[PS]Risk Management for a Commercial-Scale CO_2 Storage Project*

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Search and Discovery Article #80638 (2018)**
Posted July 16, 2018

*Adapted from poster presentation given at AAPG 2018 AAPG Annual Convention and Exhibition, Salt Lake City, Utah, May 20-23, 2018

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Abstract

The Carbon Storage Assurance Facility Enterprise (CarbonSAFE) is a USDOE-NETL funded effort to certify and develop large-scale commercial CO_2 storage sites. Project ECO_2S is a CarbonSAFE venture with the main objective of demonstrating the suitability in an area near Mississippi Power's (MPC) Kemper County Energy Facility (north of Meridian, Mississippi) for the commercial-scale injection and storage of CO_2. Project ECO_2S was designed as an accelerated project aimed at establishing an early CO_2 storage (ECO_2S) location capable of providing at least 50 million tonnes of storage capacity. This project is funded principally by the USDOE-NETL with support from Mississippi Power Company and is managed by the Southern States Energy Board.

A critical component to the development and execution of a commercial scale CO_2 injection and storage project is to comprehensively identify risk factors. Several key areas of risks to project success for commercial scale CO_2 storage include: geologic uncertainties; project management and planning; outreach; permitting and site access agreements; infrastructure development; the contractual and regulatory pathways; and a commercial development plan. Identifying and evaluating every important source of risk is of key interest to future owners/operators of such a project. Project success – the central entity that is "at risk" – consists both of project goals and objectives (e.g. contractual pathways) and of preclusions and avoidances (e.g. injury, damage to environment or reputation, etc.).

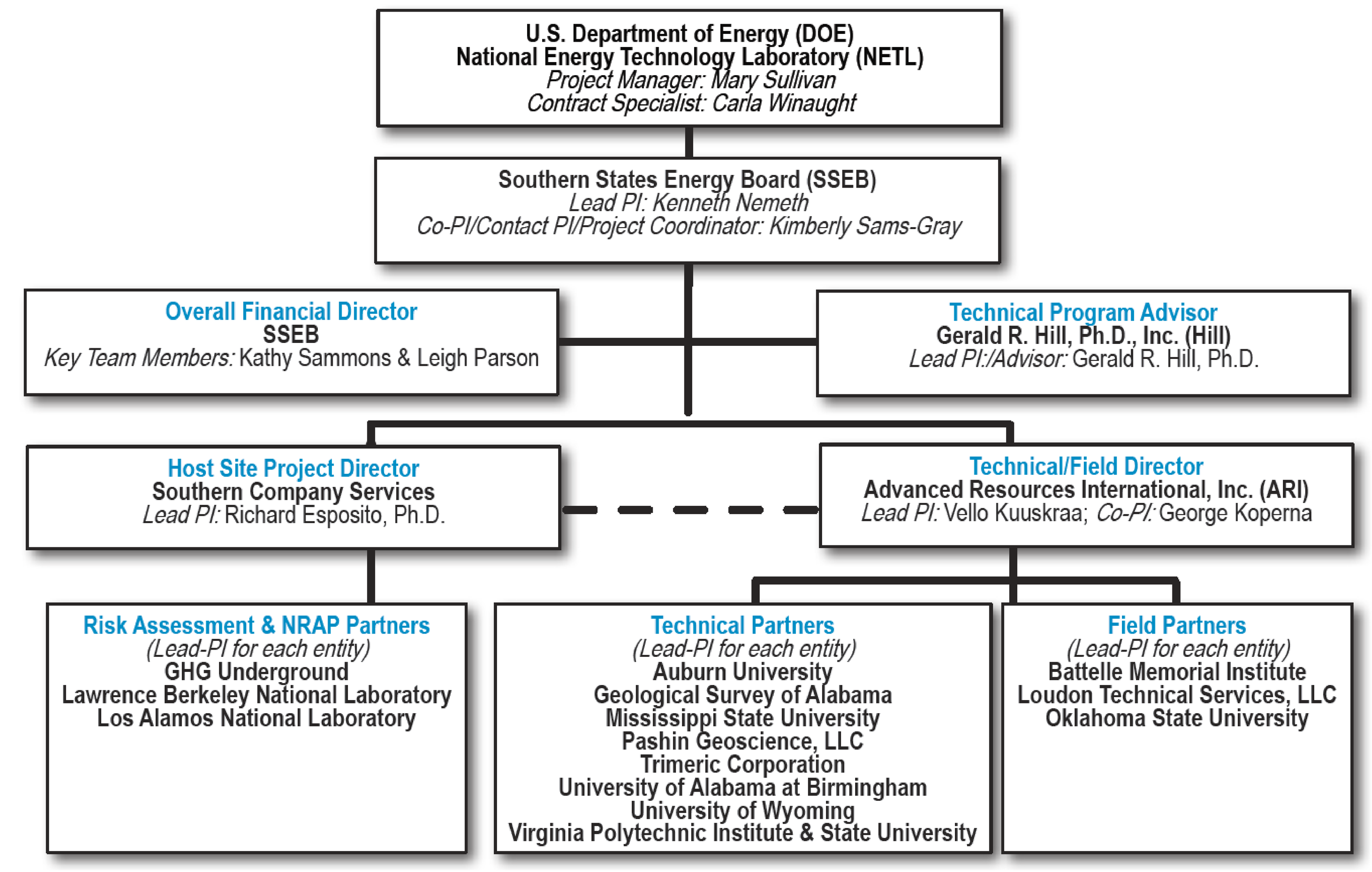
GHG Underground LLC designed and conducted a workshop-focused process to identify and evaluate risks. Within this process, project team members and stakeholders provided specific information about the project, to share this information among those involved with the risk process, and to provide semi-quantitative risk-evaluation data (e.g. Likelihood and Severity values) for analysis and reporting. The results of the ECO_2S risk workshop will be presented.

