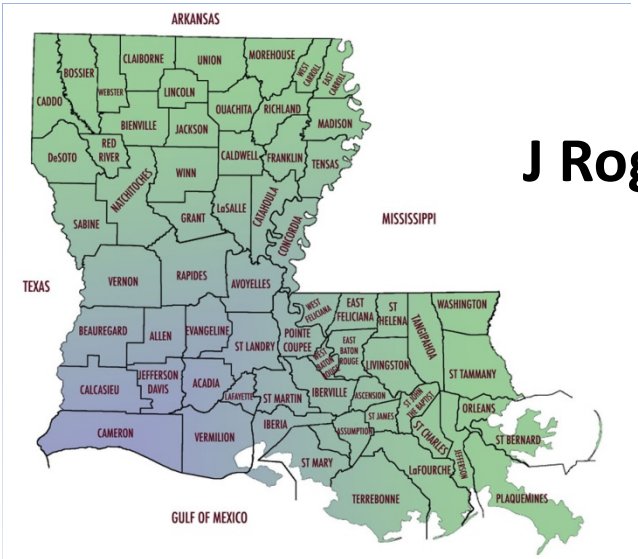
South Louisiana EOR / Sequestration R&D Project

FE0006823

Carbon Storage R&D Program Project Review Meeting

Sheraton Station Square Hotel, Pittsburgh, PA

August 20-22, 2013



J Roger Hite, Principal Investigator
Blackhorse Energy, LLC

Presentation Outline

- ✓ Benefit to the Carbon Storage Program
- ✓ Project Objectives
- ✓ Technical Status
- ✓ Accomplishments to Date

Benefit to Carbon Storage Program

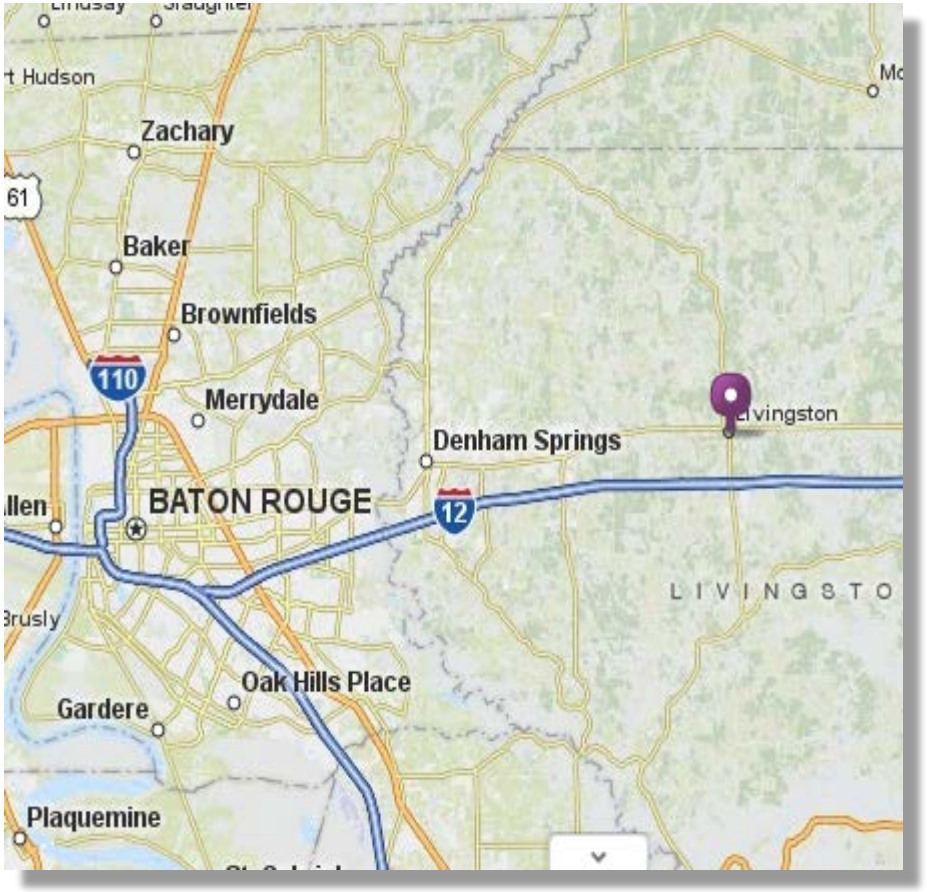
- ✓ **Program Goals:**
  - **Support industry's ability to predict CO_2 storage capacity to within 30%**
  - **Develop and validate technologies to ensure 99% storage permanence.**
  - **Develop technologies to improve storage efficiency**
  - **Develop best practices manuals**
- ✓ **Benefits:**
  - **Acquire field data on CO_2 sequestration in beach barrier bar in the State of Louisiana as part of EOR project**
  - **Evaluate technologies**
    - **3D seismic**
    - **Horizontal injector**
    - **Advanced logging tools**
    - **Fiber optic cables**
    - **CO_2 foam**

