3-108(b)
(16) See *Public Water Policy in Tennessee*, State of Tennessee Water Policy Commission, Public Administration Service, Chicago, Illinois, 1956.
(17) See Note 10 *supra*.
(18) Grant, Douglas L., *Equitable Apportionment Suits Between States*, in Beck, *Waters and Water Rights* § 45.01-577.
(19) *Lucas v. South Carolina Coastal Council*, 112 S.Ct. 2886 (1992), held that land-use regulation that denies an ov thereby deprives them of economically viable use of their riparian land.

(20) Nicki Robertshaw, 1999. "Memphis' Fine Groundwater a Growing Factor in Construction," Memphis Business Jo

(21) Tom Charlier, 1999. "Memphis Taps into DeSoto County Well Levels," *The Commercial Appeal - Memphis*, Te

(22) See: W. Parks and J.K. Carmichael (1990) *Geology and Ground-Water Resources of the Memphis Sand in Wes the Memphis Aquifer in Western Tennessee.* Water-Resources Investigations Report 88-4180. Memphis, Tennessee: U.S. Geological Survey. Also, see: J.V. Brahana, et. al. (1987) *Quality of Water from Freshwater Aquifers and Principal Well Fields in the Memphis Area, Tennessee.* Prepared in Cooperation with the City of Memphis, Memphis Light, Gas and Water Division. Water-Resources Inve known as the "500-foot" sand because the aquifer is, in general, about 500 ft. below the surface in the Memphis area. The thickness of the aquifer is from 500-890 ft. in the Memphis area. The aquifer is recharged to the east of Shelby County (see: Ground Water Institute (1995) *A Ground Water Flow Analysis of the Memphis Sand Aquifer in the Memphis, Tennessee Area.* Technical Brief #7, Memphis, Tennessee: University of Memphis, February).

(23) See, "Tennessee Water Use-Data Tabling," 1998. (no author). USGS Website (http:// www.usgs. gov/edu-cgi- Prepared in Cooperation with the City of Memphis, Memphis Light, Gas and Water Division. Water-Resources Investigations Report 93-4075. Memphis, Tennessee: U.S. Geological Survey. Kingsbury and Parks, 1993).

(24) Parks and Carmichael, 1990; also, Robertshaw, 1999.

(25) Charlier, 1999: A9; Ground Water Institute, 1995;

Parks and Carmichael, 1990, *Altitude of Potentiometr* Report 89-4048. Memphis, Tennessee: U.S. Geological Survey.

(26) Parks and Carmichael, 1990a; Brahana, Parks, & Gaydos, 1987; Robertshaw, 1999.

(27) For a summary of this stakeholder interview study, see John Wingard (2000), *The Community Dynamics of Source Water Protection: the Structure and Dynamics of the Human Dimensions of Source Wate the Minds. Source Water Protection Workshops, Coordinated by the Ground Water Institute of the University of Memphis* (Memphis, TN: University of Memphis); also, Charlier, 1999).

(28)Brahana, Parks, and Gaydos, 1987.

(29) <www.mlgw.com.>

(30) Tarlock, A. Dan, *Law of Water Rights and Resources*, § 4.06(3)

(31) See *Nashville, Chattanooga & St. Louis v. Rickert*, 19 Tenn. App. 446, 89 S.W.2d 889 (1935), *cert denied* (1936

(32) Tarlock, *supra* note 11.

EXHIBIT 6

Special Report

Tennessee's Water Supply:

Toward A Long-Term Water Policy for Tennessee

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John G. Morgan
Comptroller of the Treasury

March 2002

* * *

[p.6] source to the Columbia region.[8] This situation requires regulators, local governments and utility districts, and TDEC to carefully examine the potential effects of proposed activities both upstream and downstream of the dam and to work together to maintain the hydrologic system to support everyone's needs.

