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 Bill of Complaint
Before the Special Master, Hon. Eugene E. Siler, Jr.

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PROPOSED FINDINGS OF FACT

I. BACKGROUND FACTS

A. Study Of Aquifers Generally

1. Hydrology is the study of the overall movement and occurrence of water in the environment. Tr. 969:25-970:10 (Langseth).[1]

2. The study of hydraulics concerns the physics of how water might move, how fast it might move, and how much might be flowing. Tr. 969:25-970:10 (Langseth).

3. Groundwater hydrology concerns the occurrence, movement, and quality of water beneath the surface of the ground. J-40 at 6.[2]

4. Hydrogeology is a specialization within the general field of geology that concerns groundwater. Tr. 37:8-19 (Spruill).

5. The United States Geological Survey ("USGS") is a federal agency that is tasked, in part, with monitoring and evaluating the water resources of the United States. Tr. 568:11-16 (Larson); D-197 at 25.

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[1] Defendants' proposed findings of fact are supported by relevant record citations. These citations are not intended to be exhaustive, and there are additional citations in the record that support Defendants' proposed findings of fact.

[2] All page number citations to exhibits reference the stamped page of the exhibit.

B. Overview Of Aquifers

6. Groundwater is water that occurs beneath the land surface in the pore spaces of rocks and sediments. Tr. 47:22-25 (Spruill); 568:17-22 (Larson); D-197 at 11; J-29 at 20; J-40 at 6-7.

7. A hydrogeologic unit (or "hydrogeological unit") is a layer of geological material containing water that is recognized by hydrogeologists as a distinct formation based on similarity of hydrogeologic characteristics, principally its ability to transmit water (i.e., permeability or hydraulic conductivity). Tr. 82:7-14 (Spruill); 571:13-21 (Larson); D-191 at 10.

8. "Hydraulic conductivity" is a measure of the ease with which water will flow through an aquifer. It is also called permeability. Tr. 165:15-22 (Spruill); D-194 at 9; J-29 at 44; J-40 at 17.

9. More permeable hydrogeological units are characterized as aquifers. Tr. 571:13-21, 592:24-593:7 (Larson). An aquifer is a formation (or group of formations, or part of a formation) made of rock or sediment that contains sufficient saturated, permeable material to yield usable quantities of water to wells and springs. S17;[3] Tr. 53:6-10 (Spruill); 569:1-5 (Larson); 805:17-19 (Waldron); D-191 at 9; J-29 at 65, 324; J-40 at 11.

[3] Citations to "S__" are to the Stipulated Facts submitted as part of the parties' Joint Statement of Stipulated and Contested Facts (Dkt. No. 64).

10. An aquifer, by definition, includes both the formation's (or group of formations', or part of the formation's) geological material and the water within it. A geological formation without water is not an aquifer. Tr. 319:7-8 (Spruill); 588:8-16, 642:4-6 (Larson); 988:3-8 (Langseth).

11. Less permeable hydrogeological units are characterized as confining layers. Tr. 571:13-21, 592:24-593:7 (Larson). Confining layers can overlie or underlie a confined aquifer. Confining layers do not restrict the lateral movement of water in an aquifer. They restrict, but generally do not completely obstruct, the vertical movement of water out of the aquifer. S20; Tr. 57:16-25 (Spruill); 573:14-21 (Larson); 805:20-24, 813:5-14 (Waldron); D-197 at 11; D-191 at 9; J-40 at 11.

12. The geological material of an aquifer or confining layer may consist of consolidated sediments, such as various types of rock, or unconsolidated sediments of varying grain sizes, such as sand, silt, or clay. Tr. 48:12-52:2, 54:4-55:14 (Spruill); J-2 at 17; J-40 at 7.

13. The word "facies" is a term for the character of geological material. A "facies change" is an area of a hydrogeologic unit where there is gradual change in the character of the geological material of the hydrogeologic unit from one place to another. For example, a facies change could describe the transition in geological material from a coarse-grained material (like sand) to a finer-grained material (like clay). Tr. 607:8-13 (Larson); D-194 at 8 & n.1.

14. “Transmissivity” is the ability of an aquifer to transmit water. Transmissivity is calculated by multiplying the hydraulic conductivity of the aquifer by the saturated thickness of the aquifer. Tr. 174:19-175:15 (Spruill); 920:7-11 (Waldron); J-29 at 77. The saturated thickness of the aquifer is a measurement of the thickness of the aquifer that is fully saturated with water. J-40 at 31.

15. “Storage” is the capacity of an aquifer for containing water. The storage characteristics of an aquifer are a measure of how potentiometric levels in the aquifer will change with pumping. Storage does not imply that the water within an aquifer remains static or that there are specific water molecules permanently stored within an aquifer. D-197 at 25; D-194 at 9; J-29 at 76-80.

16. A hydrogeologic system, aquifer system, or groundwater system means a group of hydrogeologic units, such as aquifers and confining units, that are hydrologically interconnected such that water can flow from one unit to another. Frequently, a hydrogeologic system is a series of laterally extensive aquifers that are above and below each other and separated by intervening confining layers. Tr. 62:17-23 (Spruill); 571:4-12 (Larson); J-40 at 19.

17. “Discharge” commonly refers to water that moves out of an aquifer. S21; Tr. 569:23-24 (Larson); J-29 at 229; J-40 at 19.

18. “Recharge” commonly refers to water that moves into an aquifer. One example of recharge is rainfall that seeps through the ground into an aquifer. S28; Tr. 569:22-23 (Larson); J-29 at 229; J-40 at 19.

19. Recharge and discharge are constantly occurring within a typical aquifer. Tr. 582:8-9 (Larson).

C. Determining The Extent Of Hydrogeological Units

20. In hydrogeology, a cross section is a graphical representation of a vertical slice of the underground surface that shows the arrangement of the various hydrogeological units beneath the surface between two points. Hydrogeologists construct cross sections depicting the various hydrogeological units within a hydrogeological system, often based on borehole log data. Tr. 89:25-90:14 (Spruill); 999:10-1000:1 (Langseth).

21. Hydrogeologists can determine the lateral extent of an aquifer by relying on the information geologists obtain from borehole logs about the geological material beneath the ground surface. Hydrogeologists correlate areas where various properties of the materials such as grain size, sedimentation, fossil records, or biological flora are similar in order to identify distinct hydrogeological units. Tr. 824:9-17 (Waldron); 1005:9-1006:2, 1057:8-11 (Langseth); D-194 at 8; J-2 at 17; J-36 at 9; J-37 at 5, 7; J-58 at 51 (Plate 1).

22. Heterogeneity, or variations in physical properties, is common within a single hydrogeological unit. Tr. 55:22-56:13 (Spruill); 572:19-20, 593:8-10 (Larson); 825:8-19 (Waldron); J-7 at 12. A single aquifer frequently contains variations in properties like permeability, thickness, and storage. Tr. 825:1-19 (Waldron); J-29 at 66.

D. Characteristics Of Aquifers; Potentiometric Surface

23. A confined aquifer (or confined area of an aquifer) is an aquifer (or area of an aquifer) that has an overlying confining layer and in which the pressure in the aquifer is high enough that the potentiometric level in the aquifer rises above the bottom of the overlying confining layer. S19; Tr. 60:7-10 (Spruill); 575:7-15 (Larson); 816:25-817:4 (Waldron); D-197 at 11; J-40 at 11.

24. An unconfined aquifer (or unconfined area of an aquifer) is an aquifer (or area of an aquifer) in which the water level is below the overlying confining layer or in which no overlying confining layer is present. S29; Tr. 59:15-18 (Spruill); 577:6-12 (Larson); J-40 at 11.

25. An outcrop area is an area of an aquifer where the aquifer has no confining layer above and comes to the surface (or close to the surface). The outcrop area can function as a recharge zone. S25; D-197 at 12; D-191 at 10.

26. The potentiometric level in an aquifer (also called the potentiometric head or potentiometric elevation) is the elevation to which water rises inside a

tightly cased, properly screened well at a given location in a confined aquifer. Casing refers to sealing the well off from the surrounding geological materials by filling the hole outside the well with grouting material such as cement. A "well screen" is the section of the well that allows water to flow from the aquifer into the well. The potentiometric level is the sum of the elevation of the well screen and the pressure in the aquifer at the well screen. S26; Tr. 135:9-19, 137:14-18 (Spruill); 575:22-576:8 (Larson); D-197 at 11; D-194 at 8; J-29 at 39; J-40 at 15.

27. The potentiometric level or water level in a well is measured by determining the elevation of the top of the well above mean sea level and subtracting the depth to the water in the well. Tr. 577:17-578:1 (Larson).

28. A contour line (also called an equipotential line) is a line depicted on a potentiometric map along which the potentiometric level or water level in the aquifer is estimated to be the same. S22; Tr. 579:25-580:7 (Larson); 1016:23-1017:3 (Langseth).

29. A potentiometric surface of an aquifer is a representation of the potentiometric level of an aquifer over a region and is often represented on a potentiometric surface map by showing equipotential lines. S27; Tr. 147:25-148:9 (Spruill); 602:9-13 (Larson); J-29 at 67.

30. Water in an aquifer moves around the grains of sediment as it flows in a given direction. Tr. 116:10-16, 117:3-118:1 (Spruill); D-197 at 12.

31. A flow path (also called a flow line) is the average, generalized path of groundwater flow. The flow path of groundwater is perpendicular to the contour lines on a potentiometric map in the direction of decreasing potentiometric level. S23, S30, S31; Tr. 116:10-16, 117:3-118:1 (Spruill); 580:14-18 (Larson); 1017:10-15 (Langseth).

32. In order to determine the direction of groundwater flow at any given point, a hydrologist generally needs the potentiometric level for at least three different wells around that point. Tr. 338:19-24 (Spruill).

33. Considering more potentiometric-level data permits a more detailed analysis of groundwater flow patterns within an aquifer. Tr. 339:11-15 (Spruill); 859:8-16 (Waldron).

34. The groundwater within an aquifer is not static; it is constantly moving from places of higher potentiometric level to places of lower potentiometric level. Tr. 1014:18-1015:2 (Langseth); D-197 at 12, 14; D-194 at 8.

35. Groundwater generally flows from places of recharge to places of discharge. Tr. 63:22-64:1 (Spruill); 569:21-24 (Larson); D-197 at 6; J-2 at 15; J-40 at 19.

36. If the rates of recharge and discharge in an aquifer are roughly in balance, the potentiometric levels in the aquifer will remain relatively stable. Tr. 582:12-17 (Larson).

37. Even if the potentiometric levels within an aquifer remain relatively stable, the groundwater within the aquifer will still be constantly moving. D-197 at 12.

E. Groundwater Pumping, Cones Of Depression, And Groundwater Flow

38. Pumping groundwater lowers the potentiometric level in the area surrounding the well, with the lowest potentiometric level located at the well. This decrease in the potentiometric level caused by the well's pumping is called "drawdown." Tr. 584:6-12 (Larson).

39. The area of lowered potentiometric level around a well is called a "cone of depression." The term "cone of depression" describes the phenomenon of drawdown associated with pumping being greatest at the well and decreasing as the effects of pumping diminish at greater distances from the well – forming roughly the shape of a cone. S18; Tr. 585:8-16 (Larson); 1036:13-20 (Langseth); D-197 at 12-13; J-29 at 338.

40. The cone of depression is what allows a well to remove water from an aquifer. Tr. 586:6-13 (Larson); D-197 at 12-13. The decreasing potentiometric level at the well causes water to move toward the well, because water moves from areas of higher potentiometric level to areas of lower potentiometric level. Tr. 497:20-25 (Wiley); 583:12-17, 585:1-7 (Larson); D-197 at 12-13.

41. Every well creates a cone of depression, Tr. 435:15-19, 497:13-16 (Wiley), and a cone of depression is a natural result of pumping, Tr. 586:6-13 (Larson); Crawford Dep. 85:10-13; Hoffman Dep. 25:22-26:1; D-197 at 12-13. It is impossible to develop a groundwater resource without creating a cone of depression. Tr. 586:6-13 (Larson); D-197 at 12-13; J-59 at 17.

42. Individual cones of depression can overlap and combine to form a broader regional cone of depression. S32; Tr. 435:16-21, 453:5-16, 498:23-499:2 (Wiley).

43. Cones of depression are depicted on a potentiometric-level map as a series of roughly circular, closed contour lines moving outward from a pumping center, in a bullseye pattern, although the cone of depression extends beyond the outermost circular contour line. Tr. 434:21-435:4 (Wiley); 1038:5-15 (Langseth).

44. Cones of depression can also be seen on drawdown maps. Drawdown maps directly show the change in potentiometric level caused by pumping (i.e., "drawdown") – instead of showing the potentiometric levels within an aquifer. Tr. 1041:8-13 (Langseth).

45. Despite lowered potentiometric level, a confined aquifer remains fully saturated with water as long as the potentiometric level is not drawn down below the top of the overlying confining unit. Tr. 584:13-20 (Larson); J-2 at 19; J-9 at 3.

F. Groundwater Modeling

46. Hydrologists develop groundwater models to simulate real-world groundwater systems. Models can simulate how a natural system might react under certain conditions. Tr. 416:6-12, 520:24-521:1 (Wiley); D-194 at 9-10.

47. Particle tracking is a mathematical way to track the general pathway of a hypothetical molecule of water through a three-dimensional groundwater system. It is another way of representing groundwater flow paths. Tr. 510:15-21 (Wiley); 1022:25-1023:4 (Langseth).