Project Objectives

- ✓ **The primary objective**
  - **Understand CO_2 behavior and migration in a beach/barrier near shore bar depositional environment.**
- ✓ **Secondary objectives:**
  - **Demonstrate that successful sequestration projects can be performed safely in Louisiana;**
  - **Demonstrate that Louisiana is a major sequestration target; and**
  - **Enhance the future prospects for commercialization of sequestration.**

Livingston Reservoir

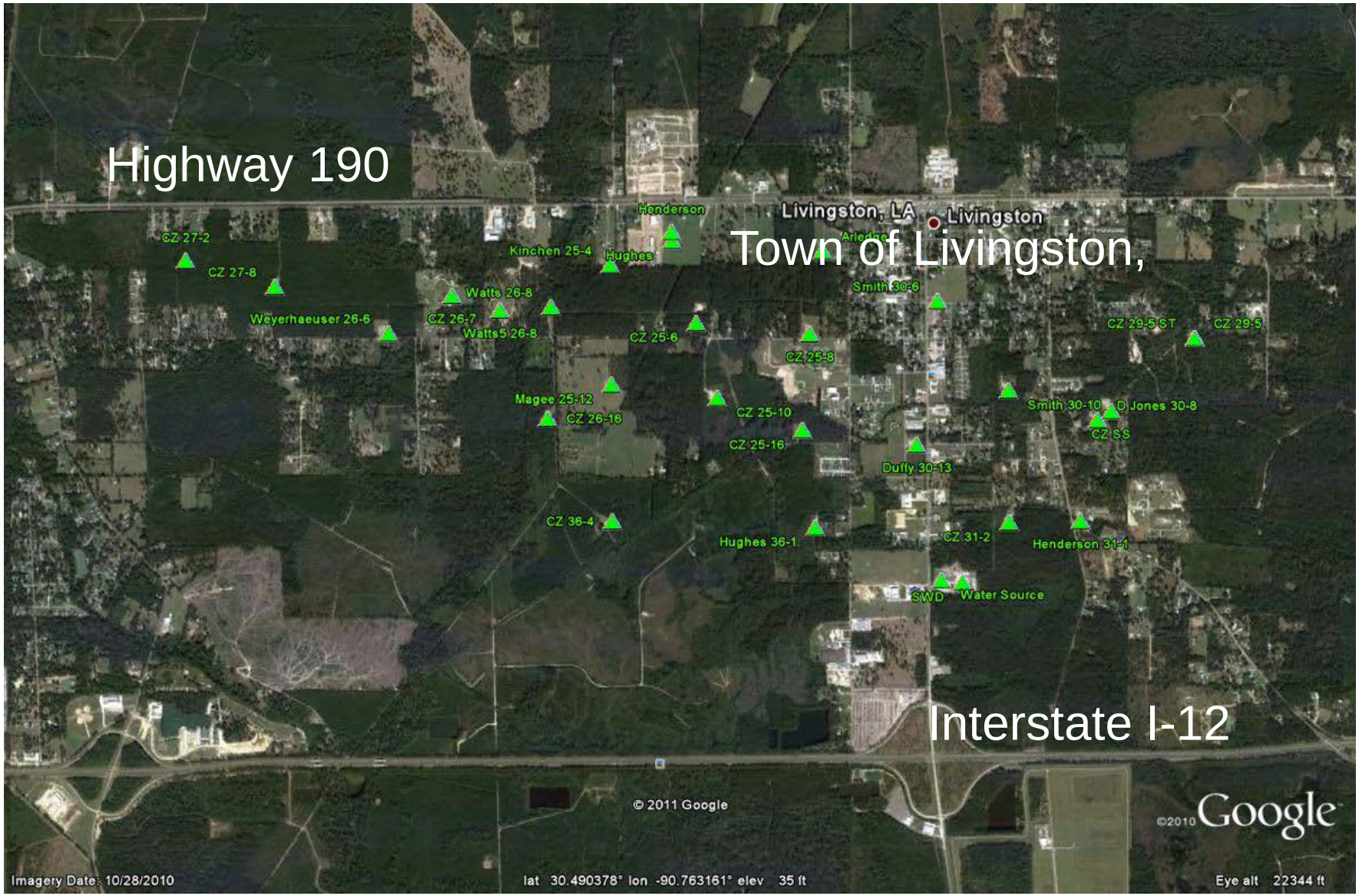
- ✓ Productive Formation: Wilcox
  - 10,000 ft deep
  - 2,200 acres
  - 25 miles east of Baton Rouge
- ✓ OOIP 28 MM Bbls of 39° API oil



