In the Matter Of:

STATE OF MISSISSIPPI vs

STATE OF TENNESSEE, ET AL

143, Original

PROCEEDINGS

May 22, 2019

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IN THE SUPREME COURT OF THE UNITED STATES

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STATE OF MISSISSIPPI,

Plaintiff,

v. No. 143, Original

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

Defendants.

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May 22, 2019

9:00 a.m.

ON BILL OF COMPLAINT

Before:

HON. EUGENE SILER,

Special Master.

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EXAMINATION

DEFENDANT EXHIBITS

(Case called)

DAVID WILEY, resumed.

DIRECT EXAMINATION (continued)

BY MR. McMULLAN:

Q. Mr. Wiley, can you hear me okay?

A. Yes, I can.

Q. Mr. Wiley, we were talking a little bit about the work that you did in your retention for the state of Mississippi to examine the effects of MLG pumping Mississippi water, and we talked a little bit about modeling yesterday. Do you recall -- I'm sure you do -- quite a bit of discussion about modeling that you did?

A. Yes.

Q. I believe you testified yesterday concerning the use of a Brahana model that you used and updated for modeling; is that correct?

A. Yes, I did.

Q. Okay. Let me ask you a few questions about other models.

Do you -- in your course of your work, did you have occasion to look at and consider and/or use the MERAS model?

A. When we started the project in 2006, the -- that model was not available, and we -- the Brahana model was the best model available at that time, so we used that model.

Q. Okay. And subsequently did you have access to the MERAS

model in your analysis?
A. Yes.
Q. Did you use the MERAS model?
A. Yes. We used it for particle tracking, and we also used it as a quick check on water budget for diversion about -- diversion analysis.
Q. Okay. So let me get this straight: You did the particle tracking unit using MERAS, but you also separately did an examination of diversion amounts using the MERAS model?
A. Yes.
Q. And how did you go about carrying out using the MERAS model to verify or cross-check against what you'd already done?
A. We just -- we simply looked at the water budget for DeSoto County to see what -- the predevelopment, and we picked a year of 2007 to see what the water budget was for that time period, to see what diversion amount would be going from Shelby County to -- or from DeSoto County to Shelby County.
Q. After you ran the MERAS model to cross-check against the diversion amounts that you calculated using the Brahana model, what did you find when you compared the two results?
A. They were -- for the year 2007, they were actually pretty close. I would -- I would say, though, when we did use the MERAS model, we used the MERAS model as is; that is, with the pumpage that was in it. We didn't change anything.
Q. How would you characterize -- well, strike that.

Did the results of the MERAS model run on the diversion analysis alter your conclusions about the effects of MLGW pumping on Mississippi water?

A. No, it didn't.

Q. As a matter of housekeeping, I'd like to take you through -- you've got the notebooks with a series of exhibits which we've already talked about. If you'd open up your notebook, there's a series of exhibits I believe that you have a copy of, 157 through 190. Do you have those, P157 through 190?

There's also a notebook up on top of the podium.

A. Yes, I've got it.

Q. Do you have those in front of you?

All right. If you need your glasses, please take a look at those, if you need to. Let's take a look at P157 first.

Are you there?

A. Yes.

Q. All right. P157, could you identify -- there's two pages, I believe, to that exhibit. Do you see that?

A. Yes.

Q. All right. There's a Table 1 and a Table 1A. What is Table 1?

A. It's the Memphis Light, Gas & Water Division pumpage from 1965 through 2016 for each of the wellfields.

Q. Okay. Did you prepare this document, or have it prepared under your direction and control, during the course of your analysis?

A. Yes.

Q. Table 1A, behind that, tell us about that document, first of all. Is that a document that you prepared, or had prepared at your direction or under your control, during the course of your analysis?

A. Yes.

Q. What is the difference between Table 1 and Table 1A, if any? Just generally.

A. The only thing I see is in a column that says -- starting Bates numbers.

Q. Okay.

A. That's the only thing I see different.

Q. Do you recall whether this alteration or whether this Table 1A was to add some additional source information or not?

A. Yes.

Q. Okay. Did the change from 1A -- from 1 to 1A alter any of your conclusions that you reached in your analysis?

A. No, it did not.

Q. All right. Let's turn to Table -- excuse me, let's turn to Plaintiff's Exhibit 158 in your notebook.

Are you with me?

A. Yes.

Q. All right. There's a Table 2, and there's also a Table 2A. Do you see that?
A. Yes.
Q. Table 2, is that something you prepared in the course of your analysis in this case?
A. Yes.
Q. Is 2A something you prepared in the course of your analysis of this case?
A. Yes.
Q. And what is the difference, if any, between Table 2 and Table 2A?
A. Just the labeling of -- the second column, the column in the middle of Table 2 has "Shelby County"; and 2A, the second column has "MLGW."
Q. Are the entries -- are the numbers on both of those tables the same?
A. Yes.
Q. Did moving from Table 2 to 2A result in any change in your conclusions in your analysis?
A. No.
Q. Let's take a look at P159. What is that?
A. Volume of groundwater taken from Mississippi due to MLGW pumpage. It's for the years 1965 through 2016.
Q. Did you prepare this document in the course of your analysis?

A. Yes.
Q. Let's turn to P160, please.
We talked a good bit about this document yesterday; do you recall?
A. Yes, I do.
Q. Likewise, is this a document you prepared in the course of your analysis of the issues in this case?
A. Yes.
Q. Let's go to P161.
Is that document one which you prepared in the course of your analysis in this case?
A. Yes, it is.
Q. P162: Likewise, is that a document you prepared in the course of your analysis in the case?
A. Yes.
Q. 163: Is that a document you prepared in preparation and conducting of your analysis in this case?
A. Yes.
MR. HILL: Your Honor, excuse me. If the point of this is just to authenticate the things in the expert report, we'll stipulate that each of these --
MR. McMULLAN: Thank you, your Honor. I understood there was an objection to authenticity on these documents, so I wanted to make sure to clean that up a bit.
MR. HILL: Sorry, the objection is not to authenticity

but our other objection's pending --

MR. McMULLAN: Understood.

THE COURT: Any other objections?

MR. L. BEARMAN: Just -- we're reserving the objections we previously made, your Honor, not to the authenticity.

MR. McMULLAN: Thank you very much. Appreciate that clarification.

THE COURT: Sure.

BY MR. McMULLAN:

Q. In the course of your analysis of the amounts of water that were diverted by MLGW's pumping from Mississippi, did you reach a conclusion about the total amount or total volume, millions of gallons of water, that were diverted over the course of the period that you looked at? I believe it was 1965 to 2016. Did you come up with a number?

A. Yes.

Q. What was that number?

A. I believe it was approximately 411 billion gallons per day.

Q. Did you say "billion"?

A. Yes.

MR. McMULLAN: The Court's indulgence, I have one slide that I would like to have the ability to put up on the screen. My IT person has just arrived. And we can talk about it, but I'd like to put it up in a few minutes, if I get to

that point.
Q. But Mr. Wiley, let's turn to Exhibit P189 in your book.
Are you there?
A. Yes.
Q. Okay. What is that exhibit, P189?
A. This is what I spoke of a few minutes ago regarding the MERAS model. It shows -- on the left-hand side, it shows predevelopment budget for model layers 5 through 10 in the MERAS model, which represent Middle Claiborne; and then on the right side, it's the water budget for 2007 for DeSoto County.
Q. Is this part of the work that you were describing you did in follow-up using the MERAS model?
A. Yes.
Q. Is this a follow-up to confirm the particle tracking that you did, or follow up the diversion that you did using MERAS?
A. No, this is not the particle tracking. This is water budget, to find out how much water was flowing from DeSoto to Shelby County.
Q. Does this reflect the testimony you gave a few minutes ago, that the MERAS run of the diversion confirmed the Brahana conclusions that you -- the Brahana model-based conclusions which you reached?
A. Yes.
Q. Tell us a little more about that, in detail, about what we're looking at here. There's two different illustrations

here; on the left there's one and on the right there's one. What is -- what is being depicted here, if you would, please?

A. The one on the left, as I said, shows predevelopment conditions for water moving through layers 5 through 10 horizontally. And it shows -- I'll just read it: 4.3 million gallons a day coming into DeSoto from Marshall; 2.3 million gallons a day coming into DeSoto from Shelby; 2 million gallons a day leaving DeSoto to Arkansas; 3.4 leaving DeSoto to Tunica County, Mississippi; and 2.7 leaving DeSoto for Tate County; again, 2.7 million gallons a day.

Then that's predevelopment.

And then on the right side we have, under 2007 pumping conditions, we have 10.19 million gallons a day coming into DeSoto from Marshall; 1.5 million gallons a day coming into DeSoto from Tate; .8 million gallons a day coming into DeSoto from Tunica County; and then 2.9 million gallons a day coming into DeSoto from Arkansas. 20.3 million gallons a day leaving DeSoto, from Shelby County.

Q. All right. So under the predevelopment conditions in that -- and "predevelopment" means before pumping by MLGW, right?

A. That -- that's before any pumping. Right.

Q. Okay. So does this indicate -- what does this indicate with respect to amounts of water flowing from Mississippi into Tennessee, predevelopment?

A. Well, it indicates that due to pumping that's going on in 2007, primarily from the Shelby County area, that there is 20.3 million gallons a day leaving DeSoto County for Shelby County. And when you look at the net change from predevelopment to 2007, you add in the 2.3 that was leaving Shelby to get a total of 22.6 million gallons a day.

Q. The water that's moved from Mississippi to Tennessee as a result of MLGW's pumping, is it going to come back?

A. Well, as I said before, this is everyone pumping. The MERAS model had -- it did not just have MLGW pumping.

Q. Understood. So this doesn't attempt to depict or quantify the amount from MLGW, but as I understand what you're saying, this was something you used as a cross-check to confirm your conclusions with -- using the Brahana and Broshears model?

A. That's right.

Q. And your conclusions were, when you compared the results of this model run to Brahana, were what?

A. That the pumping by MLGW in Shelby County is causing water from -- diversion of water from DeSoto County. And we checked -- we did -- we calculated that for multiple years, but it confirms that there's water being induced from DeSoto County into Shelby County.

Q. I want to follow up on a couple of questions I asked you yesterday about how the cone of depression might be affected by any decisions that MLGW might make about its pumping.

Let me clarify this: If MLGW pumping were to cease, would that eliminate the cone of depression that reaches into Mississippi?

A. If MLGW -- MLGW were to cease pumping, the cone of depression that they've caused extending into Mississippi would cease.

Q. Okay. And if MLGW moved its wellfields further north about 20 miles, would, in your opinion, the effect of the cone of depression in Mississippi be eliminated?

A. I haven't -- I haven't evaluated that. It would certainly shift.

Q. Fair enough.

MR. McMULLAN: One moment, your Honor. Court's indulgence.

Q. One point of clarification. I understand that a few minutes ago you mentioned that there was not as much -- well, maybe it was yesterday -- that you began your work initially in 2007; you'd had one group of data as far as pumping data is concerned. Is that correct? When you did your first initial work, you had one set of data to work with, and later you updated it; is that correct?

A. Yes.

Q. What was the source of information for the additional pumping data that you used in the follow-up work that you did later? Where did you get it?

A. For ...
Q. The additional pumping --
A. For who?
Q. The additional pumping --
A. For MLGW?
Q. Correct.
A. We got data from both the MLGW and the State of Tennessee Department of Environmental Conservation, I believe it was.
Q. Okay. It was their data?
A. Yes.
Q. And you incorporated that data into your analysis in the follow-up work that you conducted? You used it?
A. Yes.
Q. Okay. And it's considered in your analysis and conclusions that you've reached and the opinions you've given here today?
A. Well, we -- in 2017, for the 2017 report, we -- we received additional pumpage data from MLGW for a period of time that we had data from the State of Tennessee. So we updated the model with the MLGW data instead of the State of Tennessee data.
Q. And when you updated the model with the additional data, did it change any of your conclusions that you've given?
A. No.
Q. And opinions you've given here?
A. No, it didn't.
Q. Are all of the opinions you've given in court to a

reasonable degree of scientific probability?

A. Yes.

MR. McMULLAN: I pass the witness.

THE COURT: All right.

You may cross-examine.

MR. D. BEARMAN: Thank you, your Honor.

If your Honor doesn't mind, I'm going to move some boxes and get set up here.

THE COURT: Okay.

CROSS EXAMINATION

BY MR. D. BEARMAN:

Q. Good morning, Mr. Wiley.

A. Good morning.

Q. Can you hear me okay?

A. Yes.

Q. My name is David Bearman, and I represent the City of Memphis and MLGW. You and I have met before; I think started back in 2006, when you started working on this case. Isn't that about right?

A. That sounds right.

Q. Yesterday and this morning you talked about your work in 2007 on this case, and in 2014, and currently in 2017. Do you remember that?

A. Yes.

Q. And you issued expert reports in 2007, 2014, and 2017,

right?
A. Right.
Q. And the focus of all three of those reports was the same aquifer, right?
A. Yes.
Q. And we've heard terms this morning, and during the trial -- you've been here at least for part of Mr. Spruill's testimony, weren't you?
A. Yes.
Q. We've heard the term the "Memphis Sand Aquifer," the "Sparta Sand Aquifer"; do you remember that?
A. Yes.
Q. And in fact, in your 2017 report, you referred to the aquifer at issue here as the Sparta Sand, right?
A. Which report? I'm sorry.
Q. Your 2017 report.
A. I believe so. That's right.
Q. And in your 2007 report, you referred to that same aquifer as the Memphis Sand Aquifer, right?
A. Right.
Q. And you've heard the term "Middle Claiborne Aquifer" used at this trial, correct?
A. Yes.
Q. And that's the same aquifer?
A. The -- the Memphis Sand and the Sparta Sand are part of the

Middle Claiborne Aquifer.

Q. So we're all talking about the same aquifer; that's what I want to make sure.

MR. McMULLAN: Your Honor, I've got an objection. This goes beyond the scope of my direct.

THE COURT: I'm going to let you ask the question.

MR. D. BEARMAN: Thank you, your Honor.

Q. Mr. Wiley, you remember when you gave your deposition a summer ago? Do you remember that?

A. Yes.

Q. And do you remember that you were under oath when you gave that deposition?

A. Yes.

Q. And you remember that I asked you that if you had any questions about the questions I asked you, you didn't understand something, I wanted you to clarify them, correct? Right?

A. Yes.

Q. Okay. And you knew that your answers were important, correct?

A. Yes.

Q. And in your deposition, when I asked you, "Mr. Wiley, in your report you used the term 'Sparta Sand,' and you also used the term 'Sparta Memphis Sand'; I want to make sure we're talking about the same aquifer. Is that right?"

And you said, "Yes, we are."

A. That's right.

Q. And then I asked, "I think on one of your diagrams it is labeled the 'Middle Claiborne Aquifer.' That's the same aquifer also, right?"

And you said, "Yes. The middle -- the Memphis Sparta Sand is in the Middle Claiborne Aquifer."

Do you remember that?

A. Yes.

Q. And you read the report by Dr. Langseth, who is the expert for MLGW and the City of Memphis, right?

A. Yes.

Q. And he used the term in his expert report, the "Memphis Sparta Sand Aquifer," or sometimes he abbreviated that as the "MSSA." Do you remember that?

A. I recall that, yes.

Q. And that's the same aquifer we're talking about here?

A. Yes.

Q. Now, the aquifer that we've just described, for purposes of this cross-examination, I'm going to refer to as "the aquifer." Is that okay?

A. Fine by me.

Q. All right. And if either you or me talk about something other than the aquifer at issue, then we'll identify it. Is that fair?

A. That sounds good.
Q. The aquifer underlies eight different states, right?
A. The Middle Claiborne Aquifer is part of the Mississippi Embayment that underlies eight different states to some degree, yeah.
Q. I'm talking about -- the Middle Claiborne Aquifer underlies eight different states, right?
A. Yep, that's what I just said. Yeah.
Q. And the geographic extent -- that is, the size of the aquifer and the fact that it underlies eight states -- is not disputed, right?
A. That's right.
Q. It actually goes beneath the Mississippi River, right?
A. Yes.
Q. Now, you're familiar with the term "transboundary aquifer," right?
A. Yes.
Q. And a transboundary aquifer is one that exists on two sides of a boundary line, right?
A. Yes.
Q. And the boundary line could be a county line, right?
A. Yes.
Q. And it could be a state line?
A. Yes.
Q. So the Middle Claiborne Aquifer is a transboundary aquifer,

right?
A. Yes, based on that definition.
Q. The groundwater wells that are used to pump groundwater from the aquifer in Shelby County are drilled straight down, right?
A. That's -- to my knowledge, yes.
Q. You have no knowledge that there are any wells that are slanted?
A. No, I don't.
There are horizontal wells, though.
Q. But not --
A. Not here, that I know of.
Q. Okay. And the same is true of the wells in Mississippi: They're -- as far as you know, they're not slanting their wells beneath Tennessee?
A. No.
Q. And both Shelby County and -- Tennessee, and DeSoto County, Mississippi, are pumping from the same aquifer, right?
A. Yes, they are pumping from the same aquifer. There may be wells that are pumping from different aquifers there. You've got the Fort Pillow Aquifer, but -- you know, some well -- most of the wells are pumping from the Memphis Sparta Sand Aquifer.
Q. In both counties?
A. Yes.
Q. One in Tennessee, one in Mississippi?

A. Yes.
Q. Now, you agree that pumping in the aquifer in Tennessee can impact the groundwater flow of the aquifer, the same aquifer -- let me try that again.

Pumping in the aquifer in one state can impact the flow of groundwater in the aquifer in another state, right?
A. That's right. I've shown some figures, some information in my direct, that demonstrated that.
Q. Right. In fact, the entire basis of your calculation of those amounts allegedly diverted is based on the theory, on the assumption that impact of pumping in Tennessee crosses the state line into Mississippi, right?
A. Right.
Q. There are no physical barriers in the aquifer that stop the water in the aquifer in Mississippi coming up into Tennessee, right?
A. That's right.
Q. And there are no physical barriers in the aquifer that would stop the groundwater from moving from DeSoto County, Mississippi, into Arkansas, right?
A. That's right.
Q. And to be clear, my first question, when I talk about the water coming up into Tennessee, I want to make sure this is clear, that I'm talking about there's no physical barrier at the Tennessee/Mississippi line that would stop the water in

Mississippi in the aquifer from coming up into Tennessee in the aquifer, right?

A. Right.

Q. Mr. Taylor, could you pull up Slide -- Exhibit P183.

This is one of the figures, Mr. Wiley, in your exhibit notebook that was handed out. Do you recognize that?

A. Yes.

Q. That's a figure that you created, correct?

A. That's right.

Q. Now, these flow arrows are in blue and green, right?

A. Yes.

Q. And those show the path of groundwater as it would move through the aquifer in 2016, according to your calculations?

A. That's right.

Q. Now, those -- the green flow arrows are the ones that start in Mississippi, right?

A. Yes.

Q. And those arrows that you drew end in Shelby County; is that correct?

A. Yes.

Q. And that pink area on your map is the City of Memphis, outline of the City of Memphis, right?

A. Yes.

Q. And so the very south end of Memphis would be the state line, correct?

A. That's right.
Q. And you have labeled these green areas, these green arrows, "Interstate Flow," right, down in the legend?
A. Yes.
Q. And that's because you show them going from Mississippi into Tennessee, right?
A. That's right.
Q. All right. Now, every single one of your green arrows shows that the groundwater that you started in Mississippi, within the aquifer, passes through one of the major cities in North DeSoto County, right?
A. I don't know.
Q. Well, look at the map. This is --
A. Well, I don't know the major cities.
Q. All right. Let's look at your map. Those arrows pass through Olive Branch; do you see that?
A. Yes, now I see it.
Q. And it passes through Horn Lake?
A. Okay, I see it.
Q. Southaven?
A. I see it.
Q. And Hernando, right? Hernando is down to the south --
A. I see it, yes.
Q. And there are pumps within Mississippi over that entire area, aren't there?

A. There are wells in DeSoto County scattered around, that's right.

Q. Pumping from the aquifer?

A. Yes.

Q. And when you were asked yesterday why the amount of groundwater moving from Mississippi to Tennessee had slowed over the past years -- do you remember that question?

A. Yes.

Q. And it has slowed down, right?

A. That's right.

Q. You said because MLGW is pumping less. Do you remember that?

A. I said -- I said that ML -- the cone of -- I don't recall the exact question yesterday, but I thought it was related to the cone of depression.

Q. Will you agree that MLGW was pumping less --

A. Yes.

Q. -- than it was?

A. That's right.

Q. As a matter of fact, pumping in 2016 is less than it was in the 1980s, right?

A. Yeah.

Q. But another reason why the amount of water going from Mississippi into Tennessee has slowed down is because DeSoto County, Mississippi, is pumping more, right?

A. Right.
Q. And so in these green arrows that you've drawn on this map on page P183, or Exhibit P183, some of that water is being pumped by Mississippi, right?
A. Yes, because it's in the water budget.
Q. Some of that water has been pumped by Mississippi, correct?
A. Yes, it's in -- like I said, it's part of the water budget.
Q. Now, you have -- you can take that down, Mr. Taylor. Thank you.

You previously testified about cone of depression that's centered in the Memphis area, right?
A. Right.
Q. Now, every well that pumps groundwater from the aquifer that we're talking about creates a cone of depression when it's pumping, right?
A. Right.
Q. The cone of depression is one way of visualizing the impact of pumping, correct?
A. Yes.
Q. Groundwater generally moves from higher head to lower head, or higher pressure, lower pressure; is that correct?
A. That's right.
Q. So that's really how the wells work; by lowering the pressure, the water kind of comes toward the well, right?
A. That's right.

Q. Like when you drink a milkshake with a straw, the milkshake comes toward the straw, right?
A. Comes in the straw.
Q. Comes in the straw?
A. I don't know if it creates a cone of depression, though.
Q. Depends on how large and full, right? Okay?
A. I wouldn't be -- I wouldn't be ...
Q. Now, the cone of depression exists across the surface of the aquifer, right?
A. The cone of depression -- in plan view, you can see it across the surface, right.
Q. In the maps that you looked at the other day, yesterday, plan view, that means looking from above down, right?
A. That's right.
Q. In those maps, the cones of depression can be seen across the surface of the aquifer, right?
A. Well, it would be -- you can see it on the map.
Q. Right.
A. The aquifer's not -- you know, it's not in the diagram, or the -- the -- superimposing the drawdown contours on it.
Q. I'm talking about on the map.
A. Yes.
Q. And if you have wells that are forming cones of depression in a relatively similar area -- and you talked about this yesterday -- the wells can overlap, or the cones of depression

can overlap, correct?
A. If the wells are close enough together, yes.
Q. All right. Mr. Taylor, can you please bring up Exhibit P180.
Now, this is Figure 21 from your June 17 report. Do you remember that?
A. Yes.
Q. And this is what you represent to be the 2016 potentiometric surface of the aquifer in this case, right?
A. That's right.
Q. Now --
A. Well, let me clarify. That's the potentiometric surface for 2016, based on pumpage by -- from MLGW wells in DeSoto County.
Q. Right. And this is -- well, let's -- let's talk about that for a minute. Your model only includes pumping from MLGW in Shelby County, right?
A. That's right.
Q. And DeSoto County?
A. Right.
Q. Doesn't include pumping from anywhere else?
A. No.
Q. Now, you know that there is pumping in Shelby County other than MLGW, right?
A. Right.

Q. And you know that there is pumping in Crittenden County, Arkansas, which is right across the river from Shelby County, Tennessee, and DeSoto County, Mississippi, right?
A. Right.
Q. That's not in your model, though?
A. No.
Q. And there is also pumping from the aquifer in Marshall County, Mississippi, which is to the east of DeSoto County, right?
A. That's right.
Q. But there's no pumping in Marshall County represented in your model?
A. Right.
Q. So when you show a cone of depression such as represented on Exhibit P180, it's based on incomplete information, right?
A. No, it's based on complete information with respect to what we were looking -- looking to accomplish. We were only looking to find out what the simulated effects were from MLGW and DeSoto County pumping. It would not be what you measure in the real world. It's only calculations to find out what the effect is from those two pumping entities.
Q. So this Exhibit P80 and the other potentiometric maps that you have drawn, based on your model, do not show what is happening in the real world?
A. No. The real world, it would be bigger. The cone of

depression would probably -- would be bigger.
Q. And the cone of depression in your maps show the combination of pumping of MLGW and in DeSoto County, Mississippi, right?
A. That's right.
Q. So part of this cone of depression in Northern Mississippi -- as you say, it extends down -- is due to the pumping wells that exist in DeSoto County, right?
A. That's right.
Q. And in the real world, it would also show pumping from DeSoto County?
A. I'm not sure what -- I'm not sure what you're asking there, Dave.
Q. The cone of depression doesn't just show the impact of MLGW pumping on this exhibit, right?
A. Right.
Q. It includes the impact of DeSoto County pumping, correct?
A. Right.
Q. And the same would be true for all of the potentiometric maps in your expert report, or that you've talked about, that are drawn or created by your model?
A. Right. And -- yeah, in this 2017 report, that's correct.
Q. Now, the cone of depression -- you talked about this a little yesterday -- the cone of depression that you have used -- that you have modeled, that's centered in Memphis, has

actually been shrinking toward -- over the last years, correct?
A. It's been shrinking somewhat, yes.
Q. That means it's getting smaller?
A. Well, what I -- when I say "shrinking somewhat," I only evaluated MLGW and DeSoto County pumping. So with the -- if the whole world is pumping out there, I don't know what the real world cone of depression looks like and if it's shrunk. But the analysis that we did, looking at MLGW in DeSoto only, there has been a shrinking.
Q. The aquifer in this case is hydrologically connected to surface water, correct?
MR. McMULLAN: Object to the form. Ambiguous.
Q. Mr. Wiley, do you understand my question?
A. Could you ask it again, please.
Q. The aquifer in this case is hydrologically connected to surface water, correct?
A. Yes, it is. It's not directly, but through LEKINS (phonetic) -- through a number of units above the aquifer, there is connection.
Q. And one of the surface water -- one of the surface water rivers that it's connected to, the aquifer is connected to, is the Wolf River, right?
A. The Wolf River -- I get -- is that the one in Memphis?
Q. The Wolf River starts in Mississippi, east of DeSoto County, in Benton County, Mississippi; do you remember where

that is?
A. Yeah.
Q. That's two counties over from DeSoto County. And it flows north into Tennessee, and then through Shelby County and enters -- empties into the Mississippi River. Do you remember the Wolf River now?
A. Yeah.
Q. And that's one of the rivers that the aquifer is connected to, right?
A. Yeah, the -- it flows through the outcrop of the Memphis Sparta Sand.
Q. In Mississippi and in Tennessee?
A. Yes.
Q. And the aquifer also discharges ultimately into the Mississippi River, right?
A. It ultimately discharges into the river or the alluvial aquifer.
Q. So the Mississippi River would be another surface river that is hydrologically connected to the aquifer?
A. With respect to discharge, yes.
Q. Now, the water that we've been talking about in the aquifer, the groundwater that you talked about yesterday with Mr. McMullan and this morning with Mr. McMullan, that groundwater is moving, right?
A. Yes. Very slowly, but it's moving.

Q. It's always been moving, right?
A. Oh, yes.
Q. So there is a constant amount of water -- there's water constantly moving and recharging into the aquifer, right?
A. Yes.
Q. And there is groundwater constantly discharging out of the aquifer, right?
A. That's right.
Q. But there is always a volume of water beneath, for example, DeSoto County, right?
A. Right.
Q. In the aquifer?
A. In the aquifer.
Q. And you have testified before that the change in the volume of water beneath DeSoto County at any given time has changed very little since pumping began over 100 years ago, right?
A. Right.
MR. D. BEARMAN: Mr. Taylor, could you pull up Exhibit P168.
Q. Mr. Wiley, I believe you talked about this figure yesterday, did you not?
A. Yes.
Q. This is Figure 9 from your 2017 expert report, correct?
A. Yes.
MR. D. BEARMAN: And it's labeled Exhibit P168, your

Honor.

Q. Now, this map shows predevelopment conditions in the aquifer at issue here, correct?

A. That's right.

Q. Now, what I want to make sure --

MR. D. BEARMAN: Your Honor, may I approach?

THE COURT: Yes, you may.

Q. Just want to make sure we're all on the same page.

This is the state line, correct?

A. Yes.

Q. And I'm pointing to the line that's on the southern edge of the pink and the northern side of the yellow, correct?

A. Yes, that's the state line.

Q. Okay. I just want to make sure we're all on board with that.

All right. So part of the aquifer is north of the state line, right?