Case 3: Memphis Sand Aquifer

The city of Memphis, through Memphis Light, Gas and Water (MLGW), is one of the largest cities in the world to rely solely on ground water for its water supply. The city's wells tap into the Memphis Sand Aquifer, an underground reservoir that underlies nearly 7,400 square miles in West Tennessee, Northern Mississippi, Southwestern Kentucky, and Eastern Arkansas. The largest user of the aquifer, MLGW pumped an average of 208 million gallons per day in 1995, with an estimated 20 to 40 million gallons per day thought to be coming from beneath DeSoto County, Mississippi. This area of Mississippi has experienced rapid economic and population growth, in part due to the "suburbanization" of Memphis, and views the aquifer as a potential future water source, adding an interstate dimension to this case of water scarcity.[9]

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[8] Tennessee Valley Authority, "Use of Land Acquired for the Columbia Dam Component of the Duck River Project," http://www.tva.gov/environment/reports/columbiaeis/index.htm (accessed February 13, 2002).

[9] David Lewis Feldman and Julia O. Elmendorf, *Water Supply Challenges Facing Tennessee: Case Study Analyses and the Need*

The aquifer's recharge area appears to begin just inside southeast Shelby County, Tennessee (an area of intense development) and to extend east into Fayette County. Balancing local growth against the need to protect the recharge area remains a major challenge and has sparked local efforts to require open space and limit development to permit natural ponding of standing water and allow aquifer recharge. Memphis Light, Gas and Water and DeSoto County, Mississippi, officials note that as a result of long-term pumping, a cone of depression has developed in the Memphis area. Observation wells showed a decline in water levels of 77 feet between 1928 and 1985; water levels away from the cone in Memphis have also shown a decline. There are smaller cones around a major well field in Memphis, and DeSoto County has reported declines of one foot or more per year, apparently because of pumping locally and in Memphis. It is not clear whether water levels could return to normal if pumping ceased, nor has it been proven that there has been a significant decline in water levels or a measurable effect on well yields in Northern Mississippi or other areas. Also, traces of contaminants such as arsenic, lead, and mercury have been found in water from the aquifer. Though well below EPA's maximum allowable concentrations for drinking water supplies, this discovery is troubling to those who use water from the aquifer, because it demonstrates the aquifer's susceptibility to contamination in the vicinity of waste disposal sites and abandoned dump sites. This evidence of susceptibility is also contrary to previously held

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for Long-Term Planning (Knoxville, TN: Energy, Environment and Resources Center, 2000), pp. 50-53.

beliefs that a layer of clay overlying the aquifer protected it from such contamination.[10]

Officials in both Mississippi and Tennessee have called for a comprehensive study of ground water use, the movement of ground water between Mississippi and Tennessee, and the causes of declines in ground water levels. In response, the Sundquist Administration helped create the Mississippi, Arkansas, and Tennessee Regional Aquifer Study (MATRAS) to study shared [p.7] ground water issues.[11] While common law pertaining to ground water has not been extensively tested by litigation in Tennessee, legal scholars generally view rights to ground water as held by overlying landowners with some limitations. An appellate court in Tennessee has concluded that the rights of a landowner are restricted to activities that do not interfere with the rights of other landowners overlying the same aquifer.[12] However, Memphis has been pumping water from the aquifer for so long that MLGW may have acquired rights to the water through

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[10] *Ibid.*

[11] Tennessee Department of Environment and Conservation, "Report from Multi-State Water Supply Research Project," http://www.state.tn.us/environment/epo/hotlist.htm#WaterResearch (accessed February 8, 2002).

[12] David Lewis Feldman and Julia O. Elmendorf, *Water Supply Challenges Facing Tennessee: Case Study Analyses and the Need for Long-Term Planning* (Knoxville, TN: Energy, Environment and Resources Center, 2000), pp. 52-53.

prescription.[13] A number of other legal issues surround this case, including each state's liability to the other and the ability to prove damage. It appears better for parties in the three states to work together toward a mutually acceptable solution than to resolve the issue through litigation. Such a solution would probably include reducing MLGW's reliance on the aquifer.

Case 4: Lake Levels in East Tennessee

In December 2000, Congress agreed to fund a study by the University of Tennessee examining the economic impact on East Tennessee counties if the Tennessee Valley Authority (TVA) were to delay the annual drawdown of its reservoirs there. Current TVA policy lowers, or "draws down," water levels in TVA lakes beginning in August. TVA rationale for the drawdowns include hydroelectric power generation, flood control, navigation, and environmental demands.[14] These reservoirs have a significant financial impact on the surrounding communities because of the tourist and recreation dollars they attract. Drawing the lakes down in August renders them unusable or unattractive to recreational users during months when the weather supports recreational uses, reducing local business revenues, state and local sales taxes, and property values.