Project Background and Status

The Kemper County Project Project ECO2S is part of the CarbonSAFE Program and is financially supported by the USDOE-NETL and Mississippi Power Company. The project is managed by the Southern States Energy Board. Technical support is provided by Southern Company Research and Development.

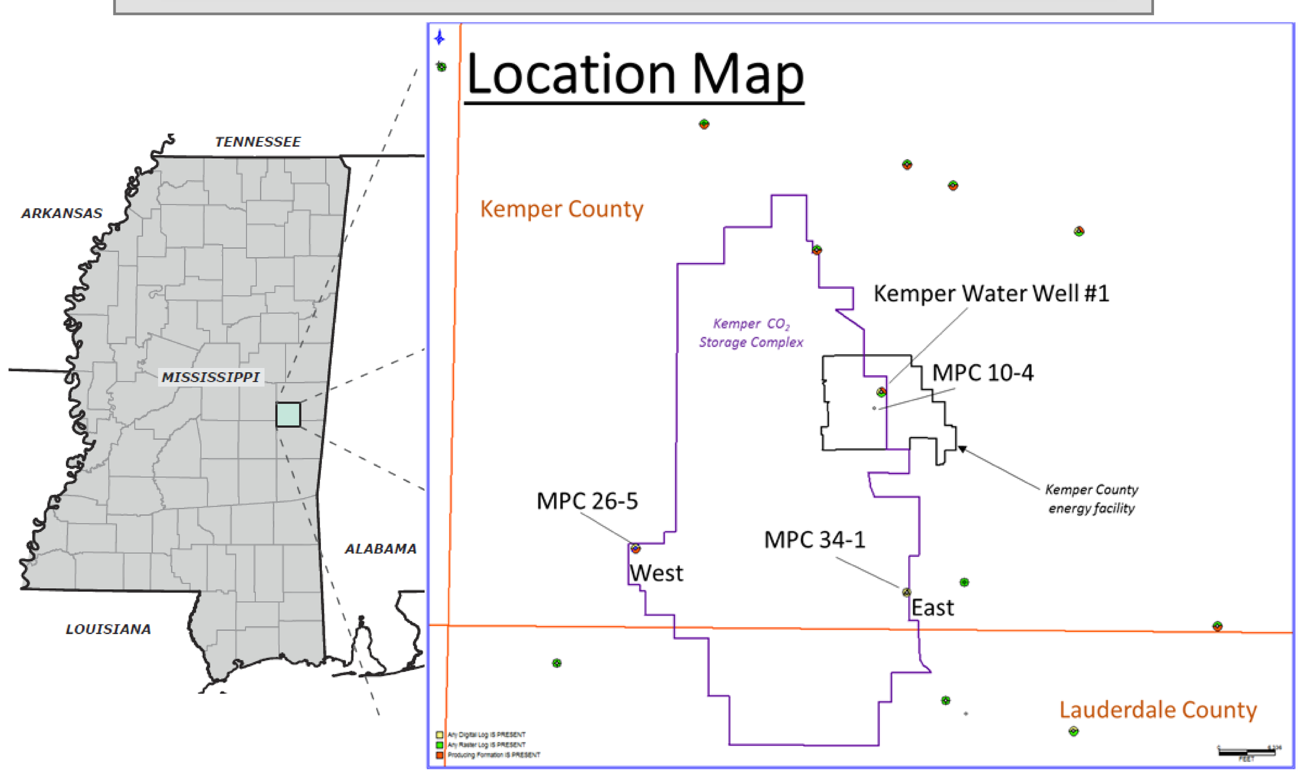
A major setback to the project was the loss of the designated CO_2 Source from the energy facility due to Mississippi Public Service Commission decision to cease coal fueled power generation.

A main focus of current work is to secure a source of CO_2 and design a gathering network toward developing a regional storage hub at the original injection site



Project ECO2S Organizational Chart

Project Details & Geologic Constraints



Kemper Energy Facility and Location

Three characterization wells were drilled during the summer of 2017 in the study area, and a suite of geophysical, geochemical data were collected to characterize the geology and petrophysical parameters controlling CO_2 storage potential. To establish the geologic framework, core analyses were conducted on caprock and reservoir rock in conjunction with structural and stratigraphic interpretations.

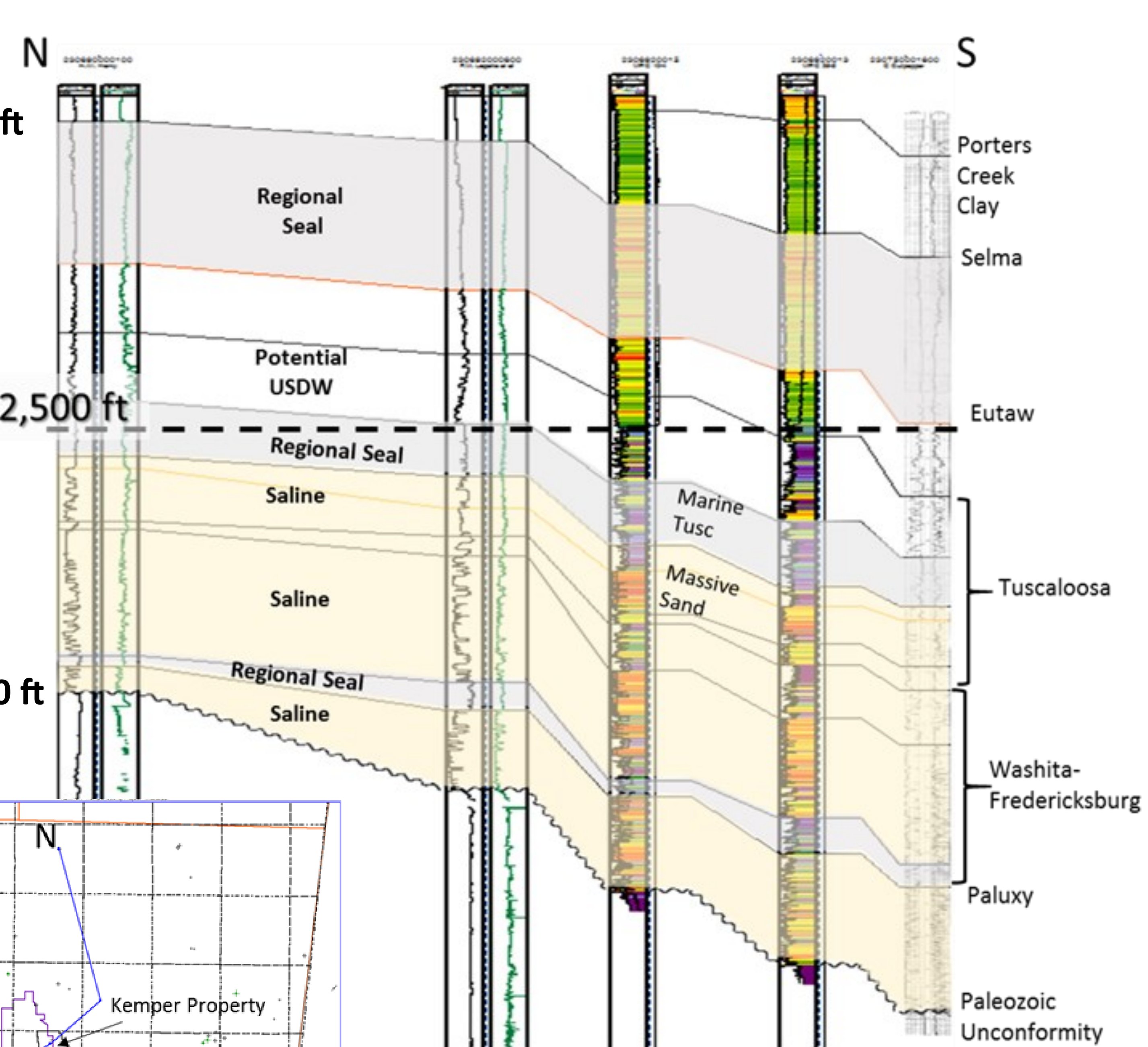
These data are applied to geologic modeling, injection simulations, flow modeling, reactive transport modeling and thermo-hydro mechanical modeling

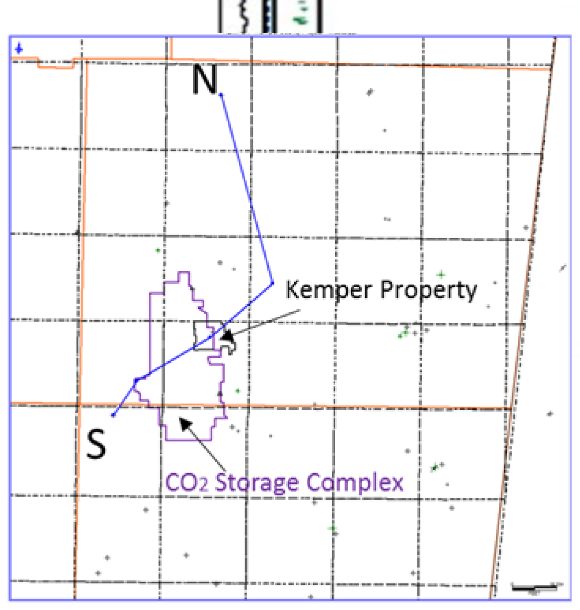
Three Prominent Seals

- Selma Chalk
- Tuscaloosa Marine Shale
- Upper Washita-Fredericksburg Shale

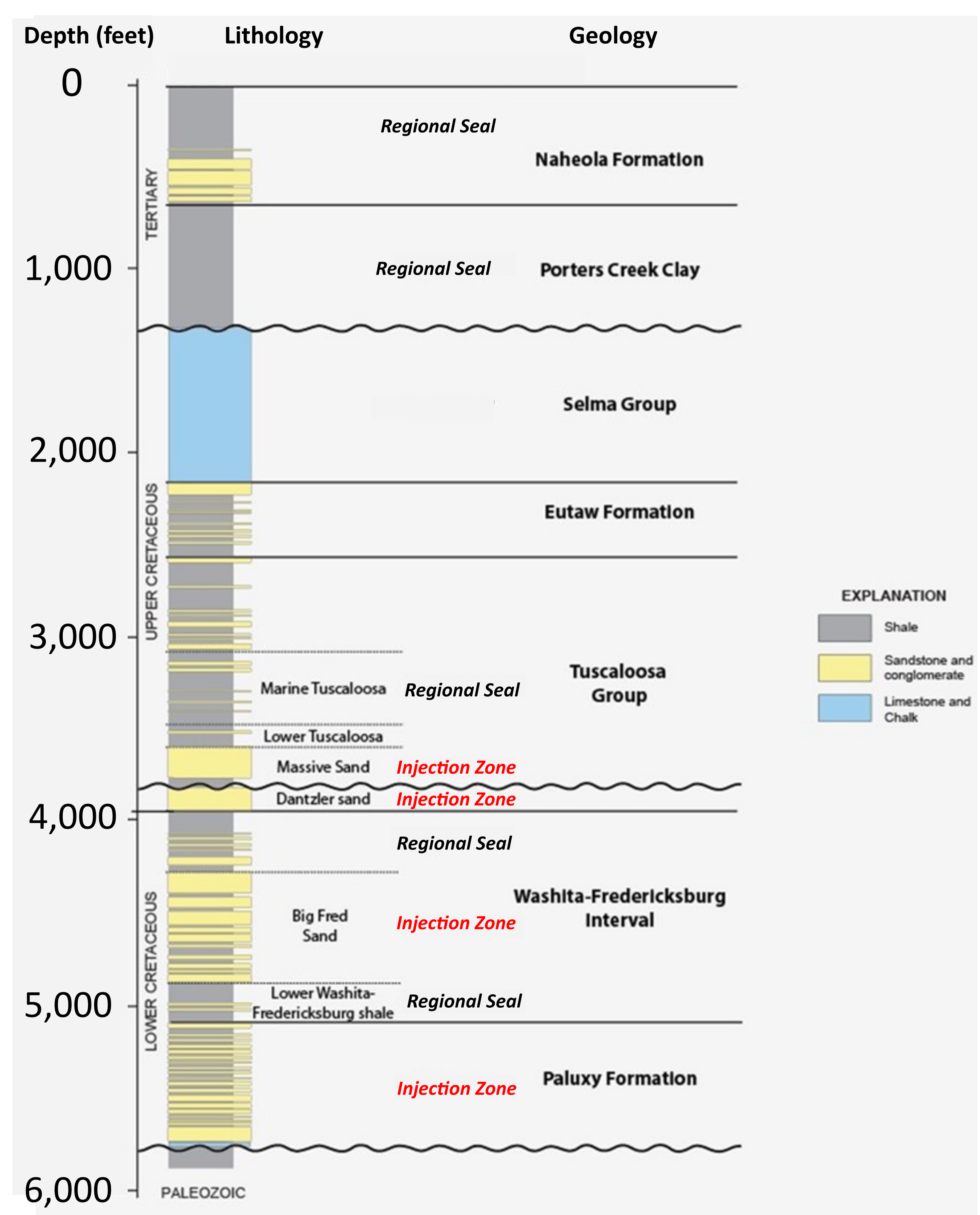
Cretaceous Sandstone Storage Zones

- Lower Tuscaloosa Group
- Washita-Fredericksburg interval
- Paluxy Formation



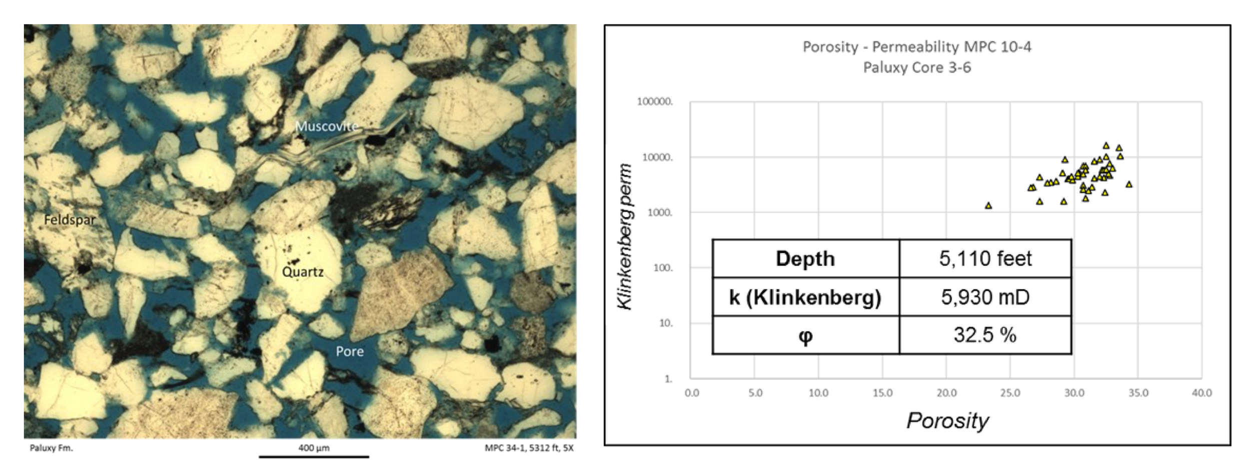


Study Area Geologic Cross Section



Study Area Stratigraphic Column

- Predictable Cretaceous-Tertiary structure
- Formations dip (deepen) to the southwest
- Marine Tuscaloosa dips 50 feet/mile
- Sub-Mesozoic unconformity dips 80 ft/mile
- High porosity in the potential sandstone storage horizons



Acknowledgments

This material is based upon work supported by the U.S. Department of Energy National Energy Technology Laboratory under Cooperative Agreement No. DE-FE0010554. Cost share and research support are provided by the Project Partners and an Advisory committee.

Southern Company | Southern States Energy Board | Advanced Resources International, Inc. | NETL | U.S. Department of Energy

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1. What is at risk? PROJECT VALUES

Overarching Objective	Store commercial volumes of CO_2 safely, permanently, and economically within a regionally significant saline reservoir system
Specific Goals & Objectives	Drill, core, and log 3 new wells
	Refine knowledge of reservoir properties
	Build geological numerical model
	Model CO_2 injection to identify physical risks
	Develop site-specific monitoring plans
	Identify contractual and regulatory pathways toward development
	Comprehensively identify and manage risks to project success
Preclusions & Avoidances	Injuries to staff or public
	Environmental damage
	Reputation damage
	Noncompliance and illegality
	Public anger, rejection, negative opinion about CCS

2. How to Quantify?

SEVERITY and LIKELIHOOD SCALES

LIKELIHOOD of Impact or Failure Occurring (L)				
1	2	3	4	5
Very Unlikely	Unlikely	50/50	Likely	Very Likely
In 50 ECO_2S-like commercial projects, might happen once.	Probably won't happen during this project. In ten such projects, once per decade.		Probably would occur during the pilot or commercial-scale ECO_2S Project. Once per several years.	Nearly sure to occur during the pilot or commercial-scale ECO_2S Project. Could happen yearly.

Workshopping Risk

During a one-day workshop involving all ECO2S project staff, 12 of 102 risk scenarios were semi-quantitatively assessed as the product of Impact Severity (S) and Likelihood (L). S and L were each judged on categorical 5-point scales (L scale shown at left). Followup via spreadsheet yielded S and L values for the remaining 90 scenarios.

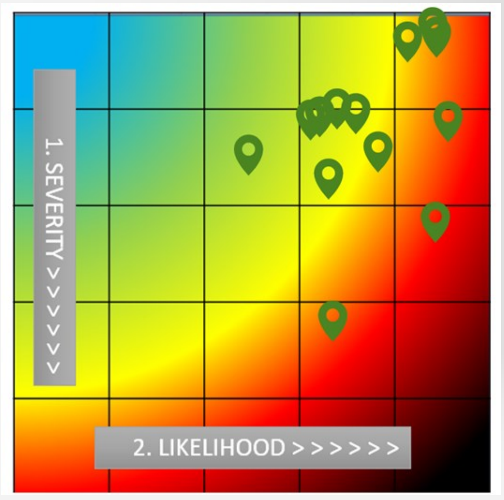
S and L values and text (comments and new scenarios) were input "live" via personal web-connected devices, and all data were displayed on screen in real time. Scenarios were presented in five topic groups. Staff identified their areas of expertise among the five groups, and evaluations from those more vs. less familiar with the subject matter were distinguished. This method preserves individual expertise, information sharing, and "the wisdom of crowds."

Several of the highest risks fall into the Program and Project Management topic group, focusing on concerns about attaining technical objectives without the Kemper CO2 source. A contingency plan for loss of that source – using the project site as a regional CO2 storage hub – also bears risks such as the loss of surface and/or pore-space rights. Among geological issues, the main concern is caprock integrity rather than reservoir. Risk rankings by participants more vs. less familiar with the specific scenario topics are similar.

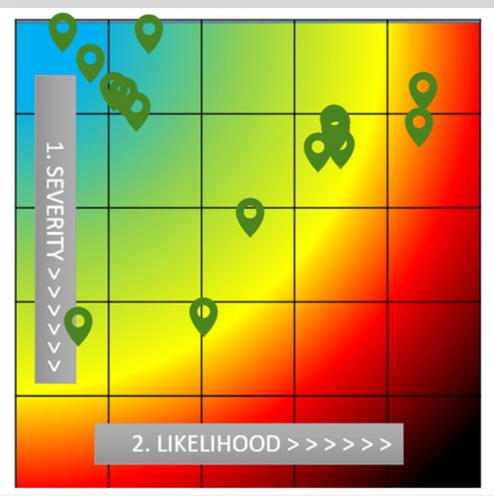
3. How to capture values from experts?

LIVE and WEB-BASED

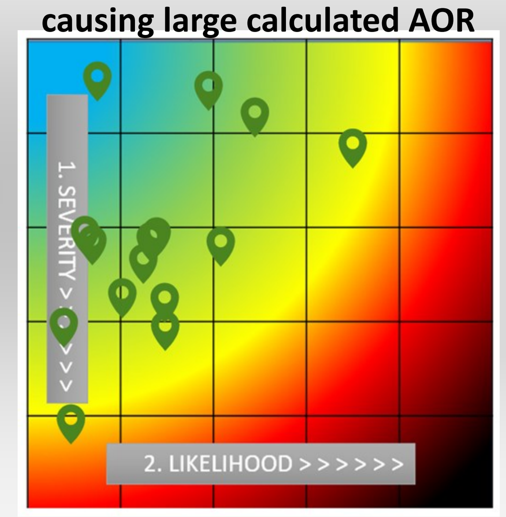
Scenario #M20: Plume geometry differs from baseline models



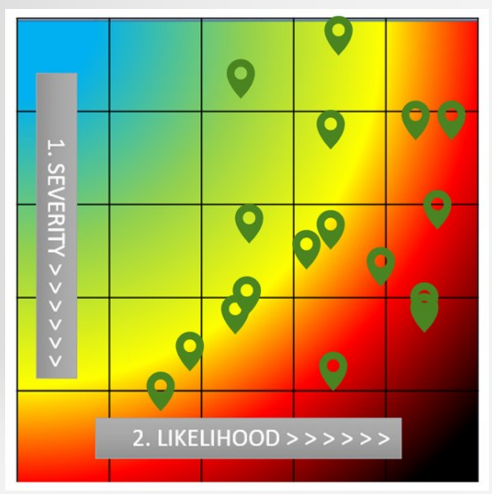
Scenario #M10: Land use changes limit monitoring methods



Scenario #M16: Overlying USDW is underpressured, causing large calculated AOR



Scenario #P09: Kemper energy facility does not become a source of CO_2



4. How to select risks to treat? MULTIPLE SCREENS

Screen ID	Risk (all) > 8	Risk (Fam) > 9.5	Risk (Less) > 8.5	L (Fam) > 3	S (Fam) > 3.7	S (all) top 10	Tally	Treatment Priority	Scenario Description
P18	x	x	x	x	x		5	1	Insufficient CO_2 supply commitments to support regional storage hub.
P12	x	x	x	x		x	5	1	MPC / SOCO management do not continue to support project during next 2-50 years.
P13	x	x	x	x			4	1	MPC / SOPO management not interested in supporting a regional storage hub.
P14	x		x		x	x	4	1	Pore space rights are insufficient for the project.
P09	x	x	x	x			4	1	Kemper energy facility does not become a source of CO_2.
O15	x	x	x	x			4	1	Operational problems at CO_2 source plant prevent delivering the CO_2 needed to show commercial-scale geological storage.
U03	x	x	x	x			4	1	Changes in U.S. government personnel or policies result in removal of government support of the CarbonSAFE program.
P04	x	x	x	x			4	1	Existing pipeline network not designed to be used as a regional hub.
P01	x	x	x				3	1	Changes in the operational status or commercial viability of CO_2 source plant prevent meeting project objectives.
O21	x	x		x			3	1	Uncertainty in CO_2 source(s) delays pipeline specifications (sizing, materials, pressure rating).
O10	x		x		x		3	1	Loss of surface access rights in area of existing or planned injection well.
O03					x	x	2	2	CO_2 leak cannot be stopped by existing technologies.
M13					x	x	2	2	Monitoring shows the possible presence of CO_2 in overlying formations soon after injection starts.
U11	x	x					2	2	Local animosity toward MPC leads to vocal opposition of ECO2S project.
P15	x		x				2	2	Potential CO_2 sources believe that no mature capture technology is available, so will not commit to project.
P11	x		x				2	2	Loss of pore space access (due to land sale or other cause) limits the overall storage capacity of the hub.
O14	x		x				2	2	Oilfield boom drives up project costs and increases lead time for equipment and services.
U16	x		x				2	2	Permitting of a Class VI UIC permit for storage is delayed.
U01		x		x			2	2	Change in CO_2 use from CO_2 for EOR to total sequestration in new wells garners negative public attention.
G01					x	x	2	2	A geological seal is compromised by discontinuity or high permeability.
U22						x	1	3	State environmental agency denies injection permit, citing risk to USDWs.
G14						x	1	3	The primary reservoir proves inadequate to store the CO_2 injection stream around which the project was designed.

Scenario ID	Scenario Group	Severity	Likelihood	Risk		Risk Scenarios
G01	Geological	3.66	1.95	7.33	7.33	A geological seal is compromised by discontinuity or high permeability.
G03		2.31	2.77	6.62	6.62	Core samples from geological seals are inadequate (for various possible reasons) to demonstrate sealing capacity.
G02		3.37	1.91	6.52	6.52	A known or unknown fault cuts a geological seal (caprock).
G15		3.49	2.00	6.49	6.49	Unforeseen spill points/leakage pathways exist in storage reservoir and/or confining units.
G14		3.69	1.71	6.38	6.38	The primary reservoir proves inadequate to store the CO_2 injection stream around which the project was designed.
G09		3.45	1.84	6.32	6.32	Presence of leaky (eg. abandoned, improperly sealed, fractured) wellbores penetrating reservoir formation introducing risk for CO_2 leakage following injection.
G06		2.65	2.41	6.28	6.28	Once injection starts, injectivity proves to be less than predicted/modeled.
G12		2.30	2.73	6.00	6.00	The lack of whole core from potential storage reservoirs leads to uncertainty as to reservoir quality.
G05		3.67	1.49	5.53	5.53	Fracturing of seal layers impairs CO_2 containment.
G04		2.80	2.04	5.16	5.16	Felt earthquakes occur on faults missed or poorly represented in geologic modeling.
G11		3.16	1.62	5.16	5.16	Reservoir and/or caprock formations are susceptible to mineral dissolution that may compromise reservoir or caprock formation integrity.
G13		2.84	1.69	4.90	4.90	The limited dataset of local seismic events suggests unrealistically low seismicity; unexpected induced seismicity occurs.
G07		3.52	1.24	4.33	4.33	Plume unexpectedly migrates to a fault, changes stresses there, and induces seismicity.
G10		2.54	1.69	4.31	4.31	Rapid mineral precipitation occurs with CO_2 injection, causing reduced reservoir permeability.
G08		3.08	1.28	3.85	3.85	Pre-Paluxy unconformity is rugose and porous, allowing long-distance updip migration of CO_2 beyond the Paluxy pinchout.
M20	Monitoring	1.97	3.91	7.56	7.56	Plume geometry differs from baseline models.
M11		2.24	3.19	7.13	7.13	Lifespan of monitoring tools and results interpretation are shorter than the 50+ year monitoring period.
M15		3.29	2.16	7.04	7.04	Numerical modeling predicts plume movement beyond secured land rights and/or monitored area.
M19		1.93	3.42	6.65	6.65	Users of project data find the data archiving/access system to be awkward and inefficient.
M07		3.42	1.86	6.44	6.44	During injection, pressure increase at a monitoring well exceeds the limit established by a Class VI permit condition.
M02		2.60	2.41	6.38	6.38	At end of the planned and budgeted post-injection monitoring period, criteria for showing plume stability remain unclear, and regulator requires continued monitoring while review continues.
M10		2.12	2.95	6.33	6.33	Land use changes limit the use of monitoring tools (e.g. surface seismic, surface deformation).
M12		2.64	2.30	6.04	6.04	Modeling suggests that existing plume/pressure front monitoring tools will be inadequate for the Kemper storage complex (ultra-high permeability with moderate anticipated pressure buildup).
M03		2.65	2.24	6.02	6.02	At end of the planned and budgeted post-injection monitoring period, regulator deems that data showing plume stability are inadequate.
M14		3.02	2.09	5.96	5.96	Monitoring wells are mislocated or mis-completed, and thus miss the developing plume.
M13		3.94	1.51	5.92	5.92	Monitoring shows the possible presence of CO_2 in overlying formations soon after injection starts.
M06		2.69	2.24	5.83	5.83	Digital data is damaged, lost, or destroyed.
M09		2.51	2.28	5.74	5.74	Insufficient baseline data (type, quality or duration) are gathered prior to injection to establish a consistent non-CO_2 signal.
M17		3.45	1.68	5.67	5.67	Pressure increase exceeds models, raising possibility that brine extraction will be needed to manage plume and/or maintain injection rate.
M18		2.93	1.91	5.56	5.56	Prior to decision to start injection, data and modeling are insufficient to confirm integrity of geological seals.
M08		2.48	2.04	5.45	5.45	Impurities in CO_2 stream cause phase behavior different from modeled.
M16		2.78	1.93	5.12	5.12	Overlying USDW is underpressured, causing a larger than expected AOR to be calculated.
M05		2.01	1.97	4.25	4.25	Data management system not appropriate for size/type of data.
M01		2.86	1.54	4.20	4.20	After some CO_2 injection, a new nearby project (e.g. oil-gas or mining) intercepts or affects the CO_2 plume.
M04		1.73	2.44	3.95	3.95	Available stress data (largely from Mesozoic units) provides little guidance on stresses at deeper levels, giving little assurance on project-induced seismicity.
O15	Operational	3.55	3.06	10.90	10.90	Operational problems at CO_2 source plant prevent delivering the CO_2 needed to show commercial-scale geological storage.
O14		2.94	3.06	8.88	8.88	Oilfield boom drives up project costs and increases lead time for equipment and services.
O10		3.61	2.31	8.48	8.48	Loss of surface access rights in area of existing or planned injection well.
O21		2.85	2.74	8.16	8.16	Uncertainty in CO_2 source(s) delays pipeline specifications (sizing, materials, pressure rating).
O17		3.20	2.25	7.30	7.30	Process problems lead to varying injection rates and problems meeting UIC requirements.
O01		2.31	3.06	7.21	7.21	Capture facility does not operate smoothly, causing interruptions in CO_2 supply.
O24		3.12	2.33	7.21	7.21	Wells within the expected Kemper plume/pressure footprint have unknown casing integrity.
O13		3.11	2.22	7.03	7.03	Numerical modeling indicates more injection wells than planned will be required to inject 3 MM tonnes per year.
O03		4.06	1.70	6.85	6.85	CO_2 leak cannot be stopped by existing technologies.
O23		3.25	1.93	6.34	6.34	Well integrity cannot be established due to primary cementing failure in one or more of the wells.
O09		2.66	2.22	6.22	6.22	Loss of downhole monitoring component results in expensive workover in order to comply with injection permit.
O08		3.28	1.90	6.21	6.21	Limited data on abandoned wellbores suggests unrealistically low leakage risk; remedial work is not pursued; injection induces leakage.
O19		2.66	2.18	6.05	6.05	Trade restrictions disrupt delivery of tubulars required for project, e.g. chrome and other alloy materials.
O16		2.72	2.12	5.77	5.77	Pipeline or other surface facility damaged by traffic, construction, excavation, etc.
O02		2.91	1.95	5.72	5.72	Captured CO_2 is out of spec with pipeline or injection limits.
O18		2.35	2.25	5.62	5.62	Screened (not open hole) completions are necessary to maintain well/reservoir integrity, making engineered well completions and injection monitoring challenging.
O22		2.31	2.38	5.44	5.44	Weather damages control system during injection resulting in unplanned shutdown.
O07		3.02	1.73	5.31	5.31	Injection causes near-wellbore formation damage in one or more injection wells.
O04		2.84	1.89	5.28	5.28	Critical equipment is stolen from injection site.
O20		2.61	1.96	5.07	5.07	Traveling to a nighttime logging run, staff member falls asleep while driving.
O05		2.94	1.68	4.80	4.80	Impurities remaining in the CO_2 stream result in equipment damage.
O06		3.16	1.43	4.56	4.56	Impurities remaining in the CO_2 stream result in subsurface contamination.
O11		2.88	1.39	4.14	4.14	Monitoring instruments placed in injection well hinder injection.
O12		1.60	2.21	3.64	3.64	Non-well (i.e. surface) monitoring equipment malfunctions or is damaged.
P01	Program Project Management	3.61	3.19	12.17	12.17	Changes in the operational status or commercial viability of CO_2 source plant prevent meeting project objectives.
P09		3.20	3.91	12.16	12.16	Kemper energy facility does not become a source of CO_2.
P18		3.56	3.22	11.48	11.48	Insufficient CO_2 supply commitments to support regional storage hub.
P13		3.53	2.94	10.10	10.10	MPC / SOPO management not interested in supporting a regional storage hub.
P12		3.73	2.67	10.06	10.06	MPC / SOCO management do not continue to support project during next 2-50 years.
P04		2.81	3.37	9.92	9.92	Existing pipeline network not designed to be used as a regional hub.
P14		3.87	2.62	9.43	9.43	Pore space rights are insufficient for the project.
P15		3.54	2.58	9.43	9.43	Potential CO_2 sources believe that no mature capture technology is available, so will not commit to project.
P11		3.64	2.44	9.09	9.09	Loss of pore space access (due to land sale or other cause) limits the overall storage capacity of the hub.
P07		2.89	2.69	8.17	8.17	Infrastructure development costs are considerably higher than expected.
P19		2.81	2.44	7.74	7.74	The single source/sink structure of ECO2S project does not does not substantively inform future design of an integrated multi-source/sink CCUS infrastructure.
P03		2.91	2.48	7.16	7.16	Competition with CO_2 for EOR prevents delivering the CO_2 needed to show commercial-scale geological storage.
P10		2.82	2.05	5.98	5.98	Lack of process information on the CO_2 source plant prevents developing an adequate design basis and cost for CO_2 compression, dehydration, and purification.
P06		2.59	2.21	5.86	5.86	Infrastructure damage from extreme weather.
P08		3.10	1.81	5.66	5.66	Insurance does not effectively cover costs of claimed project-caused damage to a non-project resource (oilfield, farm, residence, etc).
P16		2.62	2.11	5.53	5.53	Power to injection facility is outside Southern Company network resulting in undependable supply.
P02		2.21	1.94	4.77	4.77	CO_2 transmitter requires more stringent CO_2 quality.
P05		2.86	1.44	4.16	4.16	Goals of the CarbonSAFE program and this project are not adequately understood by the project team, which results in failure to meet the project objectives.
P17		1.83	1.60	3.27	3.27	Qualified drivers for CO_2 truck transport are in short supply.
U03	Publics & Stakeholders	3.65	2.99	11.13	11.13	Changes in U.S. government personnel or policies result in removal of government support of the CarbonSAFE program.
U11		2.94	2.81	8.75	8.75	Local animosity toward MPC leads to vocal opposition of ECO2S project.
U16		2.63	3.12	8.30	8.30	Permitting of a Class VI UIC permit for storage is delayed.
U21		2.60	2.79	7.40	7.40	Regulatory uncertainty causes delay to project timeline.
U18		2.96	2.40	7.28	7.28	Premature decommissioning of site results in a negative opinion from the public or potential users.
U08		3.66	1.92	6.96	6.96	Insurer of major project participant (MPC, SOCO, UAB ...) threatens policy termination based on concerns about project.
U13		3.05	2.14	6.92	6.92	News coverage of CO_2 leaks from Cranfield, MS site raises regulator and public concerns about permitting storage at Kemper site.
U19		2.87	2.35	6.79	6.79	Public opposition or unacceptable environmental impact to new pipeline construction.
U15		2.74	2.29	6.65	6.65	Opposition arises due to concerns about impact to USDWs.
U22		3.84	1.66	6.41	6.41	State environmental agency denies injection permit, citing risk to USDWs.
U06		3.77	1.63	6.33	6.33	Future legal challenge extinguishes project's porespace rights that were based on control of surface.
U04		2.26	2.76	6.31	6.31	Cultural or archaeological sites are found within area of study/interest (related to EA/EIS).
U17		2.39	2.49	6.14	6.14	Pipeline permitting delays due to crossing state lines (multiple agencies).
U01		2.12	2.43	6.03	6.03	Change in CO_2 use from CO_2 for EOR to total sequestration in new wells garners negative public attention.
U02		2.29	2.35	5.93	5.93	Changes in CO_2 stream composition over 20-30 year injection period (e.g. new sources) exceed existing UIC permit conditions, necessitating new permit(s) or major modification.
U07		2.34	2.44	5.87	5.87	In considering UIC permit application, regulator requests evidence that undocumented boreholes are unlikely to exist within the expected Kemper plume/pressure footprint.
U09		2.85	1.94	5.79	5.79	Land use changes impact injection activities (e.g. site access).
U10		2.56	2.15	5.69	5.69	Landowner refuses access for seismic shoot or other surface-based monitoring over critical area.
U05		3.30	1.66	5.57	5.57	Environmental Impact Statement is rejected due to potential impacts to wetlands or other sensitive habitats/species.
U14		2.44	2.02	5.29	5.29	NGO opposition to CCUS threatens project.
U20		3.01	1.58	4.97	4.97	Regulatory authority denies use of existing Phase II wells for monitoring purposes.
U23		2.89	1.75	4.88	4.88	The owner of land next to where property rights have been secured alleges trespass and sues.
U12		2.71	1.59	4.29	4.29	Local landowner builds residence(s) over CO_2 pipeline.
U24		2.69	1.19	3.15	3.15	Vandalism at control room damages system controls.