A. Yes.

Q. And part of the aquifer is south of the state line, right?

A. Right.

Q. The pink area on your map is an outline of the City of Memphis, correct?

A. Yes.

Q. And we can agree that the western -- on the left side of the page, the left side of that pink City of Memphis area,

that's the -- roughly the Mississippi River, correct?
A. That's right.
Q. All right. And west of the Mississippi River, of course, would be Arkansas?
A. Yes.
Q. And so part of the aquifer is also in Arkansas?
A. Yes.
Q. Now, the black curved lines on Figure 9 are lines of equal pressure, correct?
A. Correct.
Q. You talked about that yesterday, correct?
A. Yes. Yes.
Q. And so when you look at a map like this, and you draw the flow lines, you're essentially -- as you go from the right side of that figure to the left side of the figure, those flow lines are going downhill, correct?
A. Yeah. It's slight -- it's based on high pressure to low pressure.
Q. Okay. Now, there are two lines on this figure that are shaded green. Do you see that?
A. Yes.
Q. Those lines start in Mississippi, correct?
A. Yes.
Q. And they go through Tennessee into Shelby County, right?
A. Yes.

Q. And they ultimately go underneath the Mississippi River into Arkansas, right?
A. Yes.
Q. And you have labeled those green lines in the legend "Interstate Flow," right?
A. I see that, yeah.
Q. And you've done that just as you did on the previous drawing we talked about, because those flow paths cross state lines, correct?
A. Correct.
Q. And this is predevelopment, without any influence of pumping?
A. That's right.
Q. All right. Now, there's a yellow triangle. Do you see that?
A. Yes.
Q. And you drew that yellow triangle based on these equipotential lines that you drew, because your opinion is that groundwater from anywhere in that yellow triangle in Mississippi would ultimately flow into Tennessee, correct?
A. Yes, under predevelopment conditions.
Q. So even though you've just drawn two green arrows, you could draw an arrow from anywhere in that yellow triangle, right?
A. That's right.

Q. And they would go into Tennessee?
A. That's right.
Q. And you have labeled that yellow triangle "Area of Limited Natural Flow from Mississippi to Tennessee," and then in parentheses, "Interstate Flow," correct?
A. Yes, that's what it says.
Q. I want you to take a look at those three blue lines at the top of the page. Do you see those?
A. Yes.
Q. Those lines start in Shelby County, Tennessee, correct?
A. Correct.
Q. And you have labeled them "Intrastate Flow," correct?
A. That's right.
Q. But those lines flow -- actually leave Tennessee and go into Arkansas, right?
A. Yes.
Q. So those would also be interstate flow lines, right?
A. Right. I believe I labeled them "Intrastate" because they -- I was looking at only Tennessee, where they started. That was the logic there.
Q. All right. But they're interstate --
A. Yes.
Q. -- as you've drawn them, right?
A. Right.
Q. Correct?

A. Yes.
Q. Take a look at that yellow triangle for me. And you see at the bottom left of your figure, you have a scale about -- about miles. And based on what I'm looking at, it looks like roughly an inch is equal to six miles. Do you see where I'm talking about?
A. Yes.
Q. If you look at that yellow triangle that you drew, Mr. Wiley, it appears to me that that yellow triangle goes roughly two and a half miles down into Mississippi. Do you agree with that?
A. It looks about right.
Q. And it stops shy of the Marshall County/DeSoto County boundary by about two and a half miles, right?
A. Right.
Q. And just to be clear, the boundary between DeSoto County -- that would be the eastern boundary of DeSoto County -- and the western boundary of Marshall County, is the light gray line that passes through that little arrow pointing toward the yellow triangle, correct?
A. Yes.
MR. D. BEARMAN: Judge, I'm happy to come and point that out. I want to make sure everyone can see it.
THE COURT: I can see it.
MR. D. BEARMAN: Thank you.

THE COURT: You've got a pointer, don't you? You've got a pointer that's working its way up there.

MR. D. BEARMAN: Well, it's always good to have a pointer, Judge. It's my wireless pointer.

THE COURT: It's a good one.

MR. D. BEARMAN: We can put that down, Mr. Taylor. Thank you.

BY MR. D. BEARMAN:

Q. Now, part of your work on this case, you actually performed particle tracking, correct?

A. Yes.

Q. And you talked about that earlier in your direct testimony, correct?

A. Yes.

Q. Particle tracking allows a scientist to place a hypothetical water molecule within a groundwater system and follow it through as it moves through the system, right?

A. That's right.

Q. It's another way of showing the flow path direction, correct?

A. Yes.

Q. And you included, I think, your particle tracking in your rebuttal report, correct?

A. Is that what it's called?

Q. Your July 2017 report, Addendum Number --

A. "Addendum." There we go.

MR. D. BEARMAN: Mr. Taylor, will you pull up P184.

Q. All right. Now, this is the figure you talked about earlier, correct?

A. Yes.

Q. And these red lines that you have on this figure are particle tracks showing flow paths of groundwater in the aquifer we're talking about here, right?

A. That's right.

Q. All right. And I -- I don't know if you said it here, but you said in your deposition that you started these flow paths or these particle tracks on the DeSoto County/Marshall County border, correct?

A. That's right.

Q. And that's actually in the outcrop area of the aquifer, right?

A. Yes.

Q. And your first particle track starts about four miles south of the Tennessee/Mississippi border, right?

MR. D. BEARMAN: I'll tell you what: Mr. Taylor, could you blow up that area close to the border. That looks good. Right there. Can you move that up?

Q. So, Mr. Wiley, we're looking now at an enlarged portion of your particle track figure. Do you see that?

A. Yes.

Q. And that very top red line is about four miles from the Tennessee/Mississippi border, right?
A. I don't know. I don't know the scale.
Q. All right. Well --
A. I didn't measure it before you blew it up. I didn't see what the scale was.
Q. Well, you remember in your deposition telling me that you started them at about four miles south?
A. If -- I don't remember, but I -- that sounds -- if I said that, it must have been accurate, then.
Q. All right. If you look at this enlarged portion, do you see the Tennessee/Mississippi state line on this drawing?
A. Yes.
Q. And that is the horizontal line that goes above the word "Southaven," right?
A. Yes.

MR. D. BEARMAN: Mr. Taylor, could you just highlight that for a second, that state line? Just want to make sure we all see what we're talking about. Right.

Q. Is that the state line, Mr. Wiley?
A. It appears to be, yeah, appears to be.

MR. D. BEARMAN: All right. You can take that down. Thank you.

Q. All right. Now, the particle tracks that you started roughly four, five, and six miles down into Mississippi

actually flowed into Tennessee, didn't it?
A. Yes.
Q. All right. Now, this is predevelopment, correct?
A. That's right.
Q. All right. So that's -- those are flow paths that are actually further down in Mississippi than your yellow triangle, right?
A. Based on -- you know, it could be a scaling thing, but it's in the approximate same area. Maybe a little below.
Q. Now, you didn't include particle tracks north of your red lines, but you would agree that if you had done the particle trackings in that area between your top red line and the state border, those would have also crossed into Tennessee, naturally, right?
A. Right.
Q. All right. Now, let's --
MR. D. BEARMAN: We can take that down, Mr. Taylor.
Q. And I want to focus now on the area around the Mississippi River. Now, these are particle tracks that you started in Mississippi and didn't go into Tennessee, right, naturally; is that correct?
A. Could you ask -- I'm not sure what you're asking there, what you're stating there.
MR. D. BEARMAN: Let's take down the enlargement for a minute.

Q. Look at your -- you see your map?
A. Yes.
Q. Are you with me?
A. Yeah.
Q. And what I'm now going to do is ask Mr. Taylor to enlarge those particle tracks toward the Mississippi River.

Do you see the area we're enlarging?

A. Okay.
Q. All right. So these are the particle tracks that had moved across Mississippi. Some of them went into Tennessee and came back, and others just went into this area. Do you see that?
A. Yes.
Q. Now, do you remember, at your deposition I asked you how many of your particle tracks that went toward the Mississippi River crossed over into Arkansas. Do you remember I asked you that?
A. I don't remember exactly what you asked, but I assume that you did ask that.
Q. And when I asked you that question, your answer was "more than half." Do you remember that?
A. Not really, but I remember -- well, I know they do.
Q. You know that more than half of those particle tracks that started in Mississippi cross into Arkansas?
A. I don't know that -- if it's half or 25 percent or 75 percent, but I knew -- know they do cross over the river

there.

Q. All right. Well, in your deposition, on page 1260, I asked you, "Would you say that most of them cross into Arkansas?"

And your answer was "more than half."

A. Okay. Well, I'm looking at this again, and it does look like more than half.

Q. Okay.

MR. D. BEARMAN: Thank you, Mr. Taylor.

Now, would you please, Mr. Taylor, pull up Exhibit P185.

Q. Do you recognize this figure, Mr. Wiley?

A. Yes.

Q. Now, what I want to do is just make sure we're on the same page here. There's two illustrations on this figure. This is from your expert report, right?

A. Yes.

Q. The figure on the left shows the area of the aquifer that we're talking about in this case, right?

A. Yes, it does.

Q. And that figure is one that originally appeared in the expert report of Dave Langseth, Dr. Dave Langseth, who is the expert for Memphis MLGW, correct?

A. Yes.

Q. And then what Dr. Langseth did on -- and he drew those flow arrows, correct, in that illustration on the left?

A. I assume he did, yeah.
Q. And then what Dr. Langseth did was enlarge a section that's in that red square, right, and put that section on the right side of the page?
A. Yes. I remember that.
Q. All right.
MR. D. BEARMAN: Mr. Taylor, will you enlarge that section right there. Thank you.
Q. All right. Now, on this particular figure, the very top arrow, that's a flow arrow, right?
A. Yes.
Q. And this is in the aquifer we're talking about, correct?
A. Yes. Yes.
Q. That top flow arrow was one that Dr. Langseth drew, correct?
A. Right.
Q. You added the four flow arrows below that, correct?
A. That's right.
Q. All right. And what I want to do is look at the top flow arrow that you drew, which is the second from the top. Do you see that?
A. Yes.
Q. All right. That flow arrow -- and this is -- we're talking about groundwater flow in the Memphis Sparta Aquifer, right?
A. Right.

Q. In the Tennessee/Mississippi border area, correct?
A. That's close, yes.
Q. All right. Do you see the state line, Mr. Wiley?
A. Yes.
Q. Your flow arrow starts in Marshall County, Mississippi, correct?
A. Correct.
Q. Now, that's further east than your particle tracks start, correct?
A. Right.
Q. And that flow arrow that you drew goes into Tennessee, correct?
A. Yes.
Q. And it's kind of a sweeping motion through Tennessee, counterclockwise -- it actually goes back into Arkansas, right --
A. Yes.
Q. -- I mean back into Mississippi, excuse me.
Correct?
A. Oh, yes.
Q. All right. So your flow line starts in Marshall County, Mississippi, goes into Tennessee, and goes back into Arkansas -- to Mississippi, correct?
A. Yes.
Q. And then it crosses from Mississippi into Arkansas?

A. Right.
Q. And then back into Mississippi?
A. Yes.
Q. And then back into Arkansas?
A. Yes, it does.
Q. And back and forth between Mississippi and Arkansas a few more times, right?
A. Right.
Q. Now, I want you to take a look at -- do you see where your arrow started, that we just talked about?
A. Yes.
MR. D. BEARMAN: Mr. Taylor, I would like you to draw a line from that point to the beginning of Dr. Langseth's arrow. Thank you.
Q. Do you see the -- that by drawing that line, Mr. Wiley, we've created kind of a parallelogram area?
A. I -- I see where the line's almost parallel to the state, yeah.
Q. Right.
A. The state line.
Q. Right. If you had drawn flow arrows starting anywhere in that area above the red line and below the state border of the Mississippi, those flow arrows, that natural flow of the groundwater and the aquifer, would also have gone into Tennessee, correct?

A. Yeah, if you draw the lines perpendicular to all those blue potentiometric surface lines, looks like -- without doing it, but it looks like across most of that area, yes, they -- most of the lines would likely go from Mississippi to Tennessee. There may be -- there may be one or two that might not. I don't know without drawing it.

Q. Most of them would?

A. Yeah.

Q. Okay. Thank you.

You had talked earlier, Mr. Wiley, about your use of the computer model that was created by Brahana and Broshears, correct?

A. Yes.

Q. And that model was created in the -- the '70s and maybe early '80s; is that accurate?

A. Yeah. It was -- it was -- well, there was data calibrated to 1980, so ...

Q. And it wasn't published until much later --

A. Right.

Q. -- but the model was based on, I guess, the technology at the time of the late '70s, early '80s; is that fair?

A. Yes.

Q. The Brahana model consists of three layers, correct?

A. Yes.

Q. And when I say "layers," I'm talking about like a sandwich;

horizontal layers. Correct?
A. That's right.
Q. The second layer of the -- well, and each of those layers go across the entire span of the modeled area, correct?
A. That's right.
Q. And the modeled area in the Brahana model includes Mississippi, right?
A. Yes.
Q. Tennessee?
A. Yes.
Q. Arkansas?
A. Yes.
Q. And some other states also; maybe Missouri, Kentucky?
A. Yes.
Q. Layer 2 of your model, the Brahana model, is the aquifer that we're talking about here in this case, the Memphis Sparta Middle Claiborne Aquifer, right?
A. Yeah. It's -- I believe he -- I believe he labeled it the Memphis Sands in the report.
Q. Right. He labeled it the Memphis Sand in the report, and in your 2017 report you call it the Sparta, but it's the same thing?
A. Yes.
Q. The purpose of the model -- and you said this yesterday -- the computer model, is to simulate real world systems, right?

A. Yes.
Q. And so this computer model of groundwater would be showing you real world system that is underground, correct?
A. Yes.
Q. So in this case, the Brahana model that you used is designed to show what's happening in the real world, in the aquifer that we're talking about here in this case, right?
A. Yes, with respect to MLGW and DeSoto County pumpage.
Q. And we talked about this earlier, but in the real world, there is pumping in Arkansas?
A. Right.
Q. From this aquifer?
A. Yes.
Q. And there is pumping in Mississippi outside of DeSoto County?
A. Yes.
Q. Out of this aquifer?
A. Yes.
Q. And there's pumping in Tennessee outside of Shelby County in this aquifer?
A. Yes.
Q. And there's pumping in Shelby County other than pumping by MLGW, correct?
A. Yes.
Q. But you don't represent any of that in your model?

A. That's right.
Q. So you can't say, as we're sitting here today, whether any of that would make a difference in your opinions, right? You don't know?
A. No, it wouldn't change -- my opinions wouldn't change. I was evaluating what the effects of selected users was. And I ran the model to see what that was.
Q. Without the influence of any other pumping that's been omitted from your model, right?
A. Right.
MR. D. BEARMAN: Your Honor, may I have a minute to consult with my partners?
THE COURT: Sure. We can take a short recess as well. We'll recess for ten minutes.
MR. D. BEARMAN: Thank you.
(Recess)
THE COURT: Mr. Bearman, do you have further questions?
MR. D. BEARMAN: I do not. I'll pass the witness.
THE COURT: Is the State going to ask questions?
MR. HILL: Yes. I haven't spoken much, so I'll just reintroduce myself. I'm Dietrich Hill, and I'll be examining Mr. Wiley for this case.
THE COURT: Sure.

CROSS EXAMINATION

BY MR. HILL:

Q. Good morning, Mr. Wiley.

A. Good morning.

Q. We met before, but I think only at your 2017 deposition.

A. I remember, yes.

Q. Mr. Wiley, Mr. Bearman I think asked if he could just refer to the aquifer as "the aquifer," and you would understand what he was referring to, correct?

A. Correct.

Q. And I'll probably do the same, but I may refer to it as the "Middle Claiborne." Does that make sense to you?

A. Yes.

Q. You'll understand what I'm referring to?

A. Yes.

Q. Now, there was one point from your testimony that I wanted to clarify. I believe you testified at one point, when you were calculating the total diversion, that you had calculated diversion of 411 billion gallons per day?

A. No. A total of 411. Not per day.

Q. Okay. It seemed like a lot.

A. It is. That is a big number.

Q. Yeah.

A. It's not per day, though. No.

Q. That's the total over the -- over 1965 to 2016?

A. Yes.
Q. That you calculated?
A. Yes.
Q. Mr. Wiley, you discussed hydrological connections with surface waters and the aquifer. Do you recall that?
A. Yes.
Q. And I think we've heard testimony about the shallow aquifer. Do you know what I'm referring to?
A. Do you mean the surficial aquifer?
Q. Yes. And that's the aquifer above the Middle Claiborne?
A. Yes.
Q. And separated from it by a confined layer; is that correct?
A. That's right.
Q. And the Fort Pillow is the aquifer below the Middle Claiborne?
A. Separated by a confining layer.
Q. And separated?
A. Yes.
Q. The aquifer is connected to both the surficial aquifer and the Fort Pillow Aquifer, hydrologically connected; is that correct?
A. The Memphis Sparta Aquifer, is that what --
Q. Yes. Yes.
A. Yeah, it's -- there's a hydrologic connection, yes.
Q. Because water can travel through the confining layers?

A. That's right.
Q. And both of those other two aquifers, the Fort Pillow and surficial aquifer, those also underlie multiple states, correct?
A. Well, yeah, the surficial -- there's a surficial aquifer in most places, but it's pretty variable. It's more -- it's more local that -- these are confined aquifers. Surficial aquifers are -- they're all more locally controlled than the confined aquifers.
Q. The Fort Pillow underlies multiple states, right?
A. That's right.
Q. Now, you recall you testified about the Brahana and Broshears model that you used, correct?
A. Correct.
Q. And when you used that -- I believe you testified that you found there was a cone of depression centered in Shelby County and extending into DeSoto County, Mississippi; is that right?
A. That's right.
Q. And that cone of depression also extends into Crittenden County in Arkansas; is that right?
A. I don't -- I didn't talk to that, but there is a -- it would extend out across the river.
Q. Right. I'm asking, does it also extend out across the river into Crittenden County in Arkansas?
A. Yes.

Q. In other words, the pumping in Tennessee is having some effect on the water in Arkansas?
A. Yes.
Q. And the Mississippi River does not prevent that effect from crossing the river into Arkansas?
A. No, because the aquifer goes underneath.
Q. And similarly, it wouldn't affect -- it wouldn't prevent an effect from going the other way, from Arkansas back into Tennessee?
A. That's right.
Q. Now, I believe you testified that your model, based on the Brahana model, uses one layer to represent the Middle Claiborne Aquifer; is that correct?
A. That's right.
Q. And to be clear, the study area of your model is smaller than the entire extent of the Middle Claiborne, correct?
A. Yes. It -- well, to the north, east, and west, if you look at the model grid, it covers most of the Embayment, the northern part of the Embayment, but not the south.
Q. Okay. I put up a slide here, and this is Figure 14 from the 2001 paper; is that right?
A. That's right.
Q. Do you recognize this?
A. Yes.
Q. And this is also, for the record, J15 at page 35.

This is the representation, the extent of the layer of the Middle Claiborne in your model, correct?

A. That's right.

Q. And that's -- that black line that I think we can highlight, that's the representation of the boundaries in your model?

A. Yes.

Q. Now, have you heard testimony -- I believe you have -- about the facies change that occurs in this area?

A. Yes.

Q. And that occurs south of the Mississippi/Tennessee border, correct?

A. Yes.

Q. And would you agree that it's something in the range of 10 to 20 miles south of the border?

MR. McMULLAN: Objection, your Honor. I'm going to renew my objection that this cross-examination is well in excess of the scope of my direct. I think it's improper.

THE COURT: Well, I understand your objection. I'll overrule that, and let's continue.

BY MR. HILL:

Q. I'm sorry, so you agree that that was a reasonable range?

A. Could you -- what did you ask?

Q. Whether the facies change is perhaps in the range of 10 to 20 miles south of the state border between Mississippi and

Tennessee.
A. That sounds about right.
Q. Now, this model's single layer extends quite a lot further south than that; is that accurate?
A. Yes.
Q. In some places it might extend 50 miles south of the border?
A. Yes.
Q. But your model nevertheless represents the aquifer as a single layer throughout that entire grid area, correct?
A. That's right.
Q. And that goes past the facies change or transition zone area, north and south, correct?
A. Yes.
I would add that the aquifer characteristics change as you go south in the aquifer in the model.
Q. Right. But your model does not divide this layer into multiple layers, correct?
A. No. No.
Q. At the facies change or at any other point?
A. No.
Q. Mr. Wiley, do you recall that at your deposition, you and I discussed a calculation that you had made about the amount of water within the Middle Claiborne Aquifer that, under predevelopment conditions, flowed from Mississippi into other

states?
A. Yes.
Q. And I believe we had a discussion about -- you had an 84 percent number in one of your reports; do you recall that?
A. Yes.
Q. And in your deposition, you testified that the way you came up with that number was you found the volume -- this is in the MERAS model, correct?
A. Yes.
Q. That's the 2009 Clark & Hart model?
A. Yes.
Q. And the way you came up with that number is that you calculated under the model the total volume of water leaving the State of Mississippi within the aquifer, correct?
A. Yes.
Q. And then you found the total recharge within the State of Mississippi to the aquifer?
A. Yes.
Q. And then you divided that first number by the second number, and you came up with 16 percent; is that right?
A. Yes.
Q. Do you recall the actual total volume in gallons per day?
A. Not -- no.
Q. That the 16 percent would be?
A. No.

Q. I think we may be able to figure it out from the remainder of your report. In the same report, you also calculated that only 2.6 percent of the total recharge -- that's the same number, correct, the same total recharge?
A. I don't recall those numbers, but that -- if that's -- if that's what you have in the record, I -- I'm sure it is. Without having the information, I just don't know what the number is.
Q. Okay. Well, it might be helpful to just give you your report, if that would help you recall this.
A. Okay.
Q. And I believe -- you can check this in a minute in your report, but I believe --
A. Okay.
Q. -- your report said that you had calculated that 2.6 percent of that same total recharge within Mississippi crossed the border into Tennessee under predevelopment conditions. Does that sound familiar?
A. Yes.
MR. HILL: And I'll just come up, with your Honor's permission?
THE COURT: Yes, you may.
MR. HILL: Does your Honor want a copy?
THE COURT: No, I'm okay.
MR. HILL: Yes. We're looking at pages 6 and 7,

bottom of page 6 and on to page 7.

BY MR. HILL:

Q. And do you see where you calculated that 2.6 percent of the total recharge flowed from Mississippi into Tennessee? Should be at the bottom --

A. I'm on page -- okay, I see it, yes.

Q. And that's the same total recharge that you calculated with respect to the 16 percent, correct?

A. Give me a minute, please.

Q. And if you want to refer to those 16 percent, that's on the next page, is the 84 percent on page eight.

A. Yes. I see that.

Q. And those two descriptions of the total recharge are the same, correct?

A. Yes.

Q. Now, with the 2.6 percent, you also told us that that 2.6 percent was 6 -- well, less than 6 million gallons per day; is that right?

A. Yes.

Q. And that should allow us to determine what the 16 percent was, right?

A. Yes.

Q. And the way we would do that -- and I'm going to put my math up on the slide here, but I'd appreciate it if you'd check it; there's a reason I'm a lawyer, not a scientist -- is that

if you have roughly 6 million gallons per day, being 2.6 percent of the total recharge, that will let us divide 6 by .026 and tell us that the total recharge is about 230 million gallons per day.

And I've got a calculator, if you want to double-check my math.

A. It looks -- that looks reasonable. Based on that small division, you're going to get a big number.

Q. And -- does that look about right, 230 million gallons per day?

A. Yes.

Q. And 16 percent of that would be roughly 36.9 million gallons per day?

A. That -- about 10 percent of 230 would be 23. So 16 percent would be -- yeah, that looks right.

Q. And as I recall, you also testified that you believe that this 16 percent was a reliable estimate of flow under predevelopment conditions, correct?

A. Correct.

Q. So in other words, you thought it was a reliable estimate that under predevelopment conditions, almost 37 million gallons of water was flowing every day from Mississippi into other states?

A. Yes.

Q. And that's all within this aquifer, the Middle Claiborne

Aquifer, correct?
A. Yes.
Q. Now, just for reference, Mr. Wiley, do you recall which layers of the MERAS model you used to do these calculations?
A. I believe it's five -- five through ten.
Q. Five through ten?
A. I believe that was.
Q. And you believe that layers five through ten accurately described the aquifer that you were interested in, correct?
A. Well, they made up the Middle Claiborne Aquifer in the MERAS model.
Q. Layers five through ten?
A. Yes.
Q. In Mississippi as well as in Tennessee; is that correct?
A. Yes. There were different -- some of the layers had different characteristics. Layers five through seven, I believe, were more similar to each other, but then they -- the layers had different characteristics as you got down through eight, nine and ten.
Q. But you believe that all six of those layers together accurately represented the Middle Claiborne Aquifer in Mississippi?
A. Yes.
Q. Mr. Wiley, just to clarify a couple of points. You are not here today to offer any opinion about whether the groundwater

resource at issue in this case is an interstate resource; is that correct?

A. That's correct.

Q. And you don't have an opinion about an -- what an interstate resource would be; is that also correct?

A. That's correct.

Q. And you don't have any opinion about a test that one could use to determine what an interstate resource would be?

A. Could you ask that again?

Q. You don't have an opinion about how one would go about determining whether a resource is interstate; is that right?

A. Not here today.

Q. Are you aware that we're here today because the Special Master ordered a hearing in an opinion in August 2016?

A. Yes.

Q. Are you aware that the Special Master described in that opinion the reason why he was ordering an evidentiary hearing in this case?

A. I don't know all the legal stuff, so I'd have to say my answer would not be -- I'd have to say I don't know, because I don't know all the legal stuff, so ...

Q. And in fact you did not read the Special Master's opinion before you wrote your reports, correct?

A. That's right.

Q. Okay. Mr. Wiley, I think you testified earlier that the

cone of depression centered in Shelby County and extending into DeSoto County, Mississippi, also extends into Crittenden County in Arkansas, correct?

A. Yes. You asked me that -- I think that was the first question you asked me.

Q. That may well be right. I just wanted to make sure I had already asked it.

Now, in your June 2017 report, you said that the Mississippi River creates an effective hydrologic boundary that prevents the drawdown cone of depression from moving past the river into Arkansas. Do you recall that?

A. Yes.

Q. But that was not correct, was it?

A. Well, a river, like an outcrop, can be in a boundary condition in a model.

Q. But you just testified that the cone of depression does in fact move past the river into Arkansas?

A. Yes.

Q. So that sentence in your report was inaccurate, correct?

A. With respect to the -- a cone of depression going into Arkansas.

Q. With respect to this cone of depression going into Arkansas?

A. Yes.

Q. One other point I'd like to clarify. Mr. Wiley, you say

several times in your June report that the Middle Claiborne Aquifer is made of sandstone. Do you recall that?

A. Yeah, I -- yes.

Q. That's not correct, is it?

A. Well, sand is a stone.

Q. It's your view that sand is a stone?

A. Yes.

Q. And that sandstone is the same thing as sand?

A. Yes, in that context.

Q. Were you here on Monday when Dr. Spruill explained the difference between sand and sandstone?

A. Yes.

Q. But you'd disagree with Dr. Spruill on that point?

A. No.

Q. So there is a difference --

A. I was just using that as a -- the term "sandstone" I was using there was not in the same reference as what he was describing.

Q. But the accurate way to describe the substance would be "sand," correct?

A. It -- it's accurate the way I described it, which I take it means the same thing to me, in that report.

Q. In your June report, you also described Figure 9 of your report, which we've seen a number of times today, as the predevelopment potentiometric surface under natural

conditions -- I'm sure you've seen this report -- as the predevelopment potentiometric surface under natural conditions generated by groundwater -- or generated from groundwater modeling. Do you recall that?

A. This map is not. I may have said that, but this map is not from groundwater modeling.

Q. But do you recall saying that in your report?

A. Yes. That was not -- that was not intended in the report.

Q. That was inaccurate?

A. Yes.

Q. Because Figure 9 is not generated by any model, right?

A. No.

Q. And in fact this potentiometric surface was created by Criner & Parks in their 1976 paper, correct?

A. Yes.

Q. And I believe that is J24, for reference.

Do you recall that you made this same exact mistake about whether or not this surface was developed from groundwater modeling in your May 2007 report?

A. I think it was just -- in May 2007?

Q. Correct.

A. Yes.

Q. You made the same mistake?

A. I -- it was the -- that sentence was not accurate.

Q. Okay. But you had about ten years to fix that sentence,

correct?
A. No. Ten years later, the report was updated, but I -- there was a hiatus in the project, so ...
Q. But when you updated the report ten years later, you did not fix the sentence?
A. No.
Q. Mr. Wiley, I think you testified about the calibration of your model. Do you recall that?
A. I -- yes, I testified that the Brahana model was calibrated.
Q. And it was calibrated by Brahana and Broshears, correct?
A. Right, for the period of 1980.
Q. And the point of calibration is to create an accurate hydrologic tool to answer questions about an aquifer?
A. That's -- that's a good way to put it, yeah.
Q. And Brahana and Broshears calibrated this data in 1980. You said that, right?
A. Yes.
Q. Now, there is more recent water level data about the aquifer than 1980, correct?
A. Yes.
Q. There is probably a lot of data, right?
A. I would assume so, yes.
Q. Is it fair to say that calibration with more recent data would improve the model?

A. Models are always being updated and improved where there's data available, yes.
Q. So recalibration with more and more recent data would improve the model?
A. Maybe, maybe not.
Q. It could improve the model?
A. Could.
Q. But you did not recalibrate your model; is that correct?
A. That's right.
Q. Even though you knew there was -- or you could have easily found out whether there was more recent water level data than 1980?
A. Yeah. We wanted to -- we did not want to change what we had from our original -- from the start of the project. We wanted to stick with the same tool.
Q. But the answer is no, you did not recalibrate the model?
A. No.
Q. And earlier you testified that recalibration of the model would or could improve the accuracy of the model?
A. It -- it could.
Q. Okay. Mr. Wiley, I'm going to put Figure 9 back up on the screen. And again, for reference, this is both P168 and D112; both of those exhibits are the same figure.

And you discussed this a little bit already. This map depicts the predevelopment potentiometric surface of the Middle

Claiborne Aquifer, correct?
A. Correct.
Q. And we've discussed that the lines going from more or less north to south, those are the contours that represent lines of equal potentiometric levels?
A. Correct.
Q. And water will flow perpendicular to those lines?
A. That's right.
Q. So in other words, if the line were exactly north to south, the water would flow either exactly east to west or exactly west to east?
A. That's right, depending on pressure differences.
Q. Sure.

Now, I think we already covered this, but I want to make sure. The contours on your yellow triangle map -- do you mind if I refer to this map as "the yellow triangle map"?
A. Everybody has been.
Q. The legendary yellow triangle map.
A. I guess I picked the right color. I don't know.
Q. Yeah.

The contours on this yellow triangle map were prepared by Criner & Parks in their 1976 paper, correct?
A. Correct.
Q. And I would note that this -- this is the map that you used, correct?

A. Yes.
Q. And I would just note for the record that this is also Exhibit P205.
Now, Mr. Wiley, when you say that these contours were prepared by or created by Criner & Parks in 1976, you did not change any of these contours; is that correct?
A. No.
Q. And I believe you testified earlier -- if we could go back to the legendary yellow triangle map -- that this yellow triangle showed that only a very small amount of water was flowing, under natural conditions, from Mississippi into Tennessee; is that correct?
A. Yes.
Q. And you understand that this yellow triangle is important to Mississippi's case, because it shows that only a very small amount of water was flowing across the water under natural conditions?
A. I don't understand your -- what you're asking.
Q. Well, do you understand that Mississippi's theory of this case is that only a very small amount of water was flowing across the border under natural conditions, and now more is flowing across the border?
MR. McMULLAN: Object to the form.
THE COURT: Objection sustained.
Q. Mr. Wiley, you're familiar with how to create estimated

water level maps from observation levels, also called control points, correct?

A. Yes.

Q. And the idea is that you can take known water levels at the control points and estimate the water levels in between them; is that fair?

A. Yes.

Q. And is it also fair to say that the more control points you have, the better you can estimate the water level contours?

A. Yes.

MR. McMULLAN: Object to the form, and improper hypothetical.

THE COURT: Overruled.

You may answer the question.

Q. I believe you answered, but the question was the more control points you have, the better you can estimate water level contours?

A. Yes.

Q. And do you recall Dr. Spruill telling us on Monday in a confined aquifer, if you want to determine a direction of groundwater flow, you need at least three walls?

A. When was that?

Q. That was on Monday. But --

A. I think I was -- I might have missed it, but that's --

Q. Is that a fair statement?

A. Yes.
Q. And the more wells you have, the more accurately you can determine the contours?
A. Yes.
Q. Now, your June 2017 report does not include any discussion of how Criner & Parks created their predevelopment potentiometric map; is that accurate?
A. Yes.
Q. But would you agree that the Criner & Parks paper based its predevelopment surface on four data points?
A. That's -- yes, I read that in their report.
Q. And to your knowledge, Criner & Parks do not have any other data on which they base that map?
A. I -- I don't know if they had any other data. I would assume they did have other data, because they're not going to make -- they're going to -- before they make the map, they're going to check maybe other types of data, to make sure that what they produce fits with the hydrogeologic system.
Q. I'm really asking whether you know whether Criner & Parks had any other data.
A. I don't -- I don't know, but I -- like I said, knowing the USGS, I would assume that they did have other information that -- to guide them in the -- preparing that map.
Q. But you don't know what information that would be?
A. No.

Q. Now, Mr. Wiley, I think you may have already testified that the one thing you did do, you didn't change any of Criner & Parks's contours, but you did extend some of the lines into Mississippi; is that correct?

A. That's correct.

Q. And if we could look back at Criner & Parks's map -- and I made the border a little easier to see on the Criner & Parks figure -- it looks like their map only goes about four miles south of the Mississippi/Tennessee border; is that about right?

A. Maybe five. It's hard to say from that scale. Between four and five.

Q. Between four and five.

And Brahana and Broshears, who also reference this map, they didn't draw contours any further than Criner & Parks did, right?

A. No.

Q. And for reference here, it is, but you already answered.

Now, comparing that to your yellow triangle map, your map extends those lines quite a bit further south; is that fair to say?

A. Yes.

Q. Maybe at least ten miles, probably 15 miles south of the border, right?

A. That sounds about right.

Q. At least ten miles, right?

A. Yes.
Q. Now, you did not have any data that you used to extend these lines, is that correct?
A. No.
Q. You didn't have observation wells or contour points?
A. No. What I used was potential -- predevelopment potentiometric mapping information from Arthur & Taylor.
Q. And I believe you testified at your deposition that that was the 1990 Arthur & Taylor report, is that right?
A. Yes. Yes.
Q. Now, this is the 1990 Arthur & Taylor report as you reproduced it in your June report; does that look correct?
A. Yes, it does.
Q. And for reference, this is P167. And the Arthur & Taylor 1990 report is Joint Exhibit 3.

And the contours that you would have used to extend your yellow triangle extension lines would be the contours all the way in the northwestern corner of Mississippi, correct?
A. It's the blue contours there, just below the state line.
Q. In that --
A. Of Tennessee and Mississippi.
Q. Correct.

MR. HILL: And so I think it would be helpful if we zoom in a little bit. And I've highlighted the borders here to make it a little bit easier to see.

Q. Will you agree that this covers about the same territory or area that your yellow triangle map covers?

A. Pretty hard to tell from that.

Q. If we -- so I highlighted the borders again, your Figure 9, to see if -- it really covers about the same area, correct?

A. Well, I think the -- well, I'm just using the river, the Mississippi River, as my guide on comparing the two, and I'm trying to figure out what's what on the river.

It looks like the -- looks like it needs to be zoomed out a little further.

Q. On the Arthur & Taylor map?

A. Yes, unless I'm -- unless I'm interpreting the shape of the river wrong.

Q. Okay. Well, so I guess then you would say that these lines were some of the lines --

A. It's pretty close; I'll give you that.

Q. At least the area overlaps a fair amount, correct?

A. That's correct.

Q. And the lines, if I could just circle them for a moment, and maybe tilt both of the figures so that the state borders are parallel.

The lines that I've circled are roughly the same lines that you would have used on the left side to draw your lines on the right side; is that --

A. Our main intent was to -- based on the orientation of the

Arthur Taylor lines, to apply that orientation on the existing Criner contour lines.

Q. Mr. Wiley, my question was just whether those are the lines that you would have used to draw your extensions.

A. No. I -- I told you what I did. I used the orientation of Arthur Taylor's map and his lines and to apply to the Criner -- the existing Criner lines, to extend those.

That's all I did. I just used the orientation.

Q. Okay. And you didn't have any data to back up your use of this orientation?

A. That is my data. The orientation of his predevelopment map is my data.

Q. I guess what I'm -- when I say "data," I'm talking about actual observed water levels.

A. No. Just his -- the orientation of his water levels.

Q. If we could look back at the yellow triangle for a moment. And I'll make it a little bigger, so it's easier to see.

Now, again, you testified that this yellow triangle is the only place where groundwater is moving across the state border under natural conditions; is that correct?

A. In our project area.

Q. Within the project area?

A. Yes.

Q. And the triangle ends on the west side, right where the 260-foot contour crosses the state border, correct?

A. Yes.
Q. Would you take a look at the 250-foot contour on this map, which is helpfully laser-pointed.
A. I see it.
Q. Mr. Wiley, that 250-foot contour, where it crosses the border, is not perpendicular to the state border, is it?
A. Not quite, no.
Q. It's not quite perpendicular?
I just want to confirm.
A. Yes.
Q. And it crosses the border at a slight angle, in other words?
A. Right. That's right.
Q. And because of that angle, water at that location is flowing slightly north, right?
A. That would be at that angle, yes.
Q. In other words -- and that location is on the Mississippi/Tennessee border, correct?
A. That's correct.
Q. So there is natural cross-border flow where the 250-foot contour crosses the state line, correct?
A. There would be in this case, yes.
Q. And this is your yellow triangle map, correct?
A. Right.
Q. Now, if you'd look at the 230- and 240-foot contours, those

lines also do not cross the border perfectly perpendicular to the border, correct?

A. It's pretty close.

Q. But not perpendicular?

A. They're a little jagged there, but 240 looks pretty perpendicular.

Q. Would it be --

A. To --

Q. It might be helpful if we look at the original Criner & Parks map. Your contours should be identical to the Criner & Parks contours, correct?

A. Yes.

MR. HILL: And we've blown up the 230- and 240-foot contours on the Criner & Parks map, and could we have perpendicular lines?

Q. So we've drawn lines that are perfectly perpendicular to the border. I think you would agree, would you not, that neither of those lines, 230 or 240 --

A. Not on this map, no.

Q. And your map should have identical contours, correct?

A. Yes.

Q. You did not change Criner & Parks's contours, correct?

A. No. No.

Q. So on your map as well, those two contours, 230 and 240, do not cross perpendicular to the state border?

A. If -- no. If these don't, then mine don't, because I used his map.
Q. Okay. And these don't, correct?
A. Correct.
Q. They are slightly angled?
A. Very slightly. So there would be a small -- small component of flow there, going slightly to the northwest.
Q. You stole my thunder, Mr. Wiley.

There is northward cross-border flow at both the 230- and 240-foot contours, correct?
A. Yes.
Q. And so your yellow triangle -- if we can go back to the full yellow triangle map -- that yellow triangle actually should extend all the way to the 230-foot contour, correct?
A. Yes, it would be -- it would -- that -- if -- those contours not being exactly perpendicular, that looks about right.
Q. And they are not exactly perpendicular, correct?
A. That's what I just said.
Q. Well, I think you said "if," and so I just wanted to confirm. They are not exactly --
A. That's what I -- yeah, I just said that.
Q. And so -- and so you think this version is about right?
A. Yes.

MR. HILL: Those are all the questions I have. Thank

you.

THE COURT: All right.

Do you have redirect?

MR. McMULLAN: Yes, your Honor.

REDIRECT EXAMINATION

BY MR. McMULLAN:

Q. Mr. Wiley, how are you doing?

A. Good.

Q. Okay. Good.

A. I'm ready to ride my bike.

Q. I'm not sure -- as your lawyer, I'm not sure I can advise that, given your history.

A. Now you're siding with my wife.

Q. Mr. Wiley, both Mr. Bearman and Mr. Dietrich asked you to use a shorthand version and just refer to "the aquifer" throughout your cross-examination. They talked about the aquifer, and they talked about the Middle Claiborne Aquifer, talked about the Mississippi Embayment; there's been a lot of different terms used to refer to the aquifer in the testimony in the proceeding so far; would you agree?

A. Yes.

Q. Okay. We talked about the scope of your assignment and your firm's assignment. When you were hired, was your scope of your assignment to determine whether there was a single aquifer underlying Memphis and North Mississippi?

A. No. That was not part of my assignment.
Q. In your initial examination of the literature, which discussed concerns about pumping in Mississippi affecting North Mississippi, did you find variations in reference to the Memphis Sands and the Sparta Aquifer?
A. Yes.
Q. In your reports, did you at times use, for shorthand yourself, a reference to Memphis Sands and Sparta?
A. Yes.
Q. Is that because the scope of your assignment was not to discern whether there was a single aquifer or more than one aquifer?
A. That's right.
Q. And there was some discussion about the fact that there are cones of depression in this area -- project area, if you will -- that exist in Arkansas, for instance; Mr. Bearman asked you about that. I think there was cones of depression in North Mississippi. Do you recall that line of questions?
A. Yes.
Q. In your review of the literature, when you began your assignment, did any of the literature that was looking at the issues of pumping in Memphis and the effects in Mississippi raise any concerns about cones of depression, other than the ones emanating from MLGW -- or Memphis area, more clearly, more accurately?

A. Yes.
Q. My question is this: The literature that you looked at initially, the discussions in the literature about the effects of pumping in Memphis in Mississippi, did those articles indicate any concerns about cones of depression elsewhere?
A. Yes, they did.
Q. Okay. What were they?
A. They -- well, they -- all the USGS reports that I looked at, they were identified as cone of depression that were being created and what -- what the effects would be then and in the future.
Q. What cone of depression are we talking about when you referred to those articles?
A. The cone of depression that emanated from the Memphis area.
Q. Thank you for that clarification.

There's been a good bit of discussion with you about the different maps showing the predevelopment flow. Mr. Hill asked you some questions about it; Mr. Bearman, too. Let's go back to P184. I'm not sure which slide that is. You can pull that one up. It's the MERAS slide, the particle tracking slide. P184? Looks like this.

Just a moment. Slide 17.

Mr. Wiley?

A. Yes.
Q. All this discussion about predevelopment flow, all those

references to flow, would the flow we're talking about be best depicted in P184?

A. It -- it depicts -- it's a good depiction of a good bit of the flow that starts at the DeSoto County line and extends across the state of Mississippi.

Q. So all the questions you've heard that have been put to you about some water flowing into Tennessee, we're talking about over the course of a period of time that's depicted in P184; we're talking about thousands of years. Is that correct?

A. That's correct.

Q. And is it correct that your assignment was to evaluate the effects?

MR. D. BEARMAN: Objection, leading, your Honor.

MR. McMULLAN: I'll rephrase.

THE COURT: Objection sustained. Don't lead the witness.

Q. Do you recall a couple of questions about whether you'd examined the Court's opinion that related to the scope of this hearing?

A. Yes.

Q. Did you -- were you ever asked -- strike that.

In the course of your work as a hydrogeologist, have you ever been asked to examine a definition that's been described by a judge and then try to infer your opinion from that?

A. No.
Q. Did you do that -- in this assignment, did you do that?
A. No.
Q. There were some questions about the extent to which you may have relied upon information developed by others, including USGS. Do you recall some questions about that?
A. Yes.
Q. In your practice as a hydrogeologist, is it standard practice in your experience to rely on data information collected by the USGS?
A. Yes.
Q. With respect to some of the questions you were asked about some mistakes you might have made and not corrected over the course of the 13 years that you've been involved in working on this case, do you recall those questions?
A. Yes.
Q. Did the corrections you made alter any of the fundamental opinions that you reached, conclusions you reached in the case?
A. No.

MR. McMULLAN: That's all I've got.

THE COURT: All right.

Do you have any further cross-examination?

MR. D. BEARMAN: Your Honor, if the Court will indulge us a few minutes so we can talk with cocounsel to determine that?

THE COURT: Okay. We'll have another short recess of ten minutes.

MR. D. BEARMAN: Thank you.

(Recess)

THE COURT: All right. Do you have some further questions?

MR. D. BEARMAN: Your Honor, Memphis and MLGW have no further questions.

THE COURT: Okay.

MR. HILL: Your Honor, Tennessee has no further questions either, but we would like to mark this. It's a slide of -- the final slide we showed.

THE COURT: All right.

MR. HILL: Mark it as D199 and offer it into evidence.

THE COURT: Okay.

Is there any objection?

MR. McMULLAN: No objection.

THE COURT: Give it to my court clerk.

(Defendant's Exhibit D199 received in evidence)

THE COURT: All right. With that, we'll excuse you, I suppose, Mr. Wiley.

(Witness excused.)

THE COURT: Do you have another witness for Mississippi?

MR. ELLINGBURG: Your Honor, with one condition, or

limitation, plaintiff rests. We had indicated that we may call their expert, Dr. Waldron, on -- in our case. And the defendant is representing that Dr. Waldron will be called in their case, so we can examine him at that point in time. Until --

MR. FREDERICK: We can't hear you here.

THE COURT: Speak up, everybody. They've got to hear you.

MR. ELLINGBURG: I'll do it again, and I'll talk louder.

Mississippi and the defendant have discussed the testimony of Dr. Waldron, who is one of their witnesses.

THE COURT: Right.

MR. ELLINGBURG: We had indicated that we might call him in our case, but we were assured that they would put on his testimony during the hearing, and so we are not calling him now. We're resting, subject to completion of his testimony.

THE COURT: Okay.

MR. BRANSON: No objection, your Honor. That is our arrangement. We will be calling Dr. Waldron.

THE COURT: Okay. That's fine. All right.

So that completes the case for the plaintiff?

MR. ELLINGBURG: That completes the case for the plaintiff, subject to the testimony of Dr. Waldron.

THE COURT: Okay. All right.

With that, where do we go from here?

MR. FREDERICK: Your Honor, David Frederick for the State of Tennessee.

I would like to note for the record that we do not understand Rule 50, the Rules of Civil Procedure, to apply in this proceeding, and therefore we are reserving our motion for judgment on the state of the evidence at this time. But to the extent that you perceive there to be a need for us to make a Rule 50 motion, please consider it to be made on the basis of the absence of proof, at least by Mississippi in its case.

THE COURT: Okay. Well, that's the way I anticipate that we would follow it, so we can get on with the testimony. And I'm a Special Master, so it's not likely that I would grant that motion, but it should be filed, and we'll consider it filed. I'll let you argue at a later time that issue.

MR. FREDERICK: Yes. Thank you.

THE COURT: Yes.

MR. L. BEARMAN: I just want to join in on that statement by Mr. Frederick.

THE COURT: All right. We'll have a subsequent time in which we will hear argument on that. Your motion is preserved.

MR. FREDERICK: Thank you, Judge Siler.

The State of Tennessee would like to call Steven Larson to the stand.

THE COURT: All right.

STEVEN LARSON,

called as a witness by the Defendant State of Tennessee, having been duly sworn, testified as follows:

DIRECT EXAMINATION

BY MR. FREDERICK:

Q. Good morning, Mr. Larson. Would you please state your name for the record.

A. My name is Steven P. Larson.

Q. Mr. Larson, where do you work?

A. I work in Bethesda, Maryland.

Q. For what firm?

A. The firm of S.S. Papadopulos & Associates, Incorporated.

Q. If I refer to it as SSP&A, will you understand that?

A. I will.

Q. And what is SSP&A?

A. We're a consulting company that provides consulting services in the environmental area and also in -- with respect to water resources.

Q. What is your position there?

A. I'm a vice president.

Q. How long have you worked there?

A. Thirty-nine years.

Q. What is your area of expertise?

A. I'm a hydrologist, but I've worked almost all my career

basically in groundwater hydrology. So groundwater hydrology is the focal area of my work.

Q. Where did you work prior to SSP&A?

A. I worked for the Water Resources Division of the United States Geological Survey.

Q. If I refer to that as "USGS," will you understand to what I'm referring?

A. I will.

Q. How long did you work at USGS?

A. I worked at the USGS for about nine years.

Q. What was your position at USGS?

A. I was a hydrologist.

Q. And what did that position entail?

A. Initially it entailed conducting various kinds of water resource investigations in Minnesota, Minnesota office of the USGS. Later on in my work there, I was transferred to the headquarters of the United States Geological Survey in Reston, Virginia, and conducted research primarily in the development of computer simulation models.

Q. Could you briefly describe your education, please.

A. I have a bachelor's degree in civil engineering from the University of Minnesota I obtained in 1969. And I also have a master's degree in civil engineering, also from the University of Minnesota, that I obtained in 1971.

Q. Do you belong to any professional organizations?

A. Yes, I do.
Q. Which ones?
A. I belong to the American Institute of Hydrology, and also to the National Groundwater Association.
Q. Have you written about groundwater hydrology and modeling?
A. Yes, I have.
Q. And why are you here today?
A. I'm here today to provide a technical answer or response to the Special Master's question that he posed, that I understood to be the purpose of this hearing.
Q. And what did you understand the purpose of the hearing to be?
A. To answer the question of whether or not the Middle Claiborne Aquifer was an interstate water resource.
Q. Okay. Are you being compensated for your work as an expert in this case?
A. Yes, I am.
Q. What is your rate of compensation?
A. It's varied from about $308 per hour to about $316 per hour.
Q. Does the compensation you receive depend in any way on the opinions you render in this case?
A. It does not.
Q. Does the compensation you receive depend in any way on the outcome of the case?

A. It does not.
Q. Have you previously given expert testimony in litigation in connection with your work at SSP&A?
A. Yes, I have.
Q. How many times have you testified before a judge or a Special Master or in arbitration?
A. Over 50 times.
Q. Okay. Have you previously served as a hydrological expert in interstate water disputes in the Supreme Court of the United States?
A. Yes, I have.
Q. In what cases?
A. I've been an expert in the case between Colorado and Kansas on the Arkansas River. I've been an expert in the case between Kansas and Nebraska that included Colorado on the Republican River. I was involved in the case between Nebraska and Wyoming associated with the Platte River. I've been involved in the case between Montana and Wyoming on the Yellowstone River. And I've also been involved in the case between North Carolina and South Carolina on the Catawba River.
Q. Did each of those cases involve either an equitable apportionment or a claim for a breach of an interstate compact?
A. Yes, they did.
Q. Did you testify about groundwater in any of those cases?
A. Yes, I did.

Q. In how many of them?
A. Three, and to some extent four.
Q. Could you briefly describe your testimony in each of those cases.
A. In the case of Kansas vs. Colorado, or Kansas and Colorado, associated with the Arkansas River, one of the issues was the impact of groundwater development from the aquifer -- aquifers along the Arkansas River and the impact of that development on stream flows. So my work involved both the modeling of those impacts and also the evaluations of stream flow conditions.

In the case between Kansas and Nebraska associated with the Republican River, my work involved the development, along with experts from the other states, of a groundwater model. The purpose of the groundwater model was to provide a way to estimate how the impacts of pumping from the Ogallala Aquifer impacted stream flows in the Republican River, because the stream flows were regulated by the compact.

In the case of Nebraska versus Wyoming, initially I did a little bit of work on some -- on some groundwater modeling issues. Ultimately the work that I reported on dealt with evaluations of stream flow conditions along the river.

In the case of Montana versus Wyoming, I was asked to develop estimates of the potential impacts of water production associated with coalbed methane development on stream flows in the Tongue River, which is a tributary to the Yellowstone

River.

Q. Have you previously served as a hydrological expert in any nonoriginal jurisdiction cases involving the effects of groundwater use?

A. Yes.

Q. Can you give us some examples?

A. Well, one that comes to mind is in the -- what's called the Hueco Bolson -- Bolson, B-O-L-S-O-N. It's like a basin.

And this is a groundwater area that extended from Texas into New Mexico. And I was asked as part of that matter to evaluate the impacts of future groundwater development -- or the availability, I should say, of water to meet certain demands in the State of Texas. The City of El Paso was asking for permits from the State of New Mexico to develop groundwater into Mexico, and I was asked to evaluate the impacts of potential development within Texas.

Q. Thank you. Can I ask you to turn to Exhibit D154 in your binder, please.

Is this the most up-to-date copy of your curriculum vitae?

A. Yes, it is.

MR. FREDERICK: Your Honor, we offer Mr. Larson as an expert in the field of groundwater hydrology.

THE COURT: Is there any objection to that?

MR. ELLINGBURG: No, your Honor.

THE COURT: All right. He is so identified and may testify as such.

MR. FREDERICK: Thank you, your Honor.

BY MR. FREDERICK:

Q. Mr. Larson, have you prepared a report in this case?

A. Yes, I have.

Q. Could you turn to Exhibit D197 in your binder.

Is that an accurate copy of your expert report?

A. Yes, it is.

Q. What date was it submitted?

A. June 30, 2017.

Q. What was your process in putting that report together?

A. Well, the first step was to make sure I understood what the focus of my inquiry was, and that was to read over the report of the Special Master in which he posed a question that I understood to be the subject of this hearing. And understanding that question, I then undertook to begin reviewing various documents and reports that would bear on answering the question of whether the Middle Claiborne Aquifer was an interstate water resource.

I also evaluated -- or collected or evaluated -- and evaluated certain data that was available from the US Geological Survey. And then, basically relying on that information and my experience and expertise, I prepared the report.

Q. Did anyone assist you in preparing the report?
A. Yes.
Q. What will -- who was that?
A. Alex Spiliotopoulos.
Q. Okay. And what role did he perform?
A. He assisted me in gathering up information, reports, and documents. He also assisted me in terms of reviewing my drafts of the report, to help me edit and evaluate my report.
Q. What did you rely on in developing your expert report, other than the materials you cited?
A. Well, I relied on my -- my training as an engineer specializing in hydrology and my many years' experience working in the field of hydrology.
Q. Are all of the sources that you relied on in developing your report listed in your report?
A. Yes, they are.
Q. Is there anything in your report that you no longer believe to be true?
A. No.
Q. Have you prepared any other reports in this case?
A. Yes, I have.
Q. Could you turn to Exhibit D198, please.
What is that?
A. This is a rebuttal report that I prepared.
Q. When was that submitted?

A. July 31, 2017.
Q. What was your process in putting that together?
A. Well, the first step was to review the expert reports that had been prepared by experts for the State of Mississippi. Having -- and after completing -- reviewing those reports, I then went back to some of the documents and reports that I had previously examined and looked at other documents, and also looked at other data that was available to me from the US Geological Survey.
Q. Did anyone assist you in preparing the rebuttal report?
A. Yes.
Q. Who?
A. Alex Spiliotopoulos, Dr. Spiliotopoulos.
Q. How did he assist you?
A. In the same fashion -- he assisted me in this report in the same fashion that he did in the earlier report, helping me gather and collect documents and information and gather data and helping me edit and review the draft of the report.
Q. Are all of the sources that you listed in developing your rebuttal report listed in that report?
A. Yes, they are.
Q. Is there anything in your rebuttal report that you no longer believe to be true?
A. No.
Q. Now, Mr. Larson, I'd like to talk about the background on

aquifers. I believe that you refer to this aquifer as the Middle Claiborne Aquifer; is that correct?
A. Yes.
Q. Why do you call it the Middle Claiborne Aquifer?
A. Well, in reviewing the various reports, one of the most recent reports by the US Geological Survey in the development of the Mississippi Embayment Regional Aquifer System model looked to me to be the most recent characterization of the hydrogeology of this area, so I followed the terminology that they developed in that report.
Q. And remind us: What is the US Geological Survey?
A. US Geological Survey is the federal agency that -- among their other tasks, one of their tasks is to monitor and evaluate the water resources of the United States. They're a very key agency in collecting water resources data and conducting water resource investigations.
Q. What is groundwater?
A. Groundwater is the water that occurs beneath the land surface in the zone that's fully saturated with water. So below the land surface, you'll eventually encounter a zone where the rock or the sediments are completely saturated. That's the groundwater zone.
Q. Is there a name for that zone that is saturated?
A. Well, if it's sufficiently permeable, it can be called aquifer.

Q. Okay. What is an aquifer?
A. The sort of technical definition of an aquifer is it's a formation or a group of formations that are sufficiently permeable that they can provide usable quantities of water to wells.
Q. Okay. I'd like to ask you to turn to Figure 1 from your opening report. This is Exhibit D197, and PDF page ten. It's up on the screen.
What is that a figure of?
A. This is a diagram I obtained from the US Geological Survey website.
Q. Could you briefly explain to Judge Siler how water flows through an aquifer and how that relates to the water cycle.
A. Yes. The water cycle, or it's sometimes referred to as the hydrologic cycle, is one which exhibits all the different facets of how water circulates within the environment. That is, evaporation from lakes and streams and rivers goes into the atmosphere. It then falls back to earth via precipitation and ice and snow. Some of that water infiltrates into the ground, and some of that infiltration will reach groundwater, the saturated zone. And once it reaches the groundwater, it will begin to move from places to what we call recharge, where the groundwater originates, toward places of discharge, where the groundwater will leave the subsurface.
Q. When water infiltrates into the ground, does it always

remain in a single aquifer?
A. No. It will move through the subsurface, and it can go from one aquifer to another, for example, or from one aquifer through a confining unit into another aquifer.
Q. Is there a name given when there are multiple aquifers?
A. It's often referred to as an aquifer system.
Q. Are there other terms that are used?
A. Or hydrogeologic system.
Q. So if I use "hydrologic system" or "aquifer system" interchangeably, do you understand them to mean the same thing?
A. Yes.
Q. Now, I show you what has been marked Exhibit J4.
What is that?
A. This is a report from the US Geological Survey, by Arthur & Taylor, in 1998. It's the cover page of that report.
Q. Let's turn to Plate 2, which is J4 at PDF page 61 from that paper. And I'm going to put it up on -- it's up on the screen.
Can you tell us what this is, please.
A. Yes. This is a subsurface profile illustrating the different hydrogeologic units that comprise the Mississippi Embayment Aquifer System. The profile begins in the northern areas, north of Kentucky, and extends down through Tennessee and into Mississippi. So basically running from a northeasterly to southwesterly direction is the alignment of it, and then we're kind of looking at what the subsurface looks

like from the side.
Q. Does this figure depict an aquifer system?
A. It does.
Q. So can you explain again what an aquifer system is, perhaps using this figure.
A. Yes. An aquifer system is basically the collection of hydrogeologic units that are interconnected in some fashion to one another and to make -- they can be also interconnected to surface streams. And so you'll have these different layers, somewhat like layers of a cake, that comprise different hydrogeologic units. And collectively, they are the hydrogeologic system.
Q. What is a hydrogeological unit?
A. Hydrogeologic units are usually -- are principally defined based on permeability characteristics. The more permeable characteristics, formations or groups of formations that have more permeable characteristics, are aquifers, are characterized as aquifers. Those formations or groups of formations that have lower permeability characteristics can be defined as confinement units, to indicate their sort of less permeable characteristic.
Q. And can you describe briefly how hydrogeologic units are positioned in an aquifer, or how an aquifer is positioned in a hydrogeologic unit.
A. The aquifers will represent -- or the aquifer --

hydrogeologic units that are aquifers will represent more extensive areas of the permeable materials. They can be overlain, and they will have a geographic extent over some region. They can be overlain by other aquifers or other hydrogeologic units that are characterized as aquifers, or they can be overlain or underlain by less permeable hydrogeologic units that have been characterized as confining units.

Q. Now, a few minutes ago you described it as like layers. Can you describe -- explain what you mean by a "layer."

A. A layer would be the geographic extent and delineation of a particular hydrogeologic unit. Like, for example, here, the Middle Claiborne Aquifer. It would depict -- or that would be one of the layers, if you will, of the aquifer system.

If there are other hydrogeologic units that have been identified and their areal extent has been delineated, they would also be then represented, depending on where they -- where they were, let's say, physically relative to one another in the aquifer system.

Q. Are the geologic materials within a layer homogeneous?

A. No. They will vary from one place to another.

Q. Now, let's look at this figure. Is this figure to scale?

A. No, it's not.

Q. How is it not to scale?

A. The vertical scale has been greatly exaggerated, as it says on the bottom of the chart. And the reason for that is to

allow us to be able to see and visualize the various hydrogeologic units much better.

Q. Okay. Is the Middle Claiborne Aquifer depicted on this picture?

A. Yes, it is.

Q. Is it the area that's been highlighted in yellow?

A. Yes.

Q. Okay. Is the Middle Claiborne Aquifer a hydrogeologic unit within the Mississippi Embayment?

A. Yes, it is.

Q. Do you see the pink highlighted layers labeled "Confining Units"?

A. Yes.

Q. Can you explain briefly what a confining unit is.

A. As I mentioned earlier, in looking at hydrogeologic units, those units that are less permeable, and therefore water moves through them less easily than it will move through an aquifer, so they represent lower permeability materials, and the extent of those on permeability of materials would -- or can be delineated as a confining unit from a -- in terms of the hydrogeologic unit perspective.

Q. Are there any other names for these layers, other than "confining units," which you just used?

A. Sometimes they're referred to as "confining beds." Sometimes you may hear the term "aquitard" instead of

"aquifer." And that's meant to -- it's not used that much, but it's meant to illustrate the less permeable characteristic of the confining units.

Q. Are the terms synonomous?

A. Yes.

Q. Is water able to flow through these confining layers?

A. Yes.

Q. Now, can you describe how that happens.

A. Well, the confining units, as I said, are -- tend to be areas of less permeability. When the groundwater is flowing through the aquifers, in order to, say, move from one aquifer to another, however -- where it may be separated by a confining unit, it would have to move generally vertically and pass through the confining unit. And because of the permeability, it's a little more difficult for water to move through these confining units.

Q. Now, I'd like to turn to water flow patterns in different kinds of aquifers. We have a demonstrative here. Do you recognize this demonstrative?

A. Yes, I do.

Q. How was it prepared?

A. It was prepared under my direction.

Q. Does this demonstrative show confining units?

A. It does.

Q. How does it show them?

A. It shows one confining unit at the top of what we've identified as a confined aquifer, and it shows another confining unit beneath the aquifer, establishing a -- the upper and lower boundaries of the confined aquifer.
Q. So the confined aquifer is between the two confining units?
A. Yes.
Q. Now, can you explain to Judge Siler what a confined aquifer is.
A. A confined aquifer is one in which the potentiometric level -- you may hear it referred to as "potentiometric head"; you may hear it referred to as "groundwater level." But it's basically the potentiometric level of water within the aquifer, would -- that potentiometric level would rise to an elevation that's above the bottom of the overlying confining layer. In that respect, it's confined.
Q. So just so that we're clear, is there a confining unit located above or on the sides of a confined aquifer?
A. Confining units are located above the aquifer.
Q. Okay. Is there a name for the level -- but not on the sides?
A. Not on the sides.
Q. Okay. Is there a name for the level to which water will reside -- will rise inside a properly drilled well in a confined aquifer?
A. Yes. It's often referred to as the potentiometric level,

or potentiometric elevation, or it could simply be referred to as the water level in the well.

Q. What factors contribute to the potentiometric level in a well?

A. There are two factors. One is the elevation of the point at which the pressure in the confined aquifer is being measured, and the other is the pressure in the confined aquifer at that position.

Q. Okay. Now, I see there's depicted on this figure a well screen. What is a well screen?

A. A well screen is a -- represents opening -- the well is basically a pipe that's going into the ground, and at the end of that pipe there will be openings that will allow the water in the aquifer to enter the pipe. A well screen is a -- is a specifically designed mechanism for allowing -- for creating those openings and allowing the water to come in and out of the pipe.

Q. This figure also has words called "water table." Can you describe what a water table is.

A. The water table is the point beneath the ground surface where you first encounter fully saturated conditions. It's basically -- at the top of that water table, the water is at atmospheric pressure, or roughly atmospheric pressure, and that's basically the level that the water surface exists in the -- unconfined aquifer.

Q. In this figure, what is the green area below the blue line labeled "Water Table"?
A. That tends to represent an unconfined aquifer that does not have a confining unit above it, that would serve to create a confined aquifer.
Q. What is an unconfined aquifer?
A. An unconfined aquifer is an aquifer that contains the water table. So the water table would exist in an unconfined aquifer, and that's why we call it unconfined -- well, call it unconfined because there is no confining layer that would meet the definition of a confined aquifer; but it has the water table as the upper surface of the aquifer.
Q. And what happens if you drill a well into an unconfined aquifer?
A. The water level will rise to a certain level, oftentimes or most of the time near the water table.
Q. Now, using this figure, how does one determine the head or potentiometric level of a well?
A. The way it's determined is you first measure the depth to the water surface that would be in the well. So you -- you measure from the top of the well down to the water surface that is in the well. And then you take that value, and along with the elevation, the topographic elevation, if you will, of the top of the well, you compute the potentiometric elevation, which is the potentiometric level associated with that water

level in the well.
Q. And I'd like to show you a demonstrative -- this will be Slide 5.
Do you recognize this demonstrative?
A. Yes, I do.
Q. And what is it?
A. This is a -- I prepared this to illustrate how data from wells, in terms of the potentiometric elevation measured in those wells, is used to construct a potentiometric contour map and to infer the general directions of groundwater flow from that contour map.
Q. How is it prepared?
A. It was prepared under my direction.
Q. Okay. what does it show, generally?
A. It shows the steps that we undertake to -- typical steps that we undertake to -- how we go about constructing the potentiometric contour maps, and examining general path lines of groundwater flow.
Q. Let's start with Step 1. What does Step 1 depict?
A. Step 1 depicts the locations with the little crosses on them where we have a well where there's a measurement of the potentiometric elevation.
Q. And what's the difference between the head of a well labeled 2,480 feet and the head at 2,750 feet?
A. The numbers represent the potentiometric elevation measured

in that particular well, calculated in the fashion that I described earlier.

Q. So this is --

A. And --

Q. Just so the record is clear, the 2,750 is the number of feet above sea level?

A. Right. These are elevations relative to a datum. Typically the datum is sea level.

Q. Okay. What does Step 2 depict.

A. Step 2 depicts a generalized way that we would interpolate between these locations where we actually have measurements, to estimate approximately where a specific value of the potentiometric elevation would exist between each of the two points.

Q. What do the red numbers represent?

A. The red numbers are labeling locations between two points where particular elevations are estimated to occur. For example, as between the center point at 2,440 and the point near the right-hand -- lower right-hand area at 2,230, along that line we would estimate approximately where an elevation of 2,400 would occur and where an elevation of 2,300 would occur. And we would do that for the other lines connecting these points as well.

Q. Okay. What does Step 3 show?

A. In Step 3, we would interconnect the line -- via the line,

locations where the potentiometric elevation has the same value. So the contour line would represent a line along which potentiometric elevation is the same. Much like a topographic contour on a topographic map.

Q. Is there a name for those lines?

A. Well, they're referred to as "contour lines," but they could be called "potentiometric contour lines" as well.

Q. What does Step 4 represent?

A. In Step 4, we're trying to illustrate how we would use the information from the potentiometric contour map to infer directions and pathways of groundwater movement.

Q. So the -- I'm sorry. I didn't mean to cut you off.

So what do the blue lines show?

A. The blue lines are constructed -- are perpendicular to the red lines. The red lines are the potentiometric elevation contours. And we construct lines perpendicular to those contours to illustrate the average direction of groundwater flow, going from higher potential to lower potential.

Q. And when you say "average direction," what do you mean by that?

A. Well, if you actually look at individual molecules of water as they go through the subsurface, they will wiggle back and forth and go around sand grains or whatever. But there will be a general tendency to migrate in a certain -- or to move in a certain direction, and that's what these lines would represent.

Q. Now, I want to return back to the water cycle illustration. This is D197, Figure 1, at PDF page 10.

Is this flow within the aquifer occasional, or does that always happen?

A. This always happens. It's 24/7. The water is recharged into the ground, and it begins a journey toward places of discharge.

Q. And can you remind us where the water that's flowing through the aquifer comes from?

A. It comes from infiltration at the land surface, either from rainfall falling on the ground, or from snow melt, or from seepage out of streams or other surface water bodies. That infiltration goes into the ground, and some of that infiltration will reach the groundwater environment.

Q. Can you give us some examples of infiltration, and is the word "recharge" associated also with infiltration?

A. The portion of the infiltration that reaches the groundwater we would refer to as recharge.

Q. Okay. So can you give us some examples of this recharge effect?

A. Recharge is where, like I said, the infiltration and precipitation and other forms of surface reach the groundwater, and then they begin moving through the groundwater environment toward places of discharge.

Q. Can you explain how discharge works from an aquifer?

A. Discharge is basically the emergence of the groundwater into other bodies of water, say, on the land surface that could be seepage into a low-lying area. It could be seepage -- or seepage and flow to a spring, for example; that's the emergence of groundwater on the surface. It could be seepage into a water body, such as a lake or river, or it could ultimately go to the ocean and discharge into the ocean.

Q. Okay. When do discharge and recharge occur?

A. They occur all the time.

Q. Now, what happens to the water in the aquifer if the rate of recharge and discharge are roughly the same?

A. When the rate of recharge and the rate of discharge are roughly in balance, if you look at the potentiometric levels in the area where that condition exists, you will find that the potentiometric levels, elevations will remain relatively stable, indicating that there's a balance between recharge and discharge.

Q. Does the particular water within an aquifer change?

A. Yes. The water is moving through that zone, but the potentiometric levels remain relatively stable.

Q. And what happens if the rate of recharge and discharge are different?

A. If there's either an increase or a decrease in either one of those, the response will be that the potentiometric levels would change. They will either go up or down, depending on

whether the recharge was higher than the discharge or vice versa.

Q. Now, I'm showing you a figure from J40. This is at PDF page 35. What does this depict?

A. This depicts the effects of using wells to pump water on either a confined aquifer or a confined aquifer.

Q. Now, let's discuss the figure on the right. What does that represent?

A. This is depicting the conditions associated with pumping water out of a well where the well is completed in a confined aquifer.

Q. What happens when pumping begins at a particular location?

A. When the pumping from a well begins, what happens is that the water level in the well will drop, so the potentiometric level will drop. That will cause water to move toward the well from the area around the well to that point where the ground -- where the potentiometric level in the well has been lowered.

Q. Can you explain where the original potentiometric head can be seen on this figure?

A. Yes. If you look at the -- toward the top of the face of this block, and there's a horizontal dashed line that goes across, that's to illustrate where the initial potentiometric level was before the well started pumping.

Q. Can you explain where a decline in potentiometric head can be seen on this figure?

A. You can see that there's a curved line beginning at each side of the face of this, and it curves toward the center and downward into the well. And so it -- that represents the potentiometric levels associated with the area around the well when the well is being pumped.

Q. Okay. Now, that line I think that you were referring to is called "drawdown." Is that the term commonly used to describe this phenomenon?

A. Yes. "Drawdown" is the term that we use to reflect the difference between the potentiometric level that existed when the well was not pumped to the potentiometric level that would exist when the well is being pumped.

Q. Does the confined aquifer remain fully saturated when drawdown occurs?

A. Yes.

Q. Now, how does that happen?

A. Because the water level has not been drawn down below the top of the aquifer, and so the aquifer itself still contains -- is fully saturated with water. And the water begins to move toward the well.

Q. Now, what do the arrows in the confined aquifer at the base of the figure represent?

A. Those arrows are intended to depict how the water would move toward the well when the well is pumped and the water level in the well has been lowered by the pumping.

Q. Why does the water flow toward the well?
A. The well -- the water level in the well, it becomes the lowest point in terms of potentiometric elevation in the surrounding area, the area surrounding the well, and the water removed from the areas of higher potential to areas of lower potential, so it begins to move forward into the well, and then it's withdrawn.
Q. And what happens to the potentiometric head as you move away from the pump?
A. The amount of drawdown in the potentiometric level decreases generally within a radial pattern around the well, so as you get further and further away, the amount of drawdown associated with the pumping is less and less.
Q. Is there a name for that drawdown pattern?
A. The overall extent of drawdown impacts is sometimes referred to as the cone of depression.
Q. Can you explain what that looks like in three dimensions.
A. Three dimensions kind of looks like an upside-down cone, or I heard one description of a funnel, which is characterizing it as somewhat circular in nature. Because it's sort of radially around the well, so it looks like sort of an upside-down code.
Q. What affects the shape of the cone of depression?
A. The hydraulic properties of the aquifer. For example, its permeability characteristics or its storage characteristics -- "storage coefficients", we call them -- as well as the pumping

rate from the well.
Q. And what about the location of the well? Does that affect the cone of depression?
A. Yes, that will be the center part of the cone of depression.
Q. Is there any way to avoid having a cone of depression when pumping?
A. No. In order to utilize the resource and pump groundwater, you have to pump it out of the ground, and you essentially have to create a cone of depression.
Q. Is a cone of depression inherently bad for an aquifer?
A. No. I mean, that's how you get the water out of the ground.
Q. What year did pumping begin in the Middle Claiborne Aquifer?
A. In the Memphis area, you're referring to?
Q. Yes.
A. In about 1886.
Q. Okay. And how does one refer to the period before pumping?
A. Before pumping, it would be referred to as a period before development, or predevelopment.
MR. FREDERICK: Your Honor, I'm just about to go into his opinions. Would you like me to go into his -- in introducing his opinions in the case at this time?
THE COURT: Okay. Well, we can break for lunch, if

you wanted.

MR. FREDERICK: I'm happy to keep going. I just wanted to go to your schedule.

THE COURT: Okay.

MR. FREDERICK: How about if I just introduce what the opinions are, take ten or so minutes to do that, and then we have a --

THE COURT: I'm fine then.

BY MR. FREDERICK:

Q. Mr. Larson, would you briefly explain why you're here today?

A. I'm here today to address the question that the Special Master raised, that I understood to be the purpose of this hearing, to determine whether or not the Middle Claiborne Aquifer is a regional -- or is an interstate water resource.

Q. What do you consider an interstate aquifer or interstate water resource to be?

A. Well, first of all, it would be a single hydrogeologic unit that exists over multiple states and across state boundaries. And it would also -- also -- it would also be something that could -- another factor, I guess, would be one that it is interconnected to other interstate resources, such as other interstate aquifers or streams and other surface water bodies.

It would also -- it would also be one where groundwater is moving through it; the groundwater is not

static, and it's migrating to places of recharge and discharge, and it's not going to stay in one place.

Q. Now, you began that explanation by talking about -- I think you used the words "single hydrogeologic unit." Does the single unit also have to be continuous, in your opinion?

A. Yes. It would be a single continuous unit that would extend over multiple states.

Q. Okay. How does your -- does your definition of an interstate aquifer include both the water and the geological material?

A. Yes, it would include both of those, because together, the geologic materials and the water are what make an aquifer.

Q. Okay. If you took the water out, what would you have?

A. You would just have a geology of the geologic materials.

Q. Okay.

A. You would not have an aquifer.

Q. Have you used your definition of "interstate aquifer" in other disputes?

A. Not formally. But obviously I've been involved in other disputes where interstate resources were the subject of those disputes.

Q. Applying the understanding that you just gave us of an interstate aquifer, have you developed an opinion about whether the Middle Claiborne Aquifer is an interstate aquifer?

A. Yes, I have.

Q. What is that opinion?
A. In my opinion, the Middle Claiborne Aquifer is an interstate water resource.
Q. What are the bases of that opinion?
A. Well, the first one, as I said, is it is a single continuous hydrogeologic unit that spans multiple states; in this case, eight states.
Q. Okay. Does this accurately reflect the first basis for your opinion?
A. Yes, it does.
Q. And what was the next basis?
A. That the -- this hydrogeologic unit is interconnected -- hydrogeologically interconnected to other resources, both aquifers and to surface water bodies which are also interstate in nature.
Q. Okay. Does this accurately reflect the second basis of your opinion?
A. Yes, it does.
Q. What was the next basis of your opinion?
A. That the -- that the water is not static; that it's moving from places of recharge to discharge. So it's not going to permanently stay in one place.
Q. And does that opinion change whether it's predevelopment or postdevelopment?
A. No.

Q. Why is that?
A. Because the issue is whether the -- the groundwater within the aquifer is interconnected, and that interconnection will allow water to move either under natural conditions or under pumping conditions through the aquifer.
Q. And are there any other bases for your opinion that the Middle Claiborne is an interstate aquifer?
A. Well, the other basis that I have is that when you look at the work that the US Geological Survey has done collectively, in my opinion, they recognize the regional nature of the Middle Claiborne Aquifer and the need to understand and evaluate that aquifer on a regional basis that would extend across state boundaries or other political boundaries.
Q. And does this accurately reflect the fourth basis for your opinion?
A. Yes, sir, it does.
MR. FREDERICK: Your Honor, I'm about to go into a long segment about the single hydrogeological unit. May I suggest that this would be a good time to break before we move into that section.
THE COURT: Okay. Court will be in recess to 1:30.
(Luncheon adjournment)

AFTERNOON SESSION

1:32 P.M.

THE COURT: All right, Mr. Frederick.

MR. ELLINGBURG: Your Honor, before we commence, if I could, I'd like to introduce Don Kilgore, who's here on behalf of the Attorney General's Office of the State of Mississippi.

THE COURT: All right. Glad to have you.

You may proceed.

MR. FREDERICK: Thank you, Judge Siler.

And welcome back from lunch, Mr. Larson.

BY MR. FREDERICK:

Q. When we left off for lunch, you had just gone through the four bases for your opinion, and you'd gotten through all four in introducing them. So what I'd like to do now is take the first one in order and go through them in more detail.

You testified that one of the bases of your opinions was that the Middle Claiborne is a continuous hydrogeological unit that extends beneath eight states. Can you explain what you mean by that.

A. Well, it has continuity over these areas in terms of its character and physical properties. It has continuity over the area in terms of the ability of groundwater to move, as illustrated by potentiometric contours; there's a continuity to those.

And that when you look at the effects of groundwater

development, that you can see the continuity and the effects of those in terms of propagating from one area to another within the aquifer.

Q. So before we get too far into your analysis, I'd like to briefly discuss some nomenclature. Let's put Exhibit J18 -- this is the Clark & Hart 2009. And can you tell us what this is?

A. This is the cover page of the report by Clark & Hart of the USGS in 2009, documenting their development of the groundwater flow model called MERAS.

Q. And did you rely on this in formulating your expert opinion?

A. Yes. This is one of the documents that I reviewed.

Q. So let's turn to Table 1, which is at PDF page 15 of this document. Can you tell us what this is.

A. Yes. This is a table that shows the correlation between hydrogeologic units and model layers that have been identified for use in this report and how that correlates with other names that these various hydrogeologic units may be referred to.

Q. Okay. And what is the column second from the right entitled?

A. That column is the hydrogeologic -- identifies the hydrogeologic units.

Q. Can you remind us again what a hydrogeologic unit is?

A. Hydrogeologic units are distinguished mainly on the basis

of the permeability characteristics; that is, the more permeable units, hydrogeologic units, would be distinguished as aquifers; the less permeable hydrogeologic units would be distinguished as confining units. Or -- confining units.

Q. And is this how the USGS classifies hydrogeological units?

A. Yes. Looking at groundwater flow characteristics, they want to use this kind of a classification.

Q. Does the permeability have to be the same throughout the layer?

A. No, it does not.

Q. And why would it be important for the USGS to identify different hydrogeological units?

A. Because they're trying to understand the nature of groundwater flow within the overall system and how that groundwater flow might be affected or modified by the different hydrogeologic units; that is, aquifers or confining units that exist within the overall system.

Q. So this table lists the aquifers in confining units in the Mississippi Embayment Regional Aquifer System; is that correct?

A. Yes.

Q. Okay. Is the Middle Claiborne Aquifer identified as a hydrogeologic unit?

A. Yes, it is.

Q. Okay. I'd like to highlight that.

And is that the highlighted area depicted on the table

now?
A. Yes.
Q. Okay. Why does it say "Lower Claiborne Aquifer" in that part of the Middle Claiborne Aquifer hydrogeologic unit?
A. Well, portions of the Middle Claiborne Aquifer in some areas add characteristics that are considered to be more of a confined unit character. And so they are distinguishing that in areas where that might exist, they're referring to sort of a subunit of the aquifer as the Lower Claiborne Aquifer.
Q. In your opinion, is the Lower Claiborne Aquifer part of the same hydrogeological unit?
A. Yes, I believe it is.
Q. Okay. Why do you think that?
A. Because there's no barrier to interconnection between the two units. In other words, they're all -- well, groundwater can flow from one unit to the other, laterally, within the system.
Q. Now, why does the -- do you know why the USGS sometimes refers to this using different names, this section?
A. Well, I think they're trying to subdivide the hydrogeological units into things that they can then use to assemble into their overall evaluation of groundwater flow, including development of the groundwater model.
Q. Okay. And what information is contained in the columns immediately to the left of the one that we were just looking

at?
A. In the columns to the left?
Q. Yes.
A. Yeah, these are geologic names that are used at various times and in various places that correlate with the hydrogeologic units they've identified for purposes of this report.
Q. What regional names are included for the Middle Claiborne Aquifer?
A. Well, you can see that the Memphis Sand and the Sparta Sand are -- are referred to, at least as regard to portions of the Middle Claiborne Aquifer. There's also the Meridian Sand.

So you can see a number of different descriptors, geologic descriptors, of those units -- those formations that are part or within the Middle Claiborne hydrological unit.
Q. These are all names for the same hydrogeologic unit?
A. Yes. They're trying to show the correlation between those names and the hydrogeologic unit that they've identified.
Q. Are there any other names used for the Middle Claiborne Aquifer?
A. Well, it's sometimes referred to the Memphis Sand or the Memphis Sparta Sand, or sometimes it's referred to as the 500-Foot Sand.
Q. Okay. So when we were hearing testimony earlier in this hearing about the 500-Foot Sand, that is the same aquifer as

what we were calling the Middle Claiborne Aquifer?
A. Yes.
Q. Okay. Are you aware of any other aquifers where the name varies in different regions?
A. Yeah. This is not uncommon. Often when you have layered systems like this, there will be variations in names, especially between the hydrogeologic unit characterization and, say, the geologic formation characterization.
Q. I'd like to turn your attention to Figure 14G of this same exhibit. This is J18 at PDF page 37.
What does this show?
A. This is a map from Clark & Hart, 2009 report, and it depicts sand content within a portion of the Middle Claiborne Aquifer over the area of the Mississippi Embayment Regional Aquifer System.
Q. What is the thick brown line, labeled as "Model Area" on this map, show?
A. That represents the boundary of the Middle Claiborne -- Mississippi Embayment Regional Aquifer System that they were investigating -- that they are investigating.
Q. And what's the thinner black line immediately around the shading of the map?
A. That represents the extent of the Middle Claiborne Aquifer within what's called Layer 7 of the model.
Q. How does the geographic extent of the Middle Claiborne

Aquifer compare with the Mississippi Embayment?
A. It's slightly smaller than the extent for the Mississippi Embayment.
Q. What states does the Middle Claiborne extend beneath?
A. You can see it extends from Kentucky and Illinois and Missouri up on the north to Tennessee and Arkansas at the center and Mississippi and Arkansas further down, and then at the very south end, Louisiana and Alabama.
Q. Okay. Are there any barriers to water flow in the Middle Claiborne that prevent groundwater from flowing laterally across the aquifer?
A. No, there are no barriers there.
Q. And would you consider it to be an interconnected hydrogeologic unit?
A. Yes, I would consider it to be interconnected.
Q. Can you describe the composition of the geological matrix of the middle Claiborne?
A. Yes. It's predominantly a sandy environment, but it can have interbedded layers of silt or less permeable materials. But the bulk of it is sand or sand and gravel.
Q. Okay. Can you explain what the different colors of brown represent.
A. On this map, the different colors of brown represent the different amounts as a percentage of the sand content at different locations throughout the area.

Q. Mr. Larson, how do you tell that the Middle Claiborne and the water in it is hydrogeologically continuous?
A. By looking at maps like this that describe the character of the materials over the geology -- the geographic area, and the continuity of those materials.
Q. Are the hydrogeological properties of the aquifer important in determining the continuity for your purposes?
A. Yes, because you need to understand the continuity of the -- not only the characterization, like we see here, of the amounts of sand, but also the continuity in terms of the characteristics of permeability and the storage factors associated with the aquifer.
Q. Okay. And what about potentiometric surfaces and water levels? Is that factor important to determining hydrogeological continuity?
A. Yes. The mapping of the potentiometric contours illustrates continuity of the potentiometric levels within the aquifer, but also is illustrative of the groundwater flow patterns that exist within the aquifer.
Q. Are pumping effects important to determining the hydrogeological continuity of the aquifer?
A. Yes. Pumping effects are important in terms of demonstrating the degree to which pumping effects spread and are continuous throughout the aquifer.
Q. So let's talk about each of these factors. Are the

hydrological and geological properties of the Middle Claiborne the same throughout the aquifer?

A. No, they're not the same. They'll vary from place to place.

Q. And does that -- do those differences affect your conclusion about the hydrogeological continuity?

A. No, because they are just reflecting variations in the property that don't represent barriers to safe flow, or the effects of pumping, for example.

Q. Is that typical of aquifers?

A. Yes, the aquifers are more permeable units that are geographically distinguishable.

Q. Okay. And can you explain what you mean by "hydrogeological properties that extend"; what does that mean in the context of a large regional aquifer like this?

A. That as you go from place to place, you have this area, you'll be able to look at the permeability and characteristics and the storage characteristics to show that it is a continuous unit from the standpoint of its character.

Q. Do the state lines have any effect on the hydrogeological properties of the Middle Claiborne Aquifer?

A. No, as you can see on this particular slide, state boundaries do not have an influence on these patterns.

Q. What does this figure demonstrate to you about the continuity of the geological composition of the sand?

A. It illustrates their continuity in the -- the occurrence of the sand within -- at least within this portion of the Middle Claiborne Aquifer throughout the area.

Q. In the Mississippi/Tennessee border region, does the percentage of sand vary?

A. Well, the map illustrates that along that Mississippi/Tennessee border area, that there's a very high sand content; it's between 81 and 100 percent. And while there's some variation, it extends from considerably north -- that level of sand percentages extends from very north of the border to significantly south of the border.

Q. How does this figure inform your opinion about the area of the aquifer that Mississippi is calling the Mississippi Sands in Tennessee?

A. Mississippi Sands --

Q. Sorry, sorry, sorry. Let me start that over.

How does this figure inform your opinion about what Mississippi has called the Memphis Sands in Tennessee?

A. Well, this illustrates that the Memphis Sands in Tennessee has a very high sand content and is -- that sand is continuous going into Mississippi.

Q. How does it inform your opinion about what Mississippi is calling the Sparta Sand in Mississippi?

A. This diagram illustrates that that also has a high sand content, and that sand content extends -- the high sand content

extends into Tennessee.
Q. Does the similarity in the sand content influence your judgment about the identification of the Middle Claiborne Aquifer as a hydrogeological unit?
A. Yes, that's one of the factors that is -- are used to define the hydrogeological units.
Q. Does the sand composition affect the permeability of the aquifer?
A. Again, the sand itself tends to be in the more permeable range of things. So that permeability is what helps to distinguish that hydrogeologic unit as an aquifer.
Q. And is the 81 to 100 percent sand composition relatively permeable?
A. It should be relatively permeable, yes.
Q. Okay. And what does that say to you about the movement of water in that kind of sand composition?
A. That the characterization of it as an aquifer that can conduct water reasonably readily is an appropriate one.
Q. Did you consider the continuity of any other hydrogeological properties of the Middle Claiborne Aquifer?
A. Well, I considered the -- I looked at variations in hydraulic conductivity and transmissivity, as was described in here, and then I also looked at the continuity of potentiometric elevations and groundwater flow.
Q. How are those properties affected by state boundaries?

A. The state boundaries don't have an influence on the continuity of those kinds of characteristics.
Q. Let's turn to your second point, that the potentiometric surfaces and water levels within the Middle Claiborne continue across state lines without interruption.
Let's put up Exhibit J7. This is Schrader 2008 -- sorry, J71. So the record is clear, this is Exhibit J71.
What is this?
A. This is a potentiometric surface map of the Middle Claiborne. It's on -- on here it's called the Sparta Memphis Aquifer, over the Mississippi Embayment Regional Aquifer System, and it's potentiometric levels that are contoured over that region.
Q. Okay. And what does the map show about those potentiometric surfaces in the Middle Claiborne and the relationship to state boundaries?
A. Well, you can see that there's a continuity across the state boundaries, and the state boundaries do not disrupt the patterns of the contours as they -- as you cross the boundaries.
Q. And how does that relate to your conclusion about -- that the Middle Claiborne Aquifer is an interstate aquifer?
A. Well, it demonstrates that there is groundwater movement going from areas of recharged places of discharge, and so the water is moving, and that the state boundaries don't disrupt

that movement.
Q. And you can tell that by looking at these potentiometric lines?
A. That's correct.
Q. Okay. Now let's turn to the point about pumping, and how pumping in one area of the Middle Claiborne affects the water in the other.
Is there pumping in the Middle Claiborne Aquifer?
A. Yes, there is.
Q. And do you know -- what do you understand the angle of the wells in Tennessee to be?
A. My understanding is that they're vertical wells; that they go vertically down into the earth.
Q. Okay. And what happens to the potentiometric surface in the aquifer around those vertical wells?
A. Well, when the wells are pumped, as we've talked about earlier, the potentiometric levels will be drawn down, and cones of depression will develop around the wells.
Q. Now, looking again at this Schrader map, what do the light gray areas on the map represent?
A. They represent the general areas of cones of depression, or overlapping cones of depression, in different parts of the aquifer.
Q. So roughly how many different cones of depression do you see depicted on this map?

A. I think they mention about 20, if I remember correctly, something like that, some small and some larger.
Q. So 20 cones of depression in the Middle Claiborne is -- are depicted on this map?
A. Yes, I think so.
Q. Okay. Now, can you tell us a little bit more about the geographic extent and the effect on the potentiometric surface from a cone of depression around Memphis in the Middle Claiborne?

Let's expand that. This is the same Schrader 2008 map.

Can you identify -- does the circle represent where Memphis is, roughly?
A. Yes, it does.
Q. Okay. And then does pumping in Mississippi create a cone of depression?
A. Yes, it does. It creates overlapping cones of depression.
Q. All right. And in this gray area depiction, does the cone of depression cross state lines?
A. Yes, it does.
Q. Which states does it cross?
A. As depicted on here, it crosses into Mississippi, and it also crosses to the south, and it also crosses over into Arkansas to the west.
Q. Okay. And I believe you said that pumping in Mississippi

creates a cone of depression. Did I get that right?
A. Pumping in Mississippi?
Q. Yes.
A. Yeah, pumping around any well will create cones of depression.
Q. And would the cones of depression by pumping in Mississippi extend into Tennessee?
A. Yes, it can.
Q. Okay. And how would that happen?
MR. ELLINGBURG: I'm going to object to him continuing to testify about what can, might be, could, would. None of that's --
THE COURT: I understand that's not the case. You can go further on that. Overruled.
MR. ELLINGBURG: And I have a continuing objection to that.
THE COURT: You may.
MR. ELLINGBURG: Thank you.
A. Can you repeat the question?
Q. Sure. And I'll rephrase it.
Do the cones of depression from Mississippi pumping extend into Tennessee?
A. Yes.
Q. Okay. And do the cones of depression extend across other state boundaries in the Middle Claiborne Aquifer?

A. Yes.
Q. Can you show us, using this diagram on the Mississippi/Louisiana border, does this depict any cones of depression extending across state boundaries there?
A. Yes, it does.
Q. Can you explain that further to Judge Siler.
A. Yes. As you can see, there's a cone of depression that's developed in Mississippi that extends over to and slightly into Louisiana to the west. And water flow has been altered in that area toward a cone of depression in Mississippi.
Q. Now, let's look at the Arkansas/Louisiana border. What is shown there?
A. This is another overlapping -- a series of overlapping cones of depression.
Q. And do those cones of depression affect water flow across state boundaries?
A. Yes, they do.
Q. What do those cross-border cones of depression reveal about the extent of the Middle Claiborne Aquifer?
A. Well, they demonstrate to me that there is continuity in these physical properties that allows these cones of depression to spread, and to spread beyond state boundaries.
Q. Mr. Larson, were you in the courtroom when Mississippi's experts testified?
A. Yes, I was.

Q. And you heard Mississippi's experts testify about the facies change in the Middle Claiborne Aquifer, correct?
A. Yes, I did.
Q. Did that feature have any effect on your conclusion that the Middle Claiborne is a single continuous hydrogeological unit extending beneath multiple states?
A. No, it does not.
Q. What is a facies change?
A. A facies change is a gradual -- typically a gradual change in the character of the materials as you move from one place to another. It will go from, say, a more coarse-grain type of material and transition over some distance into a more fine grain.
Q. What is your understanding of the facies change in the Middle Claiborne Aquifer?
A. That there is an area, at least within portions of the Middle Claiborne hydrogeological unit, where the character transitions from a more coarse-grain type of material to a more fine-grain type of material.
Q. Let's look at Exhibit J4 and page 61, the north/south cross-section from Arthur & Taylor depicting the Mississippi Embayment.

Is the highlighted area forming a two-pronged shape the Middle Claiborne Aquifer?
A. Yes.

Q. How is the facies change we've been discussing depicted in this figure?
A. Well, you can see in between the columns of the forks, you'll see this gray area extending from the left to the right, with sort of a fuzzy edge on it on the right-hand side. That's -- that area, general area, is where the facies change occurs.
Q. Now, if I highlight in pink, does that help to show exactly what you're talking about?
A. Yes. And if you look at the right-hand side of that pink area, over to the east, you'll see the jagged line indicating there is a transition from a more permeable material, Middle Claiborne Aquifer material, changing over into a less permeable material that's then characterized as a confining unit.
Q. And what does the jagged line -- what does that represent?
A. I think that -- well, my understanding is it represents the transition, and there's not a sharp boundary where it changes from one to the other.
Q. Does the Middle Claiborne Aquifer extend both north and south of the facies change?
A. Yes, it does.
Q. Is the Lower Claiborne Confining Unit in the key the lateral flow of groundwater within the Middle Claiborne Aquifer?
A. No.

Q. Can you explain why?
A. Because when you look at the aquifer materials, the more permeable materials, there is continuity to those above and below the Middle -- the Lower Claiborne Confining Unit, and that continuity will allow water to flow one way or the other above the facies change or below the facies change. And the effects of pumping on one side or the other can be transmitted across that area from one place to another.
Q. Is there any impediment to water flowing in the Middle Claiborne from the top prong above the confining unit and into the handle of the -- of what we've got on yellow there?
A. No. They are both aquifer-type materials, and so they flow more readily back and forth across that area.
Q. Can water flow from the bottom fork of the Middle Claiborne?
MR. ELLINGBURG: Object. Objection to form. He's calling for speculation with respect to the "can."
THE COURT: Well, I understand that.
MR. FREDERICK: Your Honor, he's --
THE COURT: I understand.
Go ahead.
BY MR. FREDERICK:
Q. Does water flow, in your expert opinion, Mr. Larson, from the lower prong of the Middle Claiborne Aquifer to the larger portion of the Middle Claiborne Aquifer?

A. Yes.
Q. Does water flow from the upper part of the Middle Claiborne past the facies change to the larger section of the Middle Claiborne Aquifer?
A. Yes.
Q. Does water move in either direction, depending on hydrogeological characteristics, in the manner that I just described?
A. Yes, depending on those characteristics.
Q. Okay. Now, can a cone of depression -- or does a cone of depression, caused by pumping north of where the confining unit is, extend into the aquifer south of the confining unit?
A. Yes, it will promulgate through that area from one side or the other.
Q. And what about vice versa?
A. And vice versa.
Q. Okay. Is the potentiometric level in the Middle Claiborne continuous across the facies change?
A. Yes, it is.
Q. How do you know that?
A. By looking at maps that have been prepared that depict potentiometric levels within the Middle Claiborne aquifer.
Q. Are there any differences in the physical characteristics of the Middle Claiborne on opposite sides of that transition?
A. Well, there are variations throughout the aquifer, but

basically it tends to be predominantly sand on one side and predominantly sand on the other side.
Q. Are the naming variations related to the areas of the aquifer north and south of facies change?
A. Are there naming variations? Is that what you're asking?
Q. Yes.
A. Yes, there are.
Q. What are they?
A. Well, typically, to the north, it's referred to, say, as the Memphis Sand, perhaps, or the Memphis Aquifer, or the 500-Foot Sand. Toward the south, it may be referred to as the Sparta Sand; that upper portion could be referred to as the Sparta Sand.
Q. Are the Memphis Sand and the Sparta Sand separate aquifers?
A. No, they're all part of the hydrogeologic unit that's been defined as the Middle Claiborne Aquifer.
Q. Did you hear Dr. Spruill testify that the Memphis Sand and the Sparta Sand are separate aquifers within the Middle Claiborne?
A. Yes, I did.
Q. And do you agree with that?
A. No, I think they are part of the overall hydrogeologic unit that is the Middle Claiborne Aquifer.
Q. Okay. And why do you have that conclusion?
A. Because there's a continuity in terms of the materials and

the ability of water to move within those areas from one to the other, from one area to the other.
Q. Now, if you could assume just for the moment that there are two separate aquifers called the Memphis Sand and the Sparta Sand within a larger formation, would that change your analysis?
A. No, because there's continuity.
Q. Okay. And when you say "continuity," explain exactly what you mean by that in terms of water flow.
A. It means that there's not a -- a barrier between where it's being called one thing and where it's being called another thing that would prevent water flow from moving from one to the other, or prevent the effects of pumping from being transmitted across the place where the name change is being used, in either direction; either from one -- say, south to north or north to south.
Q. Now, Mr. Larson, can you consider for a moment just the part of the aquifer that Mississippi has been referring to as the Memphis Sand. In your opinion, is that an interstate aquifer?
A. Yes, it is.
Q. Now, why do you believe that the Memphis Sand, as conceived by Mississippi, is an interstate aquifer?
A. Because it covers multiple states, or it underlies multiple states.

Q. What states does what Mississippi calls the Memphis Sand lie beneath?
A. Well, it would lie between portions of Mississippi, portions of Tennessee, portions of Arkansas.
Q. Okay. Any other states?
A. Probably Kentucky as well.
Q. Okay. Mr. Larson, can you consider for a moment just what Mississippi has been calling the Sparta Sand: Is that an interstate aquifer?
A. Yes, I believe it is.
Q. And why do you believe what Mississippi has called the Sparta Sand an interstate aquifer?
A. Because in the table that we looked at earlier, you can see that there are several states where that terminology is being used, the Sparta Sand.
Q. And what states does what Mississippi calls the Sparta Sand lie beneath?
A. My recollection was it was Mississippi, portions of Arkansas, and Louisiana. I don't remember if it got down to Alabama or not.
Q. Okay. Is the area below the Lower Claiborne Confining Unit sometimes called by different names?
A. Yes, it is.
Q. What are those names?
A. One of them is called -- well, it's referred to as the

Lower Claiborne Aquifer hydrogeologic unit, or subunit, within the MERAS; but it's also referred to as the Meridian Sand, at least in some areas.

Q. Okay. Is the Lower Claiborne Aquifer separate from the Middle Claiborne aquifer?

A. No, I don't believe so.

Q. What does that tell you about the nature of the Middle Claiborne Aquifer?

A. That its extent covers -- well, that it's in hydraulic communication with these other areas that have been given other names.

Q. And when you say "hydraulic communication," what do you mean by that?

A. I mean that there's no barrier that presents flow from going from one to the other, or prevents the effects of pumping from being transmitted from one to the other.

Q. How does this relate to your conclusion about the Middle State -- or, sorry, about the Middle Claiborne Aquifer?

A. It relates to that in the fact that this illustrates the continuity of these aquifers and the actual materials throughout the Mississippi Embayment Regional Aquifer System.

Q. Does it support your conclusion that the Middle Claiborne is an interstate aquifer?

A. Yes.

Q. Let's move to the second basis of your opinion. What is

that?
A. That the Middle Claiborne Aquifer is hydraulically and hydrologically interconnected to other aquifers and other hydrogeologic units and surface water within the Mississippi Embayment Regional Aquifer System.
Q. Let's look at J19, which is at PDF page 21, the Clark & Hart -- well, let's first start with the first one. Let's look at J19.

Can you identify what that is?
A. This is the cover page of a report by Clark and others in 2011. It's another USGS report that I reviewed.
Q. Okay. And let's turn to Figure 6, which is J19 at PDF page 21. What does this depict?
A. This is sort of a three-dimensional cutaway of the subsurface environment and the surface environment extending to the north from an area just south of the Louisiana/Arkansas border. And it's cut away to illustrate the different hydrogeologic units and the flow patterns under the predevelopment scenario.
Q. What do the white arrows on this figure depict?
A. They illustrate how the groundwater would move under the predevelopment condition; that is, prior to any pumping, how it would move from areas of recharge to areas of discharge.
Q. Do those arrows depict movement through the confining layers?

A. Yes, you can see the arrows pointing from either side of the Embayment, east side to the right and the west side to the left, migrating within the aquifers for -- or the flow within the aquifers for some distance, and then curving up and discharging into the central part of the Embayment through other aquifers and confining units, ultimately discharging into the alluvial aquifer in the Mississippi River.

Q. What do the black arrows show?

A. The black arrows are intended to depict recharge areas -- areas where there is recharge to the groundwater system.

Q. Okay. What effects can pumping in one aquifer have on water in an adjoining aquifer?

A. Well, the pumping will reduce the potentiometric levels in the aquifer that's being pumped. That will also alter the flow patterns between the aquifers. And for example, if groundwater prior to the pumping was flowing upward from one aquifer -- the pumped aquifer to an overlying aquifer, the pumping could reduce those flows into the other aquifer, or even reverse the flows.

Q. Okay. I believe you earlier testified that there were multiple aquifers in the Mississippi Embayment.

A. Yes.

Q. Are there -- other aquifers in the Mississippi Embayment, are they also interstate aquifers?

A. Yes.

Q. How do you know that?
A. Well, for example, you can look on here. You can see that the alluvial aquifer, which is the lighter-colored area at the top of the diagram, you can see how it goes from Louisiana, an extension of Louisiana into Mississippi and up into Arkansas and portions of Tennessee and Missouri and on up. So it underlies multiple states as well.
Q. I'm showing you Figure 2. Let's look at Exhibit J19 and PDF page 16. This is Figure 2 from the same exhibit.
What does this depict?
A. This is a figure from the Clark and others 2011 USGS report, and it illustrates various streams, surface water features, throughout the Mississippi Embayment that are hydrologically connected to the sub -- the regional aquifer system.
Q. Can you remind us what the thick brown line is?
A. That's the extent of the Mississippi Embayment Regional Aquifer Study.
Q. Okay. Are the rivers hydrologically interconnected with the Middle Claiborne Aquifer?
A. Yes, they are.
Q. How do you know that?
A. By looking at the different layers -- or the different units, and how they're positioned relative to one another and how they are then related to the surface streams; that is, in

portions of the area, the surface streams, they go across the outcrop area of the Middle Claiborne Aquifer. They will also flow across portions of other aquifers, such as the alluvial aquifer, and the Middle Claiborne Aquifer is hydrologically connected in this system to that alluvial aquifer.

Q. Is it like what you were showing with the water cycle demonstrative or figure?

A. Yes.

Q. What rivers in the area around Memphis are interconnected with the Mississippi Embayment?

A. You can see the Wolf River, for example, that begins in Mississippi, over to the right-hand side, and flows generally westward across this into Tennessee, and then goes over and eventually discharges into the Mississippi River.

That's -- that's one of them.

Q. Are there any others?

A. Well, there are others that go into the outcrop areas, but not right near that boundary.

Q. Okay. But in your view, does that affect the interconnection between the surface rivers and the aquifer?

A. No. These -- these various rivers will be interconnected with various portions of the regional aquifer system, including the Middle Claiborne Aquifer.

Q. How does the flow pattern of the Wolf River affect your conclusion that the Middle Claiborne Aquifer is an interstate

resource?
A. Well, you can see that the Wolf River begins in Tennessee and flows across the Mississippi/Tennessee -- or border into Tennessee. So it is an interstate resource, and it is inter -- hydrologically interconnected with the Middle Claiborne Aquifer. And that supports -- that in part, anyway, supports my conclusion.
Q. How is the Wolf River hydrologically interconnected with the aquifer?
A. Well, there are portions of the river where seepage from the river provides recharge to the Middle Claiborne Aquifer, and there are portions where groundwater discharged from the Middle Claiborne Aquifer can go into the Wolf River.
Q. How is the Mississippi River interconnected with the Embayment and the Middle Claiborne Aquifer?
A. Well, the Mississippi River goes down the central portion of the Embayment and is connected, for the most part, to the alluvial aquifer. And as we've seen in some of these diagrams about how the various hydrostatic -- hydrogeologic units are interconnected, there is a hydrologic connection through our aquifers, or confining units, into the alluvial aquifer and subsequently into the Mississippi River.
Q. Are any of those bodies of water directly connected with the Middle Claiborne Aquifer?
A. Well, some, like the Wolf River, for example, are.

Q. But again, you described, I believe, just a moment ago, the different layers; they would be connected through the layers. Is that your --
A. Yes.
Q. -- understanding? Okay.
Are any of those rivers interstate, that interconnect with the Middle Claiborne Aquifer?
A. Well, the Wolf River, as I've talked about, is a river that goes from Mississippi into Tennessee, subsequently into the Mississippi River, which then is an interstate river as well.
Q. Mr. Larson, have you analyzed connections between groundwater and interstate bodies of surface water in other original jurisdiction cases in the US Supreme Court?
A. Yes, I have.
Q. What was the nature of the relief sought in those cases?
A. Well, the -- I'll give you an example. In the Republican River case, the relief sought was that pumping from the Ogallala Aquifer was having depletive effects on the stream flows of the Republican River. And the stream flows of the Republican River were regulated by the Republican River Compact and divided among the states. So to the extent that the pumping was affecting those stream flows, that was a factor that needed to be included in the accounting and the allocation of the water among the states.
Q. When you say "compact," do you mean an agreement between

the states over how to allocate the water?
A. Yes.
Q. Let's look at Slide 21.
How do those connections to interstate bodies of water relate to your conclusion about the Middle Claiborne Aquifer?
A. They -- I believe that the interconnection between the Middle Claiborne Aquifer and these other aquifers that are also interstate in nature, or surface water bodies that are interstate in nature, supports my conclusion that the Middle Claiborne is an interstate water resource.
Q. Thank you. Let's look at the third one.
What's the next basis of your conclusion that the Middle Claiborne Aquifer, including the water in it, is interstate? Third one.
A. I'm sorry, would you repeat the question?
Q. Yes. Tell us what your third -- the third basis of your conclusions.
A. That there is groundwater movement within the Middle Claiborne Aquifer. The water is not static; it's not stored permanently in one place. And it's moving, and it was moving in predevelopment times, and it's moving today, and that that movement takes the water across state boundaries.
Q. Just so that we're clear, when you say water is not static, what do you mean by that?
A. That it's not -- that it's not not moving.

Q. Okay. So "static" means "still"?
A. Still.
Q. Was that also true under predevelopment conditions?
A. Yes.
Q. Did you consider any predevelopment flow maps in reaching that conclusion?
A. I've looked at a number of maps that I -- that I think illustrate that continuity of flow.
Q. Are you aware of any map, or any model of predevelopment conditions, that shows no flow between Mississippi into Tennessee?
A. No, I'm not.
Q. Okay. Let's look at Exhibit J67. This is Reed, 1972.
Do you recognize this exhibit, Mr. Larson?
A. Yes, this is a USGS report by Reed in 1972. It's one of the documents that I reviewed.
Q. Okay. Let's turn to Figure 2.
What is that?
A. This is a potentiometric surface map of the Sparta Sand and Memphis Aquifer, which is equivalent to the Middle Claiborne. And associated with predevelopment conditions, so it's characterized as being in 1886.
Q. Can you remind us what those lines in the map refer to?
A. These lines are lines of equal potentiometric level.
Q. Are they also called contour lines?

A. They're also called contour lines, yes.
Q. Okay. And what do they represent?
A. They represent places along which the potentiometric elevation is the same.
Q. Can you remind us how groundwater flows in relation to those lines?
A. Yes. The groundwater will typically move at right angles to those lines, and so the flow direction will be perpendicular to the orientation of the contour lines.
Q. Does this map demonstrate water flowing out of Mississippi and into other states?
A. Yes, it does.
Q. Can you show Judge Siler in what places it shows water flowing out of Mississippi and into other states?
A. Well, you can see, along the Mississippi/Tennessee border, there is groundwater flow from Mississippi into Tennessee along portions of that border. And if you look to the -- off on the left-hand side, you can see groundwater flow from Mississippi and Tennessee into Arkansas. And if you look further down, you'll see flow between Mississippi and other locations.
Q. So I want to focus on the 400 contour line. Can you explain the direction of the water, using that 400-foot contour line as an example.
MR. ELLINGBURG: I'm going to object -- oh, no, go ahead. Go ahead and let him answer.

A. If you look at the sort of darker horizontal line near the bottom of that circle, that's the state boundary. If you then look at the potentiometric level contours, you can see how they're situated relative to that. And you can see that they're tilted sort of in a northeast-to-southwest direction; for example, on the 400, you can see that.

The groundwater flow would be perpendicular to that contour, which would mean that the groundwater in that area would be flowing toward the northwest, or west northwest, across the boundary. It would be flowing from Mississippi into Tennessee.

Q. Okay. Is there any other water that flowed out of Mississippi across state lines, according to this predevelopment flow map?

A. Yes. You can see over on the left-hand side, you can see the contours. And if you follow the contours, you'll see -- well, if you follow the path line that's perpendicular to those contours, you will see the path line leading from, say, Mississippi into Arkansas.

Q. And let's look down -- let's get the map larger.

How about between Mississippi and Louisiana?

A. Yes. You can also see, in areas to the south, you can see potentiometric contours going from 140 to 120 to 110 in the central part of that, indicating flow -- westerly flow from Mississippi into Louisiana.

Q. Is that the area near Jackson, Mississippi?
A. Yeah. It's off to the west of that area.
Q. Okay. And what direction is the water flowing away from Jackson?
A. Generally west, or west southwest.
Q. And can you show us that it's crossing the state boundary?
A. Well, further to the west, it's crossing the state boundary as you go from the 140 contour off to the west.
Q. Okay. Let's look at Exhibit J24.
This is -- well, first, do you recognize this exhibit?
A. Yes. This is a USGS report by Criner & Parks from 1976.
Q. Did you rely on this report?
A. It was among the reports that I reviewed, yes.
Q. Okay. Let's look at Figure 4. What is Figure 4?
A. This is a potentiometric surface map of the Memphis Sand. Again, a predevelopmental condition, in 1886.
Q. And what does this map show about water flowing out of Mississippi?
A. It shows areas where the directions of flow would direct the water -- or the water would be flowing from Mississippi into DeSoto County, into Shelby County of Tennessee.
Q. And any other states that you can tell from this map?
A. And off to the west, it would be flowing from Tennessee and Mississippi into Arkansas.
Q. Okay. Let's go back to J4.

Can you remind us what this is.
A. Yes. This was the USGS report by Arthur & Taylor in 1998.
Q. Let's look at Plate 5, which is at PDF page 64 of J4.
What is that?
A. These are a series of maps of different aquifer units, and -- illustrating the predevelopment potentiometric contours in the different hydrogeologic units.
Q. Well, let's zoom in on the Middle Claiborne Aquifer specifically. What does this map show about flow direction under predevelopment conditions?
A. Well, it shows that groundwater flow is crossing state boundaries in different portions of the map.
Q. What does this indicate about water flowing out of Mississippi?
A. That there's water flowing out of Mississippi into Tennessee in places, into Arkansas in other places, and into Louisiana in other places.
Q. Would all the water in Mississippi in predevelopment conditions stay permanently in Mississippi?
A. No, it's moving. So over time it will leave Mississippi.
Q. Okay. Are there any other cross-border flows that are noteworthy in this particular picture?
A. You can also see flow patterns from Arkansas into Louisiana, for example.
Q. Okay. And what about between Mississippi and Arkansas?

A. Yes. You can see flow in some areas going from Mississippi into Arkansas, and other areas where it's going from Arkansas into Mississippi.
Q. What does this map say to you in forming your conclusion about water flow in predevelopment conditions?
A. That the water is not static; it's moving. And that the patterns of movement are not impacted by state boundaries.
Q. Okay. Let's look at Exhibit D 174.
Do you recognize this exhibit?
A. Yes. This is a paper written by Waldron & Larsen in 2015.
Q. And are you related to the Larsen who was a coauthor of this report?
A. No, I'm not.
Q. Did you rely on this report in formulating your opinions in this case?
A. I reviewed it as part of the -- of the documents that I reviewed for this case.
Q. Okay. Let's look at Figure 4. This is D174, PDF page 17.
What is that?
A. This is a map of the potentiometric -- predevelopment potentiometric surface in the Memphis and near-surrounding area.
MR. FREDERICK: Can we zoom in on that a little bit?
Q. What does this map show about water flow in predevelopment conditions?

A. It shows that -- first of all, that the water is moving from areas of higher potential to low potential, so it's a motion that -- that movement is not influenced by the state boundaries, and water is moving across state boundaries.
Q. Can you tell from this map how significant the amount of water is that would be moving across state boundaries in predevelopment conditions?
A. I can't tell from looking at the map quantitatively what it is. I can only tell qualitatively that it -- which direction it's going and that sort of thing.
Q. Okay. Qualitatively, how would you characterize the significance of the water movement between Mississippi and the adjoining states?
A. We can see there's movement along -- according to this map, movement along the Mississippi/Tennessee border, over most of that border region -- in fact, all of it, looks like -- from Mississippi into Tennessee. And also, at least estimated, I would see the map from Tennessee and Mississippi into Arkansas.
Q. In your opinion, from a hydrological perspective, does Judge Siler need to decide between the competing predevelopment potentiometric surface maps and models to decide whether the aquifer is interstate?
MR. ELLINGBURG: Your Honor, I'm going to object to that question. I think the judge decides what the judge decides.

THE COURT: Well, you can make these suggestions. I understand that we don't have a jury, so I'll keep out things that I don't need.

BY MR. FREDERICK:

Q. Well, I'm asking as a factual matter: Does the state of the potentiometric map and the competing maps inform your view about whether the aquifer is an interstate aquifer?

A. Not in terms of the details. It provides an illustration of the motion of groundwater, and it's not being impacted by state boundaries.

Q. So in your view, is it important to resolve which map is the best picture of the predevelopment flow levels, flow directions?

A. Not in my view, no.

Q. Okay. And why is that?

A. Because it's really the continuity of the flow in terms of the ability of water to move from one place to another, that that is not -- there's not a barrier to that along state boundaries, and that that continuity is demonstrated by these various maps.

Q. Do you have an opinion about defining an interstate resource based on the predevelopment flow patterns?

A. No, I don't.

Q. Okay. And do you think that the predevelopment maps that we discussed represent all groundwater flow patterns?

A. No.
Q. You talked at some point about water moving in different directions. How would you model a three-dimensional groundwater flow in predevelopment conditions?
A. How difficult is it?
Q. Well, how would one do it, if one could?
A. Well, you -- first I'd want to go back and collect all the information you could about what conditions you -- had been measured or estimated to exist in those kinds of time frames. And you would have to try to use that information in the development of a model of the conditions associated with that time frame.
Q. Has Mississippi attempted to model a three-dimensional groundwater flow model for this aquifer?
A. Not to my knowledge, no.
Q. Would a model be able to demonstrate predevelopment groundwater flow patterns precisely?
A. I don't believe so. I think it would be very difficult.
Q. Why is that?
A. Because that time period is long gone. And we can't generate new data, so we have to work only with the existing data, and that would make it very difficult, I think.
Q. Does your definition of "interstate aquifer" depend upon the specific predevelopment flow patterns?
A. No, it does not.

Q. Why?
A. Because in my view, the determining factors, or factors that I believe support my conclusion, are the continuity of the materials and the characteristics of the aquifer; the fact that the aquifer is interconnected to other aquifers and streams that are also interstate in nature; and that the water movement from one place to another is not -- there's not a barrier along state boundaries that would prevent that movement, and there's not a barrier that would prevent the effects of groundwater development in one state from propagating into an adjoining state.
Q. Okay. If we were able to model predevelopment flow patterns within the Middle Claiborne Aquifer accurately, would you consider Mississippi's theory to be practical?
A. No, I don't believe so.
Q. And why is that?
A. Because I think there's a number of issues that would have to be resolved about the definition of what might constitute, say, an interstate flow path.

For example, if the flow path leads from Mississippi into Arkansas before discharging into the Mississippi River, for example, does that make it interstate? Does the -- if the flow path goes into Arkansas and then back into Mississippi and then discharges to the river, would that make it interstate?

I think there's a number of questions just defining

what might -- what that flow path might need to be in order to be characterized as interstate, and then you would have the difficulty of actually trying to quantitatively assess those in a three-dimensional sense.

Q. Is there any water that would permanently remain under Mississippi, based on current flow patterns?

A. No, not -- not in my opinion.

Q. Okay. I'm showing you Exhibit J71. We've already looked at this one. This is the Schrader 2008.

Can you remind us what that is?

A. This is the potentiometric surface map, prepared by Schrader, of the conditions in the aquifer in 2007.

Q. And what do the arrows represent?

A. They indicate directions of groundwater movement within the aquifer in various locations.

Q. Let's zoom in on the area in Northern Mississippi right below the 35th parallel. Do you see where that is?

What do the arrows show in that part of the map?

A. That groundwater is moving, say, from -- there's an arrow that indicates groundwater is moving in a northwesterly direction across the Mississippi/Tennessee border into the cone of depression, and also from the north into that area.

And off to the west, in Crittenden County in Arkansas, there's migration more in an easterly direction toward the center of the cone of depression.

Q. Okay. And how does -- how do those arrows showing the flow pattern support your overall conclusion?
A. Well, they show that the effects of pumping can be transmitted beyond state boundaries, and the state boundaries look like barriers to the effects of pumping being transmitted across state lines.
Q. Now, you mentioned a fourth factor. Can you tell us what the fourth basis of your opinion is?
A. Yes. That the USGS, I believe, has recognized that the Middle Claiborne Aquifer and the -- and other aquifers within the Mississippi Embayment Regional Aquifer System are regional in scope, and need to be evaluated on a regional scale that would include a scale encompassing more than one state.
Q. Why is that important to your analysis?
A. Because I think it demonstrates that they're effectively considering the Mississippi -- or the Middle Claiborne Aquifer hydrogeologic unit to be an interstate resource.
Q. Okay. And can you remind us again what role the USGS serves?
A. Well, one of their missions is basically monitoring and evaluating our nation's water resources. And as you can see from these reports, there are a number of studies that they've undertaken to evaluate things on a regional basis.
Q. Can you explain what kind of regional analyses the USGS does?

A. Yeah. Well, one in particular was in the mid-70s, when I was actually still working at the USGS, they started a program of regional aquifer studies called the RASA program, R-A-S-E -- R-A-S-A. And the purpose of that was to evaluate these aquifer systems that were large-scale in nature, regional in nature, fully -- rather than in sort of a piecemeal fashion, say, within certain political subdivisions, like within certain states or within a certain counties.

Q. Why do you believe that is important to the USGS?

A. Because I believe they wanted to provide evaluations and tools that could be used to assess the regional character of the system and how effects could propagate beyond state lines, for example.

Q. Has the USGS analyzed the Mississippi Embayment as part of that process?

A. Yes, it has.

Q. Do you know what publication or publications it has done so?

A. Well, there are a number of them. One of the more recent ones we've looked at is the reports on the Mississippi Embayment Regional Aquifer System.

Q. Okay. I'm showing you slide J4 -- Exhibit J4. Can you turn to page five and read the second sentence, please.

This is Arthur & Taylor's 1998 publication that was prepared as part of the RASA; is that right?

A. The second sentence reads, "In general, the boundaries of these studies are identified by the hydrologic extent of each system, and accordingly transcend the political subdivisions to which investigations have often been arbitrarily limit -- limited in the past."

Q. Okay. Did Arthur & Taylor study the Middle Claiborne Aquifer on a regional basis?

A. Yes, they did.

Q. Do other USGS publications indicate a -- an interest in studying the aquifer on a regional scale?

A. Yes, there are others.

Q. Okay. I'm going to show J25. This is the Cushing 1964 study. This is Exhibit J25.

What is this?

A. This is a report on the Mississippi Embayment by Cushing and others in 1964, a USGS report.

Q. Could I ask you to turn to page B5, which is PDF page five.

Can you read the second and third sentences beneath the heading "Introduction."

A. "Most of the water resources investigations in the Embayment have been made in cooperation with state, county, and municipal agencies and have been restricted to local areas where the need for information was urgent -- was most urgent. Reports on these studies give valuable information on parts of the Embayment, but they do not treat the subject of water

resources on a regional basis."
Q. Did the Cushing study examine the aquifer on a regional basis?
A. Yes, it did.
Q. What year was their study conducted?
A. 1964.
Q. I'm showing you what's been marked as J71. This is Schrader's 2008 report on the Middle Claiborne Aquifer, which we've already discussed.
Does that report indicate what USGS's goal in undertaking that study was?
A. Yes.
Q. And what is -- what was the goal, as you understand it?
A. This was part of the regional aquifer assessment program, trying to characterize and study the aquifer system on a regional basis.
Q. Now, I want to go to the introduction. This is J71. Do we have a page number?
This is a one-page exhibit, I'm informed. Could you read the highlighted passage there, please.
A. "Regional assessments of water-level data from the aquifer are important to document regional water-level conditions and to develop a broad view of the effects of groundwater development and management on the sustainability and availability of the region's water supply. This information is

useful to identify areas of water-level declines, identify cumulative areal declines that may cross state boundaries, evaluate the effectiveness of groundwater management strategies practiced in different states, and identify areas with substantial data gaps that may preclude effective management of groundwater resources."

Q. What do you understand, Mr. Larson, these passages to indicate about the USGS's view about the interstate nature of the aquifer?

MR. ELLINGBURG: Your Honor, I'm going to object to that. There's no foundation for this. He asked him what he understands.

THE COURT: Objection sustained.

(Reporter clarification)

THE COURT: Do you want to rephrase your question?

MR. FREDERICK: Sure.

BY MR. FREDERICK:

Q. In reviewing these reports, you read these passages, correct?

A. Yes.

Q. And what -- how did they inform your view about the USGS's recognition of the aquifer as an interstate resource?

MR. ELLINGBURG: Your Honor, I object again. There's no foundation. I mean, you read them. I've read them.

THE COURT: Well, he's an expert. Once again, I'll

overrule your objection.

You may answer the question.

A. They indicated to me that the USGS was concerned about providing information and evaluations on a regional basis that wouldn't be limited to certain geographic areas, or smaller geographic areas, as had happened in the past, and they wanted to provide a tool and evaluation that was not limited by the boundaries of some of those earlier investigations and could provide a broad regional analysis, including analyses across the boundaries that they felt was necessary.

Q. And would they have evaluated pumping in connection with those analyses?

MR. ELLINGBURG: Your Honor, I'm going to object to what they would have done.

THE COURT: Well --

MR. FREDERICK: Did they evaluate pumping?

THE COURT: I'll overrule the objection.

Go ahead and ask him the question.

A. Yes.

Q. Could you read the first two sentences on this slide, please, Mr. Larson, to satisfy those of us in the courtroom who are doubters.

A. "The most widely used aquifer for industry and public supply in the Mississippi Embayment in Arkansas, Louisiana, Mississippi, and Tennessee is the Sparta Memphis Aquifer.

Decades of pumping from the Sparta Memphis Aquifer have affected groundwater levels through the Mississippi Embayment."

Q. Is the Sparta Memphis the same as the Middle Claiborne Aquifer?

A. Yes.

Q. I'm showing you what's been marked as Exhibit J15.

What is this?

A. This is a report, a USGS report by Brahana and Broshears in 2001, discussing their evaluation of groundwater flow in the Memphis -- in the Memphis area.

Q. Did you hear Mississippi's experts testify that they were relying on this model?

A. Yes.

Q. Could you turn to PDF page ten. And I'd ask you to read the sentence that I've highlighted, please.

A. "Although the study focuses on the Memphis area, the aquifers and confining units are regional in occurrence and extend far beyond the Memphis area boundaries."

Q. How long has the USGS recognized the Middle Claiborne Aquifer as an interstate aquifer?

MR. ELLINGBURG: I'm going to object to that.

THE COURT: Overruled.

You may answer the question.

A. Well, they've recognized the regional nature of it, and they -- implicitly, I think, the interstate nature of it for

50 years or more.
Q. Let's look at Exhibit J7. This is the Bell & Nyman 1968 study.
Can you tell us what this is?
A. This is a report describing the groundwater conditions in the 500-Foot Sand in the Memphis area by Bell & Nyman in 1968.
Q. Did this paper analyze the aquifer at issue in this case?
A. Yes, it did.
Q. How do you know that?
A. Because reading the report, and what they're describing, you come to understand that the 500-Foot Sand is synonomous with Memphis Sand, or the Middle Claiborne Aquifer, in the Memphis area.
Q. How does this report support your conclusion about the USGS's recognition of the Middle Claiborne Aquifer as an interstate aquifer?
A. Because it describes the regional nature of it and the extent of it.
Q. Okay. Let's go back to the demonstrative. Let's just keep that -- all right.
So that would represent your fourth basis of your conclusion, Dr. Larson?
A. Yes.
Q. And why do those reports support your conclusion about the nature of the Middle Claiborne Aquifer?

A. Because I believe collectively they recognize the regional nature of the resource, and they recognize that those characteristics transcend state boundaries and are interstate in nature.

Q. Is the USGS authoritative in this area?

A. I believe they are, yes.

Q. Why?

A. Well, first of all, when I worked there for many years, they had a very comprehensive system, a robust system for review and evaluation of the reports that they prepared. And it was -- it's a peer-review-type process. So they took steps to ensure that their work was -- their work was appropriate and up to the standards.

And they are really the chief agency within the United States for -- with a mission to monitor and evaluate water resources, both surface water and groundwater resources within the United States.

Q. Mr. Larson, I'd like to turn to any opinions that you have about testimony that you have heard in this hearing. Did you hear Dr. Spruill's claim that you should consider the water as an interstate resource separate from the aquifer?

A. Yes, I did.

Q. What is your opinion about that statement?

A. My opinion is that you can't separate the water from the geologic materials that the water is in, because it's the

combination of the geologic materials and the water that make an aquifer. And if you had geologic materials but no water, you wouldn't have an aquifer.

Q. Okay. So an aquifer cannot exist without water?

A. No. The water is an integral part of the definition of an aquifer.

Q. Were you in the courtroom earlier, when both of Mississippi's experts testified repeatedly about the rate of groundwater flow and residence time?

A. Yes.

Q. In your opinion, is the rate of groundwater flow within the Middle Claiborne material to your conclusion that the aquifer is interstate?

A. No, it's not.

Q. Why not?

A. Because it's a fact that the -- in my view, it's a fact that the water is moving, and that recharge and discharge are occurring all the time; even today, as we speak, there's water discharging from the aquifer -- from Mississippi, for example.

And so in my view, it's that movement and continuity of the aquifer that determines or supports the conclusion that the resource itself is an interstate resource.

Q. Is water continually flowing out of the State of Mississippi within the Middle Claiborne Aquifer?

A. Yes.

Q. Why did you consider that fact?
A. Because that fact is -- shows that there's not a permanent amount of water that's -- or a permanent store of water, if you will, that's just residing in Mississippi and is not moving.
Q. Does residence time have any effect on your opinion about the interstate nature of the aquifer?
A. No, it does not.
Q. From a hydrological standpoint, does "storage" mean that there is a certain amount of water that permanently resides within the aquifer in Mississippi?
A. No, it does not.
Q. On a general level, what do hydrologists mean by "storage characteristics"?
A. Well, the storage characteristics that we talk about and use when we're evaluating aquifers is really a determination of how the potentiometric levels will -- or it's a parameter or characteristic that will determine how potentiometric levels will change when the aquifer is pumped.

And there will be different characteristics in, say, confined areas versus unconfined areas, but it doesn't reflect the overall body of water or amount of water that's in the aquifer itself.

So, for example, a confined aquifer may remain saturated even though potentiometric levels have changed.
Q. Does the Middle Claiborne Aquifer have storage

characteristics?
A. Yes, it does.
Q. Has the portion of the Middle Claiborne Aquifer beneath Mississippi always contained water?
A. Yes, it does.
Q. Is it the same water?
A. No. It's moving from place to place.
Q. Is it possible to isolate out the water that would have remained beneath Mississippi for a very long time?
A. Well, it's possible to look at how -- generally how fast things are moving, but it's not possible to follow individual molecules of water.
Q. And what is your conclusion from that?
A. My conclusion is that the rate of movement is not -- is not a determiner of whether the resource is an interstate resource. It simply reflects the fact that there's continuity to the groundwater system and groundwater movement.
Q. Mr. Larson, were you in the courtroom when Dr. Spruill addressed case two, which is defense Exhibit 130 from his opening expert report, where he identified what he claimed to be an interstate aquifer with intrastate flow?
A. Yes, I was.
Q. Let's look at the slide. Is this that hypothetical?
A. Yes.
Q. Can you briefly describe what you take away from this

hypothetical picture?
A. Well, my understanding was that the hypothetical -- hypothesized that an interstate aquifer, that's an aquifer that spans multiple states, but that the flow patterns within each of these two states, as they're depicted on here, were perfectly parallel to the boundary between the two states, and that the water -- all the water would discharge into a river that transcended the states from north to south.
Q. Now, let's assume for a moment that the flow lines in this hypothetical were correct. Would you consider a formation including water in it flowing from these directions to be an interstate resource?
A. Yes, I would.
Q. Why?
A. There's a couple of reasons that come right out in my view. Number one, the discharge of the water into the river; the river would then carry the water, say, from State A to State B and out of State B. The river would be an interstate resource, and these aquifers would be interconnected to that interstate resource.

But also, there is no barrier to the connection between State A and State B, such that if you pumped water from State A, you can affect the conditions in State B, and vice versa.
Q. Okay.

A. I think that would make it interstate in nature.
Q. In this hypothetical, could either state develop resources in the border area without affecting the water in the other state?
A. No.
Q. Why is that?
A. Because the pumping effects will spread out, and if there's no complete barrier to any aquifer between one state and the other, those effects would propagate across the state line.
Q. Mr. Larson, in your view, is this hypothetical an accurate representation of Middle Claiborne at issue here, according to Mississippi's own experts?
A. No, I don't believe so.
Q. And why is that?
A. First of all, the -- when you look at the layout of the states, the situation that we have in the real world is that on one side of the river, we have Mississippi and Tennessee; but on the other side of the river, we don't have the same states. We have Arkansas.

The other thing is that when you look at the actual flow patterns, based on some of the maps that we've looked at, there's not flow, equal flow, parallel flow, to -- toward this river boundary from both sides. But there's flow patterns that go under the river from one side to the other, which would actually take it from a state like Tennessee or Mississippi, on

the right side, into Arkansas, on the left side.
Q. Okay. Let's look at Exhibit D112.
What is this figure?
A. This is a diagram from one of the reports by Mr. Wiley.
Q. Is this the famous yellow triangle map?
A. Yes, it is.
Q. Okay. And what is it -- what is this figure showing?
A. It's illustrating estimated groundwater flow pathways from various portions of the aquifer, and where those pathways would lead.
Q. And where does it show water flowing from Mississippi?
A. It shows water flowing from Mississippi into Tennessee from the yellow triangle area. It also shows water flowing from Mississippi into Arkansas, over on the left-hand side.
Q. Does this diagram support your critique of Dr. Spruill's hypothetical?
A. Yes.
Q. Okay. Now, Mr. Larson, did you hear the claim made earlier this week that Memphis and MLGW's wellfields are not properly designed, and that the resulting cone of depression in the aquifer is injuring Mississippi?
A. Yes.
Q. What is your opinion of that allegation that Tennessee's pumping is somehow depriving Mississippi of its ability to use the Middle Claiborne Aquifer?

A. Well, my understanding is that -- that the claim is that there is -- there is some -- water declines from the cone of depression and propagated into Mississippi. As far as I'm aware, water supply users in Mississippi have been able to increase their water supply significantly over the last several decades, and I'm not aware of any difficulties that they're having in terms of obtaining their water supply.

Q. What does the ability to have a higher level or to increase pumping say to you about the availability of water in Mississippi?

A. That indicates to me that they're being able to increase their water supply to meet increasing demand.

Q. Has Mississippi presented any evidence that you've seen indicating that Mississippi has difficulty increasing its pumping?

A. No, I haven't.

Q. Mr. Larson, have you testified in an equitable apportionment action previously?

A. Yes, I have.

Q. Or should I say, have you provided expert analysis?

A. Yes, I have. I have provided analysis in --

Q. In what case?

A. In the South Carolina/North Carolina matter.

Q. And can you describe briefly what that case entailed.

A. It entailed looking at surface waters in the Catawba River,

and the regulation and use of those surface waters and how the -- that regulation and use of the water impacted stream flow conditions in downstream areas.

Q. And what was the central allegation by South Carolina, as you recall?

A. That North Carolina was taking more than their share of the water.

Q. In that case, did the -- did you consider the complaint of South Carolina had showed a real and substantial injury?

A. Yes, I thought so.

Q. Okay. In your opinion, can Mississippi show a real and substantial injury to its ability to use water in the Middle Claiborne Aquifer?

MR. ELLINGBURG: Your Honor, I'm going to object, because that's not even the issue in this case.

THE COURT: Well, it's not. But you're going to put it in, and I'll let you put it in.

MR. FREDERICK: Thank you, your Honor.

Q. In your opinion, can Mississippi show a real and substantial injury to its ability to use water in the Middle Claiborne Aquifer?

A. Not that I'm aware of.

Q. And why is that?

A. Because it doesn't appear that -- as I said a moment ago, that the ability of Mississippi to continue to develop the

groundwater resource within Mississippi continues to exist; that they can continue to increase their water use.

Q. Did you hear the testimony about supposed increased costs in raising the water additional feet because of a lowering of the potentiometric head?

A. Yes, I did.

Q. Compared to the damages that Mississippi is seeking in this case, how big would any possible damages associated with increased energy costs to lift the water additional feet be?

MR. ELLINGBURG: Your Honor, if I could object. This wasn't in the report. It wasn't the subject of discovery, and it wasn't -- this was not within any parameter of the issues.

THE COURT: I realize this was not in your direct, but I'll let you put it in, because I think that Mississippi raised it to some degree by their expert witness.

MR. FREDERICK: Thank you.

Q. Would you like me to repeat the question?

A. Yes, please.

Q. Compared to the damages Mississippi is seeking in this case, how big would any possible damages associated with increased energy costs to lift the water additional feet be?

A. I think that they would be much smaller than those claimed damages.

Q. Did you hear Mr. Wiley testify that the amount of water flowing from Mississippi to Tennessee has been decreasing?

A. Yes, I did.
Q. And did he suggest an explanation for that decrease?
A. Yes, he did.
Q. What was his explanation, as you understood it?
A. Well, as I understood it, he concluded that some of it was due to reduced pumping in the Memphis area, but also increased pumping from wells in Mississippi.
Q. I'm showing you what plaintiffs have marked as Exhibit P183. Do you recognize this figure?
A. Yes, I do.
Q. What is it?
A. This is one of the figures from Mr. Wiley's report.
Q. What does it purport to show?
A. It shows groundwater flow paths from areas on the right-hand portion of the diagram toward pumping centers within Tennessee.
Q. Where did you first see this figure?
A. When I was reviewing Mr. Wiley's reports.
Q. Okay. And did you review those reports in connection with your rebuttal report?
A. I did.
Q. Okay. Does this map depict any water flowing to wells in Northern Mississippi?
A. No, it does not.
Q. In your opinion, is that consistent with Mississippi's

theory that pumping in Northern Mississippi has reduced the groundwater flow from Mississippi to Tennessee by more than ten billion gallons per day?
A. No, it does not.
Q. Why?
A. Because that -- the rate of pumping -- or the increases in the rate of pumping in the -- from the areas in Northern Mississippi were up to almost 20 million gallons per day. One would expect some of the flow paths would have to lead into those wells, because that amount of water was being extracted from the area north of Mississippi.
Q. So we've been talking just a bit about Mississippi's pumping in the Middle Claiborne Aquifer. In what level of detail did you study the Mississippi pumping?
A. Only generally. I reviewed some of the work that Mr. Wiley had done in compiling that information.
Q. Why did you not undertake a more significant study of Mississippi pumping?
A. Because that wasn't necessary for me to determine whether or not the Middle Claiborne Aquifer was an interstate water resource.
THE COURT: I think we'll take a short recess at this time. Ten minutes.
MR. FREDERICK: Thank you.
(Recess)

THE COURT: All right. You may continue with your questions.

MR. FREDERICK: Thank you, Judge Siler.

BY MR. FREDERICK:

Q. When we broke, Mr. Larson, we were talking about pumping on the Mississippi side of the boundary. Does pumping in Mississippi have any relevance to whether the aquifer is interstate?

A. I don't believe the pumping itself does, no.

Q. Do the effects of the pumping show any relevance to whether the aquifer is interstate?

A. Well, the ability of pumping to create effects that can transcend state boundaries does have relevance, in my view, but not the amount.

Q. Okay. So is a detailed analysis of the pumping volumes relevant to whether the aquifer is interstate?

A. No, I don't believe so.

Q. Does the absolute or relative volume of the groundwater flow between Mississippi and Tennessee have any bearing on whether the aquifer is interstate?

A. Not in my opinion, no.

Q. Why is that?

A. Because in my view, it's the continuity of the materials and characteristics and the ability of water to move one way or the other across the boundaries that determine -- or that are a

factor in determining whether it's an interstate resource.
Q. Have you looked at the effect of pumping in these other states in the Middle Claiborne Aquifer?
A. Yes, I've seen references to that in various documents and reports.
Q. Okay. And in your experience, would a detailed analysis of pumping volumes be performed for the Middle Claiborne in an equitable apportionment case?
A. Yes, I believe that those kinds of issues -- or those kinds of factors could be factors that would be considered in an equitable apportionment.
Q. In your opinion, how large of an undertaking would it be to perform a detailed study of Mississippi's pumping in the Middle Claiborne Aquifer?
A. I think it would be a significant effort. USGS has done some, but you'd probably have to supplement that considerably.
Q. And Mr. Larson, I'd like to shift gears a little bit. What has happened to water levels in the Middle Claiborne Aquifer in the Memphis area in recent years?
A. The water levels -- the potentiometric level of water levels over the last, say, 20 or 30 years or so have been relatively stable, and have even shown increases in more recent years.
Q. What does that tell you, as a trained hydrologist, about recharge and discharge within the aquifer?

A. That while there was an initial decline, say, prior to the 1970s, that a leveling-off would indicate that there's been more of a balance between recharge and discharge, allowing the potentiometric levels to become relatively stable.

Q. How do you know that water levels in the Middle Claiborne Aquifer in the Memphis area have remained relatively stable?

A. By reviewing both hydrographs that were contained in some of the reports, and also reviewing data that was available from the USGS on their water information system.

Q. I'm showing you Exhibit J18. This is the Clark & Hart 2009 report, which we've already discussed.

Can you remind us what this report is?

A. This is the report by Clark & Hart in 2009 documenting their development of the groundwater flow model of the MERAS.

Q. Okay. Let's turn to Figure 16, which is joint Exhibit 18 at PDF page 57.

What is this?

A. These are a series of hydrographs, the ones on the left being hydrographs in various parts of the alluvial aquifer and ones on the right in various parts of the Middle Claiborne Aquifer.

Q. Now, remind us again, where is the alluvial aquifer in relation to the Middle Claiborne Aquifer?

A. The alluvial aquifer extends along -- basically along the axis of the Mississippi River, and it is the uppermost aquifer

above the Middle Claiborne and other hydrogeologic units.
Q. And do I understand there to be pumping out of the alluvial aquifer?
A. Yes, there is.
Q. And obviously we've been talking about pumping out of the Middle Claiborne Aquifer?
A. Yes.
Q. And what does this page purport to show about that comparative pumping in these locations?
A. Well, each hydrograph shows two types of information; one results from calculations using the groundwater model, and that's shown in sort of the red characters or boxes on the charts. And then there is the blue data that was actually collected in a well, in particular wells, at the same locations.
Q. Did you consider this figure in reaching your conclusions?
A. Yes.
Q. Do any of these charts depict a well that you analyzed in Tennessee?
A. Yes. If you look at Well Number J, in Shelby County.
Q. And would this be the well -- or the pumping that's at issue in this case?
A. This is a well in the area of pumping associated with the City of Memphis.
Q. What does this graph demonstrate?

A. It illustrates that during the period, say, from about -- well, it starts in 1870, but if you look at the data beginning in about 1930, there's a period of water decline extending into 1970s. But after that, the water levels have stopped declining and in fact, toward the end of the period of data here, of year 2010, they've actually increased some.

Q. What does that relative stability of the groundwater levels mean for aquifer equilibrium?

A. It indicates that there's a relative balance between groundwater recharge and groundwater discharge in the area.

Q. So does that mean that the amount that's being discharged is more or less in equilibrium with the amount that's being recharged?

A. Yeah, they're in a rough balance between recharge and discharge.

Q. Did you look at graph K on this same figure?

A. Yes, I did.

Q. What does that represent?

A. That represents information from an area down near Jackson, Mississippi.

Q. What does it show?

A. Well, it shows that the groundwater-level decline is beginning in the 1930s and persisted and continued to occur at the end of the period of record here, in 2010.

And you could see from the blue, the trend in the

blue, it's continuing to decline out to 2010 at a little steeper rate than what the model was projecting.
Q. Do you have an opinion about the cause of that decrease?
A. Well, it's in response to groundwater pumping. And it hasn't reached a point where it's begun to stabilize, at least at this point in time.
Q. And this is pumping done for the Jackson, Mississippi, area; is that right?
A. It's pumping from that particular area, yes.
Q. And how does the overall decrease in the water levels compare to the figure we just looked at for Shelby County, Tennessee?
A. Well, the overall decrease goes from maybe an elevation of 200 down to what looks like about 50, so 150 feet as opposed to maybe about 75 or 80 feet --
Q. Okay.
A. -- in the Shelby County area.
Q. Did you consider Figure G?
A. Yes, I did.
Q. And what is that?
A. This is a location in Jefferson County, Arkansas.
Q. Do you know approximately where Jefferson County, Arkansas, is?
A. Yeah. Roughly, it -- it's in an area where some significant water declines have occurred.

Q. Okay. If I represented to you that it's central Arkansas --
A. Yes.
Q. Okay. And what has happened to the water levels there?
A. Well, you can see at or around the year -- or just beyond the year 1950, that there was a sharp decline in the water levels for a period of decades leading out into the 1970s or 1980s, and after that, again, the period where persistent declines are not continuing.
Q. And how do the water level decreases in Jefferson County, Arkansas, compare to the water levels in Shelby County, Tennessee?
A. Well, the declines here look to be more on the order of 200 feet or thereabouts, or 100.
Q. Did you consider Figure I in your analysis?
A. Yes, I did.
Q. And where is that?
A. This is in Union County, Arkansas, down more near the border with Louisiana.
Q. Okay. And what's happening to the water levels in Union County, Arkansas?
A. You can see that there's again a fairly -- a period of fairly steep decline, beginning in -- before 1950s and descending out into 1970s, followed by a period of relative -- relatively more stable groundwater levels, so potentiometric

levels.
Q. And how does the overall decrease in the water levels in Union County, Arkansas, compare to the water levels we just looked at for Shelby County, Tennessee?
A. Well, this particular location, as well, looks like it's more on the order of 200 feet.
Q. Okay. And all of these that we've just looked at -- G, I, J, K -- are all from the Middle Claiborne Aquifer; is that correct?
A. Yes, that's correct.
Q. Okay. Now, I want to return to a different picture that we've looked at. This is Figure 14B, Exhibit J19 and PDF page 34 from the Clark & Hart study.
Remind us again what this shows.
A. This is a map depicting the amount of water level or potentiometric level change between predevelopment times and 2007.
Q. Okay. And what do the different colors represent, and how does this depict the relative change in water levels?
A. The colors represent different ranges of estimated water-level decline, with the darker brown colors representing -- the darkest brown colors representing the most significant -- the largest declines, and the lighter colors representing less declines.
Q. What are the areas of greatest drawdown?

A. Well, you can see the area, very dark brown, with an area centered in Southern Arkansas, and another area near that in Louisiana, where they have the darkest brown color. Those are probably the area -- or those as depicted on here are the most -- the largest -- areas of the largest decline.

And then north of that, also in Arkansas, is another area of relatively larger declines, although not as severe as the ones to the south.

And then there's also declines over in the area of Jackson, Mississippi, and to a lesser degree, up in the area of Memphis.

Q. And how does this map reflect the information on the graph that we just looked at?

A. These hydrographs, at least most of them, are taken from -- at least the ones in the Middle Claiborne are taken from areas within or near these significant areas of water-level decline.

Q. What does this diagram show you about pumping in adjoining states?

A. Well, what you can see is that the effects of pumping in adjoining states extends across the state boundaries, and overlap across the state boundaries from one state to another.

Q. Can you be more specific in describing the effects of cross-border pumping?

A. It's actually the cross-border impacts, but --

Q. Thank you.

A. If you look down at the area that spans the border between Louisiana and Arkansas, you can see how the impacts have coalesced across a boundary. If you look at the area to the north of that, you can see areas in Arkansas that have expanded or have propagated out across the Mississippi -- underneath the Mississippi River into Mississippi, although there's also some areas of pumping in Mississippi in that same area.

Similarly, down around Jackson, you can see how the pumping has spread out there, reaching out to the Mississippi River and slightly into Louisiana.

Q. And in terms of the color depicted for the water-level drawdowns, how does Shelby County, Tennessee compare to those other three darker areas in Central Arkansas, the Arkansas/Louisiana border, and the Jackson, Mississippi area?

A. Well, you can see the color shading is lighter in the area of Memphis, indicating that the amount of decline in the Memphis area is less than those other areas that you mentioned.

Q. Would the pumping in these various areas typically be considered in an equitable apportionment action, in your professional experience?

A. In my experience, the amounts of pumping and the impacts of those pumping would be things that would be considered in that kind of an action.

Q. Is the volume of pumping by different states important to determining whether the aquifer is interstate?

A. No, I don't believe so.
Q. Why is that?
A. Because it's really the ability of pumping in one state, for example, to impact other states, and the continuity of the aquifer and its characteristics that give it the -- in my view, determine whether it's an interstate resource. The volume of the pumping is not a specific factor.
Q. Mr. Larson, I'd like you to take a look at Figure 4 from the same report.

What is this figure showing?

A. This figure shows -- or characterizes land use patterns within the Mississippi Embayment Regional Aquifer Area.
Q. And when you say "land use," what does that mean, in lay terms?
A. Well, it kind of characterizes what's going on at the surface of the land; whether it's a populated area. For example, urban -- urban characterization would indicate that it's a populated area, and the degree of color would indicate the density in the population.

Similarly, for example, the yellow area would indicate areas where there are cultivated crops over -- over the area of the Embayment. .

MR. ELLINGBURG: Your Honor, can I just have a -- can Mississippi have a continuing objection to these questions that are outside the scope of anything that we're talking about?

THE COURT: All right. That's overruled.

You may continue.

MR. FREDERICK: Thank you, your Honor.

BY MR. FREDERICK:

Q. What does the land use in the urban red tell you about the areas of urban use in the Middle -- in the area affected by the Middle Claiborne Aquifer?

A. Well, it indicates that the largest and most populous areas would be around the City of Memphis, and the other areas would be relatively smaller.

Q. Did you look at all of the different uses throughout the Mississippi area?

A. Not in detail, but I'm aware of them.

Q. And why did you not look at them in detail?

A. Because it wasn't necessary for me to know the details in order to determine whether or not the aquifer was an interstate water resource.

Q. Thank you, Mr. Larson.

MR. FREDERICK: We'll pass the witness.

THE COURT: All right.

You're going next, for Mississippi?

MR. ELLINGBURG: Yes, your Honor.

THE COURT: Or Memphis first?

MR. ELLINGBURG: I don't know, Memphis and --

MR. D. BEARMAN: We have no cross.

THE COURT: Okay. All right. You may proceed for Mississippi.

CROSS EXAMINATION

BY MR. ELLINGBURG:

Q. Good afternoon, Mr. Larson.

A. Good afternoon.

Q. I'd like to hit a few little fundamental things; details, if you will.

You're a civil engineer, right?

A. By education, yes.

Q. Are you a professional engineer?

A. No, I'm not a professional engineer.

Q. Have you ever been a professional engineer?

A. No, I've never been a professional engineer.

Q. Do you have to take a test to be a professional engineer?

A. You do.

Q. Okay. Which would show your qualifications in that area.

It shows that you are a certified professional hydrologist. By whom have you been certified?

A. By the American Institute of Hydrology.

Q. Does that require a test?

A. It does in some circumstances. In my case, I was granted certification based on my experience and research in the area of hydrology and groundwater hydrology.

Q. Thank you.

Now, has your experience primarily been in the area of modeling?

A. I would characterize it more in the area of hydrology, and specifically groundwater hydrology. Modeling -- I have experience in modeling, and that's certainly one component of my work.

Q. Thank you.

Now, you testified to this, but I'd like a little more detail. You isolated out a statement in Judge Siler's memorandum decision, said the threshold issue in this matter is whether the aquifer is an interstate resource. Right?

A. Yes.

Q. And so you've focused everything on that one statement, right?

A. Yes. That was my understanding of what the purpose of this hearing was, so I focused on that.

Q. Did you read the rest of his memorandum?

A. I read through it, yes.

Q. I mean, did you read the order that actually set the hearing?

A. I read the one from 2016, and I don't know if that's the one you're talking about or not.

Q. No. You read the memorandum opinion, which you signed to page 36 on, right?

A. That sounds right, yeah.

Q. Did you read an order of that -- of the same date as the memorandum opinion?

A. I don't recall whether I did or not.

Q. All right. Who provided you with the memorandum opinion?

A. It was provided me by the Kellogg firm.

Q. Did you receive any instructions as to how you would use that memorandum opinion from the Kellogg firm?

A. No, I wouldn't say I was -- I didn't receive instructions. What -- well, they sent me the memorandum, and I looked at it.

MR. FREDERICK: Your Honor, I'd like to just lodge an objection. To the extent counsel intends to get into attorney-client privilege or expert privilege, we would object, and I would ask him not to venture into specific questions that we asked our expert to do.

THE COURT: I don't see whether -- whether he read my order or not. Nobody else much read it.

I don't see the purpose if either party sent that. But you may ask him other questions, but I don't think it's very relevant as to what he read they were.

MR. ELLINGBURG: Well, thank you.

BY MR. ELLINGBURG:

Q. My question is, how did you use the order to define this particular question which you said you were providing an opinion on?

A. Well, I used what I read to try to understand what the

scope of this hearing was going to be about. And my understanding of that was that the threshold issue, or the issue of this hearing, was to determine whether or not the aquifer was an interstate resource. So then I focused my work on trying to address that question from a technical perspective.

Q. Did you receive any assistance in determining that would be the issue on which you would offer an opinion?

A. I -- I don't know what you mean by that. I mean, I read the order, and I understood that to be my charge.

Q. I'm trying to find out whether you decided from reading the order that this was the issue, or whether someone assisted you in deciding it.

A. I decided that that was the issue as I saw it, based on reading the order.

Q. Okay. So you interpreted the order personally?

A. I interpreted what I read to indicate that that would be the subject of this hearing.

Q. Okay. What is your legal background?

A. I'm not a lawyer.

Q. Have you ever read the Court's order before and decided that you would identify the specific issue that was to be addressed before the Court?

A. Yes. As I remember, in some of the Kansas/Colorado case, there were -- I don't know, orders or determinations by the

Special Master as to what the scope of certain portions of the hearings -- or, I'm sorry, certain portions of the case would be about, and we used that as a focal point.

Q. And so did those contain specific instructions?

A. Well, they would -- they would outline what the scope of the inquiry would be in a particular portion of the case.

Q. The only reason I'm getting into this is because the -- about two -- a sentence or two after this statement in the order, it specifically refers to both the groundwater and the aquifer. And then in the order, it refers to the water in dispute. Have you ever focused on those two parts of either of those documents?

A. I don't -- I couldn't hear what you said on the second thing about --

Q. I said the water at issue or in dispute: Have you ever focused on either of those two documents or those two parts of the documents?

A. I remember reading that kind of information, yes.

Q. Okay. Now, do you have a specific citation you can give us to a United States Geological Survey report that defines specifically what constitutes an interstate aquifer?

A. I'm not aware of a specific definition. All I know is from reading the reports about what the focal point of some of their work was. And the word "interstate" does appear in some reports, but I don't -- I'm not aware of a specific definition

that says, "This is what an interstate water resource is."
Q. Did you ever look for one?
A. Pardon?
Q. Did you ever look for one?
A. I've read through these reports.
Q. No, I'm asking you if you've ever looked for a definition recognized either by the USGS or by the Court, or by anyone else, of interstate resource with regard to an aquifer? Have you ever seen any of that?
A. I didn't look for it specifically. I just understood -- applied the common definition of "interstate" to water resources, and that's the basis for my determination.
Q. Is that a scientific definition, interstate resource?
A. Well, I think the word "interstate" is -- in my view, there's a common definition. It means it's something that transcends or occupies more than one state. And I just applied that adjective to water resources, and that's how I approached my problem.
Q. That really wasn't my question. My question was, is there a scientific basis for you defining "interstate aquifer"? Do you have actual science that you use, other than the two things you've mentioned?
You've testified about 90 times now -- I think that may be an exaggeration; a little hyperbole -- that the basis is that there is sand, which has similar qualities under multiple

states. Right? That's -- those are the two things. They underlie multiple states, and -- I forget exactly the phrase you used; you used it over and over.

What was the phrase you used to describe the geology of sand?

A. What was the phrase I used to describe the geology of sand?

Q. Yes, as you talked about --

A. I'm not sure what you're referring to.

Q. Well, didn't you say that there was continuity, right? You said there was continuity in the materials within the aquifers within the multiple states that crossed borders; did you say that?

A. I said there was continuity in the aquifer itself, and in the characteristics of the aquifer, and in the physical properties of the aquifer.

Q. So how much independent study did you do to look at the actual physical properties of the aquifer system throughout the Mississippi Embayment?

A. I reviewed various USGS reports which had characterizations of those properties, and that was the basis for my review of those properties.

Q. Has the United States Geological Survey ever made the statement that all of the sands or aquifer materials or aquitard materials within these eight states are sufficiently similar that you can just move from one state to the other

without expecting any actual impact?
A. I'm not sure I understand your question.
Q. Okay. You used the MERAS report, right?
A. That was one of them, yes.
Q. Okay. That's your primary basis for saying that it's an interstate aquifer, isn't it?
A. Well, that's one -- a report that illustrates the extent and the nature of the aquifer, but there are others as well.
Q. Do you acknowledge that there are substantial local variations within the aquifer units throughout the MERAS model?
A. I would acknowledge that there are variations in aquifer units, as a general matter.
Q. I didn't ask that. I asked substantial variations in local conditions throughout the MERAS model area. Would you acknowledge that?
A. I -- I can't, because I don't know what you're meaning by "substantial."
Q. Well, are there places in the MERAS model where you may have the aquifer, but you may not be able to produce usable quantities of water?
A. Where you have an aquifer but you're not able to produce usable quantities of water?
Q. Yes.
A. Well, that would not meet the definition of an aquifer.
Q. Okay. Are there places where the quality of water is not

as good as it is in others?
A. There are.
Q. Okay. And can you tell us where the best quality water is and where the worst quality water is, within the MERAS model?
A. In general terms, you can, yes.
Q. Okay. So have you identified those areas?
A. I haven't tried to map them out, no.
Q. You didn't look at anything?
A. I didn't try to map them out, no.
Q. Okay. Well, can you give any detail on that?
A. Well, my understanding is throughout most of the area, the water quality is quite good. When you get deeper into the -- some of the hydrogeologic units, you get into areas of saline water.
Q. Is it -- do you know what transmissivity is?
A. Transmissivity?
Q. Yes, sir.
A. Yes, I do.
Q. Okay. Is the transmissivity in the Sparta Sand in Mississippi the same as it is in the Memphis Sand that's primarily in Tennessee?
A. The transmissivity will vary from one point to another.
Q. No --
A. I don't know, without you specifying exactly where you're talking about, whether it is or it isn't.

Q. Okay. Where -- where it changes to the Sparta Sand from the Memphis Sand, in terms of the way those two -- those are two separate aquifer units, aren't they?
A. There are aquifer names used in Mississippi area and there are aquifer names used in the Memphis area, and there are combinations of those names that are used.
Q. So it's your testimony under oath that there's no difference in the Sparta Sand in Mississippi and the Memphis Sand in Tennessee; is that correct?
A. I didn't testify to that, no.
Q. Well, it sounded like you were. My question to you was, are there material differences in those two aquifer units within the two states?
A. I think I testified that they're not homogeneous, and so there are variations. And I don't know what you mean by the word "material."
Q. Well, what about transmissivity? Is there a material difference in the transmissivity of the Sparta Sand in Mississippi and the Memphis Sand in Tennessee? That's a straightforward question.
A. Repeat that?
Q. Are there material differences in the transmissivity of the Sparta Sand in Mississippi, south of the border, and the Memphis Sand in Tennessee?
A. Well, I don't know what you're defining as "material."

There are differences in the transmissivity.

Q. Okay. What would you define as material?

A. Well, it would have to be -- have some material effect on some thing that you're trying to calculate.

Q. Okay. Have you done any calculations of anything in this case?

A. Yes, I have.

Q. And so what calculations have you done?

A. I have -- I've looked at groundwater levels. I've looked at how they've changed over time and how they trended over time.

Q. I haven't asked what you looked at. I'm sure you've looked at a lot. But you're here as a scientist, supposedly providing expert testimony. So I would like to know what calculations of any kind you've actually done.

A. I've looked at groundwater flow rates. I've looked at -- as I said, calculations of trends in water levels.

Q. Okay. I'm sorry, we have a communication issue here. I'm not asking what you looked at. I'm asking if you've done any calculations at all of any characteristics of groundwater applicable to this case.

A. And I'm trying to explain to you that I have done some calculations.

Q. Okay. What calculations have you performed?

A. I've looked at how the groundwater levels have changed.

I've looked at how those groundwater levels have trended during certain periods to understand how those groundwater level trends are indicated in the data that's been collected.

Q. I think you've said -- and I know you've told me in your deposition -- that you didn't consider groundwater flow paths to have any relevance -- any importance with regard to your opinion; is that correct?

A. I don't remember exactly what I said. I don't -- well, whatever. My conclusion is that the specific groundwater flow paths know that the continuity of the aquifer system and groundwater flow within it.

Q. What do you mean by "continuity"?

A. That the state boundaries and other political boundaries do not influence, for example, potentiometric elevation contours and the groundwater flow patterns.

Q. And you base that on regional studies, right?

A. Yes.

Q. You don't base that on any local studies?

A. Well, it depends on what you call "local." I mean, I --

Q. Well, there's an area that's been defined by the USGS for decades called "the Memphis area." Okay?

A. Yep.

Q. Are there differences, even within the Memphis area, from what you would find anywhere else in the Middle -- in the Mississippi Embayment Regional Aquifer System?

A. Are there differences in what, you said?
Q. Are there differences in the -- in the groundwater availability and -- well, within the Memphis area? Are there differences within the Memphis area with regard to the availability of groundwater?
A. There are differences in the characteristics in the Memphis area.
Q. Go ahead.
A. In the characteristics of the aquifer.
Q. And so what are those differences?
A. There are variations in transmissivity. There are variations in permeability.
Q. Have you plotted or charted any of that, even for a local area?
A. I've looked at reports that characterized that, and that's how I understand that.
Q. Okay. So you're telling us what your version is of the reports that you've reviewed, right? That's today that you're doing?
A. I've reviewed a number of reports, and that -- and those reports, along with my experience and education, are what I base my conclusions on.
Q. Okay. But you really don't know if there's any difference in the Sparta Sand within Mississippi, as a known formation, and the Memphis Sand in West Tennessee? You can't tell us what

those differences are?
A. Well, I can tell you that there are differences, based on what I've read. There are differences in thickness. There are differences in permeability. There are differences in -- or in transmissivity. And I'm aware of those.
Q. Do any of those things make any difference with regard to how much groundwater can be produced from that particular formation?
A. They could have influences on the amount of groundwater that you can produce in a particular location, yes.
Q. Now, could they have influences on the flow direction of a particular location?
A. They can.
Q. Okay. Could they have -- make differences in the amount of water within storage in any particular location?
A. They can.
Q. Did you look at any of that?
A. Yes, I have.
Q. Okay. So tell me what the difference is in storage in the Sparta Sand and Memphis.
A. They're -- if you're talking about the water -- storage coefficients, there are variations in the storage coefficients characterized in the reports.
Q. Okay. But can you -- can you tell us what any of them are?
A. Not specifically, no.

Q. No? That's not important to you?
A. Well, it's not important to the conclusion that I reached about whether or not this is an interstate water resource.
Q. Let's talk about that just a little bit.

Now, other than you, can we look anywhere where we can find the definition and the factors that you have used that has been recognized either by scientists or by a court? Has your definition, and your factors for your definition, to your knowledge, ever been used by scientists, as you stated it -- not kind of generally alike, maybe inferred, maybe somewhere -- has it ever been used by another scientist that you know of?
A. I'm not aware of a specific definition, no.
Q. Okay. Of your definition. You're not aware of anyone else using your definition. Is that correct?
A. I'm not aware of ever seeing a definition related to that. I'm just applying the common definition of the word "interstate," and that's what I'm using to draw my conclusions.
Q. Okay. But in terms of other scientists, because this is scientific testimony, can you point me to any other scientists or any other scientific literature that supports your specific -- that uses your specific definition?
A. I know Dr. Langseth in this case. I've read his report, and his approach seems to be consistent with mine.
Q. Okay. So one of the other experts for the defendants and you have agreed, right?

A. Yes.
Q. Okay. Beyond that universe of the experts for the defendants, have you -- do you know of anyone that has utilized, adopted, or applied your definition outside of this case?
A. I'm not aware of a place where that specific definition has been given.
Q. So you kind of -- you made it up from whole cloth?
A. No. The answer to that is no. I made that determination from looking at the words.
Q. Okay. Do you believe that the judge in this case, and the Supreme Court in this case, can't look at those same words? Do you think they're somehow impaired so that they can't look at those words?

MR. FREDERICK: Your Honor, I'd like to object to this.

THE COURT: Well, objection sustained.

MR. ELLINGBURG: Okay.

THE COURT: We of course will make the final decision.

MR. ELLINGBURG: Okay.

BY MR. ELLINGBURG:
Q. Now, one of the components of your definition is that it is possible to pump groundwater from one state into the next; is that correct?
A. Well, it's possible that it's also being observed in the

data and information that I've reviewed.
Q. Okay. Now, this issue has come up in a couple places, but do you -- is it your opinion pumping is a condition found in nature? Is it a natural condition?
A. Pumping from wells is not a natural condition.
Q. Okay. And what you do when you put pumps in the ground -- and I think you've talked about it -- is you lower -- in that confined aquifer, you lower the pressure in the area of influence or cone of depression of that pump; is that correct?
A. Well, as I've testified, you lower the water level, which is the potentiometric level in the well, and that causes water to flow toward the well.
Q. It draws it toward the well?
A. Yes.
Q. Okay. And if that pumping weren't taking place, that water wouldn't be drawn toward the well in that particular cone of depression in that particular way; is that correct?
A. It wouldn't go to that point; it would go somewhere else.
Q. Right. Now, within the cone of depression -- because you explained the concept, or you touched on it earlier, that took me a long time to understand. But within the cone of depression, the pore spaces in the earth and confined aquifer stay saturated, right?
A. Yes, in a confined aquifer.
Q. Okay. But there's not as much water within that cone of

depression as there was before the pumping, is there?
A. The water has been -- when you pump, the water decompresses involuntarily. It's a tiny bit different.
Q. Right. I saw something in the -- in some earth science thing that said that if water were truly incompressible, all the oceans would be 90 meters high, or something like that. Which gave me the idea that you could compress it a little, right?
A. It's slightly compressible.
Q. But it also will press those pore spaces open a little further, so you can store -- at full pressure, you've got more water in each pore space, right?
A. The aquifer skeletons are elastic, and they can expand and contract slightly as well.
Q. Thank you.

And so within the cone of depression, there is in fact less water; is that right?
A. Within the cone of depression, water has been taken out of -- excuse me, the storage -- you can calculate the storage depletion based on the compressibility of the water and the aquifer skeleton.
Q. And someone who sinks a well within the confines of the cone of depression can't recover as much water as they could have with the cone not there, can they?
A. I'm not quite sure I follow your hypothetical earlier.

Q. It was not a hypothetical. Total available drawdown, and what that means is there was not as much water as there was before the cone was created within the cone of depression which can be recovered by pumping, is there?
A. I'm not quite sure what you mean by "not as much water."
Q. Well, we just talked about the fact that some of the water has been released out of the pore spaces. Right?
A. There's been some decompression and some shrinkage of the skeleton.
Q. Okay.
A. Inside a cone of depression and a confined aquifer.
Q. Right. And whether someone can still sink a well in Mississippi and get groundwater doesn't mean there's still as much water in Mississippi as there was before the cone of depression in this case was formed, does it?
A. The water is changing all the time as it moves.
Q. You've said that. But in terms of total available drawdown, it has been reduced in Mississippi, hasn't it?
A. Potentiometric level would have been reduced around the pumping well.
Q. Okay. Can you recover as much water -- because you said earlier -- can you recover as much water within the cone of depression within Mississippi as could have been recovered by wells before the formation of the cone of depression?
A. Well, the overall potentiometric level would be lower, so

you would have to lift the water somewhat higher.
Q. But there's not as much water to produce the maximum yield, is it?
A. Well, you can still produce water. It's only a matter of -- you have to lift it somewhat higher.
Q. Well, unless you need more, right?
A. Unless you need more than what?
Q. What I'm saying is that if you need to use that groundwater resource within the State of Mississippi, you cannot produce as much water as you could if the cone of depression were not there; is that true?
A. I don't know if it's true, in the abstract.
Q. Okay. I'm talking about in reality, within the confines of the cone of depression. What does "total available drawdown" mean?
A. Well, it can mean a number of things. But one of the things it can mean is if you draw the water level from its potentiometric level all the way down to the top of the aquifer, that may be a total available drawdown, or maybe considered a total available drawdown.
Q. Okay. And does that get reduced if you do that in one area in the surrounding area within the cone? Does the total amount that can be pumped out of the aquifer -- is it less?
You don't understand my question?
A. I don't understand the question.

Q. Okay. That's fine.

But you do understand the concept of total available drawdown?

A. I know there are characterizations of total available drawdown.

Q. Okay. Now, how much have you studied geology in your area of groundwater hydrogeology?

A. Well, most of my studies of geology are through the reading of books and reports characterizing geologic conditions in different areas. In a number of different areas.

Q. I just want to know for sure -- I'm going to ask a couple of questions, then I'll move on to something else.

But is it your testimony that the cone of depression in the Memphis area is drawing water from Kentucky -- it was drawing water from Kentucky; is that your testimony?

A. That's not my testimony, no.

Q. Why not? I mean, if it's all one big aquifer, why isn't your pumping in Memphis drawing water out of -- or reducing the available water in Kentucky?

A. Because the cones of depression have limits.

Q. Okay. Now, an illustration was put up by Tennessee's counsel which was taken from Dr. Spruill's report. And you were asked the question if it was possible to move the pumping further away and avoid the cone of depression overlapping, right? And you said it wasn't possible.

MR. FREDERICK: Objection, your Honor. I don't think that question was asked, and I don't think Mr. Larson gave that testimony.

MR. ELLINGBURG: Oh, okay.

THE COURT: I don't know what you asked, but you can ask it.

MR. ELLINGBURG: I'll ask a different one.

BY MR. ELLINGBURG:

Q. Were you asked a question about Dr. Spruill's hypothetical in his report?

A. I was, yes.

Q. And were you asked a question about what the impact would be of placing wells in different areas of that hypothetical aquifer on whether that water would be drawn off state lines?

A. I was asked, as I remember it, whether pumping near the state line could affect conditions across the state boundary.

Q. Were you asked whether moving it away from the state line would eliminate the cone of depression?

A. Not that I remember.

Q. Okay. So but again, we're talking about the hypothetical. It could affect it, right? Moving the pumping location of pumping could affect?

A. Yeah, there was no barrier to that impact being transmitted across the state boundary.

Q. I was interested in that. Let's talk about the barrier a

little bit.

Now, you completely homogenize the geology and the water, right? You say it's all the same? That you can't separate the water from the geology and the aquifer, as you define it, which includes the entire Mississippi Embayment. That's your position, right?

A. No. What I'm saying is that geology without water in it is not an aquifer.

Q. Okay. But when you say the entire Mississippi Embayment is one aquifer -- that's your testimony, isn't it?

A. No, it's not my testimony.

Q. Okay. What is your testimony?

A. That there are multiple hydrogeologic units within the Mississippi Embayment. Some of those units are aquifers; some of those units are characterized as confining units. And they're juxtaposed against one another in certain patterns that are illustrated in some of the reports.

Q. Okay. Is the water in that entire eight-state area all available for all producers in all eight states?

A. I'm not sure I understand that question about -- what do you mean by "available" -- available to users within those areas?

Q. With all eight states from -- all of the water in the Mississippi Embayment, is that aquifer system, is all of that water available to users in every state, just -- just by

putting the well down and pumping it?
A. By putting wells in, you can develop groundwater resources at different places throughout the area.
Q. Did local variations make any difference?
A. Well, local variations can affect transmissivity conditions and affect groundwater flow to some degree.
Q. Is it reasonable to take a regional model and make determinations about local conditions without using the local information with regard to the actual groundwater conditions in the local area?
A. I don't know. It depends on what you're trying to do.
Q. Well, is it reasonable to determine the impacts of local pumping by looking at a regional model?
A. You can make estimates with the regional model.
Q. All right. You've done that, haven't you?
A. I've made estimates with various models, yes.
Q. I mean, but you actually made an estimate of the amount of water that was being taken from one state, under a compact, out of a river, and you used a regional model to estimate it, didn't you?
A. In the -- in a couple of different cases. But in the Kansas and Nebraska case, we developed a model. It's a regional groundwater model, but it's also interconnected to streams, and that model is used to estimate effects on stream flows.

Q. Well, you also did that in Wyoming vs. -- in Montana vs. Wyoming, didn't you?

A. Yes, but that was related to coalbed methane water development.

Q. I'm not asking about the details. I'm asking you, what -- did you use a regional model to give opinions in the United States Supreme Court case as to the impact of local pumping in an area around a river? Did you do that?

A. No.

Q. You didn't? Okay.

Do you recall the Special Master's report that was issued on December 29, 2014, in Montana vs. Wyoming?

A. Yes, I think I've seen that report.

Q. You've seen it. You testified in that case, didn't you?

A. Excuse me?

Q. You testified in that case, didn't you?

A. I did.

Q. And you gave opinions in that case, didn't you?

A. I did.

Q. Okay. And what did the Special Master conclude with regard to your opinions?

A. He concluded that the estimated flows -- or as I understood it, anyway, the estimated -- well, first of all, I was assessing the impacts of coalbed methane development throughout the regional area in Wyoming and the potential impacts of that

on the stream flows in the Tongue River. And I think he concluded that the estimates were relatively small, and there was uncertainty about them, and therefore he did not utilize those in his -- in his determination.

Q. Did he actually explain in his report that he found your testimony to be insufficiently reliable for him to rely on?

A. I recall something like that. I think it related to issues about potential effects of amount of aspirations along the streams.

Q. Yes. But actually, one of the things he specifically says, I believe, when he's explaining why your report -- your testimony is not sufficiently reliable to be utilized in his decision, was that you used a regional groundwater model to project --

THE COURT: I think he's raising an issue.

MR. FREDERICK: Objection, your Honor. If he's got a transcript to show us, or if he's got an opinion to show us, maybe he could produce this, rather than provide a characterization of what a Special Master in another original action is said to have held.

THE COURT: Okay. If you want him to see that, share it.

MR. ELLINGBURG: I think that's reasonable.

Here you go.

THE COURT: Do you need time to look this over?

MR. ELLINGBURG: I'm going to point to specific pages and specific language from the Special Master's report.

THE COURT: If you need time to look it over ...

MR. FREDERICK: Did the witness get a copy?

MR. ELLINGBURG: I'll give him a copy.

THE COURT: We'll take a short recess, and then come back in ten minutes.

(Recess)

THE COURT: You may proceed, if your witness has had a chance to look at whatever you're talking about.

BY MR. ELLINGBURG:

Q. Have you had a chance to look at it?

A. I've looked at it some, yes.

Q. Do you recall this testimony and this ruling by the Special Master?

A. I recall the ruling and what he said about it, yes.

Q. Okay. I mean, and he found some specific faults with your use of the regional model in that case, didn't he?

A. We used a model developed by the BLM, and I think what he found was the -- well, the impacts were -- that we were estimating with the model, which was developed to look at coalbed methane, the impacts on the stream were relatively small, and they were probably within the uncertainty of the model. And that's what he found.

Q. They were relatively small compared to what you testified

to, right?

I said they were relatively small impacts compared to the impacts that you testified to, based on the model; is that correct?

A. No, that's not correct.

Q. That's not correct? Okay.

Did he criticize your use of that model?

A. He indicated that he didn't believe the model was sufficiently reliable to estimate those impacts.

Q. Okay. And why did he reach that conclusion? I think one of the things was it covered 8,000 square miles, right?

A. That wasn't my understanding.

Q. Would you please look at page 212.

A. 212?

Q. Yes. 212.

Do you see, about the middle of the page, where it says "Mr. Larson chose"? Do you see that? On 212.

A. Yes.

Q. Okay. It says, Mr. Larson chose the BLM model because quote, "a lot of effort went into the development of that model" (including detailed mapping and elevations), and BLM was a disinterested party giving the model some -- quote, "some credibility."

Is that -- is that what the judge reported in his recommendation?

A. I think that's what I said.
Q. Okay. So he was quoting you, and it was one of the reasons he didn't accept the model, wasn't it? Why would he say this if he weren't finding fault with that element -- that level of an --

MR. FREDERICK: Objection. Calls for speculation from a Special Master.

THE COURT: Objection sustained. We can't decide why the Special Master decided.

BY MR. ELLINGBURG:

Q. "He also believed" -- he's now talking about you, the Special Master, right?

He says, He also believed that the model had the quote "appropriate structural features," closed quote, needed to make reasonable calculations. Right?

A. He's talking about me.
Q. Yes. Did you give that testimony?
A. Yeah.
Q. Okay. And the Special Master also then started talking about the model, and he said that it covered 8,000 square miles. Right?
A. Yes.
Q. And that the model itself recorded that it had limitations that -- in the available data. Is that correct?

It's at the bottom of the page.

A. Yes.
Q. Okay. Did you look at the limitations on the MERAS model?
A. I've reviewed some of the calibration information.
Q. No. Did you read, in the MERAS report that you have testified to extensively, the limitations the USGS reported for that model?
A. I've read the report, so ...
Q. Do you recall any of the limitations?
A. Well, my recollection was that they characterize it as a regional model, and therefore it may not be appropriate to look at very localized conditions.
Q. Okay. The regional model; that was the one in the Montana case the judge said covered I think -- what do we say -- what did I say, 8,000 miles, square miles?
A. Yes.
Q. Okay. How many square miles does the MERAS model cover?
A. Some -- somehow the number 70,000 sticks in my mind, but I don't remember exactly.
Q. 70,000 square miles. Right. And it uses a model grid of one mile squares for that entire 70,000 miles, right?
A. Yes, the grid spacing is one mile.
Q. And there -- I don't want to misstate this. If you would -- I'll need to let you see this -- this is Joint Exhibit 18, and you've testified to it a great deal on direct. It's in your notebook, I believe.

Yes, I can see you've got a couple right there. Thank you. Could you look at page 56 of Joint Exhibit 18.

A. Okay.

Q. At the top, do you see where it says "Limitation of analysis"?

A. Yes, I see that.

Q. And beginning with the second sentence -- I'm going to read it, and you tell me if I've misrepresented it. It says: "The accuracy of groundwater model is limited by simplification of complexities within the flow system, conceptual model, space and time, discretization." What does "discreditization" mean? What does that word mean?

A. Time discretization?

Q. No. It says time "discretization." What does that mean?

A. Time discretization. That's what you're asking me?

Q. Yes. What does it mean?

A. It means that the model solves differential equations numerically, and in numerical schemes, the time is divided into segments. And the size of those segments are time discreditizations; that's how they calculate -- they calculate from one time to the next in discrete segments.

Q. Thank you.

So it's -- "The model is limited by simplification of complexities within the flow system, space and time discretization effects, and assumptions made in the formulation

of the governing flow equation."

Did I read that correctly?

A. Yes. You did.

Q. And then further down -- and I'm just picking out some highlights, but further down on that same column, to I'd say the bottom fifth or so -- this is a long paragraph -- it starts with "Areas of sparse geophysical information."

Did you see that?

A. Are you in the next paragraph, or the same?

Q. I'm in the next paragraph, almost all the way at the bottom of the page. "Areas of sparse geophysical" --

A. Yes, I've got it.

Q. Okay.

"Sparse geophysical information may affect model results through assumptions in the altitude and thickness of these geohydrological units and the lack of definition of structural controls that may affect groundwater movement."

Now, this is talking about throughout the entire MERAS model, right?

A. They're talking about areas of sparse geophysical information.

Q. Right. But I'm saying this is -- this is relating to this particular regional model, right?

A. It's talking about the MERAS model, yes.

Q. Right. And so this is a warning of limitations. And I

think in the next -- the top of the next paragraph, the column is probably the part that's most important -- it says, "The goal of the MERAS model is to develop a model capable of suitable accuracy at regional scales.

"The intent was not to reproduce individual local scale details, which are typically not possible, given the uniform scale size of a mile -- one mile squared. Although the MERAS model may not represent each location detail, it is relevant for a better understanding of the regional flow systems."

So you've given a lot of opinions about the flow paths shown by the MERAS model, right?

A. The flow paths shown by the MERAS model?

Q. The arrows on the maps shown from one state to another are generated by that model?

A. The general patterns, yeah, the regional patterns, right.

Q. Now, this -- this is a warning that you're to be careful about that; is that right?

A. Yes, that's something that you would consider with any model.

Q. Okay. And in this case, we have a local or -- model, which had been worked on for years by the USGS, do we not, the Brahana Broshears model?

A. You have a different model applied that -- back in the 1980s, and its resolution is a lot different than the models we

have now.
Q. Okay. But you're saying that the Brahana model was never changed from the time of the 1980s; there were no changes to that. Is that your testimony?
A. I'm not aware that there was any changes in the model.
Q. Okay. It was published, I think, in -- what, '98 or '99, or 2001?
A. That's when the report was published, but I think the work was done in the 1980s.
Q. Right. But you don't know if there was anything that was changed between the time of the initial work and then?
A. In 2001?
Q. Do you know if there was any changes?
A. Not that I'm aware of, no.
Q. Okay. You say not that you're aware of, but does that mean you don't know if there were or were not?
A. I don't -- I don't know whether there were or were not. I'm not aware of any changes, and what I've looked at, the model structure that people have used, it appears to me to be the model that was constructed in the 1980s.
Q. Okay. But that was a -- that's a local model for the Memphis area, based on Memphis data; is that correct?
A. I --
Q. The Brahana and Broshears model?
A. I wouldn't characterize that. That model extends from

south of the Mississippi border up almost to the extent of the Embayment.

Q. The MERAS model does?

A. No, the --

Q. The Brahana model?

A. Yes.

Q. All the way to the top of the Mississippi Embayment?

A. Almost, yes.

Q. Okay. Now, do you now recall that the Special Master in the Montana case found your testimony unreliable because you used a regional model, where the local model should have been used; at least, that was one of his bases?

MR. FREDERICK: Your Honor, could I just ask for a page reference to this 200-and-some-page Special Master report?

THE COURT: You may cite the page.

MR. ELLINGBURG: I thought I'd given it to you.

If you begin reading -- because on page 211, there is an analysis of the evidence and expert testimony. And to your -- in your defense, it points out that groundwater is really difficult to completely analyze, because it's underneath the ground, and you can't see it, right?

And he starts off, he says, This case demonstrates -- As this case demonstrates, determining whether groundwater pumping interferes with the continued enjoyment of surface rights is often difficult."

And so he talks about that, and then he starts talking about -- he says, "Montana's" --

A. Could I ask you where you're reading from?

Q. I'm reading from page 211.

Do you see where it says, "Analysis of the evidence and expert testimony"?

A. Yes, I do.

Q. Okay. And it says, "Montana's principal groundwater expert, Mr. Steven Larson" -- that's you, right?

A. Yes, it's me.

Q. All right.

"Used the MODFLOW groundwater model developed for a BLM study of the CBM groundwater production in the Powder River Basin to estimate the impact." Right?

A. Yes.

Q. Okay. And then I read you already what he starts off with in terms of your description of the model and your basis for relying on it. And one of them is appropriate structural features.

Now, you've used this phrase "continuity" to support your position that the groundwater at issue in this case is all the water in the Mississippi Embayment; is that correct?

A. No. I'm trying to answer the question of whether or not the aquifer is an interstate water resource.

Q. Okay. Are you separating the water in the aquifer from the

aquifer, or are you just saying that because the geology underlies multiple states, the water is necessarily interstate?

A. No, I'm looking at the extent of this aquifer, which, by definition, is the geology and the water.

Q. Okay. Now, you were shown some of the USGS maps, toward the end of your testimony, that showed cones of depression, right?

A. Yes.

Q. Now, is it your testimony that the cone of depression in South Central Mississippi or Southwest Mississippi is actually capturing groundwater from the Memphis area?

A. No, it's not my testimony.

Q. Okay. It can't, can it?

A. Well, as scientists, we often don't say "can't," but it's not likely.

Q. Okay. Nothing that you know about groundwater hydrology would suggest that that pumping that was emphasized in that lower part of Mississippi is -- would have an impact on the local condition in this case?

A. Not on the condition on the aquifer. The only thing I can think of is if there was some connection through the surface water system.

Q. Now, before I go to that, the -- what about the pumping in Louisiana and Arkansas that is near the border of Louisiana and Arkansas? Is that large cone of depression, in your opinion,

withdrawing groundwater from Northwest Mississippi?
A. My opinion is that those cones of depression have spread across state lines from both directions and have coalesced.
Q. But in Arkansas and Louisiana?
A. Yes.
Q. But you're not giving the testimony that those cones of depression are withdrawing groundwater out of Northwest Mississippi, next to Memphis, are you?
A. No, I'm not giving that opinion.
Q. Okay. Because it isn't, is it?
A. Not that I'm aware of.
Q. Okay. Now, the surface water and groundwater connection, I believe you've testified that there is a hydrologic connection between the Mississippi River and the Sparta Sand and Memphis Sand; is that correct?
A. Yes. To the regional aquifer system and the intervening layers.
Q. So did you ever perform any calculations with regard to the travel time of that groundwater from the outcrop until the point that it was discharged into the Mississippi River?
A. The travel time from the outcrop to the river? No, I did not.
Q. Okay. Do you have any estimate of how long that would be?
A. No, I don't.
Q. Okay. You didn't look at it at all, did you?

A. I didn't try to estimate travel times, no.
Q. Okay. Did you attempt to determine the residence time, which I believe is somewhat related, of a groundwater molecule, as it's been described, entering the outcrop of the Sparta Sand or Memphis Sand in Mississippi, within the state of Mississippi?
A. I am not sure how that's different from the question you just asked me, in terms of the travel time.
Q. Me either. But so -- so residence time would be the equivalent of travel time?
A. Well, it certainly can be, yes.
Q. Right. Now you do --
A. But you're talking about a specific time, residence time, from where it went in the outcrop area into the river?
Q. Yes. Yes.
You do environmental work, right?
A. Yes, I do.
Q. And in the case of environmental work, do you calculate travel times in terms of pollutants, in the point that they were, I guess, spilled on the ground or -- you know, poured on the ground, to a -- another water resource?
A. At times, yes.
Q. I mean, is that part of trying to remediate it and control it?
A. It can be part of that.

Q. Okay. So it's not -- you know how to calculate travel time and residence time, right?
A. Well, I'm going to put it this way: I know how to make estimates of travel time.
Q. Okay. That's good. But you didn't do it in this case because you didn't think it was important?
A. I didn't think it was necessary for me to draw the conclusions that I drew about the interstate water resource.
Q. Did you make any effort to determine the relative storage capabilities of the aquifer within Mississippi and Tennessee across the board, stored -- in the storage capacity? How much groundwater could the aquifer hold?
A. No, I haven't tried to figure that out.
Q. Okay. Because you didn't consider it important?
A. No, I did not. At least to the question that I was addressing. It may be important in other situations, but ...
Q. Now, the question you were addressing was the question that you took out of the order and interpreted as you interpreted it; is that correct?
A. Yeah, it was a question, as I understood it, as to whether or not this was an inter -- the Middle Claiborne Aquifer was an interstate water resource.
Q. Okay. Now, do you -- a lot of your opinions are stated in either absolute or very broad terms. So when you say as an expert that the groundwater that came in at the outcrop in

Mississippi and was moving across Mississippi would not be there permanently, did you put any kind of range on what you meant by "permanently"? You just meant it would never leave, right?

A. My conclusion was that it would leave.

Q. Right. So that it would not be there permanently?

A. Correct.

Q. But you made no effort to determine how long it might reside there?

A. No, I did not.

Q. Okay. And based on what you know from --

A. Well, maybe I should rephrase that.

I didn't try to make a travel time calculation from the outcrop to the point of discharge. I mean, I recognize that even as we sit here today there's water discharging --

Q. Right.

A. -- from the Mississippi into other areas.

Q. Right. The groundwater is pumped out of the cone of depression that's been taken out of storage, right?

A. Well, not -- if you look at the recent water level trends in the area of Memphis, they've been relatively stable. So within those areas, where the water level has been relatively stable, the storage hasn't changed.

Q. Do you know where the recharge is coming from? Can you state an expert opinion as to where the recharge coming into

the Memphis Sand and Sparta Sand is coming from? Is it all coming from the outcrop?

A. Coming from the outcrop. It can also come from other underlying and overlying aquifers.

Q. Do you know where it's coming from, within that larger universe?

A. I haven't tried to see a detail where it's coming from. I've only observed that the water level declines in that -- those areas have been relatively stable over the last number of years.

Q. Now, you also gave a lot of testimony in terms of -- certain things could take place. Right?

A. To some degree, yes.

Q. Okay. But you -- those statements aren't intended to be opinions, are they, when you say something could take place?

MR. FREDERICK: Objection, your Honor. I think his testimony speaks for itself. And if I was asked to redo his questions, which I did upon his first objection, I was quite happy to rephrase them to satisfy Mr. Ellingburg.

THE COURT: I'll overrule the objection if the witness can understand the question.

MR. ELLINGBURG: I need to try to do better with the questions, based on that, your Honor.

Q. Have you designed any wellfields?

A. At times, yes.

Q. Okay. Is that an area that you claim expertise in?
A. I've designed wells and pumping systems in my time.
Q. Have you done any real study of the wellfields in this particular case with the kind of detail you would need to make any recommendations as to those wellfields?
A. No, I haven't studied at that level of detail.
Q. So when you made comments about the wellfields, they aren't based on the study -- they aren't based on any studies that you've made, any study you've made in this particular case; is that correct?
A. They're not based on a particular study that I might have done, no.
Q. Okay. Now, does the USGS actually play any role in groundwater management within specific states?
A. I'm not aware of -- that they are involved in groundwater management. They may be, but I'm not aware.
Q. They provide scientific data to the various cities and states that are using groundwater; is that correct?
A. They -- that's generally what their mission is, certainly. The only caveat was I was involved in some -- or I'm aware that the USGS was involved in some projects while I was at the USGS where they were somewhat acting as a consultant to a municipal entity.
Q. But ultimately they don't have the authority to make a groundwater management decision within the states, do they?

A. Well, I'm not aware that they do groundwater management.
Q. Is that something typically handled by each separate state, based on your experience?
A. It could be states, it could be municipalities, it could be water purveyors.
Q. To the extent that Tennessee is -- the City of Memphis and Shelby County are pumping water that is, at the time the pumping takes place, is known to be coming from the State of Mississippi, how can Mississippi regulate that pumping, that you know of?
A. Could you repeat the first part of that?
Q. How can Mississippi regulate pumping that is taking place in the State of Tennessee, in Shelby County or by the City of Memphis, if that pumping is withdrawing groundwater from within the State of Mississippi?

MR. FREDERICK: Your Honor, I have an objection, because he used the word "regulates," which is a legal term of art. Mr. Larson is a trained hydrologist. He's not a lawyer.

THE COURT: I'll sustain the objection on that.

MR. ELLINGBURG: Thank you.

Q. Is the word "interstate" a scientific term of art?
A. I wouldn't call it a scientific term of art. I would call it just a -- it's a word that has a meaning.
Q. It's an observation anybody can make?
A. Excuse me?

Q. It's an observation anyone could make; is that correct?
A. Well, "interstate" has a common meaning.
Q. Right. And you're applying the common meaning, and anyone could do that, right?
A. I'm applying the common meaning of "interstate" to the term "water resources."
Q. Right. And that's ...
Have you done any calculations of groundwater velocity within either the State of Mississippi or the Southwest area or West Tennessee, to give your opinion?
A. Not for purposes of this particular case, no.
Q. Have you evaluated the amount of groundwater that can be withdrawn from the available aquifer system within -- within West Tennessee? Have you done an evaluation of that?
A. No, I have not.
Q. Because it's not important to you?
A. Excuse me?
Q. It's not relevant to your opinion, right?
A. How much water can be developed?
Q. Right.
A. Yeah, no, I don't think that's relevant to the conclusion as to whether this is an interstate water resource.
Q. And what do you base that on?
A. Because I believe that the determination of whether this is an interstate water resource is determined by the continuity of

the aquifer and its characteristics, the connection between that aquifer and other aquifers and surface waters that might be interstate in and of themselves, and also on the ability of pumping in one area to affect another area that could go across state boundaries.

Q. Can you provide us with any metric of any kind, other than sand, as to what you mean by "continuity"?

A. Well, "continuity" just means that within an area, the entity -- which in this case is the Middle Claiborne Aquifer -- exists, and that it has physical properties that allow communication hydraulically throughout that area.

Q. What are those specific physical properties within DeSoto County, Mississippi, that you have identified?

A. Properties of permeability, properties of transmissivity, storage characteristics.

Q. Are those properties, based in -- what you have studied, uniform throughout DeSoto County, Mississippi?

A. No, they're not uniform.

Q. And I believe that this whole system would be -- DeSoto County, Mississippi, and Shelby County, Tennessee, is complex; is that fair?

A. There are complexities.

Q. Okay. And what kind of complexities?

A. Well, there are variations in the amounts of sand, for example, that you might find in one area versus another. There

are areas where the materials become finer grain and become confining units.

Q. Thank you.

Those things affect all of the properties that determine groundwater flow and direction and storativity, don't they, those variations?

A. They can have impacts.

Q. They can have impact -- they determine impact?

A. Well, that's not the only thing that determines those.

Q. There's more, right? There are other factors?

A. Well, there are places where the water is recharged and places where the water is discharged. Those also play a role in that.

Q. And those are all local conditions?

A. Not necessarily. I mean, the Mississippi River is a large river.

Q. Thank you.

MR. ELLINGBURG: Would you put the slide up, the first slide.

Q. Okay. Now, you used this chart during your direct examination; is that correct?

A. I don't remember if we used this one or another one.

MR. FREDERICK: Your Honor, I don't think we used this one.

MR. ELLINGBURG: Okay. So you used Arthur & Taylor in

1990; I used another Arthur & Taylor.

MR. FREDERICK: We didn't use this one.

MR. ELLINGBURG: Okay.

BY MR. ELLINGBURG:

Q. Well, is this similar? Is there some continuity between this chart and the chart you looked at earlier?

A. The one that we used was showing generalized flow patterns, as I remember, in the predevelopment condition.

Q. Okay. Is this a very, very high-level generalization?

A. A very, very high-level what?

Q. Generalization.

A. Yes, this is a generalization of a profile through the Mississippi Embayment.

Q. Because it doesn't show any -- any separate aquifers within the Middle Claiborne Aquifer group, does it?

A. It shows the Middle Claiborne Aquifer, and it shows the Upper Claiborne Aquifer.

Q. Does it show a Lower --

A. And a Lower Claiborne Aquifer. I'm sorry.

Q. I thought you said there wasn't a separate Lower Claiborne Aquifer.

A. I didn't say that. There's a Lower Claiborne hydrogeologic unit that was defined as part of MERAS.

Q. But this says "Lower Claiborne Aquifer." Right?

A. That's what it says, yes.

Q. Is that a separate aquifer from the Middle Claiborne Aquifer?
A. It's been identified as a -- at least a subhydrogeologic unit within the Middle Claiborne hydrogeologic unit.
Q. Do you know if a Lower Claiborne Aquifer exists in the State of Tennessee?
A. Not to my understanding. In terms of where it was characterized, it was further south.
Q. Thank you.
MR. ELLINGBURG: Well, I'd like to pull up another chart. MERAS, the next slide, if you would.
Q. Now, this -- was this the slide you looked at on direct?
A. No.
Q. It was not?
A. Not this particular one, no.
Q. Okay. Does it contain the same hydrogeologic units as the one you discussed?
A. Yes, it does.
Q. Now, over in the "Hydrogeologic Unit" column, there seems to be some separation between the Lower Claiborne Aquifer or -- exactly where it exists. Is that what that indicates, the little area where it's all hatched off? What does that show?
A. That indicates to me that there is a transition from what they're calling the Middle Claiborne Aquifer to what they're calling the Lower Claiborne Aquifer within that overall

hydrogeologic unit.
Q. I believe counsel highlighted everything that's -- Sparta, Lisbon, and then over, and then came back and came under where it says Meridian Sand member here. Does this indicate that all of that is continuous as the Middle Claiborne? From looking at this particular chart, as a hydrogeological unit?
A. My understanding is that there's a continuity to those connections between the Middle Claiborne Aquifer and the Lower Claiborne Aquifer.
Q. "Continuity" means that they have somewhat similar sands; is that right?
A. Well, there's not a barrier that separates one from the other.
Q. Okay. It's the barrier thing. Because from your description, "barrier" has to be a geological feature or something that's been installed that just cuts off any potential flow; is that correct?
A. Well, in order for them to be somehow separated, there would have to be a barrier between them.
Q. Does groundwater flow from the area of higher pressure to lower pressure?
A. A higher potentiometric level to lower potentiometric level.
Q. Thank you very much. I always appreciate that.
So does the pressure drive the direction and the flow

of the water within the confined aquifer unit?
A. The potentiometric level will determine the flow of the water, which is a combination of pressure and elevation.
Q. Okay. So if the natural pressure pushes that water in a specific direction, then until somebody introduces the well, that water will follow that path, will it not?
A. Well, the water will move from higher potentiometric levels to lower potentiometric levels.
Q. So that will determine direction, will it not?
A. Well, it isn't just two points. It has to be more than two points to figure out which direction it's going.
Q. Right. But if you've got more than two points, and you've got the potentiometric pressures, you can determine the direction of the natural flow; is that correct?
A. If you have more than two potentiometric levels -- more than two potentiometric levels, you can estimate the directions of groundwater movement.
Q. And groundwater hydrologists do that all the time, don't they?
A. Yes, that's part of the work that we do.
Q. Now, you've given some testimony which is a little, seems to me -- I can't completely -- excuse me. I strike that question.
I can't completely synthesize some testimony about the USGS work. I mean, do you believe the USGS does high-quality

work?
A. Yes, I do.
Q. And do they have very rigorous guidelines in place that are required to be met before they will publish material?
A. They did when I worked there.
Q. Okay. Good enough. Do you think they've lowered those standards?
A. I do not.
Q. Thank you.
Do you believe that the work that was -- has been performed in the Memphis area, in that local area, by the USGS, has been high-quality work?
A. I -- I believe that the reports that they've issued would meet their standards for release, and obviously the work over time improves as more and more information becomes available.
Q. That was another thing I wanted to touch on. I mean, the USGS has been collecting groundwater data in the Memphis area for a very, very long time, isn't that right?
A. They have, yes.
Q. I think going back at least to the early 1900s?
A. Yeah, I don't remember what the first data points are.
Q. And is their process to build on their prior studies?
A. Generally speaking, I think that's true.
Q. Unless they find some error, and they'll correct it, right?
A. That would be my understanding.

Q. Have you identified any -- any errors in the Brahana and Broshears model that were correct on the MERAS, or is the MERAS model just an expanded version of the regional, and covers more layers?

A. No, I think it's a little more nuanced than that. I think the Brahana model, back at the time that was done, modeling in general was limited by computer capacity, and so certain assumptions and simplifications are made in order to accommodate that.

More recently, in the MERAS model, now we're in a different era of computing power, and some of those assumptions are -- some of the issues don't have to be made.

Q. Have you identified specific assumptions and simplifications that have been removed from the MERAS model?

A. Yes.

Q. Okay. And what are they?

A. Well, the one that sticks in my mind is that the communication between the layers in the model, there were three layers. The way they defined the interconnection between those layers was to a parameter called LEKINS. And LEKINS is sort of an idealization that tries to represent the ability of water removed vertically, but it doesn't represent the actual layer that the water is moving through.

Similarly, there are assumptions about the surficial aquifer and the shallow aquifer; they imposed what we call a

constant head condition throughout that area and did not actually simulate movement of groundwater within those aquifers. Those have now been improved in the MERAS model.

Q. Could you tell me what the constant head boundary was in the Brahana model?

A. The outermost layer in the model was set at a constant head.

Q. Can you tell me what it was?

A. Well, it varied from place to place. It wasn't just one number.

Q. Okay.

THE COURT: I think we'll stop for the evening at this time, and we'll resume tomorrow at 9:00 a.m.

How are we doing on our schedule to get through with the defense case? Can you all give me an idea?

MR. FREDERICK: Well, your Honor, we've got two more witnesses to present, and then we will rest. Once Mr. Larson is done, we have two more witnesses.

MR. ELLINGBURG: And I will attempt to be brief.

THE COURT: Is there a chance we'll get through by Friday --

MR. ELLINGBURG: It depends on how long they're on direct.

MR. FREDERICK: Well --

MR. ELLINGBURG: And how long I cross.

MR. FREDERICK: How much more cross do you have for Mr. Larson?

MR. ELLINGBURG: I believe, once I've conferred with cocounsel, there won't be a great deal.

MR. FREDERICK: So, your Honor, our expectation is that very early tomorrow, as soon as the cross is finished, we would present Dr. Brian Waldron, and that our expectation is that Dr. Waldron could be completed tomorrow; and that we would then have David Langseth, that MLGW would be presenting, and his presentation would either start at some point tomorrow or first thing Friday morning.

THE COURT: Okay. Does that make you think you might get through Friday, or does that make you think you might not get through?

MR. ELLINGBURG: It's certainly a possibility.

THE COURT: All right.

MR. ELLINGBURG: I've been learning how to answer questions.

THE COURT: Okay. Very good. Just trying to see how -- where we are on our schedule. If we have things next week we have to postpone, we'd have to do so, and so forth.

MR. FREDERICK: Thank you, your Honor.

THE COURT: We'll recess until 9:00 tomorrow morning.

(Adjourned to Thursday, May 23, 2019, at 9:00 a.m.)

STATE OF TENNESSEE:

COURT REPORTER'S CERTIFICATE

I, PATRICIA A. NILSEN, Licensed Reporter for the State of Tennessee, CERTIFY:

1. The foregoing deposition was taken before me at the time and place stated in the foregoing styled cause with the appearances as noted;

2. Being a Court Reporter, I then reported the deposition in Stenotype to the best of my skill and ability, and the foregoing pages contain a full, true and correct transcript of my said Stenotype notes then and there taken;

3. I am not in the employ of and am not related to any of the parties or their counsel, and I have no interest in the matter involved.

WITNESS MY SIGNATURE, this, the_____ day of _____, 2019.

_____

PATRICIA A. NILSEN, RMR, CRR, CRC
TN Licensed Court Reporter
LCR Number: 717
Expiration: 6/30/2020

Q