II. FACTS PROVING THAT THE MIDDLE CLAIBORNE AQUIFER, INCLUDING THE GROUNDWATER IN IT, IS AN INTERSTATE RESOURCE

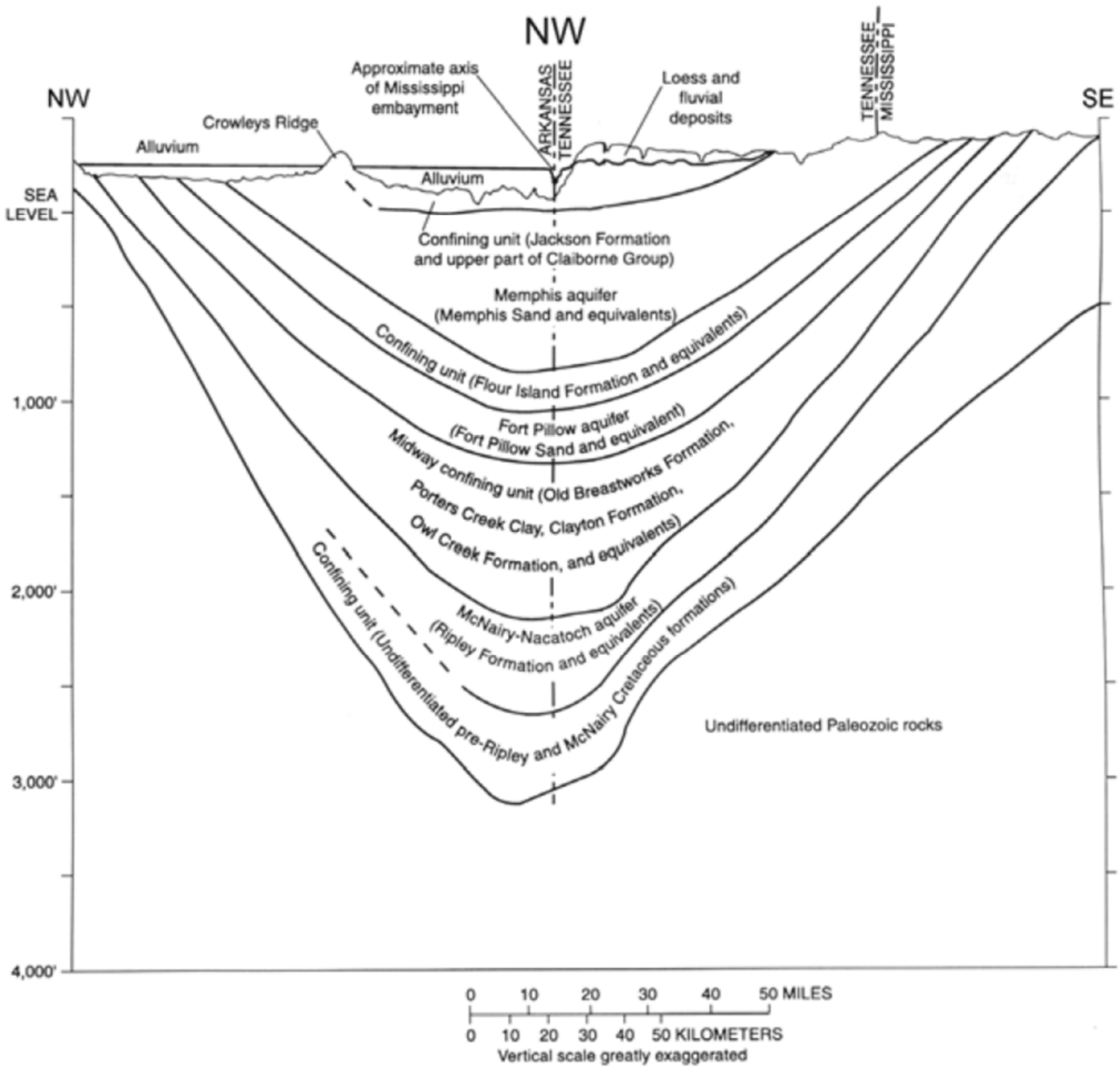
A. Background Facts About The Mississippi Embayment And The Middle Claiborne Aquifer

48. The Mississippi Embayment Regional Aquifer System (sometimes "Mississippi Embayment") is a regional hydrogeological system located in the Gulf Coast Plain generally around the Mississippi River. S24; Tr. 805:7-16 (Waldron); D-191 at 10; J-3 at 11; J-5 at 20; J-10 at 12; J-17 at 16; J-36 at 14.

49. The Mississippi Embayment is a south-plunging trough. The axis of the Mississippi Embayment (the line connecting the deepest points) is generally understood to be roughly below and parallel to the Mississippi River, falling on the western side of the river. S24; D-197 at 24; D-191 at 10; J-15 at 12.

50. The Mississippi Embayment is composed of multiple hydrogeologic units. Tr. 78:9-17 (Spruill); 570:19-21 (Larson); 805:7-16 (Waldron); J-4 at 10; J-5 at 21; J-19 at 11.

51. The figure on page 32 of J-76 is a northwest-southeast cross section of the Mississippi Embayment and shows the generalized stratigraphy of the hydrogeological units in the Mississippi Embayment in the area of Memphis.



52. The hydrogeologic units in the Mississippi Embayment are hydrologically interconnected, which means that there is an exchange of water between different units. Tr. 615:2-5 (Larson); 812:19-813:1 (Waldron).

53. Under pre-development conditions, groundwater in the Mississippi Embayment, including in the Middle Claiborne Aquifer, generally moved from

areas of significant recharge on the eastern and western edges of the Embayment, migrated laterally within the aquifers (generally toward the deepest part of the Embayment), and then traveled upward through overlying confining units and aquifers before ultimately discharging into the alluvial aquifer near the Mississippi River. Tr. 615:20-616:7 (Larson); D-197 at 16, 25; J-4 at 28; J-5 at 22; J-19 at 21, 24; J-34 at 13.

54. The northern extent of the Mississippi Embayment is approximately where the Ohio River joins the Mississippi River, and the southern extent is in southern Mississippi and central Louisiana. S24; Tr. 570:19-23 (Larson); J-3 at 10; J-4 at 14.

55. The approximate geographic extent of the Mississippi Embayment is depicted by the brown outline on page 37 of J-18. Tr. 596:16-20 (Larson); 806:4-16 (Waldron); 997:18-24 (Langseth); *see* J-4 at 10.

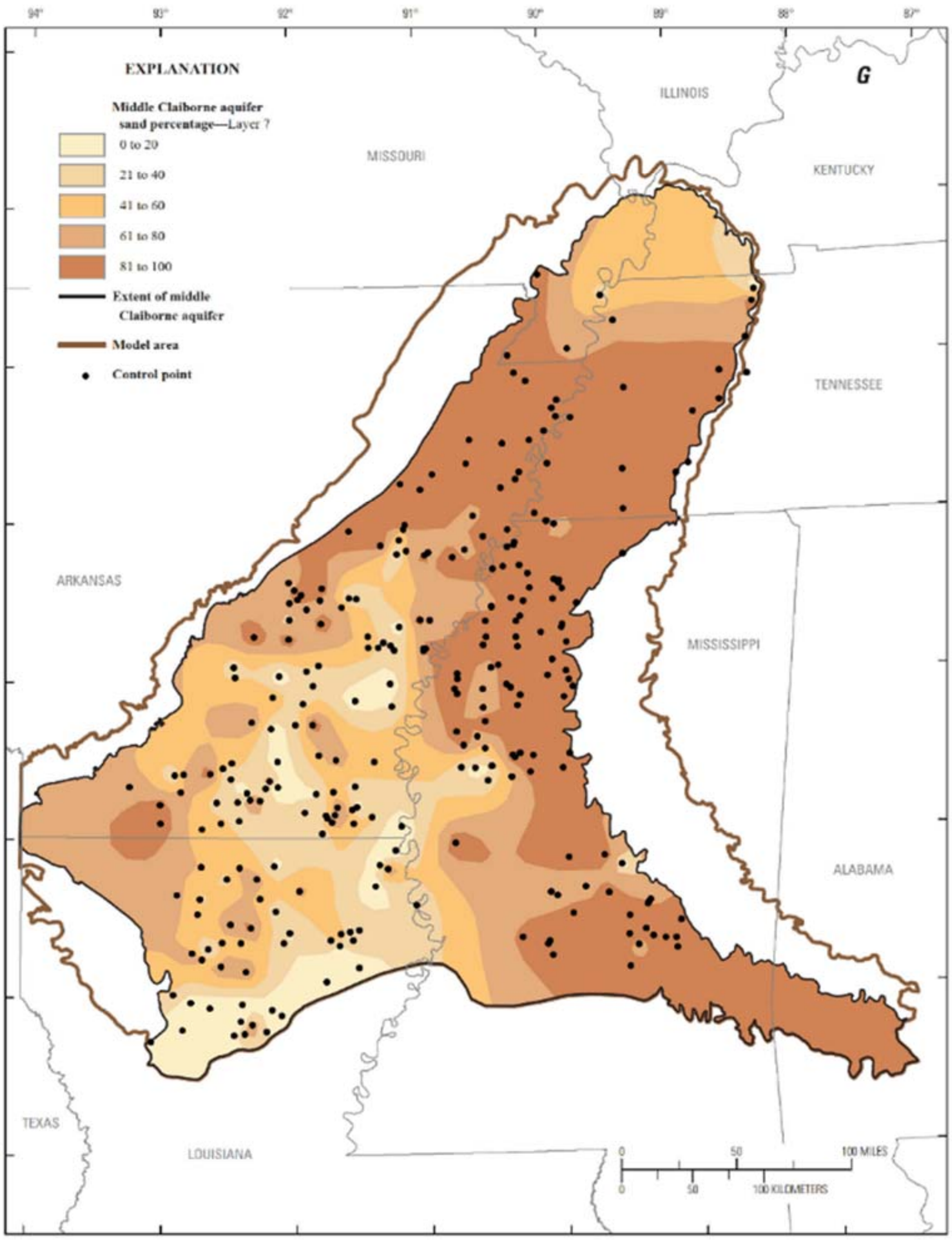


Figure 14. Sand percentage for select hydrogeologic units in the Mississippi Embayment Regional Aquifer Study area.—Continued

56. The Mississippi Embayment underlies Louisiana, Mississippi, Alabama, Arkansas, Tennessee, Kentucky, Missouri, and Illinois. Tr. 278:15-22 (Spruill); 596:12-597:8 (Larson); J-3 at 10.

57. The Middle Claiborne Aquifer is an aquifer within the Mississippi Embayment. Tr. 87:4-5, 278:8-14 (Spruill); 491:3-4 (Wiley); 572:8-13, 593:18-23, 616:20-22 (Larson); 805:25-806:3 (Waldron); 997:4-8 (Langseth); D-197 at 7; J-4 at 20-21; J-5 at 21.

58. The Middle Claiborne Aquifer is composed of geologic materials – primarily sand with interbedded layers of less permeable materials such as silt – saturated with water. Tr. 597:16-20 (Larson); D-197 at 6, 13; J-7 at 9-11; J-15 at 21; J-17 at 16; J-22 at 22; J-49 at 5.

B. The Middle Claiborne Aquifer Is An Interstate Aquifer Because It Underlies Portions Of Tennessee, Mississippi, And Six Other States

1. *Geographic extent of the Middle Claiborne Aquifer*

59. The USGS commonly refers to the aquifer at issue in the case as the Middle Claiborne Aquifer, but sometimes the Aquifer or portions of the Aquifer are called by various other names (including the Sparta Aquifer, Memphis Aquifer, and variations of those names such as the Memphis-Sparta Aquifer). All of these names refer to the same Aquifer. Tr. 87:4-88:15 (Spruill); 523:7-15 (Wiley);

567:25-568:10 (Larson); 814:20-815:10 (Waldron); 986:7-987:14 (Langseth); D-194 at 5; J-4 at 20-21; J-5 at 21; J-55 at 326.

60. The Middle Claiborne Aquifer extends throughout most of the Mississippi Embayment. Tr. 278:23-25 (Spruill); 596:25-597:3 (Larson); 807:1-10 (Waldron); 997:25-998:5 (Langseth); J-36 at 22, 26.

61. The approximate geographic extent of the Middle Claiborne Aquifer is generally agreed upon by scientists. Tr. 491:9-12 (Wiley).

62. Two scientifically accepted maps, below, depict the extent of the Middle Claiborne Aquifer as the shaded area within the black outlined boundary on the first figure, the map on page 37 of J-18, Tr. 596:21-24 (Larson); 806:4-19 (Waldron), and the blue-shaded areas within the blue outlined boundary on the second figure, the map on D-13, Tr. 997:15-998:5 (Langseth). Although they are not entirely identical, these maps illustrate the general scientific consensus around the Middle Claiborne Aquifer's eight-state geographic extent.

