Southeast Regional Carbon Sequestration Partnership (SECARB)
Phase III Anthropogenic Test and Plant Barry Carbon Dioxide Capture and Storage Demonstration

Presented to:

CSLF Projects Interaction & Review Team
Washington, D.C., USA
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Presented by:

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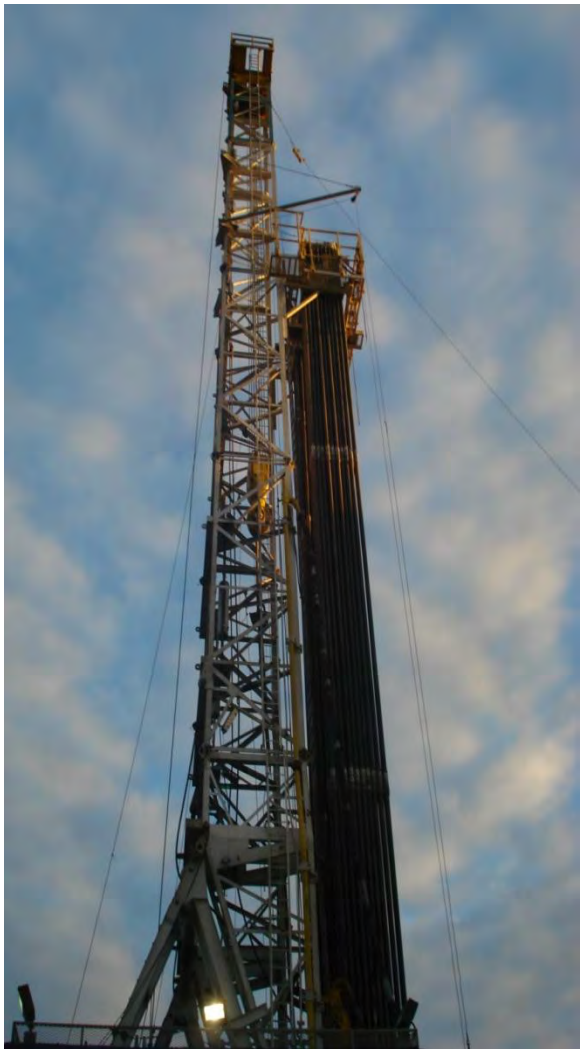
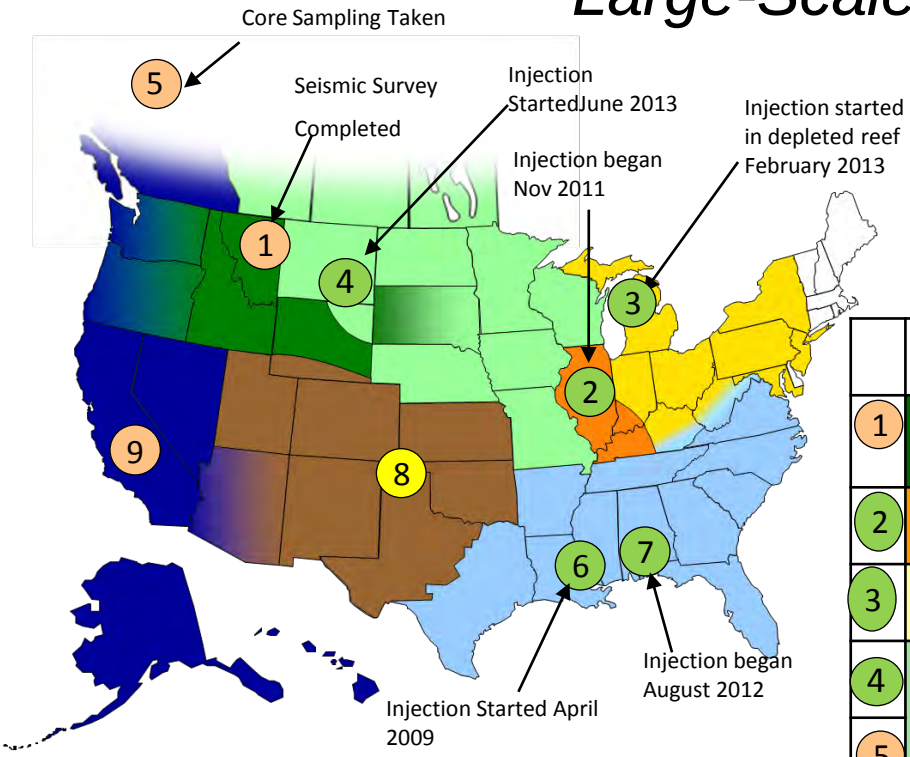
Presentation Outline

- Regional Carbon Sequestration Partnerships
  - Seven Regional Entities
  - SECARB Phase III Projects
- SECARB Anthropogenic Test
  - Plant Barry Capture Unit
  - Dedicated CO2 Pipeline
  - Injection & Monitoring Systems
- Project Integration & Risk Management
  - Key Integration Questions
  - Risk Management & Assessment
  - Public Outreach and Education



RCSP Phase III: Development Phase

Large-Scale Geologic Tests



- Injection Ongoing
- 2013 Injection Scheduled
- Injection Scheduled 2013-2015

Note: Some locations presented on map may differ from final injection location

- ✓ *Large-volume tests*
- ✓ *Four Partnerships currently injecting CO_2*
- ✓ *Remaining injections scheduled 2013-2015*

	Partnership	Geologic Province	Target Injection Volume (tonnes)
1	Big Sky	Nugget Sandstone	1,000,000
2	MGSC	Illinois Basin-Mt. Simon Sandstone	1,000,000
3	MRCSP	Michigan Basin-Niagaran Reef	1,000,000
4	PCOR	Powder River Basin-Bell Creek Field	1,500,000
5		Horn River Basin-Carbonates	2,000,000
6	SECARB	Gulf Coast – Cranfield Field- Tuscaloosa Formation	3,400,000
7		Gulf Coast – Paluxy Formation	250,000
8	SWP	Regional CCUS Opportunity	1,000,000
9	WESTCARB	Regional Characterization	