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[13] Acquiring ground water rights through "prescription" means acquiring the rights through long-term pumping without the other users taking any action, though it may affect yields of other users of the same aquifer.

[14] Richard Powelson, "Congress funding study of TVA lake levels," *Knoxville News-Sentinel*, December 17, 2000.

An October 1998 report by the UT Center for Business and Economic Research examined the economic impact of keeping water levels in two East Tennessee Lakes constant during the months of August and September rather than beginning the drawdown in August. The table at the top of the next page summarizes the findings of that study and comparisons with other similar studies.

* * *

EXHIBIT 7

U.S. Department of the Interior
U.S. Geological Survey

Basic Ground-Water Hydrology

Water-Supply Paper 2220

Prepared in cooperation with the North Carolina Department of Natural Resources and Community Development

USGS
Science for a changing world

Basic Ground-Water Hydrology

By RALPH C. HEATH

Prepared in cooperation with the
North Carolina Department of
Natural Resources and Community
Development

U.S. GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2220

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

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CONTENTS

[p.v] PREFACE

Ground water is one of the Nation's most valuable natural resources. It is the source of about 40 percent of the water used for all purposes exclusive of hydropower generation and electric powerplant cooling.

Surprisingly, for a resource that is so widely used and so important to the health and to the economy of the country, the occurrence of ground water is not only poorly understood but is also, in fact, the subject of many widespread misconceptions. Common misconceptions include the belief that ground water occurs in underground rivers resembling surface streams whose presence can be detected by certain individuals. These misconceptions and others have hampered the development and conservation of ground water and have adversely affected the protection of its quality.

In order for the Nation to receive maximum benefit from its ground-water resource, it is essential that everyone, from the rural homeowner to managers of industrial and municipal water supplies to heads of Federal and State water-regulatory agencies, become more knowledgeable about the occurrence, development, and protection of ground water. This report has been prepared to help meet the needs of these groups, as well as the needs of hydrologists, well drillers, and others engaged in the study and development of ground-water supplies. It consists of 45 sections on the basic elements of ground-water hydrology, arranged in order from the most basic aspects of the subject through a discussion of the methods used to determine the yield of aquifers to a discussion of common problems encountered in the operation of ground-water supplies.

Each section consists of a brief text and one or more drawings or maps that illustrate the main points covered in the text. Because the text is, in effect, an expanded discussion of the illustrations, most of the illustrations are not captioned. However, where more than one drawing is included in a section, each drawing is assigned a number, given in parentheses, and these numbers are inserted at places in the text where the reader should refer to the drawing.

In accordance with U.S. Geological Survey policy to encourage the use of metric units, these units are used in most sections. In the sections dealing with the analysis of aquifer (pumping) test data, equations are given in both consistent units and in the inconsistent inch-pound units still in relatively common use among ground-water hydrologists and well drillers. As an aid to those who are not familiar with metric units and with the conversion of ground-water hydraulic units from inch-pound units to metric units, conversion tables are given on the inside back cover.

Definitions of ground-water terms are given where the terms are first introduced. Because some of these terms will be new to many readers, abbreviated definitions are also given on the inside front cover for convenient reference by those who wish to review the definitions from time to time as they read the text. Finally, for those who need to review some of the simple mathematical operations that are used in ground-water hydrology, a section on numbers, equations, and conversions is included at the end of the text.

Ralph C. Heath

[p.1] GROUND-WATER HYDROLOGY

The science of hydrology would be relatively simple if water were unable to penetrate below the earth's surface.
Harold E. Thomas

Ground-water hydrology is the subdivision of the science of hydrology that deals with the occurrence, movement, and quality of water beneath the Earth's surface. It is interdisciplinary in scope in that it involves the application of the physical, biological, and mathematical sciences. It is also a science whose successful application is of critical importance to the welfare of mankind. Because ground-water hydrology deals with the occurrence and movement of water in an almost infinitely complex subsurface environment, it is, in its most advanced state, one of the most complex of the sciences. On the other hand, many of its basic principles and methods can be understood readily by nonhydrologists and used by them in the solution of ground-water problems. The purpose of this report is to present these basic aspects of ground-water hydrology in a form that will encourage more widespread understanding and use.