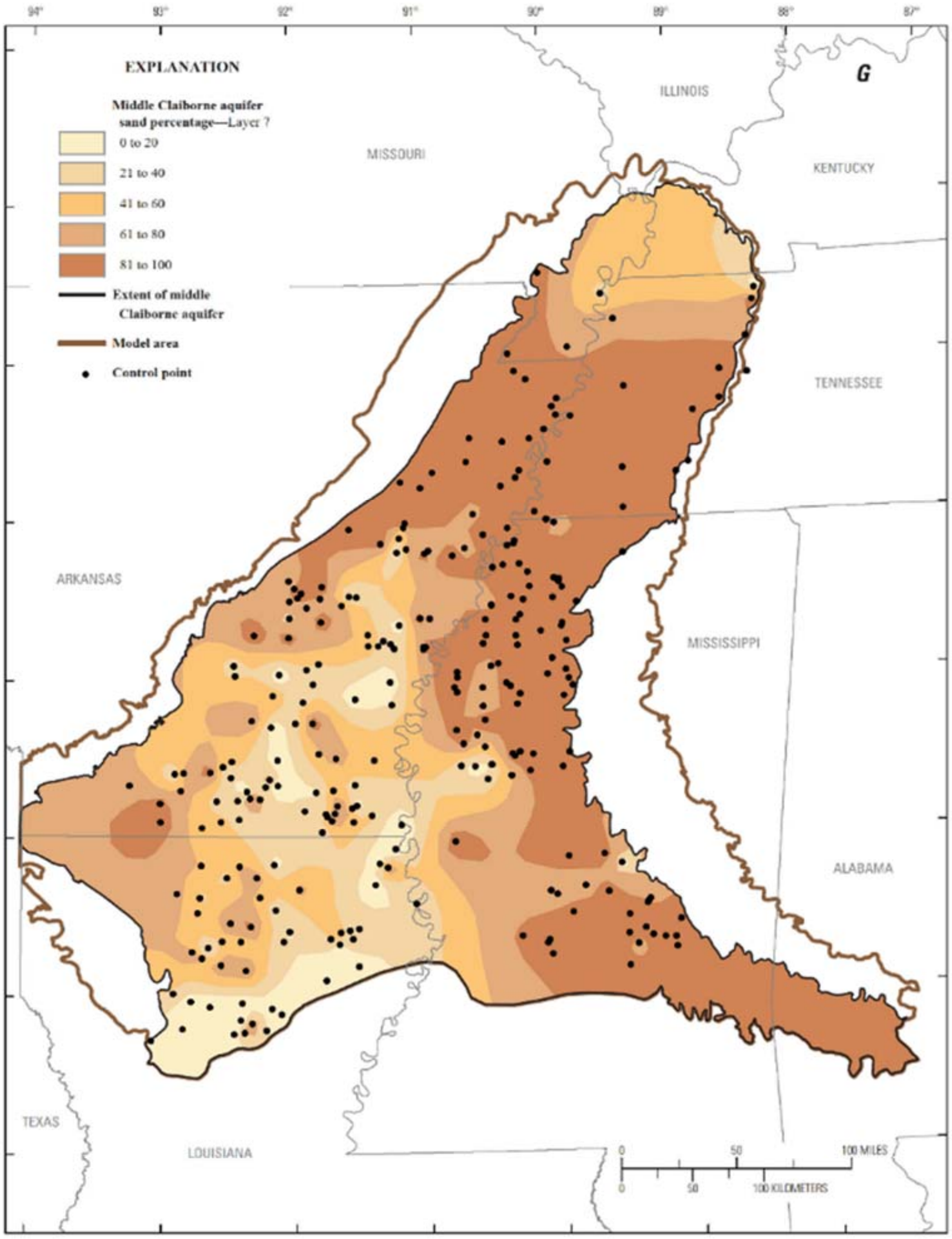
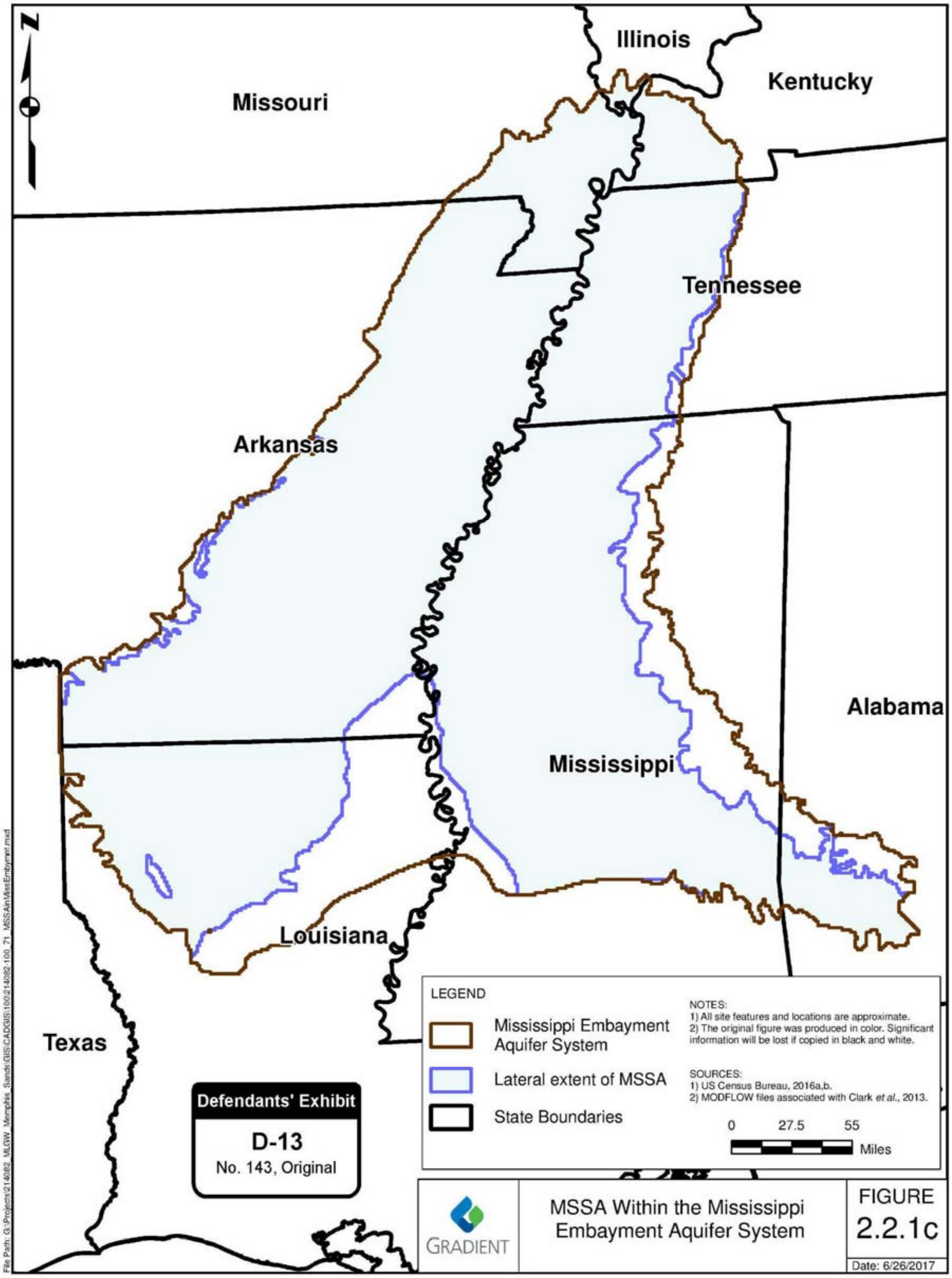


Figure 14. Sand percentage for select hydrogeologic units in the Mississippi Embayment Regional Aquifer Study area.—Continued



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63. The Middle Claiborne Aquifer extends beneath the Mississippi River. Tr. 491:13-14, 535:8-24 (Wiley); D-195 at 5.

2. *The Middle Claiborne Aquifer is a single hydrogeological unit that extends across multiple state boundaries*

64. The Middle Claiborne Aquifer is a hydrogeologic unit that extends beneath portions of eight States: Kentucky, Illinois, Missouri, Tennessee, Arkansas, Mississippi, Louisiana, and Alabama. Tr. 103:23-104:4, 278:8-279:8, 354:24-355:5, 366:23-24 (Spruill); 505:16-20, 506:3-7, 572:8-13 (Wiley); 572:8-13, 597:4-8 (Larson); 807:15-25, 904:21-905:1 (Waldron); 987:7-14, 998:15-20 (Langseth); D-197 at 6; D-194 at 5.

65. Borehole log data indicate that the Middle Claiborne Aquifer is a single hydrogeological unit that continues without interruption across the Mississippi-Tennessee state line. Tr. 824:9-21 (Waldron); 1052:13-1053:6, 1057:2-22 (Langseth); J-19 at 50; J-35 at 13; J-36 at 22.

66. Wells in both Mississippi and Tennessee are pumping groundwater from the Middle Claiborne Aquifer. Tr. 492:17-493:1 (Wiley).

67. The composition of the Middle Claiborne Aquifer is continuous as the aquifer crosses state borders, including the Tennessee-Mississippi border. Political borders do not affect the composition of the Middle Claiborne Aquifer. Tr. 598:1-12, 600:4-11 (Larson); J-18 at 35-37.

68. The Middle Claiborne Aquifer is not homogenous throughout its extent. There are differences in thickness, sand percentage, hydraulic conductivity, storage, porosity, and other properties between different portions of the Middle Claiborne Aquifer. Tr. 598:25-599:4 (Larson); 825:1-10 (Waldron); J-5 at 34; J-10 at 28; J-7 at 9; J-16 at 17.

69. Variations in the hydrological properties of the Middle Claiborne Aquifer do not align with political boundaries, and political boundaries have no effect on the Middle Claiborne Aquifer's hydrological properties. Tr. 825:20-826:1 (Waldron).

70. Variations in the hydrological properties of the Middle Claiborne Aquifer do not represent or create barriers to groundwater flow or to the effects of pumping. Tr. 599:5-9 (Larson).

71. The hydraulic conductivity of the Middle Claiborne Aquifer is continuous across state borders, including the Tennessee-Mississippi border. Tr. 601:19-602:2 (Larson); J-18 at 26, 29.

72. The potentiometric levels within the Middle Claiborne Aquifer extend across state borders without interruption, including the Tennessee-Mississippi border. Tr. 598:13-19, 602:14-20 (Larson); J-71; J-4 at 64; J-22 at 66 (Plate 4).

73. Continuous potentiometric levels reflect the continuity of an aquifer and the groundwater flow patterns within an aquifer; state borders do not affect the

flow of water. Tr. 598:13-19, 602:21-603:4 (Larson). The fact that cones of depression in the Middle Claiborne Aquifer propagate across state borders demonstrates the Aquifer's continuity across state lines. Tr. 606:18-22 (Larson); 1042:8-13 (Langseth).

74. The fact that the cone of depression in the Middle Claiborne Aquifer around Memphis crosses the state line into Mississippi indicates that the Middle Claiborne Aquifer extends continuously beneath Tennessee and Mississippi. Tr. 1040:13-23 (Langseth).

75. Groundwater within the Middle Claiborne Aquifer moves from areas of recharge to areas of discharge, flowing continuously beneath state borders. Tr. 602:21-603:4 (Larson).

76. There is no physical or hydrological barrier that stops the flow of water in the Middle Claiborne Aquifer across the Mississippi-Tennessee border in either direction. Tr. 298:17-24, 361:4-364:16 (Spruill); 493:14-17, 493:22-494:3 (Wiley); 597:9-12 (Larson); 826:2-8 (Waldron); 1011:18-24 (Langseth); D-197 at 13; D-194 at 13, 15.

77. Under pre-development conditions, there was no physical or hydrological barrier that stopped the flow of water in the Middle Claiborne Aquifer across the Mississippi-Tennessee border in either direction. Tr. 299:10-300:1, 363:18-364:16 (Spruill).

3. *Facies change*

78. There is a facies change (i.e., a change in the character of the geological material) in a portion of the Middle Claiborne Aquifer that occurs approximately 6 to 20 miles south of the Mississippi-Tennessee border. It occurs entirely south of that border. Tr. 282:9-12, 389:15-390:25 (Spruill); 527:11-528:2 (Wiley); 822:2-5 (Waldron); J-3 at 12-13; J-4 at 21.

79. North of this facies change, the entire Middle Claiborne Aquifer is composed primarily of coarse-grained sand saturated with water. At the facies change, or transition zone, a section in the middle (vertically) of the Middle Claiborne Aquifer gradually transitions to a finer-grained clay material (with some finer-grained sand) saturated with water. Tr. 91:19-92:5 (Spruill); 607:14-19, 608:10-18 (Larson); J-4 at 21; J-5 at 24; J-10 at 17.

80. As one moves farther south of the facies change into Mississippi, that clay material is present in increasing quantities until it is present in sufficient quantities that hydrogeologists recognize a separate hydrogeological unit known as the Lower Claiborne Confining Unit. Tr. 90:25-91:2, 101:9-12 (Spruill); 608:10-25 (Larson); 821:16-822:1 (Waldron); D-197 at 15; J-4 at 22-23; J-5 at 24; J-36 at 22, 28; J-42 at 17, 21.

81. The more permeable sands of the Middle Claiborne Aquifer continue uninterrupted above and below the Lower Claiborne Confining Unit. Tr. 283:17-

23 (Spruill); 608:19-21, 609:2-8 (Larson); 820:3-821:10 (Waldron); J-10 at 17; J-42 at 21-23.

4. *Confined and unconfined portions of the Middle Claiborne Aquifer*

82. Portions of the Middle Claiborne Aquifer are confined. In its confined areas, the Middle Claiborne Aquifer has an overlying lower-permeability confining unit and its potentiometric level rises above the bottom of that unit. Tr. 816:7-10, 816:25-817:4 (Waldron); D-194 at 8; J-11 at 10.

83. Portions of the Middle Claiborne Aquifer are unconfined. For example, it is unconfined in the outcrop area on the western edges of the formation where the geological formation comes to the ground surface. In its unconfined areas, the Middle Claiborne Aquifer is not overlain by a confining unit, and water is able to recharge directly into the Aquifer. Tr. 111:8-12 (Spruill); 816:7-24 (Waldron); D-194 at 8; J-7 at 12; J-11 at 12; J-22 at 22; J-34 at 14; J-35 at 14; J-42 at 12.

84. The confined and unconfined parts of the Middle Claiborne Aquifer are part of the same hydrogeologic unit. Tr. 817:12-19 (Waldron).

85. There is no barrier to the flow of water between the confined and unconfined portions of the Middle Claiborne Aquifer. Tr. 817:5-11 (Waldron).

5. *Interstate / transboundary aquifer: definition and as applied to the Middle Claiborne Aquifer*

86. An interstate aquifer is a continuous hydrogeological unit that is classified as an aquifer and extends beneath two or more States. Tr. 316:25-318:11 (Spruill); 587:16-588:7 (Larson); 827:1-5 (Waldron); 1001:16-21 (Langseth).

87. If an aquifer extends beneath multiple States, then water is capable of flowing within the aquifer from beneath one State to beneath a different State – whether under natural conditions or in response to pumping. Tr. 587:16-588:7 (Larson); 827:1-5 (Waldron); 1002:20-1003:1 (Langseth); D-194 at 5.

88. Defining an "interstate aquifer" as an aquifer that extends beneath two or more States is consistent with the use of that term in a report from the Advisory Committee on Water Information's groundwater subcommittee, to which Dr. Langseth contributed as a member of the subcommittee, concerning developing a national groundwater monitoring network. Tr. 1003:10-19 (Langseth); J-1 at 77.

89. Defining an "interstate aquifer" as an aquifer that extends beneath two or more States is consistent with the common meaning of the word "interstate," the scientific meaning of the word "aquifer," and the use of the term "interstate aquifer" in the scientific and technical literature. Tr. 1003:2-9, 1003:20-25 (Langseth).

90. A "transbouandary aquifer" is an aquifer that physically underlies a political boundary. Tr. 279:19-22 (Spruill); 491:15-20 (Wiley); 827:13-16 (Waldron); 1004:1-10 (Langseth).

91. The term "transboundary aquifer" is a hydrogeological term. Tr. 828:2-7 (Waldron).

92. The term "transboundary aquifer" has been used in scientific and technical literature to refer to aquifers that cross political boundaries – including state boundaries. Tr. 1004:1-10 (Langseth).

93. The Middle Claiborne Aquifer physically crosses multiple political boundaries – specifically, boundaries between States, including the boundary between Mississippi and Tennessee. Tr. 366:9-11, 366:23-24 (Spruill); 491:18-492:2 (Wiley); 828:8-12 (Waldron); 1004:13-1005:8 (Langseth).