SECARB Phase III

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Anthropogenic Test

Capture: Alabama Power 's Plant Barry, Bucks, Alabama

Transportation: Denbury

Geo Storage: Denbury's Citronelle Field, Citronelle, Alabama

Early Test

Denbury Resources' Cranfield Field Near Natchez, Mississippi

CO_2 Source: Denbury

CO_2 Transportation: Denbury

Saline MVA: GCCC

Gulf Coast Carbon Center

SECARB Southeast Regional Carbon Sequestration Partnership | NETL | Southern States Energy Board | Bureau of Economic Geology | Gulf Coast Carbon Center | EPRI | Advanced Resources International, Inc. | Southern Company | Denbury

SECARB's Anthropogenic Test Citronelle, Alabama

CSLF Gaps Analysis: SECARB Anthropogenic Test

GENERAL	
Project Scale	
Demonstration	✔

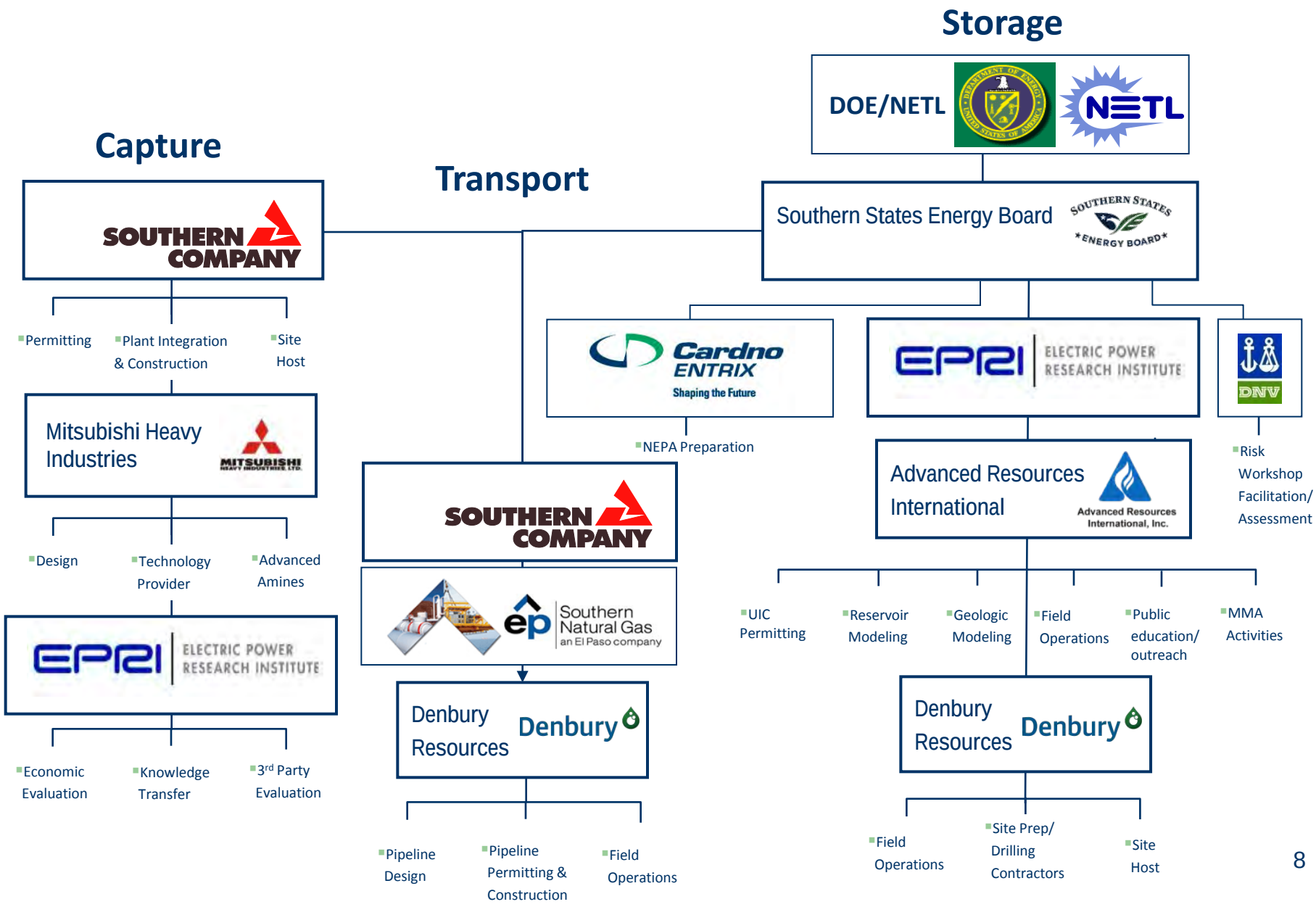
CAPTURE TECHNOLOGIES	
Capture Type	
Post-combustion capture	✔
Technology	
Advance the capture technology	✔
Advance purification and compression technology	✔

TRANSPORT	
General	
Pipeline Transport	✔

STORAGE AND MONITORING	
Storage Complex Type	
Saline formations	✔
Storage complex characterization	
CO_2-water-rock (or coal) interactions	✔
Impact of the quality of CO_2 on storage	✔
Improved modelling of complex	✔
Effects of CO_2 rock/water interactions and induced changes in temperature, pressure and stress on permeability, injectivity, migration, trapping and capacity.	✔
Monitoring the storage complex including risk assessment	
Development of new or improved CO_2 monitoring technologies	✔
Improve baseline monitoring and distinguish between natural and anthropogenic CO_2	✔
Development of risk minimization/mitigation methods and strategies, including leakage	✔
Improve well integrity, well abandonment practices, and/or remediation of existing wells	✔

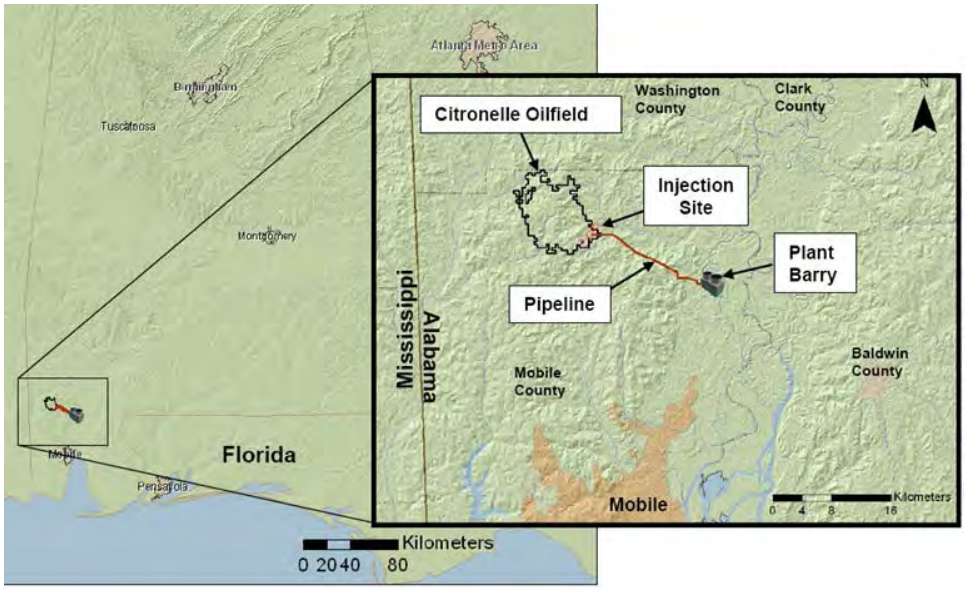
- Project goals/objectives aligned with overall aims and mission of CSLF
- Improving CCS technologies and reducing related costs through project demonstrations, information exchange, and collaboration
- Supports CSLF Technology Roadmap's Summary of Key Technology Needs and Gaps

Anthropogenic Test Organization Chart



SECARB Phase III Anthropogenic Test

- Carbon capture from Plant Barry equivalent to 25MW.
- 12 mile CO_2 pipeline constructed by Denbury Resources.
- CO_2 injection into ~9.400 ft. deep saline formation (Paluxy)
- **100,000 metric tons injected (29 October 2013)**
- Monitoring CO_2 during injection and 3 years post-injection.




Power Plant


Capture


Transport


Storage

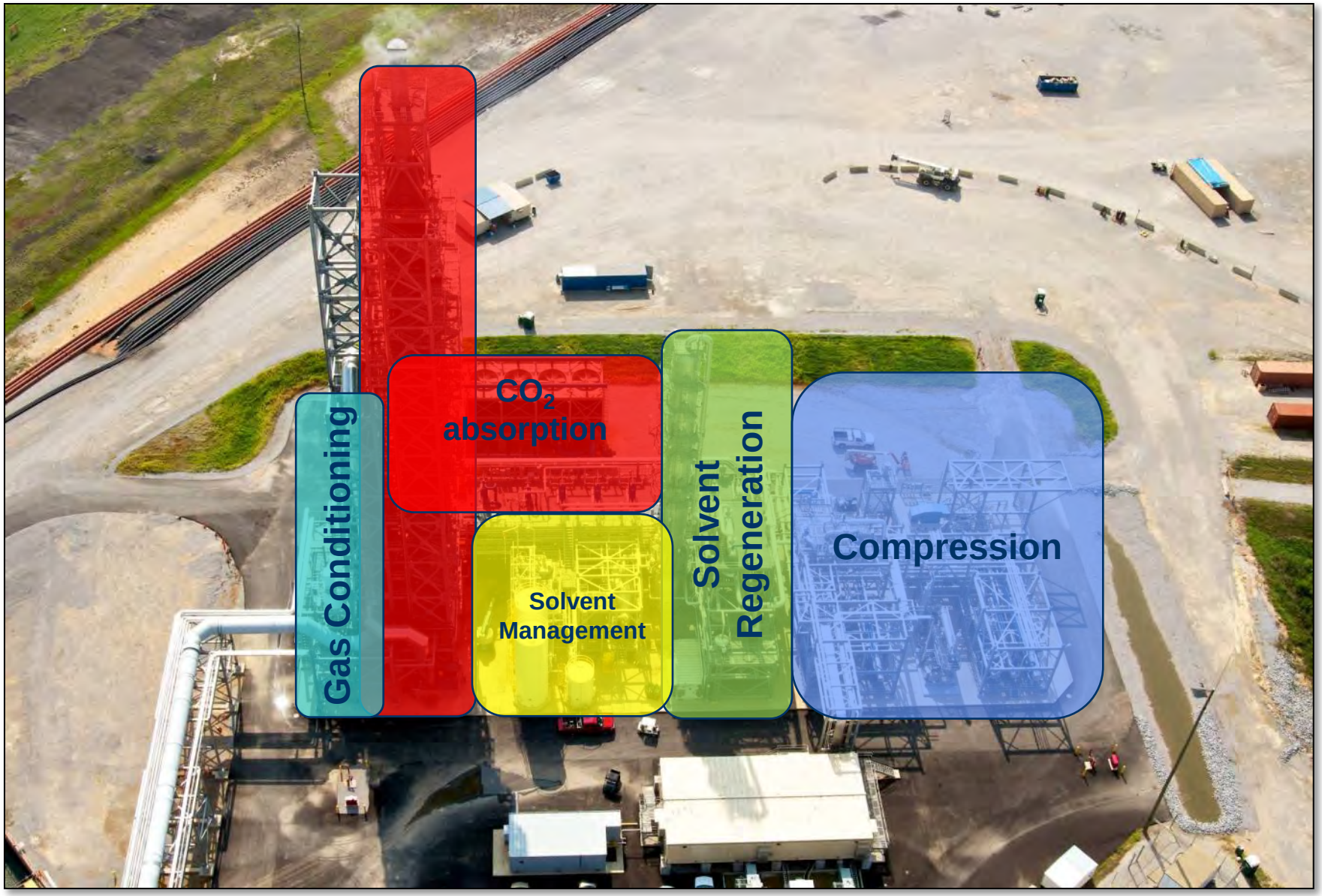
CO_2 Capture Demo

- **Southern Company's CCS Commercialization Program Goals**
  - Deploy integrated CCS demo to understand the integration of capture plant and injection field
  - Advance capture technology performance to preserve the new and retrofit PC coal option
  - "Learn by doing" to create competitive advantage and maintain leadership position in technology development

- **The Plant Barry (Alabama Power) 25MW Demo**
  - Southern Company Services & Mitsubishi Heavy Industries collaboration with partners
  - KM-CDR capture technology (500 TPD)


11/04/2010

Plant Barry Capture Unit: 25MW, 500 TPD

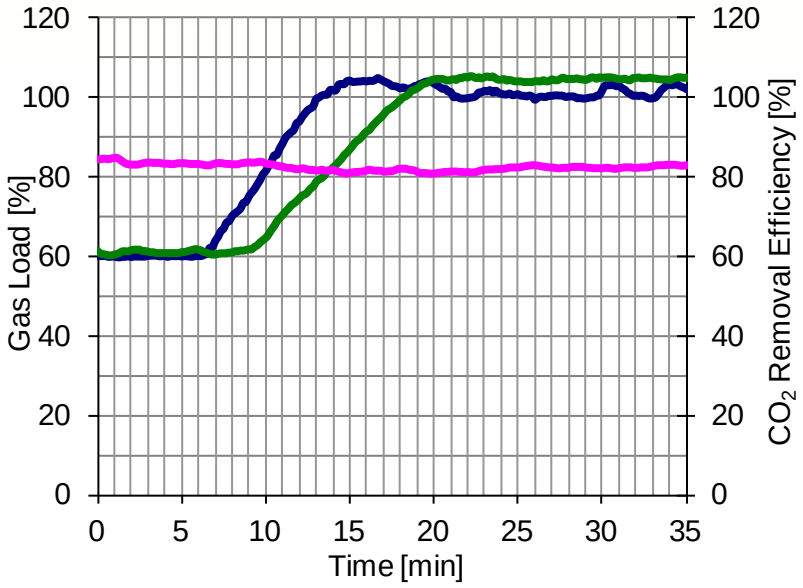


Plant Performance

- Flue gas CO_2 concentration is dependent on boiler load
- KM-CDR process can be adjusted to achieve the desired CO_2 capture rate and production rate with varying boiler conditions

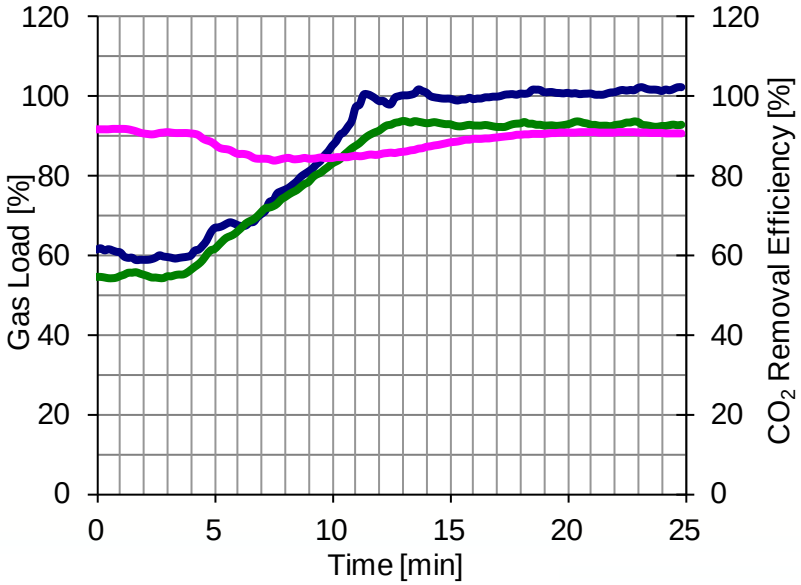
		Base Case	High Energy Efficiency Case	High Loading Case
Flue Gas Condition	Flue Gas Flow Rate [Nm^3/hr]	109,000	112,000	116,000
	CO_2 Concentration at the Quencher Inlet [vol.% (w)]	10.8	10.5	10.8
Operation Results	CO_2 Capture Rate [TPD]	**505**	**509**	**543**
	CO_2 Removed Efficiency [%]	**91**	**91**	**91**
	Steam Consumption [tonne-steam/tonne-CO_2]	0.98	0.95	1.02

Actual load following data in 2 modes



CO_2 compliance scheme
- Demand dictated by additional boiler load (leads to more flue gas flow)
- Ramp of ~5%/minute
- Small dip in removal (5%), but recovery to 90% within 10 minutes

CO_2 Production Scheme
- Demand dictated by additional CO_2 product requirement
- Ramp of ~5%/minute
- Very stable removal rate
  - Capture Rate
  - CO_2 Flow
  - Flue Gas flow



NEPA/Permitting at SECARB's Integrated Project

- UIC Class V permit application
  - Submitted to Alabama Dept. of Env. Quality December 2010
  - Updated March 2011
  - Revise for EPA August 2011
- Environmental Assessment (EA)
  - Mitigation
    - 3 mi of wetlands (wetland mitigation planned)
    - 23 gopher tortoise burrows
  - Consultation
    - Fish & Wildlife Service for the gopher tortoise
    - Corp of Engineers for wetlands
    - SHPO (State cultural/archeological assets)
    - Storm-water construction (BMPs)

SHPO Survey, April 14, 2010

NEPA Finding of No Significant Impact (FONSI)

Directional drilling required to avoid disturbing Gopher Tortoise habitat

Images Courtesy Southern Company

CO_2 Pipeline and Measurement Design

- Applicable regulatory standard: US Depart of Transportation, 49 CFR Part 195 —Transportation of Hazardous Liquids by Pipeline
- 4-inch (10 cm) pipe diameter carbon steel pipe
- Normal operating pressure: 1,500 psig (10.3 MPa) maximum
- Buried average of 5 ft (1.5 m) with surface re-vegetation and erosion control

Handling pipe for horizontal directional drill

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CO_2 Pipeline Overview

- Typical Pipeline/Injection Operations
  - 1,448 psi and 90^0F at the transfer station
  - Rate: 9.64MMcfd (~480 tonnes/day) at 1,314 psi (wellhead) 63^0F.

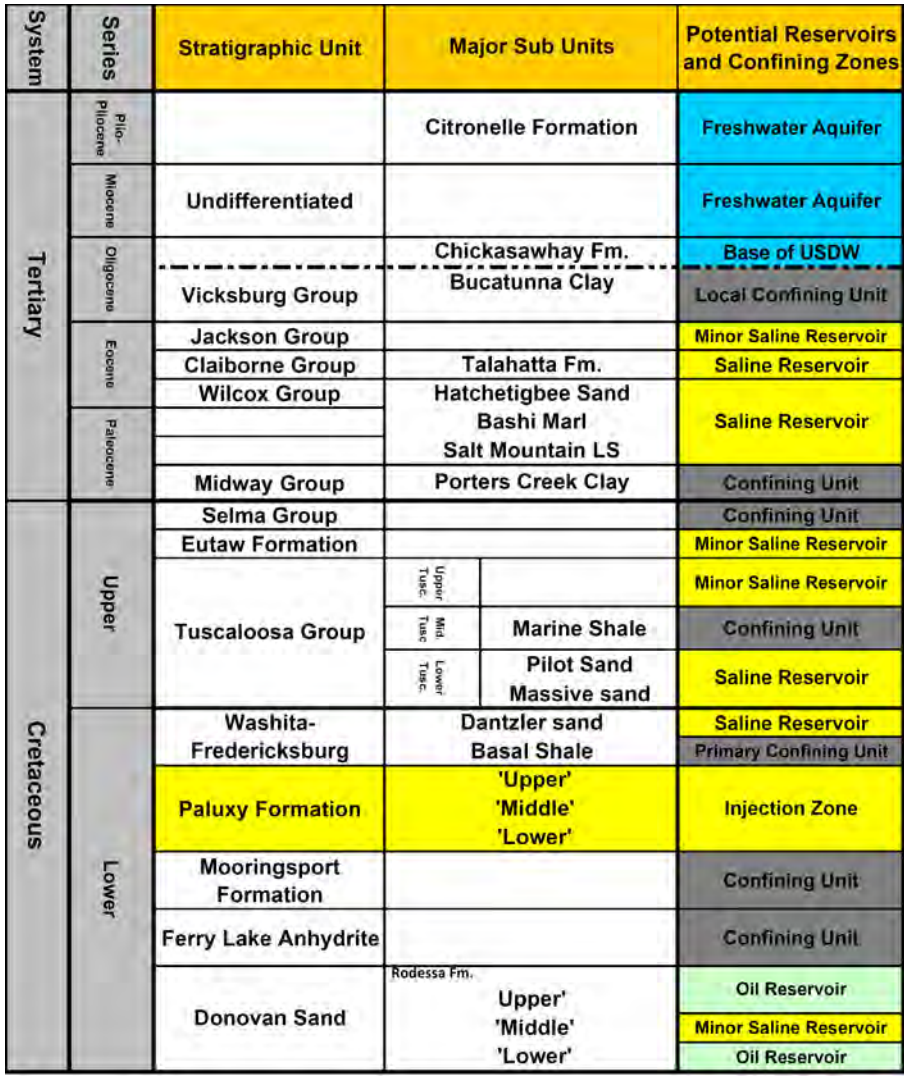
- Typical CO_2 Purity

Component	%
N_2	0.011
O_2	0.010
CO_2	99.979

Detailed Characterization of the Injection Site

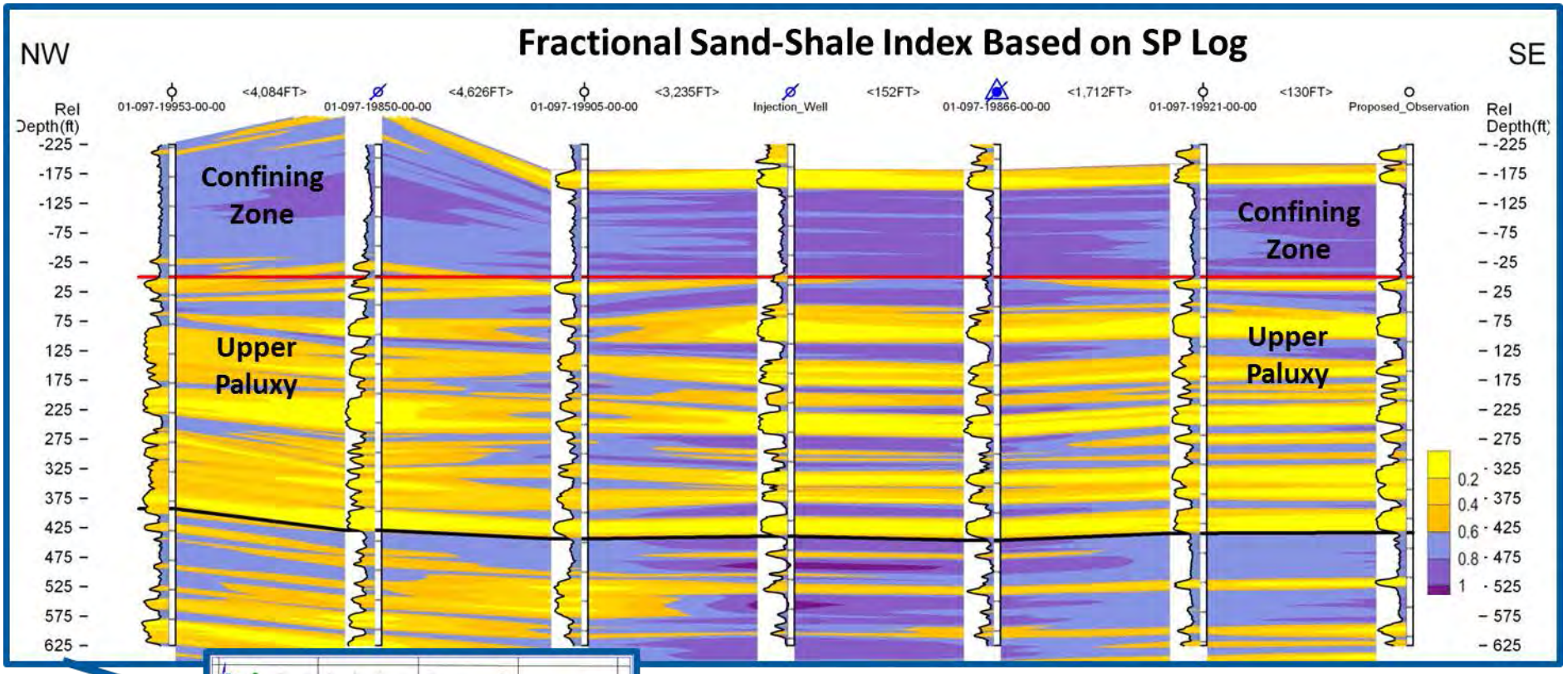
Characterization Well D9-8 #2 at Citronelle Field - Drilled (Dec. 2010/Jan. 2011)

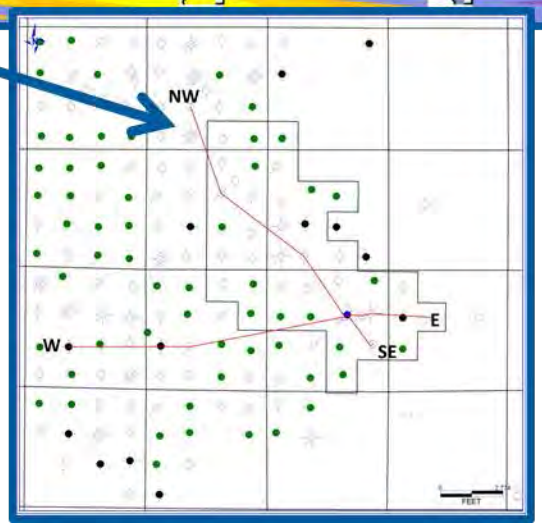
Selecting a Good Storage Formation



System	Series	Stratigraphic Unit	Major Sub Units	Potential Reservoirs and Confining Zones
Tertiary	Plio-Pliocene		Citronelle Formation	Freshwater Aquifer
	Miocene	Undifferentiated		Freshwater Aquifer
	Oligocene		Chickasawhay Fm.	Base of USDW
		Vicksburg Group	Bucatunna Clay	Local Confining Unit
	Eocene	Jackson Group		Minor Saline Reservoir
		Claiborne Group	Talahatta Fm.	Saline Reservoir
		Wilcox Group	Hatchetigbee Sand Bashi Marl Salt Mountain LS	Saline Reservoir
	Paleocene			
		Midway Group	Porters Creek Clay	Confining Unit
Cretaceous	Upper	Selma Group		Confining Unit
		Eutaw Formation		Minor Saline Reservoir
		Tuscaloosa Group	Upper Tusc.	Minor Saline Reservoir
			Mid. Tusc. Marine Shale	Confining Unit
			Lower Tusc. Pilot Sand Massive sand	Saline Reservoir
	Lower	Washita-Fredericksburg	Dantzler sand Basal Shale	Saline Reservoir Primary Confining Unit
		Paluxy Formation	'Upper' 'Middle' 'Lower'	Injection Zone
		Mooringsport Formation		Confining Unit
		Ferry Lake Anhydrite		Confining Unit
		Donovan Sand	Rodessa Fm. Upper' 'Middle' 'Lower'	Oil Reservoir Minor Saline Reservoir Oil Reservoir

- Proven four-way closure at Citronelle Dome
- Injection site located within Citronelle oilfield where existing well logs are available
- Deep injection interval (Paluxy Form. at 9,400 feet)
- Numerous confining units
- Base of USDWs ~1,400 feet
- Existing wells cemented through primary confining unit
- No evidence of faulting or fracturing (2D)





Extrapolated Continuity of Upper Paluxy Sandstones At Citronelle Southeast Unit Northwest - Southeast

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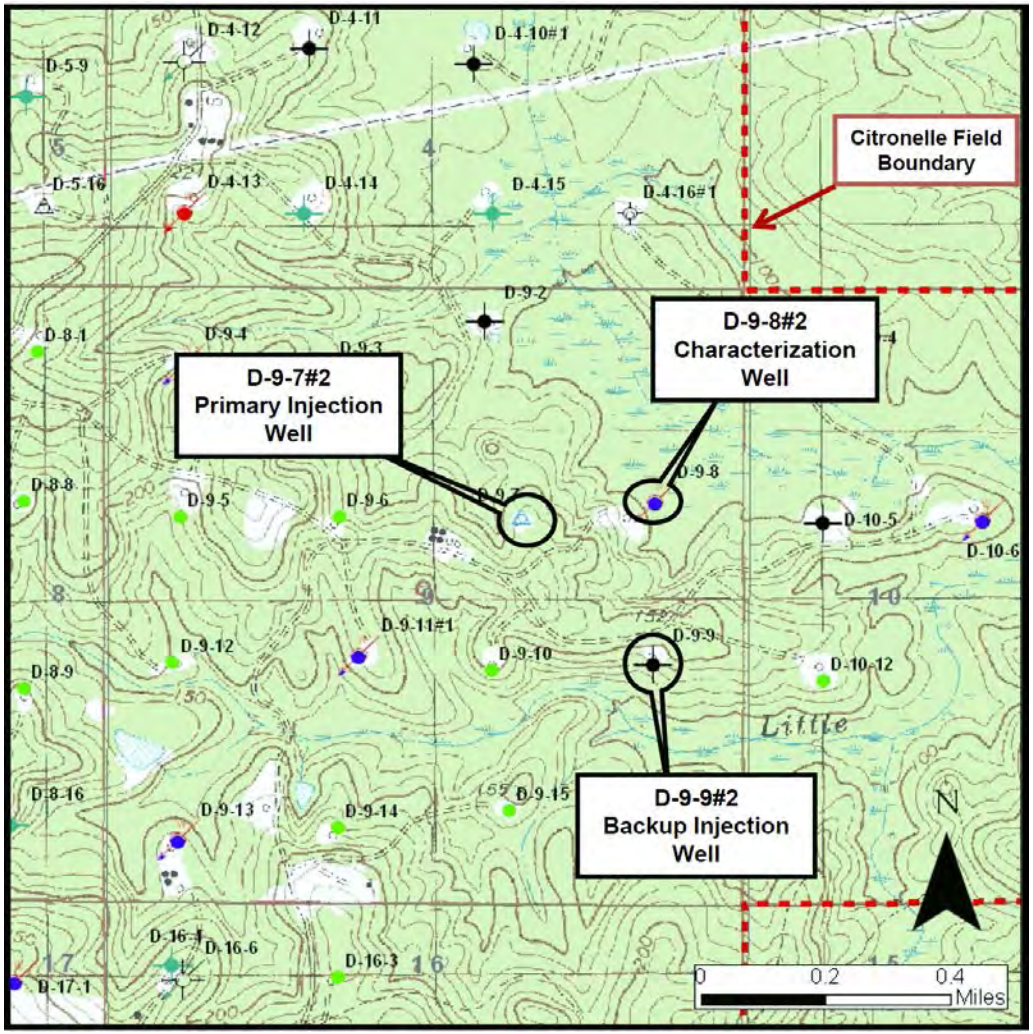
SECARB Citronelle: MVA Sample Locations



- One (1) Injector (D-9-7 #2)
- Two (2) deep Observation wells (D-9-8 #2 & D-9-9 #2)
- Two (2) in-zone Monitoring wells (D-4-13 & D-4-14)
- One (1) PNC logging well (D-9-11)
- Twelve (12) soil flux monitoring stations

Whole Core Analyses & Confining Unit Characterization

CoreAnalysis	D 9-7 #2	D 9-8 #2	D 9-9#2
Spectral Gamma Ray	**X**	**X**	**X**
Routine Porosity, Permeability, Grain Density	X	X	X
Vertical and Orthogonal Permeability	X	X	X
Relative Permeability		X	
X-ray Diffraction Mineralogy	X	X	X
Fluid Sensitivity – Permeability vs. Throughput		X	
Thin-Section Petrography	X	X	X
Mercury Injection Capillary Pressure		X	
Total Organic Carbon		X	X
Source Rock Analysis		X	X
Shale Rock Properties		X	X
Methane Adsorption Isotherm		X	X

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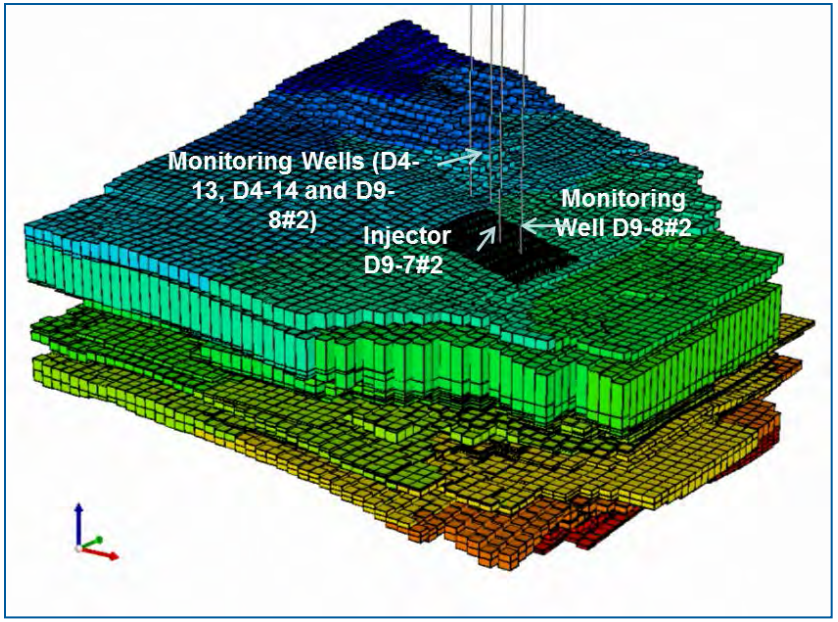
Geology Summary for Simulation

- Proven four-way closure at Citronelle Dome with existing logs
- Injecting into Paluxy @ 9,400 feet
- >260 net feet of “clean” sand
- Average porosity of 19% (ranges from 14% to 24%)
- Average permeability of 300 md (ranges from 30md to 1,000 md)
- No evidence of faulting/fracturing (2D)



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SECARB's Anthropogenic Test
Project Integration & Risk Management

Business Integration

- Key business integration questions:
  - What business relationships must be established?
  - How can CO_2 transportation and injection impact the capture unit?
  - How can plant shutdown impact CO_2 transportation and injection?
  - What types of communications and control systems are needed?

Monitoring & Compliance

- Key monitoring & compliance questions:
  - How are risk-based monitoring programs developed and implemented?
  - What safeguards and mitigating strategies can be employed to reduce risk?
  - How can risk management tools assist in project compliance?

Project Risk Assessment Matrix: DNV KEMA Approach

CONSEQUENCE SEVERITY	CONSEQUENCE				LIKELIHOOD				
					A: Remote	B: Unlikely	C: Possible	D: Probable	A: Certain
	Health and safety (HS) And Environmental protection (E)	Cost	Reputation	Schedule to start-up of operations	Very unlikely (P<0.05) to occur during life of project	Unlikely to occur during life of project	50/50 chance of occurring during life of project	Likely to occur during life of project	Very likely (P>0.95) to occur during life of project
E: Persistent Severe	HS: On site & off site exposures/injuries. E: Persistent severe damage, Extensive remediation required. Environment restored > 5 years.	More than $10 million	National or International media attention. Regulators shut down operations.	More than 12 months	M	M	H	H	H
D: Severe	HS: On site injuries/exposures leading to absence from work more than 5 days or long term negative health effects. E: Severe environmental damage. Remediation measures required. Environment restored < 5 years	$1 to $10 million	Regional media attention. Regulatory or legal action taken	6-12 months	L	M	M	H	H
C: Moderate	HS: Lost time event/on site injury leading to absence from work up to 5 days, or affecting daily life activities more than five days. E: Damage managed by Company response teams, env. restored < 2 years.	$100 to $1000 k	Local media attention. Regulatory or legal action likely	3-6 months	L	L	M	M	H
B: Minor	HS: Minor injury or health effect - affecting work performance, such as restricting work activities, or affecting daily life activities for up to 5 days. E: Damage, but no lasting effect.	$10 to $100 k	Public awareness may exist, but there is no public concern	1-3 months	L	L	L	M	M
A: Slight	HS: Slight injury or health effect - not affecting work performance or daily life activities. E: Damage contained within premises.	Less than $10 k	On-site communications	Less than 1 month	L	L	L	L	M

Evolution of risk profile

- Risk scenarios (by reference no.)
- Risks in yellow “tolerable” band gradually reduced through implementation of risk treatment: 15 (June 2011) -> 8 (Jan. 2012) -> 6 (May 2013).
- Open risks reduced from 47 (June 2011) to 38 (Jan. 2012) to 35 (May 2013).

Total risk June 2011

Likelihood	Slight	Minor	Moderate	Severe	Persistent Severe
Frequent					
Probable	25	3	31		
Possible		41	1, 11, 14, 30, 32, 34, 38		
Unlikely	46, 48	4, 12, 15, 19, 37, 39, 40, 43, 44	6, 18, 26, 36	8, 21	23, 24
Remote	22	20, 35, 45, 47	2, 13, 16, 33, 42	5, 7, 27, 29	9, 10

Consequence

Total risk Jan. 2012

Likelihood	Slight	Minor	Moderate	Severe	Persistent severe
Certain / Frequent					
Probable	25				
Possible		41	38		
Unlikely	46, 48	4, 12, 15, 19, 37, 39, 40	11, 14, 18, 26, 32, 36	8, 21, 29	23
Remote		20, 45, 47	1, 2, 6, 7, 13, 16, 17, 33, 42	27	9, 10, 31

Consequence

Total risk May 2013

Likelihood	Slight	Minor	Moderate	Severe	Persistent severe
Certain / Frequent					
Probable					
Possible		38			
Unlikely	46, 48	4, 12, 15, 19, 37, 39, 40	14, 18, 21, 32, 50	8, 23, 41, 52	
Remote	25, 26	20, 45, 47	1, 2, 6, 17, 29, 33, 36, 42	27	9, 10

Consequence

SECARB Citronelle: Top ranked risks

- Initially **June 2011** the top ranked risks related to:
  - **Permitting** – 30, 31
  - Injectivity and containment – 8, 9, 10, 11
  - Modelling and monitoring – 14, 32
  - Reliable operations – 1, 23, 24, 38,
  - Pipeline and wells – 3, 21, 34
- In **January 2012**, Class V permit had been granted and drilling of monitoring wells and pipeline construction had been completed. Top ranked remaining risks related to:
  - **Authorization to inject** – 31
  - Containment – 8, 9, 10 (low likelihood, but high consequence)
  - Reliability of operations – 23, 38
  - Pipeline or casing leak – 21, 29
- In **May 2013** project had been operating for 9 months. Top remaining risks related to
  - Possible loss of containment – 8, 9, 10
  - Reliability of operations – 23, 41
  - Post-injection MVA / **Authorization for closure** – 52

Public Outreach and Education

- Public Outreach Plan using DOE Best Practices Model
- Active Community Engagement through Open House Meetings and Tours
- Communicating Project Status
  - Local, Regional, International Outreach
  - Annual SECARB Stakeholders' Briefing
  - Dedicated Website
  - Facebook Page: facebook.com/SECARB
  - Twitter Feeds: @SECARB1
  - Press Releases & E-blasts
  - RCSP Working Groups
- Knowledge Sharing
  - Lessons Learned presented in Various Workshops & Conferences
- Education: Training Center (separately funded)
  - SECARB-Ed (secarb-ed.org)
    - Classroom Training and Webinars
    - RECS-2011, 2012, and 2013 (hosted in AL)

SECARBON.ORG