The ground-water environment is hidden from view except in caves and mines, and the impression that we gain even from these are, to a large extent, misleading. From our observations on the land surface, we form an impression of a "solid" Earth. This impression is not altered very much when we enter a limestone cave and see water flowing in a channel that nature has cut into what appears to be solid rock. In fact, from our observations, both on the land surface and in caves, we are likely to conclude that ground water occurs only in underground rivers and "veins." We do not see the myriad openings that exist between the grains of sand and silt, between particles of clay, or even along the fractures in granite. Consequently, we do not sense the presence of the openings that, in total volume, far exceed the volume of all caves.

R. L. Nace of the U.S. Geological Survey has estimated that the total volume of subsurface openings (which are occupied mainly by water, gas, and petroleum) is on the order of 521,000 km^3 (125,000 mi^3) beneath the United States alone. If we visualize these openings as forming a continuous cave beneath the entire surface of the United States, its height would be about 57 m (186 ft). The openings, of course, are not equally distributed, the result being that our imaginary cave would range in height from about 3 m (10 ft) beneath the Piedmont Plateau along the eastern seaboard to about 2,500 m (8,200 ft) beneath the Mississippi Delta. The important point to be gained from this discussion is that the total volume of openings beneath the surface of the United States, and other land areas of the world, is very large.

Most subsurface openings contain water, and the importance of this water to mankind can be readily demonstrated by comparing its volume with the volumes of water in other parts of the hydrosphere.[1] Estimates of the volumes of water in the hydrosphere have been made by the Russian hydrologist M. I.

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[1] The hydrosphere is the term used to refer to the waters of the Earth and, in its broadest usage, includes all water, water vapor, and ice regardless of whether they occur beneath, on, or above the Earth's surface.

L'vovich and are given in a book recently translated into English. Most water, including that in the oceans and in the deeper subsurface openings, contains relatively large concentrations of dissolved minerals and is not readily usable for essential human needs. We will, therefore, concentrate in this discussion only on freshwater. The accompanying table contains L'vovich's estimates of the freshwater in the hydrosphere. Not surprisingly, the largest volume of freshwater occurs as ice in glaciers. On the other hand, many people impressed by the "solid" Earth are surprised to learn that about 14 percent of all freshwater is ground water and that, if only water is considered, 94 percent is ground water.

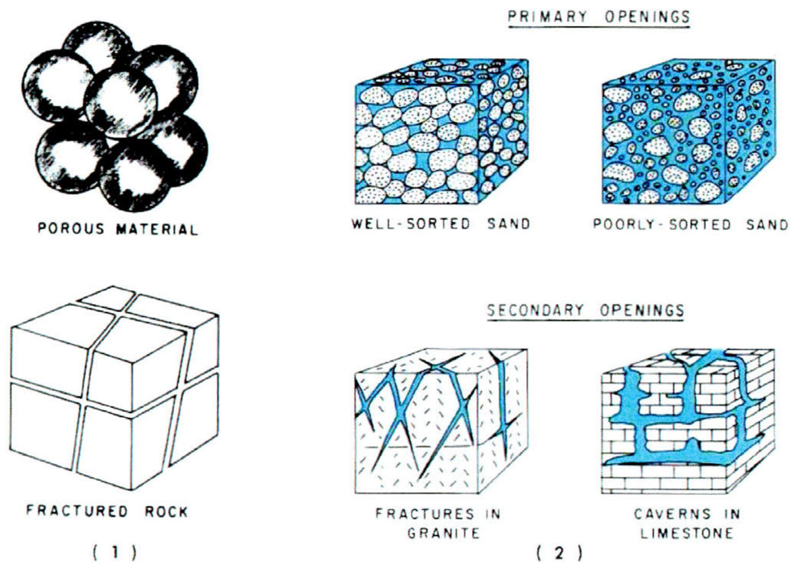
Ground-water hydrology, as noted earlier, deals not only with the occurrence of underground water but also with its movement. Contrary to our impressions of rapid movement as we observe the flow of streams in caves, the movement of most ground water is exceedingly slow. The truth of this observation becomes readily apparent from the table, which shows, in the last column, the rate of water exchange or the time required to replace the water now contained in the listed parts of the hydrosphere. It is especially important to note that the rate of exchange of 280 years for fresh ground water is about 1/9,000 the rate of exchange of water in rivers.

Subsurface openings large enough to yield water in a usable quantity to wells and springs underlie nearly every place on the land surface and thus make ground water one of the most widely available natural resources. When this fact and the fact that ground water also represents the largest reservoir of freshwater readily available to man are considered together, it is obvious that the value of ground water, in terms of both economics and human welfare, is incalculable. Consequently, its sound development, diligent conservation, and consistent protection from pollution are important concerns of everyone. These concerns can be translated into effective action only by increasing our knowledge of the basic aspects of ground-water hydrology.

FRESHWATER OF THE HYDROSPHERE AND ITS RATE OF EXCHANGE
[Modified from L'vovich (1979), tables 2 and 10]

Parts of the hydrosphere	Volume of freshwater km³	Volume of freshwater mi³	Share in total volume of freshwater (percent)	Rate of water exchange (yr)
Ice sheets and glaciers -----	24,000,000	5,800,000	84.945	8,000
Ground water --	4,000,000	960,000	14.158	280
Lakes and reservoirs --	155,000	37,000	.549	7
Soil moisture ---	83,000	20,000	.294	1
Vapors in the atmosphere --	14,000	3,400	.049	.027
River water ----	1,200	300	.004	.031
Total ------	28,253,200	6,820,700	100.000	

[p.2] ROCKS AND WATER



Most of the rocks near the Earth's surface are composed of both solids and voids, as sketch 1 shows. The solid part is, of course, much more obvious than the voids, but, without the voids, there would be no water to supply wells and springs.

Water-bearing rocks consist either of unconsolidated (soil-like) deposits or consolidated rocks. The Earth's surface in most places is formed by soil and by unconsolidated deposits that range in thickness from a few centimeters near outcrops of consolidated rocks to more than 12,000 m beneath the delta of the Mississippi River. The unconsolidated deposits are underlain everywhere by consolidated rocks.

Most *unconsolidated deposits* consist of material derived from the disintegration of consolidated rocks. The material consists, in different types of unconsolidated deposits, of particles of rocks or minerals ranging in size from fractions of a millimeter (clay size) to several meters (boulders). Unconsolidated deposits important in ground-water hydrology include, in order of increasing grain size, clay, silt, sand, and gravel. An important group of unconsolidated deposits also includes fragments of shells of marine organisms.

Consolidated rocks consist of mineral particles of different sizes and shapes that have been welded by heat and pressure or by chemical reactions into a solid mass. Such rocks are commonly referred to in ground-water reports as *bedrock*. They include sedimentary rocks that were originally unconsolidated and igneous rocks formed from a molten state. Consolidated sedimentary rocks important in ground-water hydrology include limestone, dolomite, shale, siltstone, sandstone, and conglomerate. Igneous rocks include granite and basalt.

There are different kinds of voids in rocks, and it is sometimes useful to be aware of them. If the voids were formed at the same time as the rock, they are referred to as *primary openings* (2). The pores in sand and gravel and in other unconsolidated deposits are primary openings. The lava tubes and other openings in basalt are also primary openings.

[p.3] If the voids were formed after the rock was formed, they are referred to as *secondary openings* (2). The fractures in granite and in consolidated sedimentary rocks are secondary openings. Voids in limestone, which are formed as ground water slowly dissolves the rock, are an especially important type of secondary opening.

It is useful to introduce the topic of rocks and water by dealing with unconsolidated deposits on one hand and with consolidated rocks on the other. It is important to note, however, that many sedimentary rocks that serve as sources of ground water fall between these extremes in a group of *semi-consolidated rocks*. These are rocks in which openings include both pores and fractures–in other words, both primary and secondary openings. Many limestones and sandstones that are important sources of ground water are semiconsolidated.

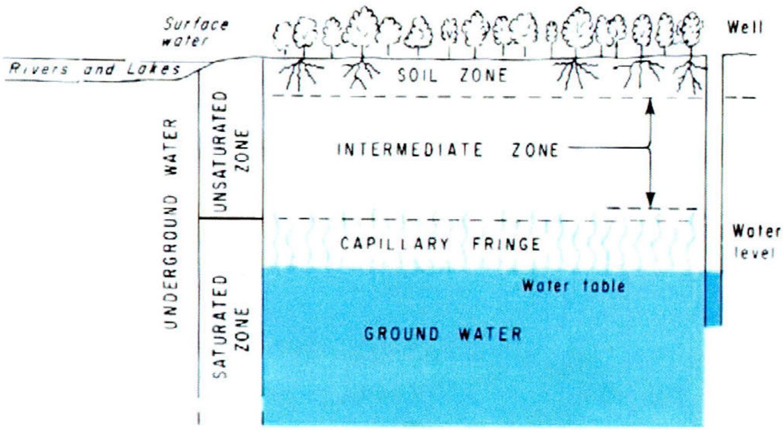
[p.4] UNDERGROUND WATER

All water beneath the land surface is referred to as *underground water* (or subsurface water). The equivalent term for water on the land surface is *surface water*. Underground water occurs in two different zones. One zone, which occurs immediately below the land surface in most areas, contains both water and air and is referred to as the *unsaturated zone*. The unsaturated zone is almost invariably underlain by a zone in which all interconnected openings are full of water. This zone is referred to as the *saturated zone*.

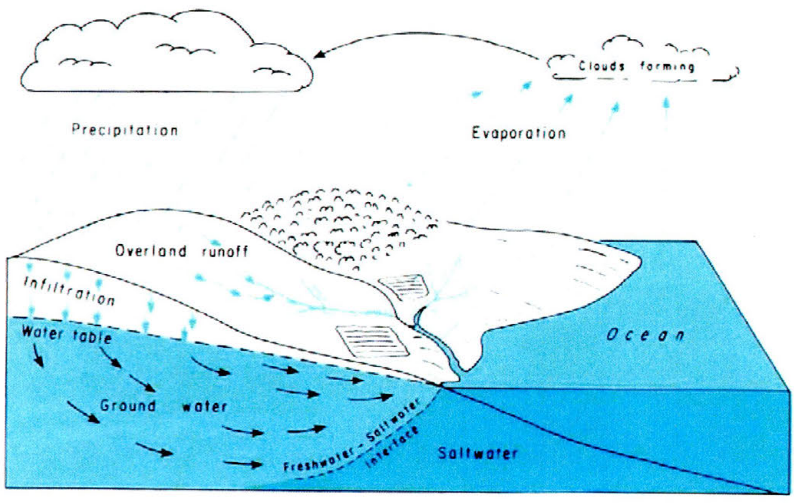
Water in the saturated zone is the only underground water that is available to supply wells and springs and is the only water to which the name *ground water* is correctly applied. Recharge of the saturated zone occurs by percolation of water from the land surface through the unsaturated zone. The unsaturated zone is, therefore, of great importance to ground-water hydrology. This zone may be divided usefully into three parts: the soil zone, the intermediate zone, and the upper part of the capillary fringe.

The soil zone extends from the land surface to a maximum depth of a meter or two and is the zone that supports plant growth. It is crisscrossed by living roots, by voids left by decayed roots of earlier vegetation, and by animal and worm burrows. The porosity and permeability of this zone tend to be higher than those of the underlying material. The soil zone is underlain by the *intermediate zone*, which differs in thickness from place to place depending on the thickness of the soil zone and the depth to the capillary fringe.

The lowest part of the unsaturated zone is occupied by the *capillary fringe*, the subzone between the unsaturated and saturated zones. The capillary fringe results from the attraction between water and rocks. As a result of this attraction, water clings as a film on the surface of rock particles and rises in small-diameter pores against the pull of gravity. Water in the capillary fringe and in the overlying part of the unsaturated zone is under a negative hydraulic pressure–that is, it is under a pressure less than the atmospheric (barometric) pressure. The *water table* is the level in the saturated zone at which the hydraulic pressure is equal to atmospheric pressure and is represented by the water level in unused wells. Below the water table, the hydraulic pressure increases with increasing depth.



[p.5] HYDROLOGIC CYCLE



The term *hydrologic cycle* refers to the constant movement of water above, on, and below the Earth's surface. The concept of the hydrologic cycle is central to an understanding of the occurrence of water and the development and management of water supplies.

Although the hydrologic cycle has neither a beginning nor an end, it is convenient to discuss its principal features by starting with evaporation from vegetation, from exposed moist surfaces including the land surface, and from the ocean. This moisture forms clouds, which return the water to the land surface or oceans in the form of precipitation.

Precipitation occurs in several forms, including rain, snow, and hail, but only rain is considered in this discussion. The first rain wets vegetation and other surfaces and then begins to infiltrate into the ground. *Infiltration rates* vary widely, depending on land use, the character and moisture content of the soil, and the intensity and duration of precipitation, from possibly as much as 25 mm/hr in mature forests on sandy soils to a few millimeters per hour in clayey and silty soils to zero in paved areas. When and if the rate of precipitation exceeds the rate of infiltration, *overland flow* occurs.

The first infiltration replaces soil moisture, and, thereafter, the excess percolates slowly across the intermediate zone to the zone of saturation. Water in the zone of saturation moves downward and laterally to sites of ground-water discharge such as springs on hillsides or seeps in the bottoms of streams and lakes or beneath the ocean.

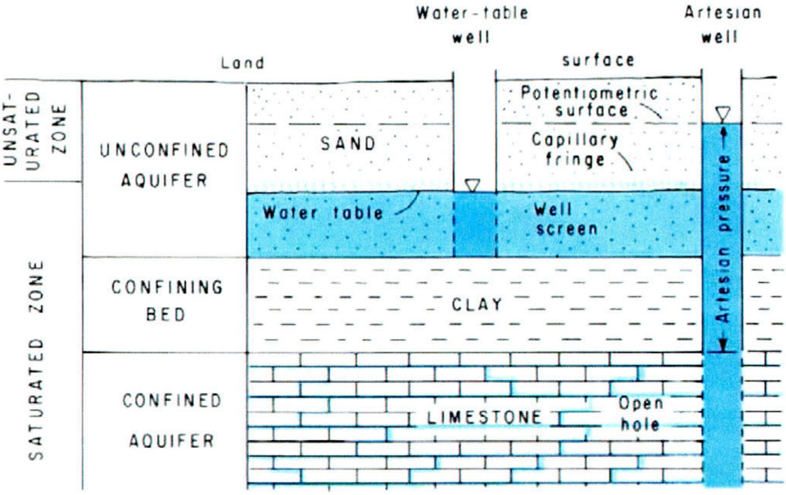
Water reaching streams, both by overland flow and from ground-water discharge, moves to the sea, where it is again evaporated to perpetuate the cycle.

Movement is, of course, the key element in the concept of the hydrologic cycle. Some "typical" rates of movement are shown in the following table, along with the distribution of the Earth's water supply.

RATE OF MOVEMENT AND DISTRIBUTION OF WATER
[Adapted from L'vovich (1979), table 1]

Location	Rate of movement	Distribution of Earth's water supply (percent)
Atmosphere ---	100's of kilometers per day	0.001
Water on land surface ------	10's of kilometers per day	.019
Water below the land surface --	Meters per year	4.12
Ice caps and glaciers ------	Meters per day	1.65
Oceans -------	--	93.96

[p.6] AQUIFERS AND CONFINING BEDS



From the standpoint of ground-water occurrence, all rocks that underlie the Earth's surface can be classified either as aquifers or as confining beds. An *aquifer* is a rock unit that will yield water in a usable quantity to a well or spring. (In geologic usage, "rock" includes unconsolidated sediments.) A *confining bed* is a rock unit having very low hydraulic conductivity that restricts the movement of ground water either into or out of adjacent aquifers.

Ground water occurs in aquifers under two different conditions. Where water only partly fills an aquifer, the upper surface of the saturated zone is free to rise and decline. The water in such aquifers is said to be *unconfined*, and the aquifers are referred to as *unconfined aquifers*. Unconfined aquifers are also widely referred to as water-table aquifers.

Where water completely fills an aquifer that is overlain by a confining bed, the water in the aquifer is said to be *confined*. Such aquifers are referred to as *confined aquifers* or as *artesian aquifers*.

Wells open to unconfined aquifers are referred to as *water-table wells*. The water level in these wells indicates the position of the water table in the surrounding aquifer.

Wells drilled into confined aquifers are referred to as *artesian wells*. The water level in artesian wells stands at some height above the top of the aquifer but not necessarily above the land surface. If the water level in an artesian well stands above the land surface, the well is a *flowing artesian well*. The water level in tightly cased wells open to a confined aquifer stands at the level of the *potentiometric surface* of the aquifer.