94. The Middle Claiborne Aquifer is a "transboundary aquifer" under the ordinary hydrogeological understanding of that term. Tr. 491:25-492:2 (Wiley); 828:8-12 (Waldron); 1004:1-10 (Langseth).

95. The Middle Claiborne Aquifer is an interstate aquifer. Tr. 318:12-16 (Spruill); 588:22-589:3 (Larson); 826:21-827:5 (Waldron); 987:22-988:2 (Langseth); D-197 at 6.

96. During Mississippi's case-in-chief, Mississippi's experts – Dr. Spruill and Mr. Wiley – did not offer an opinion about whether the Middle Claiborne

Aquifer or the groundwater at issue in this case is interstate or intrastate in nature. Tr. 316:12-24 (Spruill); 533:24-534:12 (Wiley). However, on cross-examination, Dr. Spruill admitted that he has previously used the term "interstate aquifer" to describe an aquifer that exists beneath two or more States, and, based on that definition, the Middle Claiborne Aquifer would be an interstate aquifer because it physically exists beneath multiple States. Tr. 318:12-16 (Spruill).

6. *The Middle Claiborne Aquifer is and has been recognized by hydrogeologists, including for the State of Mississippi, as a shared, regional resource*

97. For at least the past 90 years, the USGS has recognized that the Aquifer at issue in this case (which it now calls the Middle Claiborne Aquifer) is a regional aquifer extending beneath multiple States. J-71; J-15 at 10; Tr. 281:6-9 (Spruill); 638:20-639:5 (Larson); 991:9-13, 1013:21-1014:7 (Langseth); D-197 at 26.

98. The USGS has recognized the importance of studying the Middle Claiborne Aquifer on a regional (i.e., multi-state) basis. J-71; Tr. 636:17-638:10 (Larson); D-197 at 25.

99. In the late-1970s, the USGS started the Regional Aquifer System Analysis ("RASA") program. The purpose was to evaluate large-scale, regional aquifer systems like the Mississippi Embayment Regional Aquifer System as a single entity rather than evaluating them in a piecemeal fashion, artificially

constrained by political boundaries. Tr. 633:24-634:8 (Larson); D-197 at 25; J-28 at 5; J-68 at 9-10.

100. The USGS studied the Middle Claiborne Aquifer on a regional basis as part of the RASA program. Tr. 634:14-635:8 (Larson); J-3 at 10; J-4; J-5 at 3; D-197 at 26.

101. The USGS has recognized that many older studies of the Middle Claiborne Aquifer were artificially limited to local areas based on political boundaries rather than studying the aquifer on a regional basis. J-4 at 5; J-25 at 5; Tr. 634:22-636:4 (Larson).

102. Similarly, other hydrogeologists, including in a study funded by the Environmental Protection Agency ("EPA"), have recognized that early studies of the Middle Claiborne Aquifer were less scientifically useful because they were not coordinated across state lines. Tr. 810:1-22 (Waldron); J-76 at 5.

103. The same EPA-funded study, like the USGS, recognized the importance of studying the Middle Claiborne Aquifer on a regional basis. Tr. 810:6-811:7 (Waldron); J-76.

104. The Mississippi, Arkansas, Tennessee Regional Aquifer Study, or "MATRAS," was an effort to study the Middle Claiborne Aquifer in a cooperative way. The members of MATRAS included representatives of the various Mississippi, Arkansas, and Tennessee state agencies charged with managing water

resources; the University of Memphis; the USGS offices in Mississippi, Arkansas, and Tennessee; Shelby County; and the US Army Corps of Engineers. Tr. 811:8-25 (Waldron); Hoffman Dep. 43:7-15.

105. The Mississippi Department of Environmental Quality ("MDEQ") is the official agency for the State of Mississippi that administers, studies, and researches groundwater. Crawford Dep. 23:20-24; J-57 at 5-14.

106. MDEQ, through the testimony of its Federal Rule of Civil Procedure 30(b)(6) designee, agrees that, to efficiently protect the Middle Claiborne Aquifer, Mississippi and Tennessee must cooperate. Crawford Dep. 136:11-18, 138:13-15.

107. MDEQ, through its Rule 30(b)(6) designee, agrees that, because earlier aquifer studies in different States occurred at different times of the year, it is important to take a regional approach to studying the Middle Claiborne Aquifer that involves Tennessee, Mississippi, and Arkansas. Crawford Dep. 142:23-143:18. MDEQ has used regional-scale USGS models to study the Mississippi Embayment on a regional basis. J-59 at 21-22.

108. Citizens in Tennessee, Mississippi, and Arkansas rely on the Middle Claiborne Aquifer as a public water source. Tr. 368:7-19 (Spruill).

109. The groundwater in the Middle Claiborne Aquifer is a "shared natural resource." Tr. 321:13-18 (Spruill).

7. *Interstate aquifers are common in the United States*

110. There are numerous interstate aquifers within the United States in addition to the Middle Claiborne Aquifer. Tr. 996:3-8 (Langseth). *See* Tr. 564:6-16 (Larson) (the Hueco Bolson Aquifer underlies parts of Texas and New Mexico); J-16 at 14 (the Cambrian-Ordovician Aquifer underlies Montana, North Dakota, South Dakota, Wyoming, and parts of Canada); J-26 at 18 (the Ozark Aquifer underlies Kansas, Oklahoma, Missouri, and Arkansas); J-54 (the Potomac-Patapsco Aquifer underlies New York, New Jersey, Delaware, Maryland, Virginia, North Carolina, and South Carolina); J-55 at 13 (the High Plains Aquifer underlies South Dakota, Wyoming, Nebraska, Kansas, Colorado, Oklahoma, New Mexico, and Texas); J-55 at 16 (the Chattahoochie River Aquifer underlies Mississippi, Alabama, Georgia, South Carolina, and Florida); *see also* J-28 at 24, 35 (the Entrada-Preuss Aquifer and the Navajo-Nugget Aquifer underlie Wyoming, Utah, Colorado, Arizona, and New Mexico; three other aquifers underlie Wyoming, Utah, and Colorado); J-32 at 42 (the Columbia River Basalt Aquifer underlies Idaho, Oregon, and Washington); J-73 (same); J-44 at 17 (Upper Floridan Aquifer underlies Florida, Georgia, and Alabama); J-45 at 88-109 (describing various aquifers underlying groups of States); J-46 at 13 (Spokane Valley-Rathdrum Prairie Aquifer underlies Washington and Idaho); J-47 (same); J-51 at 6 (Madison Aquifer underlies Wyoming, Montana, South Dakota, North Dakota, and

Nebraska); J-55 at 17, 287, 310 (the St. Peter-Prairie du Chien-Jordan Aquifer underlies Wisconsin, Michigan, Illinois, Indiana, Missouri, Iowa, and Minnesota); J-55 at 283-85, 308-09 (the Silurian-Devonian Aquifer underlies Ohio, Indiana, Illinois, Iowa, Wisconsin, and Michigan); J-52 (same).

111. Many of the "Principal Aquifers of the United States" identified by the USGS are interstate aquifers, underlying multiple States. Tr. 995:14-996:14 (Langseth).

C. The Middle Claiborne Aquifer Is An Interstate Aquifer Because The Impact Of Pumping From The Aquifer In One State Can And Does Affect The Aquifer In Other States

1. *Cones of depression form from pumping*

112. A cone of depression is an effect of pumping. Tr. 583:3-6 (Larson). When cones of depression cross state lines, the effects of pumping can be seen directly crossing states lines. Tr. 1040:13-1042:17 (Langseth).

113. Cones of depression that cross state lines confirm that the aquifer in which the cone of depression exists also crosses state lines. Tr. 1040:13-23 (Langseth).

114. Cones of depression are not affected by overlying state lines. Tr. 1043:1-5 (Langseth).

115. The fact that pumping from an aquifer in one State affects the water in the same aquifer in another State demonstrates that the aquifer is an interstate resource. Tr. 663:3-7 (Larson); 1035:22-1036:9 (Langseth).

116. In an interstate aquifer, there is no way to withdraw meaningful quantities of water from an area near a state border without affecting the groundwater in the other State. Tr. 645:21-646:9 (Larson); D-198 at 7.

2. *Pumping groundwater from the Aquifer in Tennessee affects the groundwater in the Aquifer beneath Mississippi and vice versa*

117. Wells in the Middle Claiborne Aquifer in the Memphis area are drilled straight down and are not slanted. S35; Tr. 300:7-16 (Spruill); 492:3-16 (Wiley); 603:10-13 (Larson).

118. Wells in the Middle Claiborne Aquifer that are drilled in Tennessee do not extend into Mississippi, and wells that are drilled in Mississippi do not extend into Tennessee. S35; Tr. 300:7-16 (Spruill); 492:3-16 (Wiley); 603:10-13 (Larson).

119. Cones of depression from pumping in Mississippi extend into Tennessee. Tr. 605:21-23 (Larson); 1045:4-18 (Langseth).

120. The regional cone of depression around Memphis is caused in part by pumping in DeSoto County, Mississippi. Tr. 501:6-9 (Wiley).

121. The regional cone of depression around Memphis crosses the border between Mississippi and Tennessee. Tr. 435:22-25, 525:15-18 (Wiley); 604:15-24, 605:21-23 (Larson); 1040:1-10 (Langseth); J-19 at 49.

122. The regional cone of depression around Memphis crosses beneath the Mississippi River and the border between Arkansas and Tennessee. Tr. 525:15-25, 535:8-24 (Wiley); 604:18-24 (Larson); 1040:1-12 (Langseth); J-19 at 49.

123. Pumping from the Middle Claiborne Aquifer within Mississippi near the Mississippi-Tennessee border affects the flow of groundwater in the same Aquifer beneath Tennessee and can cause groundwater to flow south across the state line from Tennessee into Mississippi. Tr. 300:17-20 (Spruill); 826:16-20 (Waldron); Crawford Dep. 136:1-10; D-198 at 11.

124. Pumping from the Middle Claiborne Aquifer near the Mississippi-Tennessee border within Tennessee affects the flow of groundwater in the same Aquifer beneath Mississippi and can cause groundwater to flow across the state line from Mississippi into Tennessee. Tr. 300:2-6, 358:10-18 (Spruill); 493:2-13 (Wiley); 826:9-15 (Waldron); Crawford Dep. 136:1-10; D-198 at 11.

125. Pumping from the Middle Claiborne Aquifer within Tennessee affects the flow of groundwater in the same Aquifer beneath Arkansas. Pumping from the Middle Claiborne Aquifer within Arkansas affects the flow of groundwater in the same Aquifer beneath Tennessee. Tr. 526:1-10 (Wiley); J-76 at 20.

3. *There are at least four cones of depression in the Middle Claiborne Aquifer that show that pumping within that aquifer has cross-border effects*

126. Based on a USGS potentiometric map of the Middle Claiborne Aquifer for the year 2007, there were many cones of depression in the Middle Claiborne Aquifer, at least four of which touched or crossed state lines. Tr. 1038:3-1040:12 (Langseth); J-71.

127. There is a cone of depression in the Middle Claiborne Aquifer caused by pumping in southern Mississippi near the Arkansas-Louisiana state line that extends across the border into Louisiana. Tr. 1038:3-1039:10 (Langseth); J-71.

128. There is a large cone of depression in the Middle Claiborne Aquifer caused by pumping in Mississippi near the City of Jackson that extends across the border into Louisiana. This cone of depression causes water to flow from Louisiana into Mississippi. Tr. 606:7-10, 661:17-662:10 (Larson); J-19 at 49; J-71.

129. There are a series of large overlapping cones of depression in the Middle Claiborne Aquifer caused by pumping near Union County, Arkansas, that extend across the Arkansas-Louisiana border. The pumping in that area affects the flow of water in Louisiana and causes water to flow from Louisiana into Arkansas. Tr. 606:11-17 (Larson); 1042:10-25 (Langseth); J-19 at 49; J-71.

130. There is a large cone of depression caused by pumping near Stuttgart, Arkansas, that extends across the Arkansas-Mississippi border. This cone of

depression affects the flow of water in Mississippi and causes water to flow from Mississippi into Arkansas. Tr. 1043:6-16 (Langseth); J-19 at 34, 49; D-31; J-71.

D. The Middle Claiborne Aquifer Is An Interstate Aquifer Because Groundwater Naturally Flowed Across State Lines Before Pumping Began

1. *General background*

131. Pre-development conditions (also called natural conditions) refer to the state of an aquifer prior to the influence of pumping. Pre-development conditions in the Middle Claiborne Aquifer are generally understood to be the state of the Aquifer prior to 1886. Tr. 442:13-16, 458:21-23 (Wiley); 586:14-21 (Larson); 831:22-832:5 (Waldron); J-4 at 26; J-5 at 11; J-7 at 14; J-10 at 33; J-11 at 5.

132. A pre-development potentiometric surface map shows the estimated potentiometric levels of an aquifer or portion of an aquifer prior to pumping within that aquifer. Tr. 602:9-13, 622:19-22 (Larson).

2. *Interstate flow paths*

133. "Interstate flow" describes the flow of groundwater that crosses state boundaries. Examples in the Middle Claiborne Aquifer include the interstate flow from Mississippi to Tennessee, and from Tennessee to Arkansas, under pre-development conditions. Tr. 304:13-306:17 (D-112), 318:20-319:2 (D-129) (Spruill); 506:19-507:13, 508:3-509:1 (P-168) (Wiley).

134. Any "flow paths" or "flow lines" (i.e., estimates of the direction of groundwater flow starting from a particular point) that cross state boundaries are "interstate flow paths" or "interstate flow lines." Tr. 507:7-10, 508:7-18 (Wiley).

3. *Every study of pre-development conditions in the Middle Claiborne Aquifer concludes that there was natural groundwater flow from Mississippi into Tennessee*

135. Every study of pre-development conditions in the Middle Claiborne Aquifer has concluded that there was natural flow across state borders. Tr. 304:7-11, 360:21-361:1 (Spruill); 506:19-507:13, 507:14-508:2 (P-168) (Wiley); 858:3-6 (Waldron); 1020:10-15, 1025:24-1026:7 (Langseth); D-194 at 16; J-5 at 35.

136. All of the pre-development potentiometric maps of the Middle Claiborne Aquifer based on observed or measured data reflect natural flow across state borders: the Reed (1972) map (J-67); the Criner & Parks (1976) map (J-24 at 23, figure 4); Mr. Wiley's own "Figure 9" map (D-112, P-168); and the Waldron & Larsen (2015) map (D-174 at 17, figure 4); D-194 at 16.

137. Reed (1972) is a USGS publication that includes a water-level contour map of pre-development conditions in the Middle Claiborne Aquifer that, the author suggests, was based on observed data. J-67; D-196 at 25. Reed's map shows groundwater flowing, under natural conditions, from Mississippi to Tennessee, and also from Mississippi and Tennessee into Arkansas and from

Mississippi into Louisiana. Tr. 623:10-625:8 (Larson); 1019:25-1020:9 (Langseth); *see* Tr. 875:20-876:2 (Waldron); D-194 at 26.

138. Criner & Parks (1976) is a USGS publication that includes a map depicting pre-development conditions, based on four observed data points. J-24 at 23, figure 4 (also P-205). Criner & Parks also shows water flowing from Mississippi into Tennessee and from both Mississippi and Tennessee into Arkansas. Tr. 625:9-24 (Larson); 1016:7-1017:20 (Langseth); *see* Tr. 875:20-876:2 (Waldron); D-198 at 6; D-194 at 20-21.

139. Figure 9 from the report of Mississippi's expert David Wiley (D-112 and P-168) depicts an area identified within a yellow triangle from which Wiley reports that groundwater in the Aquifer flowed naturally from Mississippi into Tennessee. Tr. 305:3-20 (Spruill); 459:15-24, 507:11-25, 541:8-13 (Wiley). *See also* Tr. 647:2-14 (Larson); 875:20-876:2 (Waldron); D-194 at 21-22.

140. Figure 9 from David Wiley's report (D-112 and P-168) also includes pre-development flow paths showing water in the Aquifer naturally flowing from Mississippi into Tennessee, which the figure identifies as "Interstate Flow." Tr. 306:5-13 (Spruill); 495:2-7, 506:19-507:13 (Wiley).

141. The contours on David Wiley's Figure 9 show that the actual area from which groundwater in the Aquifer would naturally have flowed from Mississippi to Tennessee during pre-development times is larger than the yellow triangle depicted

on Wiley's Figure 9. Tr. 550:12-24 (Wiley); 1034:11-1035:14 (Langseth). The actual area of natural cross-border flow would extend farther west, as depicted by the red triangle shown on D-199. Tr. 550:23-24, 556:10-19 (Wiley). The area of natural flow from Mississippi into Tennessee would also extend farther east than the yellow triangle depicts, extending across Marshall County, Mississippi, and into Benton County, Mississippi. Tr. 517:5-519:9 (Wiley); *see* P-185.

142. Waldron & Larsen (2015) published a peer-reviewed journal article that included a map of pre-development conditions in the Middle Claiborne Aquifer derived from early USGS data dating from between 1886 and 1906. Tr. 832:9-833:4, 837:11-838:25 (Waldron); D-194 at 27-28; J-21. The state border had no effect on the methods by which Waldron & Larsen created their map. Tr. 889:20-890:1 (Waldron).

143. Waldron & Larsen's map also shows water moving from Mississippi into Tennessee, and from both Mississippi and Tennessee into Arkansas. Tr. 627:8-628:18 (Larson); 857:4-10 (Waldron); 1018:21-1019:24 (Langseth); D-194 at 28.

144. The existence of natural cross-border flow in the Middle Claiborne Aquifer from Mississippi into Tennessee is also confirmed by all existing computer or "numerical" groundwater models that can be used to estimate pre-development conditions: the Arthur & Taylor (1998) model (J-4), the Brahana & Broshears

(2001) model (J-15), and the Mississippi Embayment Regional Aquifer Study model[4] first described in Clark & Hart (2009) (J-18); D-194 at 16, 26-27. The Mississippi Embayment Regional Aquifer Study model is sometimes referred to as the "MERAS model."

145. Arthur & Taylor (1998) is a USGS publication describing a regional model, which included a modeled estimate of pre-development conditions in the Middle Claiborne Aquifer. J-4 at 64 (Plate 5). This map depicts water flowing from Mississippi into Tennessee, Arkansas, and Louisiana; there is also water flowing from Arkansas into Louisiana and from Arkansas back into Mississippi. Tr. 626:3-627:3 (Larson); 1025:13-23 (Langseth); *see* Tr. 875:20-876:2 (Waldron); D-194 at 16-17.

146. Although no map was presented during the hearing showing the Brahana & Broshears (2001) *model*[5] results for pre-development conditions (as opposed to their figure 16, which is a reproduction of the contours in the Criner & Parks (1976) map), Brahana & Broshears's model also demonstrates cross-border flow under pre-development conditions. Tr. 450:14-19 (Wiley); 1025:5-12 (Langseth); J-15 at 48.

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[4] *See* proposed findings of fact concerning the MERAS model *infra* ¶¶ 272-281.

[5] *See* proposed findings of fact concerning the Brahana & Broshears model *infra* ¶¶ 282-285.

147. Using the MERAS model to generate pre-development water-level contours shows water naturally crossing multiple state borders, including from Mississippi into Tennessee. Tr. 873:12-874:11 (Waldron); 1023:14-1024:6, 1027:4-1029:20 (Langseth); D-194 at 26-27.

148. Using the MERAS model for particle tracking analyses shows cross-border flow in the Middle Claiborne Aquifer under pre-development conditions, including from Mississippi into Tennessee, Tennessee into Mississippi, Tennessee and Mississippi into Arkansas, and Arkansas into Mississippi. Tr. 514:5-515:6, 516:9-518:8 (P-185) (Wiley); 1030:8-1032:19 (D-27) (Langseth).

149. A "water budget" analysis using the MERAS model (i.e., calculating total inflows and outflows within a given area of the model) also shows water flowing across the Mississippi-Tennessee border under pre-development conditions. Tr. 482:24-483:18 (Wiley).

150. A reasonable estimate, based on the MERAS model, is that, under pre-development conditions, approximately 37 million gallons of water naturally flowed within the Middle Claiborne Aquifer from Mississippi into other States every day. Tr. 532:20-533:2 (Wiley).

4. ***The Waldron & Larsen (2015) study shows substantially more pre-development flow from Mississippi into Tennessee than previous studies***

151. Waldron & Larsen's map of water-level contours estimated that the predominant direction of pre-development flow in the Middle Claiborne Aquifer near Memphis was naturally from Mississippi into Tennessee, in a southeast-to-northwest direction across the state border. Tr. 850:25-851:4 (Waldron).

152. Waldron & Larsen's estimate of flow direction shows even more substantial flow across the border, in a more northerly direction, than other efforts to estimate the direction of pre-development flow. Tr. 857:4-15 (Waldron); *see* D-174; D-194 at 28.

153. Waldron & Larsen compared the amount of estimated pre-development flow from Mississippi to Tennessee based on their map to the amount of estimated groundwater flow from Mississippi to Tennessee in 2007 based on the Schrader (2008) publication. Tr. 851:16-23 (Waldron). Schrader (2008) used the most recent data available and mapped water levels in the Aquifer in both the confined and unconfined areas and across state borders. Tr. 851:24-852:9 (Waldron).

154. Waldron & Larsen's analysis concluded that the average estimated cross-border flow from Mississippi into Tennessee for 2007 was lower than the average estimated cross-border flow from Mississippi into Tennessee under pre-development conditions. Tr. 853:6-15 (Waldron); D-194 at 6. In other words,

it concluded that groundwater flow in the Middle Claiborne Aquifer from Mississippi into Tennessee has declined over the past 130 years.

155. One reason why the overall cross-border flow volume has diminished is that water users in Mississippi have also increased their pumping out of the Aquifer significantly, causing the well fields in Shelby County to draw water from other directions, either from other parts of Tennessee or from Arkansas. Tr. 496:23-497:1 (Wiley); 853:16-854:6 (Waldron); *see* Tr. 651:25-652:11 (Larson: Mississippi's depiction of "diversion" flow paths does not reflect substantial pumping in Mississippi).

156. At the same time, pumping from the Middle Claiborne Aquifer in Shelby County has increased the rate of recharge from the overlying surficial aquifer, providing an alternative source of water and decreasing the need for groundwater in surrounding areas of the Middle Claiborne Aquifer to flow toward the well fields in Shelby County. Tr. 853:16-854:23 (Waldron); J-4 at 41; J-35 at 30.

5. *Waldron & Larsen's 2015 analysis offers the most reliable estimate of pre-development conditions in the Middle Claiborne Aquifer*[6]

157. Waldron & Larsen's 2015 paper was a peer-reviewed publication whose sole purpose was to investigate pre-development conditions in the Middle Claiborne Aquifer in the Memphis area. Tr. 832:6-833:4 (Waldron).

158. The pre-development potentiometric map created by Waldron & Larsen used the earliest known data, reported in three USGS publications dating to 1903 through 1906, derived from measurements that were taken close in time to the pre-development period. Tr. 837:9-838:25 (Waldron); D-194 at 27-28; *see* J-21; J-30; J-31.

159. Waldron & Larsen's pre-development potentiometric map is based on 27 control points across nine counties. Tr. 839:15-840:2, 945:18-21 (Waldron).

160. Dr. Waldron verified the locations and elevations of the control points used in his research using a variety of methods. Tr. 840:3-844:7 (Waldron: verifying locations), 844:16-847:7 (Waldron: estimating elevations), 847:8-848:24 (Waldron: confirming that wells were screened in the correct aquifer).

161. Dr. Waldron performed an error analysis to determine whether uncertainty about location or elevation of a control point could have a significant

[6] Defendants do not believe it is necessary to decide which of the pre-development maps is the most reliable because all of the maps show pre-development flow from Mississippi into Tennessee. Defendants include these facts for the Special Master's convenience and to preserve their positions.

effect on the ultimate map, and found that, even assuming the highest statistical error rate, there was little change in the overall location of the water-level contours or direction of groundwater flow. Tr. 854:24-857:3 (Waldron).

162. The findings in Waldron & Larsen (2015) are based on more control points, data closer in time to pre-development conditions, and better-quality data than previous studies of pre-development conditions in the Middle Claiborne Aquifer. Additionally, Waldron & Larsen (2015) is the only study of the Middle Claiborne Aquifer focused solely on developing an accurate depiction of pre-development conditions. Tr. 858:23-25, 868:19-22, 869:20-870:6, 873:8-11, 874:12-15, 876:3-10 (Waldron).

163. Criner & Parks (1976) had only four control points and no data south of the Tennessee-Mississippi state border. Tr. 341:14-16 (Spruill); 859:8-860:9 (Waldron). A map is more reliable when it has more data spread out over a larger area, so that a hydrologist can avoid extrapolating too far away from data points. Tr. 859:8-16 (Waldron). Further, of Criner & Parks's four data points, the one closest to the Mississippi-Tennessee border is not a well; it is a tunnel to a 40-foot cistern. Tr. 862:18-863:7 (Waldron). Because water-level measurements taken from such a cistern are less accurate than water-level measurements taken from a well, Criner & Parks's reliance on the 40-foot cistern further undermines the

relative accuracy of their pre-development map. Tr. 864:6-17 (Waldron); D-196 at 19.

164. Without any data points near or south of the state border, there is no apparent scientific basis for the bends in Criner & Parks's contours near the state border. These unsupported contours create the misleading impression that the direction of the water flow in the Aquifer was more east-to-west (parallel to the border) rather than south-to-north (across the border). Omitting the unsupported bends in the contour lines on Criner & Parks would result in more natural flow from Mississippi to Tennessee. Tr. 345:12-347:11 (Spruill); 860:10-862:17 (Waldron).

165. Criner & Parks's control points are based on measurements taken 40 to 70 years after development began in 1886, compared with no more than 20 years post-development for Waldron & Larsen's data. D-196 at 24; J-24 at 11-15.

166. Data based on measurements taken nearer in time to pre-development is preferable and tends to yield more reliable results. Tr. 864:11-25 (Waldron).

167. Because Mr. Wiley's Figure 9 map is based almost completely on the Criner & Parks (1976) map, it suffers from the same deficits that the Criner & Parks map does. Tr. 869:20-870:6 (Waldron).

168. The only substantive change Mr. Wiley made from Criner & Parks was to extend the water-level contour lines even farther south into Mississippi. Tr.

544:1-5 (Wiley). However, Mr. Wiley did not use any observation wells, control points, or other data to extend those lines. Tr. 545:2-6 (Wiley); 870:7-871:9 (Waldron).

169. Like Mr. Wiley's Figure 9, Brahana & Broshears (2001)'s Figure 16 derives its contours directly from Criner & Parks (1976) without change and, therefore, suffers from the same deficiencies. The only substantive change was the erroneous notation on the map of an additional fifth control point, which did not appear on Criner & Parks's map and, in fact, did not actually exist. Tr. 865:17-869:1 (Waldron).

170. The potentiometric map and associated text published by Reed (1972) did not include any explanation of Reed's methodology, supporting data, or how many control points might have been used. Tr. 347:24-348:6 (Spruill); 874:16-875:19 (Waldron); 1015:24-1016:2 (Langseth); *see* J-67. Without such supporting data, Reed (1972) provides a less reliable basis for estimating the Middle Claiborne Aquifer's pre-development equipotential surface than does Waldron & Larsen (2015).

171. Both Arthur & Taylor (1998) and MERAS are numerical computer models that simulate pre-development conditions in an aquifer based on computer data rather than observed data. For estimating conditions in an aquifer at a

particular time in the past, it is preferable to rely on observed water levels that are obtained close in time to the period being estimated. Tr. 872:16-873:3 (Waldron)

6. *Groundwater was and is leaving Mississippi*

172. The water within the Middle Claiborne Aquifer is not static. Before and after pumping began, the groundwater in the Middle Claiborne Aquifer was and is constantly moving. Tr. 303:17-25, 364:17-21 (Spruill); 503:21-504:2 (Wiley); 589:19-22, 621:23-622:2 (Larson); 831:8-10 (Waldron); D-197 at 8; J-55 at 327.

173. Recharge and discharge are constantly occurring in the Middle Claiborne Aquifer. Tr. 582:8-9 (Larson).

174. Under pre-development conditions and since then, all of the water within the Middle Claiborne Aquifer beneath Mississippi has already left or will eventually leave the State of Mississippi. Tr. 307:5-10 (Spruill); 626:18-20 (Larson); 1048:12-20 (Langseth); D-197 at 8.

175. The groundwater in the Middle Claiborne Aquifer leaving the area beneath Mississippi is constantly replaced by water recharging into the Aquifer from rainfall infiltration, surface water, or groundwater flow from overlying or underlying hydrogeologic units. D-197 at 8, 24.

E. The Middle Claiborne Aquifer Is An Interstate Aquifer Because It Is Hydrologically Connected To Interstate Surface Water And Other Interstate Aquifers

1. *The Aquifer is hydrologically connected to interstate surface water*

176. The Middle Claiborne Aquifer is hydrologically connected to interstate surface waters. Tr. 358:25-360:13 (Spruill); 502:15-19 (Wiley); 617:11-21 (Larson); J-35. Groundwater should not be studied in isolation but must be considered together with the surface water to which it is hydrologically connected. J-79 at 6-7.

177. Water in the outcrop area of the Middle Claiborne Aquifer has a direct hydrological connection to surface water. Tr. 302:12-15 (Spruill); J-7 at 29.

178. The Wolf River begins in Mississippi, then flows into Tennessee before discharging into the Mississippi River. Tr. 502:23-503:7 (Wiley); 618:11-14 (Larson); 1047:7-17 (Langseth); J-18 at 13; J-19 at 16.

179. The Wolf River flows through the outcrop area of the Middle Claiborne Aquifer. Tr. 503:5-11 (Wiley); J-7 at 29; J-10 at 19.

180. The Middle Claiborne Aquifer has a direct hydrological connection to the Wolf River in the outcrop area. Water from the Wolf River in the outcrop area can directly recharge the Middle Claiborne Aquifer, or water from the Middle Claiborne Aquifer can directly discharge into the Wolf River, depending on the

relative water levels in the river and the Aquifer. Tr. 619:8-13 (Larson); 1046:17-24 (Langseth); D-197 at 17, 23; J-7 at 29; J-10 at 19; J-11 at 13; J-58 at 11-13.

181. The alluvial aquifer is situated above the Middle Claiborne Aquifer. It is separated from the Middle Claiborne Aquifer by a confining layer. The alluvial aquifer has a direct hydrological connection to the Mississippi River. Tr. 619:14-22 (Larson); J-6 at 9.

182. The Mississippi River is an interstate river. Tr. 620:6-10 (Larson); D-198 at 8.

183. The Middle Claiborne Aquifer is hydrologically connected to the Mississippi River. Groundwater in the Middle Claiborne Aquifer can flow upward through overlying confining layers and aquifers into the Mississippi River. The Mississippi River is an area of discharge in the Mississippi Embayment. Tr. 303:13-16 (Spruill); 503:14-20 (Wiley); D-197 at 16; D-198 at 8.

184. The Middle Claiborne Aquifer is directly hydrologically interconnected to the Mississippi River where the Middle Claiborne Aquifer outcrops in the northern portion of the Mississippi Embayment. Tr. 1046:1-8 (Langseth); J-4 at 18; J-5 at 21.

185. The Middle Claiborne Aquifer is interstate because it is hydrologically connected to interstate bodies of surface water. Tr. 587:21-23 (Larson); 1045:21-1046:12 (Langseth).

2. *The Middle Claiborne Aquifer is hydrologically connected to other interstate aquifers*

186. Within the Mississippi Embayment, groundwater is able to flow from one aquifer to another aquifer through confining units because confining units in the Mississippi Embayment limit, but do not prevent, the vertical flow of groundwater. Tr. 301:1-19, 303:2-6 (Spruill); 615:24-616:7, 619:18-22 (Larson); J-7 at 13; J-8 at 7; J-15 at 9; J-35 at 7.

187. Pumping within one aquifer can affect groundwater in adjoining aquifers. Tr. 616:13-19 (Larson); J-15 at 9; J-35 at 20.

188. The Middle Claiborne Aquifer is hydrologically connected to the overlying and underlying aquifers within the Mississippi Embayment because water can flow through the intervening confining units between the aquifers. Tr. 524:7-525:1 (Wiley); J-7 at 13; J-8 at 7; J-19 at 20; J-15 at 9; J-35 at 23-24.

189. The Fort Pillow Aquifer is located beneath the Middle Claiborne Aquifer and separated from it by a confining layer. The Fort Pillow Aquifer extends beneath at least Arkansas, Tennessee, and Mississippi. The Middle Claiborne Aquifer is hydrologically connected to the Fort Pillow Aquifer because water is able to flow through the intervening confining unit. Tr. 524:19-525:1 (Wiley); 818:6-10 (Waldron); J-76 at 32; J-4 at 53.

190. The Middle Claiborne Aquifer is interstate because it is hydrologically connected to other interstate aquifers. Tr. 587:21-23 (Larson).

III. FACTS REFUTING MISSISSIPPI'S POSITIONS[7]

A. Mississippi's Contention That There Are Two Aquifers Is Not Supported By The Facts

1. *Naming conventions*

191. There are a variety of different regional names sometimes used to refer to the Middle Claiborne Aquifer. Tr. 595:8-12, 595:19-23 (Larson); 814:15-815:6 (Waldron); 986:7-19, 986:23-987:16 (Langseth); D-197 at 6, 16.

192. Local naming conventions are variations in how people refer to the Aquifer in different locations; they do not change the hydrogeological nature of the Aquifer. Tr. 814:19-815:14 (Waldron).

193. The area of the Middle Claiborne Aquifer north of the Mississippi-Tennessee border is sometimes called the Memphis Sand Aquifer or Memphis Aquifer. Tr. 88:8-10, 354:11-15 (Spruill); 814:20-25 (Waldron); D-197 at 6.

194. The area of the Middle Claiborne Aquifer south of the Mississippi-Tennessee border is sometimes called the Sparta Sand or Sparta Aquifer. Tr. 814:20-815:6 (Waldron); D-197 at 6.

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[7] Many of the proposed findings in Section III concern issues that are the subject of Defendants' pending motions in limine, including the motion to exclude irrelevant evidence. By including these proposed findings here, Defendants do not suggest that they are relevant, nor do Defendants waive their arguments to limit or exclude evidence. Defendants therefore request that the Special Master grant their pending motions and exclude all evidence (on both sides) about these topics as irrelevant and prejudicial. That said, these proposed findings are included here for the Special Master's convenience and to preserve and support Defendants' factual position if the Special Master were to find them relevant.

195. The area sometimes called the Sparta Aquifer and the area sometimes called the Memphis Aquifer are part of a single hydrogeological unit: the Middle Claiborne Aquifer. Tr. 298:1-9 (Spruill); 611:14-612:2 (Larson); 814:20-815:3, 822:13-17 (Waldron); D-197 at 16.

196. The terms "Sparta Sand," "Sparta Aquifer," "Memphis Sand Aquifer," and "Memphis Sand" are often used interchangeably to refer to the Middle Claiborne Aquifer. Tr. 293:23-294:4 (Spruill); 487:21-490:18 (Wiley); 595:8-23 (Larson).

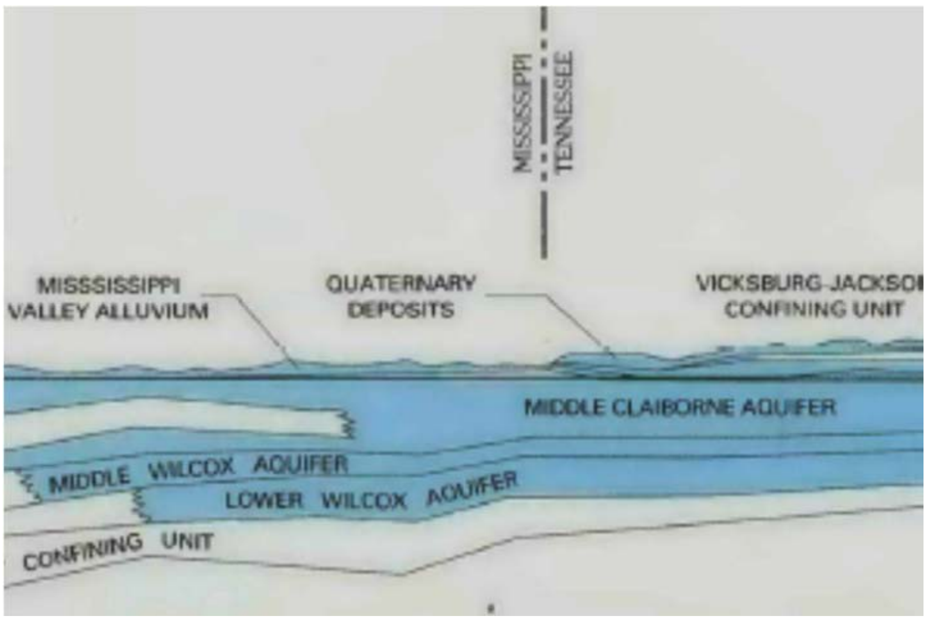
197. The Middle Claiborne Aquifer is sometimes called the Memphis-Sparta Sand Aquifer or Sparta-Memphis Sand Aquifer, a combination of the more commonly used regional names. Tr. 293:5-9 (Spruill); 986:11-19 (Langseth).

2. *The Middle Claiborne Aquifer is continuous north and south of the facies change*

198. Moving south through the Aquifer from Tennessee, the facies change begins 6 to 20 miles south of the Tennessee-Mississippi border where a clay layer begins to form in the middle part (from a vertical perspective) of the Middle Claiborne Aquifer. The permeable Middle Claiborne Aquifer continues above and below the intervening confining layer. This continuation of the Middle Claiborne Aquifer above and below the facies change can be conceptualized as a two-pronged fork. The "handle" of the fork is the part of the Middle Claiborne Aquifer that lies north of the facies change. Moving south, the "handle" splits into an

"upper prong" above and a "lower prong" below the intervening clay layer. Tr. 607:23-25 (Larson); 820:1-821:10 (Waldron); J-13 at 13; *see also* J-42 at 35; J-76 at 35.

199. One scientifically accepted depiction of the facies change is a figure on Plate 2 of J-4. J-4 at 61. An excerpt is shown here with the area referred to as the "handle" appearing on the right of the figure (north of the facies change):



200. The Lower Claiborne Confining Unit, the intervening clay confining unit resulting from the facies change, does not impede the lateral flow of groundwater within the Middle Claiborne Aquifer. Tr. 608:22-25 (Larson).

201. The Lower Claiborne Confining Unit does not prevent water within the Middle Claiborne Aquifer from flowing across the Mississippi-Tennessee border. Tr. 299:15-23 (Spruill).

202. North of the facies change, the “handle” of the Middle Claiborne Aquifer is sometimes called the “Memphis Sand,” “Memphis Aquifer,” or “500-Foot Sand.” Tr. 91:16-18, 97:21-23 (Spruill); 595:19-23, 611:5-13 (Larson); D-197 at 15; J-4 at 20; J-5 at 23; J-7 at 9; J-13 at 16-18; J-25 at 24; J-58 at 15-16.

203. South of the facies change, the “upper prong” of the Middle Claiborne Aquifer (the part above the Lower Claiborne Confining Unit) is sometimes called the “Sparta Sand” or “Sparta Aquifer.” Tr. 88:2-15, 97:22-23, 354:11-15 (Spruill); 611:5-13 (Larson); 814:20-815:3, 822:6-12 (Waldron); Hoffman Dep. 32:16-20; D-197 at 6; J-4 at 20; J-5 at 23; J-13 at 16-18; J-15 at 12-13.

204. South of the facies change, the “lower prong” of the Middle Claiborne Aquifer (the part below the Lower Claiborne Confining Unit) is sometimes called the “Lower Claiborne Aquifer” or the “Meridian Sand.” Tr. 88:16-19, 102:13-22 (Spruill); 613:21-614:6 (Larson); 823:5-23 (Waldron); J-5 at 24; J-13 at 16-18.

205. Water can flow within the Middle Claiborne Aquifer from the “handle” of the Middle Claiborne Aquifer (sometimes called the Memphis Sand) to the “upper prong” area of the Middle Claiborne Aquifer (sometimes called the Sparta Sand), and vice versa. There is no physical barrier that prevents groundwater in the Middle Claiborne Aquifer from flowing laterally above the facies change. Tr. 609:9-13 (Larson); 822:18-22 (Waldron).

206. A cone of depression from pumping within the “handle” of the Middle Claiborne Aquifer (sometimes called the Memphis Sand) can extend south into the “upper prong” of the Middle Claiborne Aquifer (sometimes called the Sparta Sand), and vice versa. Tr. 610:10-16 (Larson).

207. Water can flow within the Middle Claiborne Aquifer from the “handle” of the Middle Claiborne Aquifer (sometimes called the Memphis Sand) to the “lower prong” of the Middle Claiborne Aquifer (sometimes called the Meridian Sand or Lower Claiborne Aquifer), and vice versa. There is no physical barrier to water flowing laterally below the facies change. Tr. 284:19-24, 285:6-8, 388:21-389:8 (Spruill); 609:23-610:9 (Larson); 823:20-824:8 (Waldron).

208. A cone of depression from pumping within the “handle” of the Middle Claiborne Aquifer (sometimes called the Memphis Sand) can extend south into the “lower prong” of the Middle Claiborne Aquifer (sometimes called the Lower Claiborne Aquifer or Meridian Sand), and vice versa. Tr. 610:10-16 (Larson).

209. Potentiometric levels within the Middle Claiborne Aquifer are continuous across the facies change. Tr. 610:17-22 (Larson).

3. *Lower Claiborne Aquifer*

210. The “lower prong” of the Middle Claiborne Aquifer (sometimes called the Lower Claiborne Aquifer) and the “handle” of the Middle Claiborne Aquifer

are part of the same hydrogeological unit. J-18 at 11; Tr. 594:10-17, 782:18-783:8 (Larson); 823:20-824:3 (Waldron); J-22 at 19.

211. In some publications, the USGS includes the Lower Claiborne Aquifer as part of the Middle Claiborne Aquifer. J-15 at 15, figure 3; Tr. 291:20-292:25 (Spruill).

212. The USGS sometimes labels the Lower Claiborne Aquifer separately from the Middle Claiborne Aquifer in order to identify the presence of the Lower Claiborne Confining Unit above it. Tr. 784:16-785:2 (Larson); J-4 at 21; J-5 at 24; J-18 at 15.

4. *The various names by which the areas of the Middle Claiborne Aquifer are identified are irrelevant to any hydrogeological facts and do not change the interstate character of the Aquifer*

213. Even if Mississippi's claim were valid (which it is not) that the areas of the Middle Claiborne Aquifer commonly called the Memphis Aquifer and Sparta Aquifer should be considered separate sub-aquifers (or "units," or "sub-units," or "aquifers"), the resource would still properly be considered interstate. The part of the Middle Claiborne Aquifer called the Memphis Aquifer and the part of the Middle Claiborne Aquifer called the Sparta Aquifer are hydrogeologically continuous. There is no barrier that prevents water from flowing from one area to the other or prevents the effects of pumping from being transmitted across the

place where the name change is being used – in either direction. Tr. 612:3-16 (Larson).

214. Even if the "handle" of the Middle Claiborne Aquifer, sometimes called the Memphis Aquifer, were considered to be a separate aquifer, it would be an interstate aquifer because it extends beneath Mississippi, Tennessee, Arkansas, and Kentucky, and because there is a continuity of properties across these state borders. Tr. 391:1-4 (Spruill); 612:17-613:6 (Larson); J-4 at 20; J-5 at 23.

215. Even if the "upper prong" of the Middle Claiborne Aquifer south of the facies change, sometimes called the Sparta Aquifer, were considered to be a separate aquifer, it would be an interstate aquifer because it extends beneath Mississippi, Arkansas, and Louisiana and there is a continuity of properties across these state borders. Tr. 613:7-20 (Larson); J-4 at 20-21; J-5 at 23.

216. Even if Mississippi's claim were valid (which it is not) that the areas of the Middle Claiborne Aquifer commonly called the Lower Claiborne Aquifer and the Middle Claiborne Aquifer were considered separate sub-aquifers (or "units," or "sub-units," or "aquifers"), the resource would still properly be considered interstate. The Lower Claiborne Aquifer and the Middle Claiborne Aquifer are hydrogeologically continuous. There is no barrier between the two that prevents water from flowing from one to the other or prevents the effects of pumping from

being transmitted across the place where the name change is being used – in either direction. Tr. 388:21-389:8 (Spruill); 785:11-20 (Larson); 824:4-8 (Waldron).

217. Mississippi's claims only allege that Defendants are responsible for taking water in the "Sparta Sand" – i.e., the part of the Middle Claiborne Aquifer that continues above the facies change.

B. Mississippi Produced No Evidence To Support Its Contention That MLGW Was Not A Good Manager Of The Aquifer

218. Water can be removed from an aquifer only using a well. Tr. 134:9-16 (Spruill). Well drillers use a variety of techniques to determine where to place a well in order to obtain the desired quantity of water, including consulting with other water users; reviewing relevant literature; and drilling exploratory or "pilot" holes. Tr. 136:10-137:13 (Spruill).

219. Well fields are designed based on knowledge of the hydraulic properties of the aquifer in which the wells are drilled. Tr. 145:21-146:1 (Spruill). Based on the hydraulic properties of the aquifer, a hydrologist can predict how pumping from the well will affect the surrounding area and, in particular, how much drawdown will occur in the aquifer's water levels around the well. Tr. 151:19-152:9, 163:1-165:14 (Spruill).

220. A cone of depression is an unavoidable consequence of using a well. Tr. 465:7-8 (Wiley). Well fields generally have wells close enough together that their cones of depression overlap, creating "well interference." Tr. 177:9-179:16

(Spruill). As a practical matter, all well fields exhibit well interference, meaning that the cones of depression overlap. Well fields in Mississippi, like MLGW's well fields, exhibit well interference. Tr. 336:16-21 (Spruill).

221. Dr. Spruill did not opine that MLGW's well fields were inconsistent with good well-field design. *See generally* Tr. 183:19-201:4, 204:24-221:7, 250:16-256:15, 273:9-277:5 (Spruill).

222. Dr. Spruill did no analysis to determine how many wells are located in Mississippi within one mile of the state border. Tr. 336:12-15 (Spruill).

223. Dr. Spruill had no basis to disagree with the assertion that there is a well field in Southaven, Mississippi, less than one mile from the Mississippi-Tennessee border, where the wells are placed much closer together than they are in MLGW's Davis, Palmer, or Lichterman well fields. Tr. 336:22-337:4 (Spruill); *see* J-56 at 1-13.

224. Dr. Spruill made no effort to analyze whether groundwater wells in Mississippi that are pumping from the Middle Claiborne Aquifer are consistent with the principles of good well design. Tr. 337:5-9 (Spruill).

C. There Is No Evidence That Pumping From The Aquifer In Shelby County, Tennessee, Exceeds The Amount Of Water Recharging Into The Aquifer

225. MLGW's groundwater pumping system currently consists of approximately 160 wells located in 10 different well fields in Shelby County, Tennessee. S11.

226. MLGW's total pumping increased from 1965 to 2000 from roughly 72 million gallons of water per day to roughly 162 million gallons per day. From 2000 to 2016, it decreased to approximately 124 million gallons per day. Tr. 200:14-21 (Spruill).

227. The regional cone of depression in the Middle Claiborne Aquifer around the Memphis area is caused by the combined pumping of MLGW and other users, including pumping in other States. Tr. 499:15-501:22 (Wiley); J-76 at 20-21.

228. The regional cone of depression created by pumping from the Aquifer in the Memphis area (including in north Mississippi) has stabilized and begun to shrink, in part because MLGW has been pumping less. Tr. 456:9-19 (Wiley); D-198 at 10.

229. There is no evidence in the record that MLGW is withdrawing groundwater from the Middle Claiborne Aquifer at a rate greater than the recharge rate. Tr. 325:14-17 (Spruill); D-198 at 10.

230. The stabilization of the cone of depression in the Middle Claiborne Aquifer around Memphis means that there is a relative balance or equilibrium between recharge and discharge (including withdrawal). Tr. 657:7-15 (Larson); D-198 at 10.

231. The volume of groundwater in the Aquifer flowing from Mississippi to Tennessee has decreased over the past years because pumping in Shelby County, Tennessee, has decreased and, at the same time, pumping in DeSoto County, Mississippi, has increased. Tr. 496:5-497:1 (Wiley). In recent years, groundwater withdrawals in DeSoto County from the Middle Claiborne Aquifer have increased to approximately 20 million gallons per day from approximately 3.6 million gallons per day in 1983. Tr. 652:5-11 (Larson); P-158; J-76 at 20-21.

232. Around the Memphis area, potentiometric levels within the Middle Claiborne Aquifer declined until roughly the 1970s, then stabilized, and have increased in recent years. Tr. 654:17-655:4 (Larson); D-197 at 23; D-198 at 10; J-18 at 57.

233. When recharge and discharge are relatively stable, the total volume of water within the Aquifer does not change significantly, but water is constantly flowing out of the Aquifer and is replaced by new water that is constantly flowing into the Aquifer. D-197 at 8, 12.

D. Mississippi's Groundwater Model Is Unreliable

234. There is pumping from the Middle Claiborne Aquifer in Arkansas, in Mississippi outside of DeSoto County, in Tennessee outside of Shelby County, and in Shelby County other than by MLGW. Tr. 499:23-25, 500:1-4, 500:7-13, 521:9-24 (Wiley); J-76 at 20-21.

235. Mississippi's groundwater model simulates pumping from the Middle Claiborne Aquifer only by pumpers in DeSoto County, Mississippi, and by MLGW in Shelby County, Tennessee. Tr. 499:15-22 (Wiley).

236. The groundwater model used by Mississippi's expert did not simulate pumping in Shelby County, Tennessee, by anyone other than MLGW; pumping in Crittenden County, Arkansas; or pumping in Marshall County, Mississippi. Tr. 500:1-13, 521:25-522:1 (Wiley).

237. The results produced by Mississippi's model do not reflect the impact of pumping from the Middle Claiborne Aquifer from wells in Mississippi outside of DeSoto County, from wells in Arkansas, or from wells in Tennessee other than MLGW. Tr. 499:23-25, 500:1-6, 521:9-522:10 (Wiley).

238. Mississippi's groundwater model was calibrated with real-world data only up until the year 1980. Tr. 538:7-12 (Wiley). Mississippi's expert did not recalibrate his model with more recent data, even though such data are available,

and recalibration with more current data could have improved the accuracy of the model. Tr. 538:19-539:20 (Wiley).

E. Mississippi Provided No Meaningful Evidence Of Any Injury

1. *No evidence of meaningful harm to Mississippi water users*

239. Mississippi's experts did not attempt to calculate the reduction in total available drawdown in Mississippi caused by the regional cone of depression. Tr. 325:18-326:1 (Spruill).

240. Given the current water demand in Mississippi, water purveyors in Mississippi are currently able to meet demand for water from the Middle Claiborne Aquifer beneath Mississippi. Tr. 325:6-10 (Spruill).

241. The volume of water beneath DeSoto County, Mississippi, at any given time has changed very little since pumping began more than 100 years ago. Tr. 504:14-17 (Wiley).

242. There is no evidence that water users in Mississippi have been unable to withdraw as much water as desired from the Aquifer. D-198 at 10.

243. Water users in Mississippi have been able to significantly increase their usage of water from the Middle Claiborne Aquifer over the last few decades, without having any difficulty withdrawing the desired quantities of water. Tr. 647:23-648:16 (Larson); D-198 at 12.

244. Drawdown in an aquifer increases the cost of electricity required to pump water from a well located within the cone of depression, but Mississippi's expert made no attempt to quantify the potential cost of additional electricity needed to pump water from the Aquifer due to a decline in water levels. Tr. 213:21-214:3 (Spruill). Any such cost would be much smaller than the damages sought in this case. Tr. 650:19-23 (Larson).

245. It is theoretically possible that a user might need to lower a well's pump as a result of drawdown, Tr. 214:4-10 (Spruill), but Mississippi's experts offered no evidence that any well user in Mississippi has had to lower the well's pump as a consequence of the regional cone of depression.

246. Pumping water from an aquifer can theoretically cause water from other aquifers to migrate into the pumped aquifer more quickly, Tr. 209:12-24 (Spruill), but Mississippi's experts had no evidence of any degradation in water quality (from any cause) in the Middle Claiborne Aquifer in Mississippi. *See*, *e.g.*, Tr. 325:11-13 (Spruill).

247. Mississippi's expert admits that pumping has not caused any subsidence to the Middle Claiborne Aquifer. Tr. 198:13-20 (Spruill).

248. Mississippi's experts have not estimated any costs associated with the impact of the cone of depression in the Middle Claiborne Aquifer. *See*, *e.g.*, Tr. 335:22-336:3 (Spruill).

249. Mississippi offered no evidence that pumping by MLGW or any other pumper in the Memphis area has damaged the aquifer. If all the pumping wells in the Middle Claiborne Aquifer were turned off, the cone of depression caused by those wells would disappear, and the Aquifer would return to its pre-development conditions. Tr. 198:1-11 (Spruill); J-19 at 32.

2. *Mississippi's experts agreed that there would be significant costs associated with moving MLGW's groundwater wells farther north*

250. Dr. Spruill speculated that moving MLGW's well fields farther to the north (if even feasible) might lessen the extent of the cone of depression across the Mississippi-Tennessee state line. Tr. 326:2-8 (Spruill). However, Dr. Spruill had no basis to disagree with an analysis done by Mr. Wiley, in which Mr. Wiley concluded, among other things, that moving the three MLGW well fields closest to Mississippi (Davis, Palmer, and Lichterman) all the way to the northern part of Shelby County would cause very little change in the cone of depression's extent into Mississippi. Tr. 328:23-330:10 (Spruill).

251. Mr. Wiley could not say whether, in his opinion, moving all of MLGW's well fields north by 20 miles would eliminate the extent of the cone of depression into Mississippi. Tr. 485:7-11 (Wiley).

252. Dr. Spruill agreed with Mr. Wiley's conclusion that moving most of MLGW's wells north of Shelby County, Tennessee, would require the design and

construction of hundreds of new wells and many miles of pipeline, at an enormous cost. Tr. 332:16-333:6 (Spruill).

253. Dr. Spruill did not calculate, or offer any opinion concerning, how much it would cost to move MLGW's well fields. Tr. 326:9-327:5 (Spruill).

3. *The regional cone of depression around Memphis is less significant than other cones of depression in the Middle Claiborne Aquifer*

254. The cone of depression centered in the southwest Tennessee–northwest Mississippi area in the Middle Claiborne Aquifer is neither the largest nor the deepest cone of depression in the Middle Claiborne Aquifer. J-19 at 34; J-18 at 57-58; Tr. 660:25-661:11, 662:11-17 (Larson); J-71.

255. Compared to historical decreases in potentiometric levels in the Middle Claiborne Aquifer in the southwest Tennessee–northwest Mississippi area, more significant declines have been caused by pumping near Jackson, Mississippi; Jefferson County, Arkansas; and Union County, Arkansas. Tr. 658:3-660:10 (Larson); J-18 at 57.

256. In contrast to water levels around Memphis, which have stabilized and in fact have increased in recent years, Tr. 654:17-655:9, 656:25-657:6 (Larson), the decreases in water levels in Madison County, Mississippi – near Jackson, Mississippi – caused by wells pumping in that area have continued to decline, Tr. 658:3-6 (Larson); J-18 at 57.

257. The cones of depression caused by pumping in Union County, Arkansas, and nearby Louisiana; Jefferson County, Arkansas; and Jackson, Mississippi, are the deepest and largest cones of depression in the Middle Claiborne Aquifer. Tr. 660:18-662:17 (Larson); J-19 at 34; J-71.

258. The Memphis metropolitan area is the largest urban area overlying the Middle Claiborne Aquifer. Tr. 664:5-13 (Larson); J-18 at 11; J-19 at 15.

259. Memphis relies on groundwater as its primary public water source. There has been pumping in Memphis since 1886. J-7 at 14; J-17 at 16; J-18 at 11; J-19 at 11, 27.

F. The Velocity Or "Residence Time" Of Groundwater Is Not Relevant To Whether The Aquifer Is Interstate

260. Neither the velocity of groundwater nor the amount of time it would remain in a particular State ("residence time") is material to whether the Aquifer is interstate. Tr. 642:7-643:7 (Larson); 830:23-831:10 (Waldron).

261. Groundwater velocity can be significantly slower than the velocity of flowing surface waters. Tr. 121:1-126:4 (Spruill); 405:10-16, 461:8-15 (Wiley).

262. The velocity of groundwater movement can vary in confined and unconfined areas of an aquifer. In unconfined groundwater systems, water generally moves from areas of recharge to areas of discharge over a period of weeks or years. In confined groundwater systems, water generally moves from areas of recharge to areas of discharge over centuries. Tr. 63:20-64:14 (Spruill).

263. A typical velocity for groundwater in the confined areas of the Middle Claiborne Aquifer is approximately one inch or inches per day. Tr. 106:3-17, 121:1-10 (Spruill); 450:20-24 (Wiley).

264. Groundwater is continually flowing, although slowly, and water is continually recharging into and discharging out of the Middle Claiborne Aquifer. Tr. 504:3-8 (Wiley); 642:15-22 (Larson); 831:1-10 (Waldron); D-197 at 12.

265. Groundwater in the Middle Claiborne Aquifer is continually moving across the Mississippi-Tennessee border, as well. Tr. 642:16-25 (Larson); 828:17-21 (Waldron).

266. There is no permanent "store" of particular water molecules in Mississippi (or anywhere else) within the Middle Claiborne Aquifer. Tr. 643:1-11 (Larson); D-197 at 23, 24.

267. The portion of the Middle Claiborne Aquifer beneath Mississippi is always saturated with water, but it does not always contain the *same* water molecules; the water is moving from place to place. Tr. 644:3-7 (Larson); D-197 at 25.

268. Mississippi's expert estimated that under pre-development conditions approximately 37 million gallons of groundwater in the Middle Claiborne Aquifer naturally flowed out of Mississippi into other States every day. Tr. 532:20-533:2 (Wiley).

G. A Hydrologist Cannot Isolate Individual Water Molecules From Within A Hydrogeological Unit

269. It is possible to draw general conclusions about the average speed or direction of water movement within an aquifer, but it is not possible to follow individual molecules of water. Tr. 644:8-12 (Larson).

270. Hydrologists do not work on the level of individual molecules, which are not observable, or even on the level of larger water particles, which are still microscopic. Generally, hydrologists work on the macroscopic scale, meaning they look at how – on average – large numbers of water particles travel through porous media (like sand). Tr. 829:2-22 (Waldron); D-197 at 6.

271. The Middle Claiborne Aquifer is a continuous hydrological unit, and there is no scientific basis to isolate artificially a particular piece of that aquifer or water in it for purposes of hydrological analysis. All of the water in the Middle Claiborne Aquifer is hydrologically connected to, and acting on, water in the neighboring areas of the Aquifer. Tr. 830:5-17 (Waldron).

IV. COMPUTER MODELS OF THE MISSISSIPPI EMBAYMENT REGIONAL AQUIFER SYSTEM

A. The MERAS Model

272. The most recent computer model of the Mississippi Embayment Regional Aquifer System was developed by the USGS as part of the Mississippi

Embayment Regional Aquifer Study ("MERAS"). The model is called the "MERAS model." Tr. 992:16-993:11 (Langseth); J-18 at 9.

273. The studies developing the MERAS model used the term "Middle Claiborne Aquifer" to refer to the Aquifer at issue. Tr. 568:4-10 (Larson); *see generally* J-18; J-19.

274. The MERAS model is based on, among other data, reviews of 2,600 borehole logs within the Mississippi Embayment area to refine the vertical and horizontal delineation of the various hydrogeological units. Tr. 1021:6-12 (Langseth); J-18 at 28; J-19 at 24.

275. The geographic scope of the MERAS model covers portions of eight States. The boundaries of the MERAS model follow the extent of the Mississippi Embayment and are not limited by political boundaries. Tr. 596:21-597:12 (Larson) (J-18 at 37); D-197 at 7, 17; J-18 at 9; J-19 at 23.

276. The MERAS model includes the aquifers and confining units within the Mississippi Embayment. Tr. 993:5-11 (Langseth); J-18 at 11; J-19 at 23.

277. The MERAS model is a fully three-dimensional model. Tr. 1023:9-10 (Langseth); J-18 at 8, 16; J-19 at 23.

278. The MERAS model represents the various hydrogeological units within the Mississippi Embayment in 13 model layers. D-197 at 17; D-198 at 12; J-18 at 15; J-19 at 23.

279. The MERAS model uses multiple model layers to represent some of the hydrogeological units within the Mississippi Embayment in order to study each unit in greater detail. Tr. 779:22-780:10 (Larson); D-197 at 18; J-18 at 16.

280. The Middle Claiborne Aquifer is present in all or portions of layers 5-10 in the MERAS model. Tr. 482:6-9 (Wiley); D-191 at 10; J-18 at 15.

281. The MERAS model simulates the hydrological connections between surface water and groundwater within the Mississippi Embayment. D-197 at 18, 23; J-18 at 23, 25.

B. The Brahana & Broshears Model

282. The model of the Mississippi Embayment used by Mississippi's experts in this case was created by Brahana & Broshears in the 1970s-1980s based on technology available at that time. Tr. 519:10-22 (Wiley); J-15 at 34.

283. The Brahana & Broshears model consists of three horizontal layers. Tr. 519:23-520:2 (Wiley); J-15 at 34.

284. All three layers of the Brahana & Broshears model extend across the entire span of the modeled area, which includes portions of Mississippi, Tennessee, Arkansas, Missouri, and Kentucky. Tr. 520:3-14 (Wiley).

285. The Middle Claiborne Aquifer is represented in the Brahana & Broshears model as layer 2. Layer 2 represents the Middle Claiborne Aquifer as a single, continuous layer throughout the model's extent – extending well north and

south of the Mississippi-Tennessee boundary. Tr. 520:15-23, 528:9-14 (Wiley); J-15 at 34, 35.

V. EXPERT QUALIFICATIONS

A. Steven Larson Qualifications

286. Mr. Steven Larson, expert for the State of Tennessee, is a Vice President at S.S. Papadopulos & Associates, an environmental consulting firm. Tr. 559:9-21 (Larson); D-197 at 27.

287. Mr. Larson has worked for S.S. Papadopulos for 39 years. Tr. 559:22-23 (Larson); D-197 at 27.

288. Mr. Larson specializes in groundwater hydrology. Tr. 559:24-560:2 (Larson).

289. Before working at S.S. Papadopulos, Mr. Larson worked nine years for the Water Resources Division of the United States Geological Survey. Tr. 560:3-10 (Larson); D-197 at 27.

290. At the USGS, Mr. Larson was a hydrologist who worked on water resource investigations and conducted research in the area of computer simulation models. Tr. 560:11-19 (Larson).

291. Mr. Larson has a bachelor's degree in civil engineering and a master's degree in civil engineering, both from the University of Minnesota. Tr. 560:20-24 (Larson); D-197 at 27.

292. Mr. Larson belongs to the American Institute of Hydrology and the National Groundwater Association. Tr. 560:25-561:4 (Larson); D-197 at 27.

293. Mr. Larson has published papers about groundwater hydrology and modeling. Tr. 561:5-6 (Larson).

294. The purpose of Mr. Larson's testimony is to offer an opinion about whether or not the Middle Claiborne Aquifer is an interstate water resource. Tr. 561:7-14 (Larson).

295. Mr. Larson has testified before a judge or Special Master or in arbitration more than 50 times. Tr. 562:2-7 (Larson).

296. Mr. Larson has served as a hydrological expert in interstate water disputes before the Supreme Court of the United States in several matters including: *Colorado v. Kansas*, *Kansas v. Nebraska*, *Nebraska v. Wyoming*, *Montana v. Wyoming*, and *North Carolina v. South Carolina*. Tr. 562:8-20 (Larson); D-197 at 27.

297. Mr. Larson's testimony in *Kansas v. Colorado*, *Kansas v. Nebraska*, *Nebraska v. Wyoming*, and *Montana v. Wyoming* included opinions concerning groundwater. Tr. 562:24-564:1 (Larson).

298. Mr. Larson has also testified as a hydrological expert in non-original actions involving the effects of groundwater use. Tr. 564:2-16 (Larson).

299. Mr. Larson was tendered as an expert in the field of groundwater hydrology without objection. Tr. 564:22-565:2 (Larson).

B. Brian Waldron Qualifications

300. Dr. Brian Anthony Waldron is an associate professor at the University of Memphis in the department of civil engineering and director of the Center for Applied Earth Science and Engineering Research ("CAESER"). Tr. 797:1-9 (Waldron).

301. Dr. Waldron has been at the University of Memphis for approximately 20 years and has been a tenured professor there since 2010. Tr. 797:10-14 (Waldron).

302. Dr. Waldron teaches undergraduate and graduate courses including groundwater hydraulics, which covers the construct of water moving through porous media. Tr. 797:17-24 (Waldron).

303. Dr. Waldron has taught groundwater modeling at the university for more than 10 years. Tr. 798:1-8 (Waldron).

304. Dr. Waldron received his undergraduate degree in civil engineering at Memphis State University, now the University of Memphis; his master's in civil engineering at the University of Memphis; and his doctorate in civil engineering specializing in groundwater from Colorado State University. Tr. 798:9-18 (Waldron).

305. At CAESER, Dr. Waldron conducts research and engages in director-type operations. Tr. 798:19-23 (Waldron).

306. Dr. Waldron's research includes numerical modeling of groundwater and contaminant transport in the Middle Claiborne Aquifer; subsurface mapping of the confining clay above the Middle Claiborne Aquifer in the Memphis area and elsewhere; water sampling and age dating of the groundwater in the Middle Claiborne Aquifer; studies of recharge to the Middle Claiborne Aquifer; and water-level measurements and water-level maps of the Middle Claiborne Aquifer and shallow aquifer; and educational outreach to kids about water and how to conserve it. Tr. 798:24-799:16 (Waldron).

307. Dr. Waldron has published approximately 22 research papers, 16 of which concern groundwater hydrology. Tr. 799:21-800:3 (Waldron).

308. Dr. Waldron has studied the Middle Claiborne Aquifer for more than 20 years. Tr. 800:4-22 (Waldron).

309. Dr. Waldron spends 50-60% of his professional time studying the Middle Claiborne Aquifer. Tr. 800:23-801:2 (Waldron).

310. Dr. Waldron has studied the Middle Claiborne Aquifer for approximately 20,000 hours of his professional life. Tr. 801:3-6 (Waldron).

311. Dr. Waldron was admitted as an expert in the field of groundwater hydrology without objection. Tr. 802:10-13 (Waldron).

C. David Langseth Qualifications

312. Dr. David Langseth obtained a bachelor's degree in civil engineering and mathematics at the University of Minnesota in 1977. Tr. 966:3-8 (Langseth).

313. Dr. Langseth's undergraduate courses included a general water resources course that included groundwater, and a series of courses called geotechnical engineering that had a heavy component of the flow of water through granular materials, which is effectively groundwater flow. Tr. 966:12-19 (Langseth).

314. Dr. Langseth's undergraduate studies included work in mathematical modeling, which is how we understand groundwater flow. Tr. 966:20-24 (Langseth).

315. Mathematical or computer modeling is how we characterize groundwater flow. When looking at large natural systems, they are too complicated to solve mathematical equations by hand, so we use computers, through methods called numerical methods, to break down a large area into small pieces. We use the same mathematics over all those small pieces, doing hundreds of thousands – in some cases millions – of calculations in order to solve those same fundamental equations over a long area. Tr. 967:4-22 (Langseth).

316. While an undergraduate student at the University of Minnesota, Dr. Langseth was employed at Barr Engineering where a large part of his work was

hydrologic monitoring; for example, measuring groundwater monitoring levels, surface water monitoring, and installing groundwater monitoring wells. Tr. 967:23-968:18 (Langseth).

317. Dr. Langseth obtained his master's and doctorate from the Massachusetts Institute of Technology ("MIT"). Tr. 968:19-21 (Langseth).

318. During his postgraduate work at MIT, Dr. Langseth took courses in hydrology and, specifically, groundwater hydrology. Tr. 968:22-969:1 (Langseth).

319. Dr. Langseth's postgraduate work at MIT also included a course focused on numerical methods for solving environmental problems, which included a course in solving equations of groundwater flow. Tr. 969:4-9 (Langseth).

320. Since graduating from MIT, Dr. Langseth's focus has been in groundwater and surface water hydrology and hydraulics. Tr. 969:13-17 (Langseth).

321. After MIT, Dr. Langseth worked at Metcalf & Eddy, where he was asked to develop the company's groundwater modeling expertise. Dr. Langseth then went to Arthur D. Little for 12 years where he conducted groundwater modeling in addition to other groundwater-type projects. Tr. 970:11-971:5, 972:24-25 (Langseth).

322. Dr. Langseth then worked for Exponent and continued to work on projects that involved water hydrology until he joined the faculty at Northeastern University in the civil and environmental engineering department. Tr. 973:1-18 (Langseth).

323. At Northeastern, Dr. Langseth taught graduate level groundwater hydrology and quality courses, surface water hydrology and water quality courses, and general environmental management. He also taught undergraduate hydraulic engineering. Tr. 973:19-25 (Langseth).

324. Dr. Langseth's primary research area at Northeastern was a detailed study of groundwater and surface water interactions. Tr. 974:1-7 (Langseth).

325. After leaving Northeastern, Dr. Langseth joined Gradient, which is an environmental and risk sciences consulting firm. Dr. Langseth is a principal at Gradient and has worked on a variety of projects, many involving groundwater and surface water hydrology. Tr. 974:9-19 (Langseth).

326. Dr. Langseth belongs to the American Society of Civil Engineers, and a subgroup of that organization called the Environmental Water Resources Institute. Tr. 974:20-975:1 (Langseth).

327. Dr. Langseth belongs to the National Groundwater Association and, within that organization, is a representative on the Federal Advisory Committee on Water Information, which advises all of the federal agencies that deal with water

information such as the USGS, and is also a member of the Subcommittee on Groundwater that was established under the Advisory Committee. Tr. 975:2-18 (Langseth).

328. Dr. Langseth has served as an expert or given expert testimony in cases involving groundwater approximately 20 times, including serving as a groundwater expert in *Florida v. Georgia*, No. 142, Orig., before the United States Supreme Court. Tr. 975:19-976:25 (Langseth).

329. Dr. Langseth served as an expert concerning this same Aquifer in *Mississippi v. City of Memphis, et al.*, No. 2:05CV0032 (N.D. Miss.). Tr. 977:1-8 (Langseth).

330. Dr. David Langseth was admitted as an expert in the field of groundwater hydrology without objection. Tr. 978:14-18 (Langseth).

Respectfully submitted,

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<u>CERTIFICATE OF SERVICE</u>

Pursuant to Paragraph 3 of the Special Master's Case Management Plan (Dkt. No. 57), I hereby certify that all parties on the Special Master's approved service list (Dkt. No. 26) have been served by electronic mail, this 19th day of September 2019.

/s/ *David C. Frederick*

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