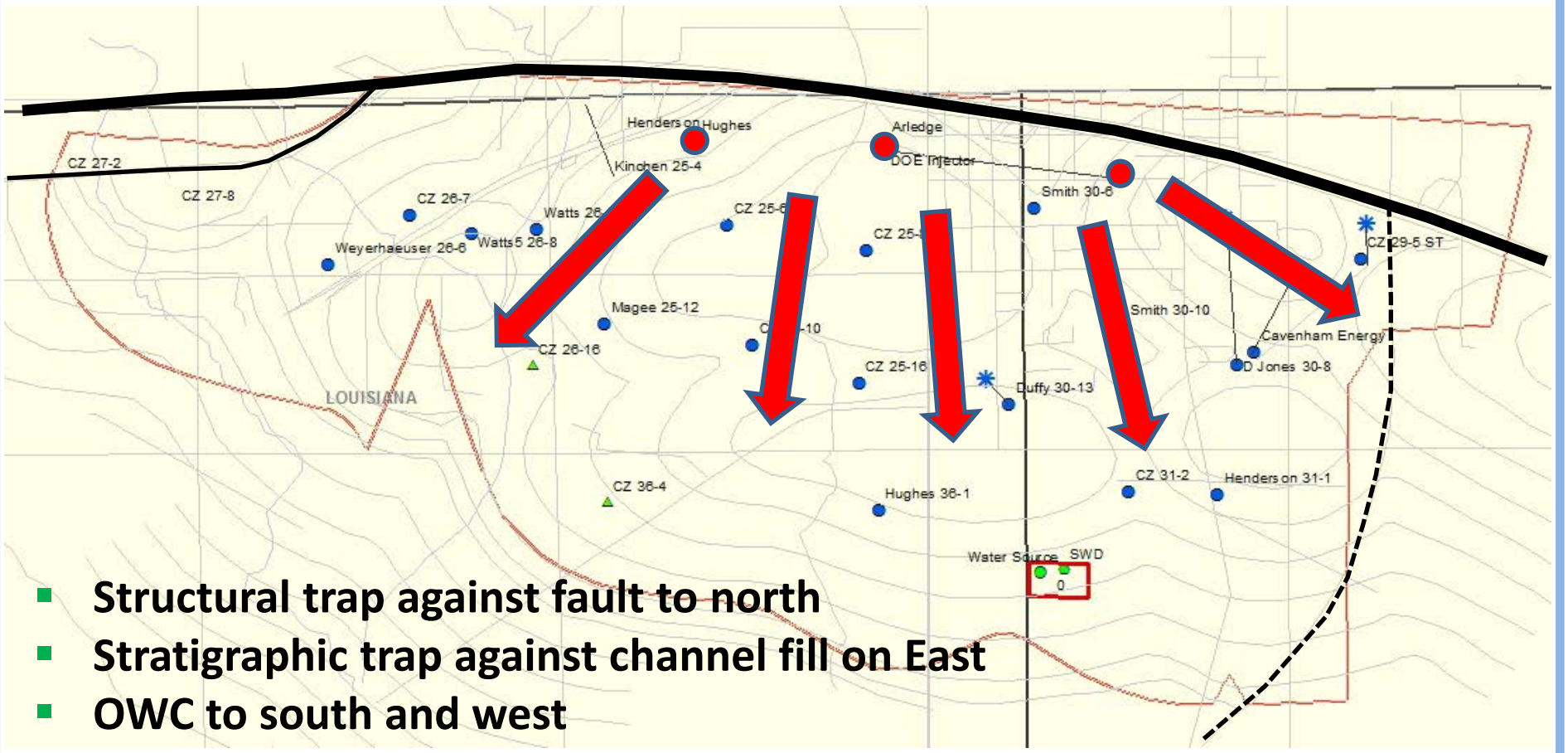
Production History

- ✓ Discovered in 1983
- ✓ Waterflooding began in 1987 by Amoco
- ✓ Primary and waterflood recovery 8.2 MM Bbls (29% OOIP)

Livingston Reservoir Location



Well Map



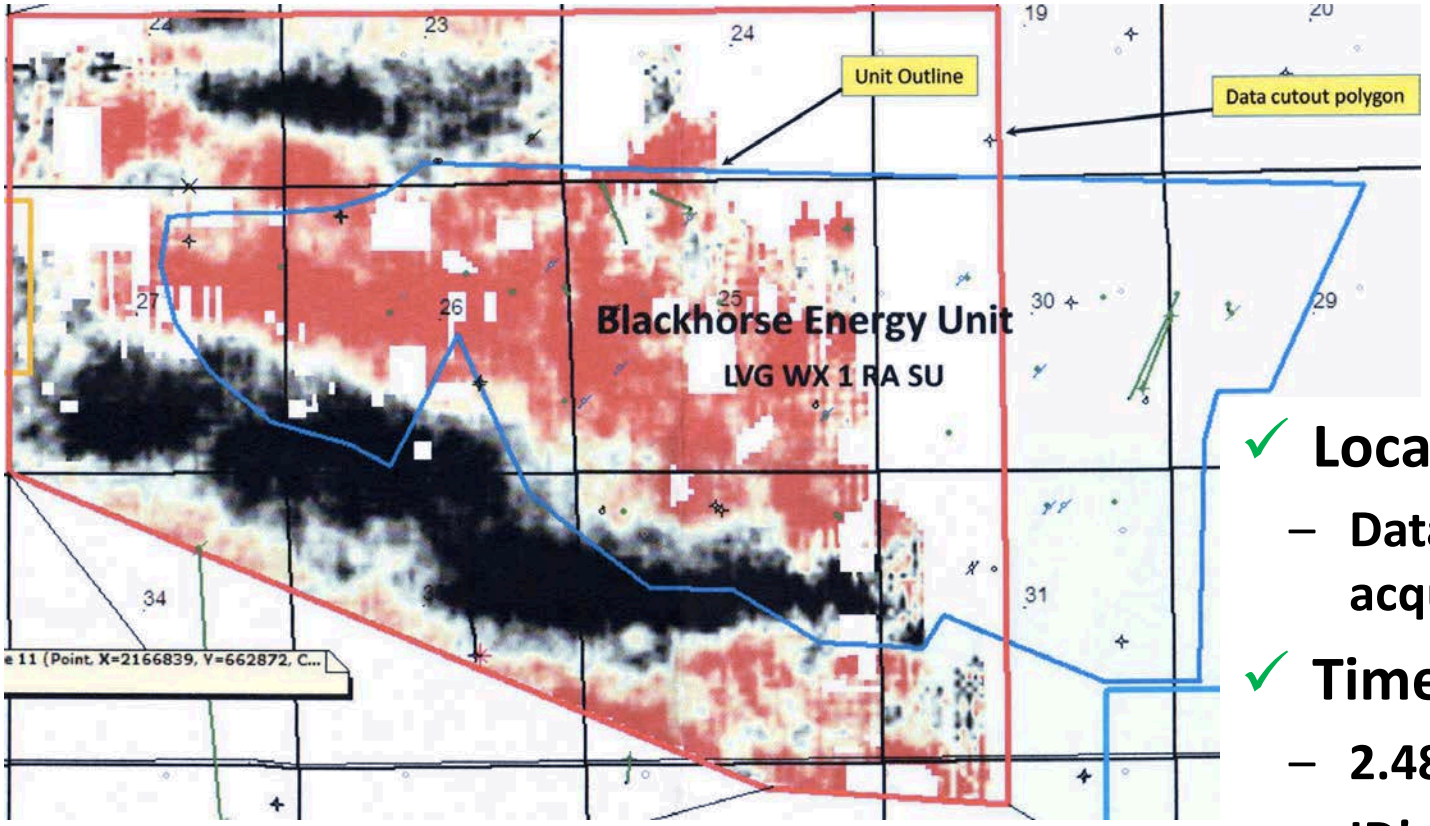
- Structural trap against fault to north
- Stratigraphic trap against channel fill on East
- OWC to south and west

- Updip CO_2 injection
- New injector located to northeast
- CO_2 front moves downdip to south and west

Technical Status

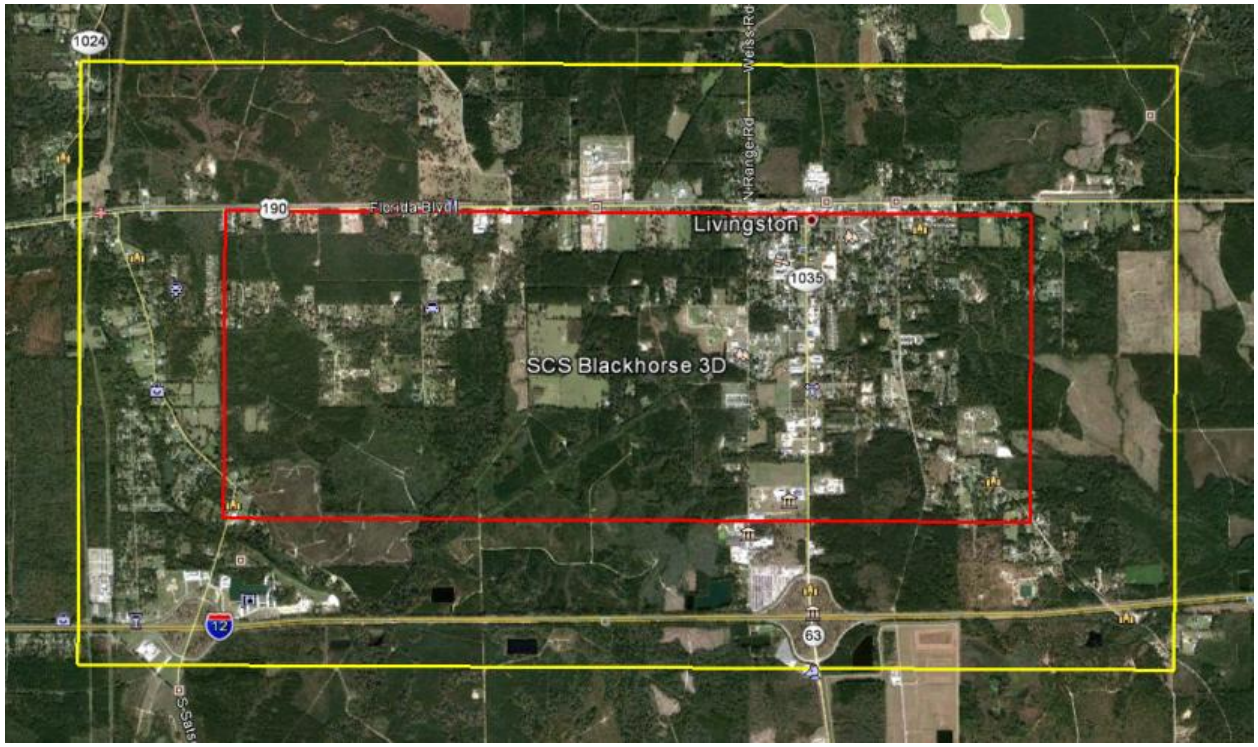
- ✓ **Reservoir Characterization and Modeling**
  - Reservoir model honors all log and core data
  - Describes CO_2 migration
- ✓ **Seismic Survey**
  - Acquired 3D survey data from third party
  - 3D, and eventual 4D, survey
- ✓ **University Support**
  - Surveillance
  - Geochemistry
  - CO_2 foam design

Third Party Seismic Survey



- ✓ **Location**
  - Data in red boundary acquired by Blackhorse
- ✓ **Time Slice**
  - 2.488 seconds
  - ID's fault on north boundary
  - Dip to south and west

Seismic Survey



- ✓ **Location**
  - Yellow border shows survey outline
  - Red border shows area of full fold
- ✓ **Acquisition**
  - Western Geco's UniQ system
  - Explosive sources
  - Vibrator trucks within city limits

University Research

Projects:

- ✓ Assess how CO_2 affects carbonate deposits and cements in the reservoir (LSU and UT)
- ✓ Develop less expensive methods of characterizing CO_2 plume migration in the reservoir (UT)
- ✓ Support CO_2 foam development (Rice and UT)

University Research

LSU Project 1 – Geochemical Evaluation

- The interaction of CO_2, minerals found in sandstone reservoir rocks (especially carbonates and clays), and brine/water can produce geochemical changes which in turn can affect reservoir/cap rock properties.
- A common example found in natural systems is the interaction of carbonic acid (H_2CO_3) with feldspar to form kaolinite, which results in additional porosity, lower permeability, reduced pore throat sizes.
- In addition carbonate minerals present in sandstone will most likely be unstable under low pH conditions and this can potentially change porosity/permeability and therefore injectivity of CO_2.
- The purpose of this project is to identify and quantify such geochemical changes under laboratory conditions and provide the data for models capable of predicting behavior of the reservoir rock in the field.

University Research

LSU Project 2 –CO2 Foam Modeling

- In addition to CO_2 injection, it is intended to use about 150,000 lbs of surfactants to produce CO_2 foams in the reservoir.
- This attempt, if successful, is expected to delay the breakthrough of injected fluids and improve sweep efficiency by overcoming or mitigating reservoir heterogeneity, gravity segregation, and viscous fingering.
- Such a success in the field trial requires tailor-designed surfactant chemicals and foam rheological properties meeting the characteristics of the fields of interest, including rock and fluid properties, chemical-rock interactions, foam stability influenced by reservoir fluids and wettability, thermal degradation of chemicals and so on, to name a few.
- This research component aims to achieve a reliable evaluation and implementation of mobility-control foam processes and an accurate up-scaling of laboratory flow tests to field-scale flooding by understanding foam rheological properties during foam displacement in the reservoir.
- A mechanistic foam modeling technique based on foam catastrophe theory is a key aspect to meet these goals.

University Research

UT Austin Project 1: Inexpensive Monitoring and Uncertainty Assessment of CO_2 Plume Migration using Injection Data

- The overall objective of this project is to develop a new computational approach for monitoring the location of CO_2 during injection.
- The proposed approach has two notable advantages: it is very inexpensive, and it quantifies the uncertainty in the plume location. The former advantage arises because the method can work with data that will be measured in every storage project, namely injection rates and pressures at each well versus time. The latter advantage arises because the approach abandons traditional pixel-based methods of parameter estimation and instead yields multiple geologically consistent models that reflect the injection characteristics observed at wells.
- The method is geologically based and inherently flexible enough to use other types of data, such as surface deflection or seismic, to infer plume location with greater accuracy. The objectives of the main research tasks are to develop the mathematical formulation for a model-based approach to develop modular software that can be readily integrated with existing flow simulators and with frameworks for monitoring and verifying plume location, and to demonstrate the approach on field datasets.

University Research

UT Austin Project 2: Alterations in mechanical properties of rocks due to CO_2 injection -- implications for field scale monitoring of sequestration processes.

- The primary focus here is to relate the changes in elastic properties of the host formation observed at the laboratory scale to larger field or seismic scale changes.
- This upscaling process has important bearing on the development of seismic techniques for monitoring the progress of the CO_2 plume post-injection.
- To accomplish this objective, we propose to develop extensions to the current effective media models to incorporate velocity anomaly induced by frame alteration of the rock. In conjunction, our research objective is also to develop high-resolution seismic inversion capability using basis pursuit and very fast simulated annealing that incorporate improved forward models reflecting the rock physics associated with CO_2 injection in the subsurface.

University Research

UT Austin Project 3: High Pressure CO_2 Foam Experiments

- UT is developing surfactants for mobility control and will supervise high pressure CO_2 foam flooding experiments.
- Oil displacement flow experiments at reservoir conditions are required to confirm the viability of the surfactant selection and optimize slug size for reservoir design and application.
- UT and Rice have established a proven record of collaboration to understand the governing chemistry and fluid flow behavior of foams in porous media.
- The methods they have developed will be used and hopefully will yield an effective foam mobility control system for South Louisiana EOR/CCUS R&D Project

University Research

Rice University Project 1A: Locate a surfactant for CO_2 mobility control at Livingston

- Adsorption of surfactant on reservoir minerals: This is complex - The reservoir is a mixture of the sandstone, clays and highly concreted zones where carbonates and clays have precipitated in the otherwise clean beach sand.
- Dynamic and static adsorption studies on minerals are required to quantify potential surfactant loss, governing mechanisms, sacrificial agents (if required) and surfactant selection and slug size.

Rice University Project 1B: Study transport of surfactant and foam

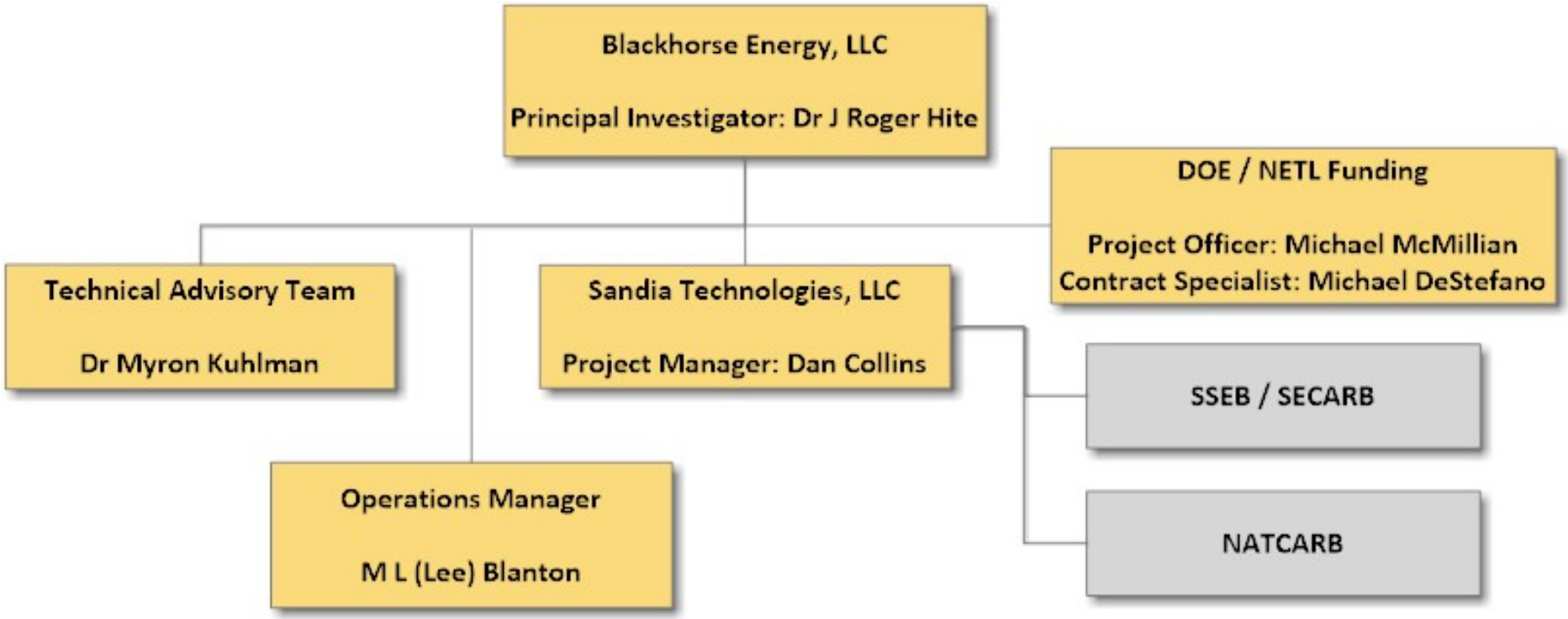
- Surfactant partitioning behavior is an important aspect of surfactant transport and possible chromatographic separation. Phase behavior and partitioning studies of surfactant between CO_2, brine and oil will be used recognize surfactant chromatographic separation and transport.

Accomplishments to Date

- ✓ **Reservoir Characterization**
  - A complete reservoir description has been prepared
  - Honoring all log and core data
- ✓ **Simulation**
  - Model describes CO_2 placement and distribution in reservoir
  - Predicts CO_2 migration
- ✓ **Seismic survey**
  - Acquired third party survey
  - First 3D survey by Schlumberger Carbon Services

Discussion

Project Organization

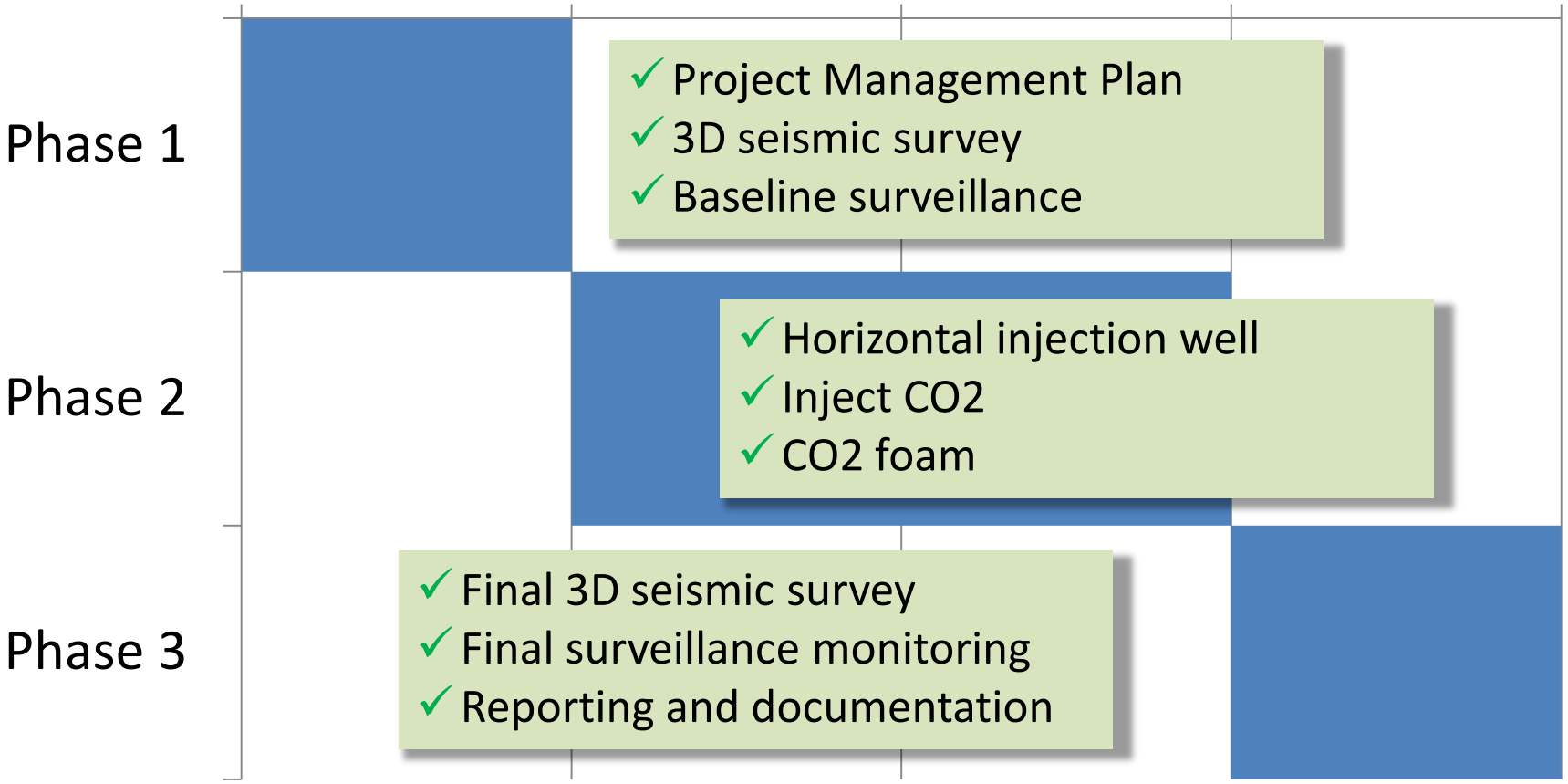


Project Organization

- ✓ **Other Participants**
  - Universities
  - Rice University
  - Louisiana State University
  - University of Texas - