Project ECO$_2$S Phase 2 CarbonSAFE Field Project

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DOE Disclaimer

The CarbonSAFE Project: Background

In mid-2016, the U.S. Department of Energy/National Energy Technology Laboratory (DOE/NETL) issued a Funding Opportunity Announcement to develop an integrated CCS storage program ready for commercial operation by 2025.

This program called CarbonSAFE (Carbon Storage Assurance Facility Enterprise) consisted of four distinct phases:

- Phase I. Pre-Feasibility Study
- Phase II. Storage Complex Feasibility Study
- Phase III. Site Characterization and Permitting
- Phase IV. Infrastructure Construction

A consortium of companies, led by Mississippi Power Company (MPC), submitted a proposal and were awarded a Phase II portion of CarbonSAFE. The project called ECO_2S (Early CO_2 Storage) is located in Kemper County, Mississippi.

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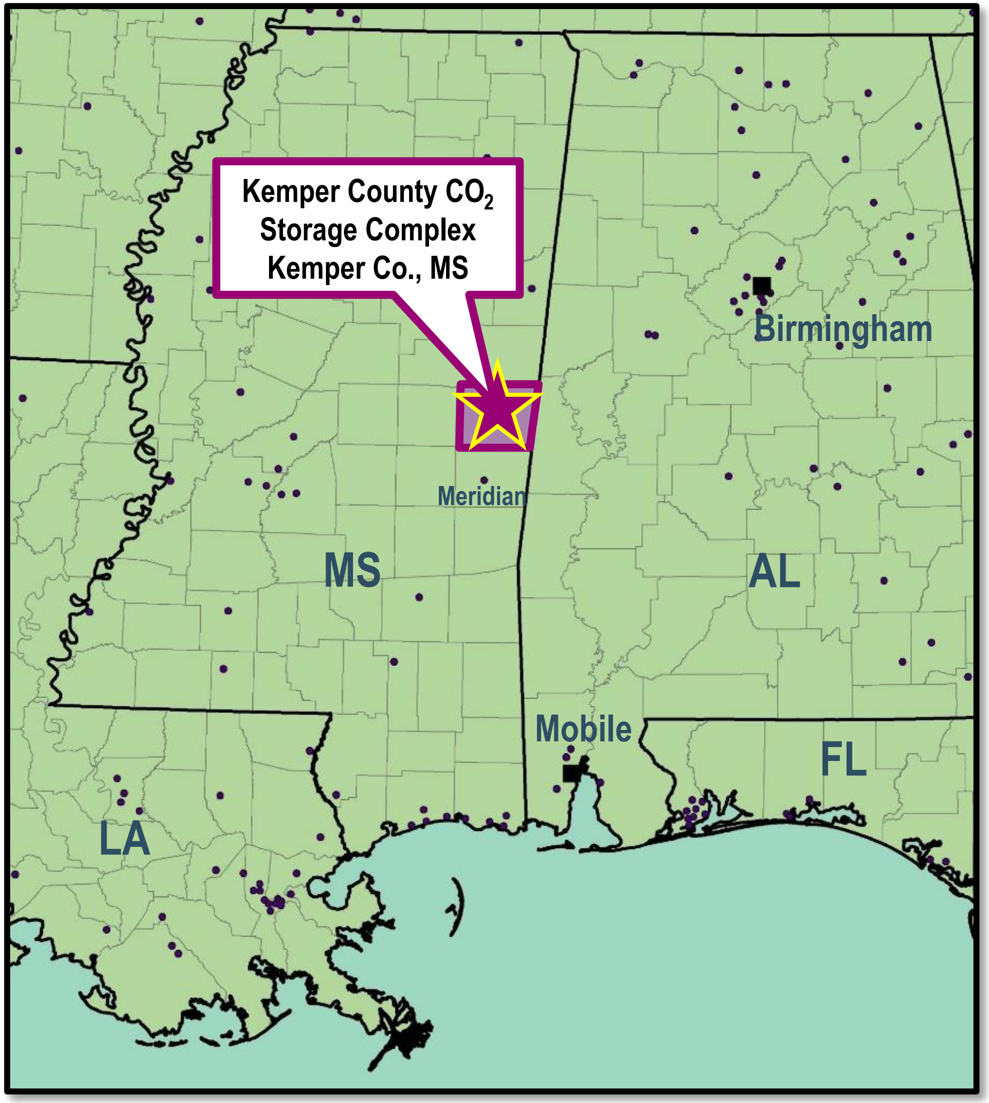
Kemper County CO_2 Storage Complex



The Kemper County CO_2 Storage Complex is located in Kemper County, east-central Mississippi, north of Meridian, Mississippi.

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Background

Prior Pre-Feasibility on the Kemper County CO_2 Storage Complex. Mississippi Power Company (MPC), in conjunction with Southern Company Services (SCS), Advanced Resources and others had performed considerable pre-feasibility work on the Kemper County CO_2 Storage Complex. This enabled the project to qualify for the Phase II: Storage Complex Feasibility for CarbonSAFE.

The storage pre-feasibility work involved:

1. Performing a Geologic Evaluation of the Proposed CO_2 Storage Site
2. Establishing the Presence of Sufficient CO_2 Storage Capacity
3. Utilizing Data from Prior Deep Well Drilling
4. Performing Reservoir Modeling for the Areal Extent of the CO_2 Plume and a More Rigorous Estimate of CO_2 Storage Capacity
5. Establishing the Availability and Reliability of the CO_2 Source
6. Securing Surface Pore Space Rights, and
7. Conducting Initial Stakeholders Analysis and Other Pre-Feasibility Tasks

This presentation will discuss the pre-feasibility work conducted by the study team in preparation for proceeding with the Phase II. Storage Complex Feasibility Study that is now underway.

1. Performing Geologic Evaluation of the Proposed CO_2 Storage Site

The first pre-feasibility effort was a comprehensive, multi-disciplinary geologic evaluation by the Geological Survey of Alabama (GSA), with Dr. Jack Pashin as Principal Investigator, entitled, "Geological Evaluation of the Potential for CO_2 Sequestration in Kemper County, Mississippi."

This study identified two Lower Cretaceous strata, the Paluxy and the Washita-Fredericksburg sandstone saline formations, and one Upper Cretaceous interval, the Lower Tuscaloosa Massive Sand, as geologically favorable settings for storing CO_2 in Kemper County.

These three formations are overlain by the thick Tuscaloosa Marine Shale, a regionally extensive confining unit (seal).

The study used a 25 well data set, plus information from two previous drilled wells, to establish the geologic foundation for the CO_2 Storage Complex.

Kemper County - Generalized Stratigraphy

Tertiary	**Eocene**	**Lower Wilcox Group**	**Nanafolia Fm.**	USDW
	Paleocene	**Midway Group**	**Naheola Fm**	Potential USDW
			Porter's Creek Clay	Regional Seal
Cretaceous	**Upper**	**Selma Group**	**Predominately Chalk**	Regional Seal
		Eutaw Fm.		Potential USDW
		Tuscaloosa Group	**Upper**	Potential USDW & Water Supply
			Marine Shale	Regional Seal
			Lower & Massive Sand	Potential Saline Fm.
	Lower	**Washita- Fredericksburg**		Saline Fm.
		Paluxy Fm.		Saline Fm.

Paleozoic Unconformity

(Lower Cretaceous Morringsport, Ferry Lake & Rodessa Fms missing @ Kemper Co.)

Source: Pashin, J.C., D.J. Hills, D. C. Kopaska-Merkel, M.R. McIntyre, Geological Evaluation of the Potential for CO_2 Sequestration in Kemper County, Mississippi, Final Report, prepared for Southern Company Research and Environmental Affairs, June 1, 2008.

- **Tuscaloosa Massive Sand**
  - Depth: 3,000’ to 3,252’
  - Porosity: 20%
  - Net Sand: 246’
- **Washita-Fredericksburg**
  - Depth: 3,252’ to 4,225’
  - Porosity: 18%
  - Net Sand: 638’
- **Paluxy**
  - Depth: 4,225’ to 4,808’
  - Porosity: 18%
  - Net Sand: 444’

2. Establishing the Presence of Sufficient CO_2 Storage Capacity

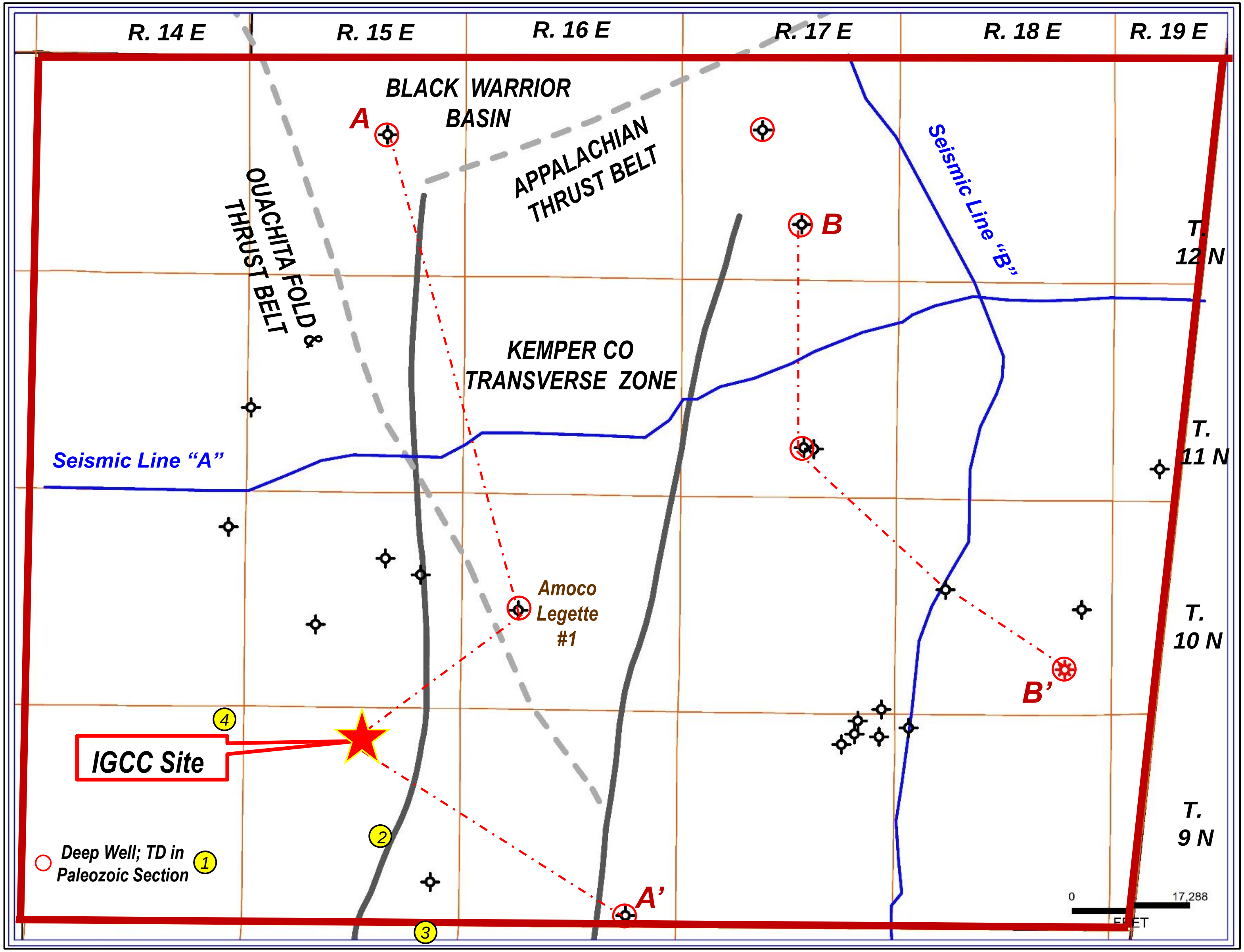
The GSA study provided a preliminary CO_2 storage capacity estimate (at 10% efficiency) of 4 to 5 MMmt per square mile (640 acres) for the Paluxy Sandstone implying a storage capacity of 200+ MMmt for the proposed CO_2 storage unit.

Subsequently, Advanced Resources performed additional geologic work and constructed a series of geological cross-sections for the CO_2 storage site. These cross-sections confirmed that all three of the saline formations - - the Paluxy, the Washita-Fredericksburg, and the Tuscaloosa Massive Sand - - are regionally extensive with considerable net sand thickness.

Using this additional information, the Project Team calculated a CO_2 storage capacity of 480 MMmt for the proposed CO_2 storage site using the volumetric DOE/NETL CO_2 storage capacity estimation methodology (at 10% efficiency):

- 170 MMmt for the Paluxy,
- 220 MMmt for the Washita-Fredericksburg, and
- 90 MMmt for the Tuscaloosa Massive Sand.

Index Map of Kemper Co., MS Showing Paleozoic Structural Features, IGCC Site and Oil & Gas Exploratory Wells



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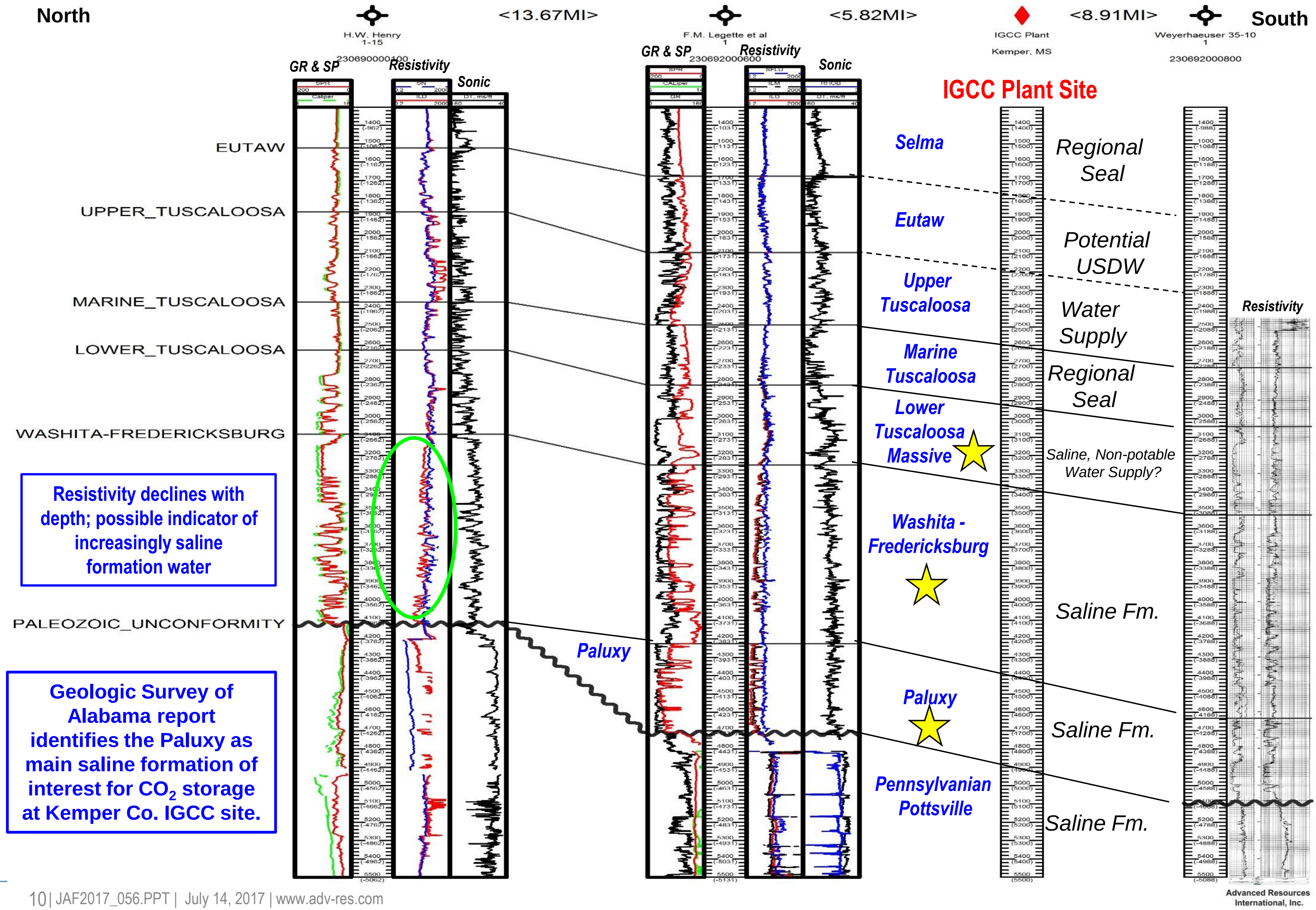
Structure Cross-Section A-A'; Depth 1300' – 5500'



3. Utilizing Data from Prior Deep Well Drilling

To characterize the reservoir setting and establish a potential water source, MPC and SCS drilled two deep wells in the area:

- The first well was a small-diameter test hole drilled to 3,962 ft (below surface) through the Massive Sand formation of the Tuscaloosa Group. A geophysical log suite, involving gamma ray, multi-resistivity and spontaneous potential, was run in this well.
- The second well was a large-diameter water production well to 3,442 ft (below surface) with an 80 ft screened interval in the Massive Sand.

Once the second well was drilled and completed, pumping tests, up to 1,200 gallons per minute, were conducted to quantify the flow potential (product of permeability, pressure and sand thickness) of the Tuscaloosa Massive Sand.

Water samples from the Tuscaloosa Massive Sand indicated a Total Dissolved Solids (TDS) of 23,000 mg/L (ppm), establishing that the water is non-potable.

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4. Performing Reservoir Modeling to Establish the Areal Extent of the CO_2 Plume and A More Rigorous Estimate of CO_2 Storage Capacity

Advanced Resources undertook reservoir modeling to: (1) better understand CO_2 injectivity, (2) calculate the areal extent of the CO_2 plume, and (3) provide a more rigorous estimate of CO_2 storage capacity.

The reservoir model used 43 distinct layers to represent the individual sands and shales of the three proposed CO_2 storage formations - - Tuscaloosa Massive Sand, Washita-Fredericksburg and Paluxy, including their interburdens and seals.

Reservoir modeling showed that the 30,000 acre proposed CO_2 storage site had an overall CO_2 storage capacity of 300 MMmt and could readily accommodate 3 MMmt/yr of CO_2 injection for 30 years.

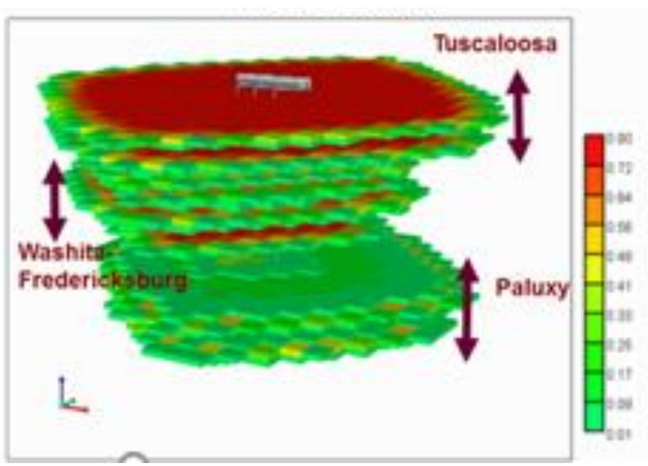
Name		Rock Type	Depth (ft)	Thickness	Porosity (%)	Permeability (md)
Tuscaloosa Massive Sand	1	Sand	3360	36	20	360
	2		3396	37	20	360
	3		3433	37	20	360
	4	Interburden	3470	65	7	0.002
	5	Sand	3535	38	20	360
	6		3573	38	20	360
	7		3611	39	20	360
	8	Interburden	3650	30	7	0.002
	9	Sand	3680	20	20	360
Washita-Fredericksberg	10	Interburden	3700	40	7	0.002
	11	Sand	3740	30	18	170
	12		3770	30	18	170
	13	Interburden	3800	60	7	0.002
	14	Sand	3860	30	18	170
	15		3890	30	18	170
	16	Interburden	3920	50	7	0.002
	17	Sand	3970	50	18	170
	18		4020	50	18	170
	19		4070	50	18	170
	20		4120	50	18	170
	21		4170	50	18	170
	22	Interburden	4220	20	7	0.002
	23	Sand	4240	30	18	170
	24		4270	30	18	170
	25		4300	30	18	170
	26	Interburden	4330	50	7	0.002
	27	Sand	4380	40	18	170
	28	Interburden	4420	160	7	0.002
	29	Sand	4580	20	18	170
	30	Interburden	4600	40	7	0.002
Paluxy	31	Sand	4640	33	18	170
	32		4673	33	18	170
	33		4706	34	18	170
	34	Interburden	4740	40	7	0.002
	35	Sand	4780	40	18	170
	36	Interburden	4820	10	7	0.002
	37	Sand	4830	10	18	170
	38	Interburden	4840	20	7	0.002
	39	Sand	4860	46	18	170
	40		4906	46	18	170
	41		4952	46	18	170
	42		4998	46	18	170
	43		5044	46	18	170

Geologic Model of the CO_2 Storage Facility

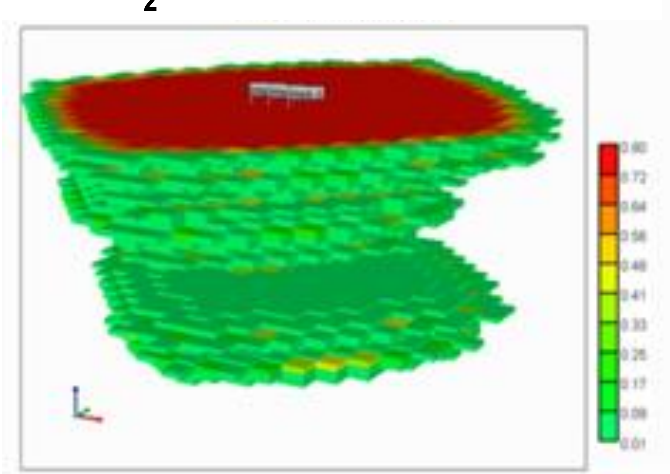
- Numerous shale interburdens ("reservoir architecture") will help constrain vertical flow and CO_2 override within each formation.
- The reservoir pressure is estimated to be hydrostatic (1,844 psi) with a temperature of 130°F.
- The salinity of the brine is in excess of 20,000 ppm.
- Relative permeability data was obtained from the Citronelle CO_2 storage test.

CO_2 Plume Model for Kemper County CO_2 Storage Complex

CO_2 Plume After 30 Years

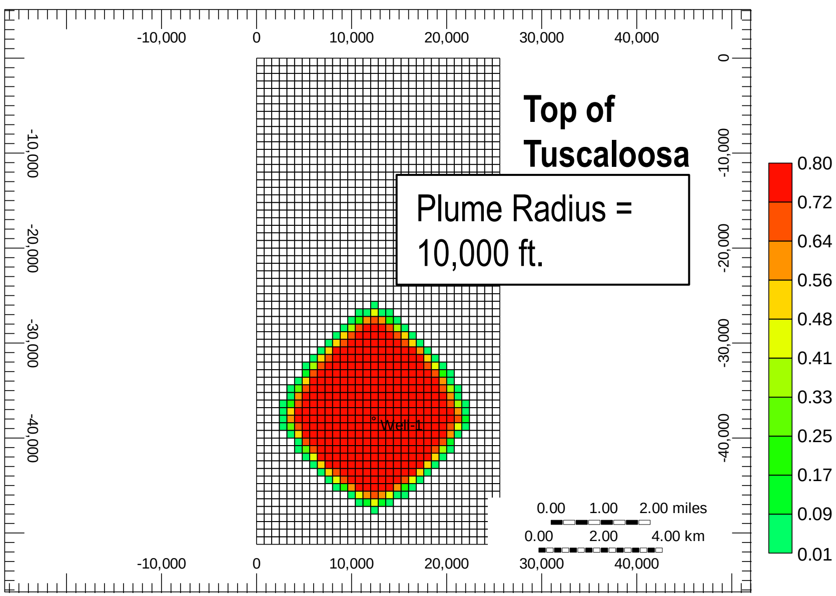


CO_2 Plume After 50 Years



The reservoir model used 30 years of CO_2 injection at 3 MMmt/ year and 20 years of shut-in to establish the maximum areal extent of the CO_2 plume.

CO_2 Plume After 50 Years



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5. Establishing the Availability and Reliability of the CO_2 Source

Kemper energy facility, with CO_2 output of about 3 MMmt per year, is the intended source of the CO_2.

Source: Mississippi Power Company https://www.flickr.com/photos/mississippipower/27709115165/

A $141 million, 61-mile pipeline for transporting CO_2 already exists.

As such, the project only needs short distance gathering lines for connecting the CO_2 source with CO_2 injection wells.

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6. Securing Surface and Pore Space Rights for the Kemper CO_2 Storage Complex

The proposed CO_2 storage area would encompass a ~30,000 acre area surrounding the Kemper energy facility. As part of defining and securing the proposed CO_2 storage site, MPC had performed the following work:

- Defined the protected and environmentally sensitive areas at and near the proposed well pad to avoid potential conflict.
- Successfully secured surface and pore space rights in the center of the CO_2 storage site.
- Examined and resolved any conflicts with lignite development and mineral rights in the CO_2 storage area.

7. Conducting Initial Stakeholder Analysis and Other Pre-Feasibility Tasks

MPC, as part of siting and constructing the Kemper energy facility, had already conducted extensive stakeholder analysis in the communities near the CO_2 storage site and within the expected areal extent of the CO_2 plume.

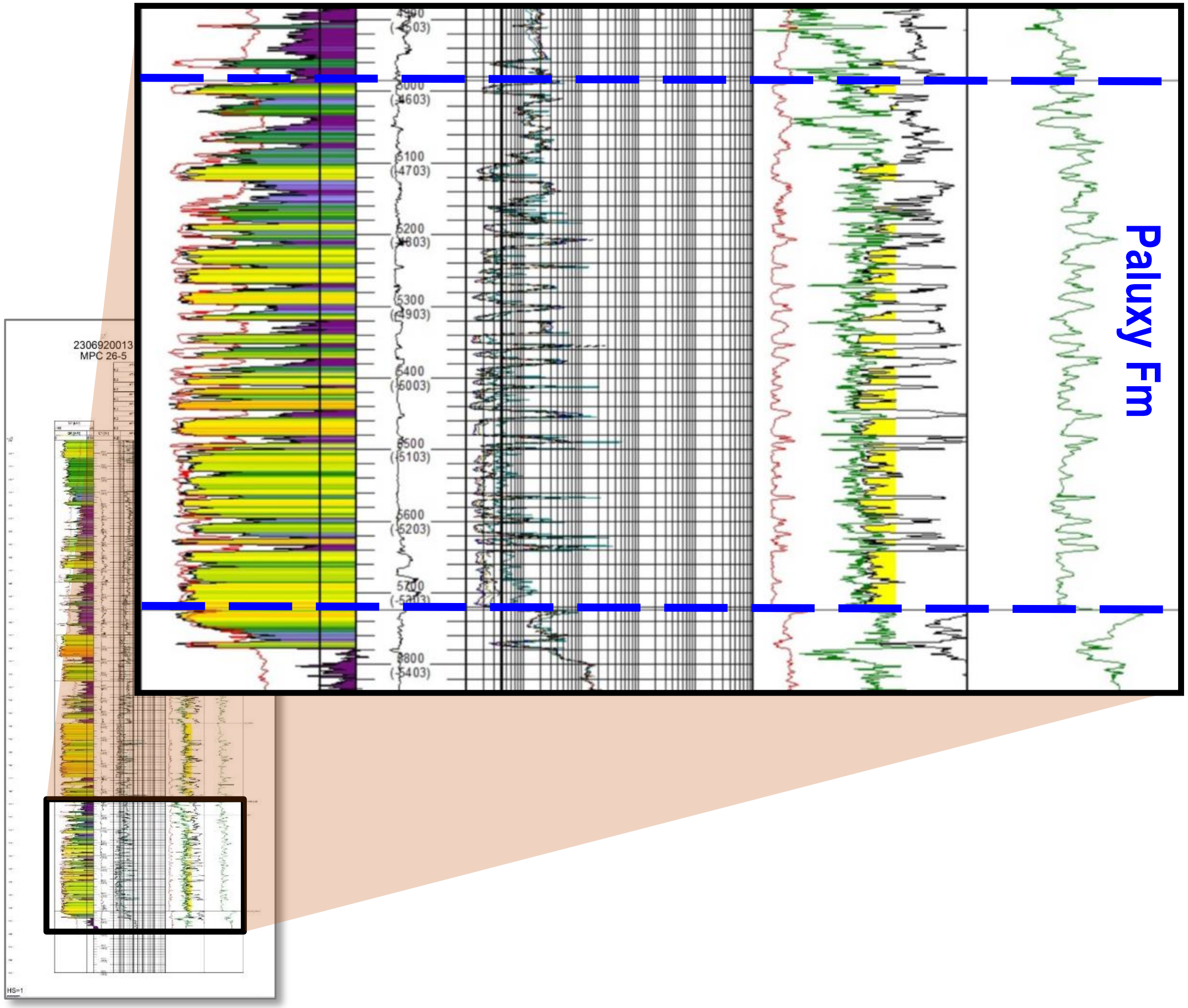
MPC, in conjunction with ARI, also prepared preliminary capital and operating costs for commercial-scale CO_2 storage at the Kemper County CO_2 Storage Complex.

Current Status of ECO_2S

Currently, two deep wells have been drilled, logged and cored to provide more site specific reservoir characterization data.

These wells will subsequently become key CO_2 plume and pressure monitoring wells for the commercial phase of Project ECO_2S.

Collection of Reservoir Characterization Data



A suite of geophysical logs were run across the 3,160 foot reservoir interval, from 2,560’ to 5,720’.

Obtaining core samples in the unconsolidated sand portions of the reservoir has been a challenge.

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Acknowledgements

The Project Team led by Southern States Energy Board, Mississippi Power Company and Southern Company Services, with technical support from Advanced Resources and a host of key subcontractors, acknowledge the valuable support provided by the U.S. DOE National Energy Technology Laboratory on this challenging and valuable CarbonSAFE field project.

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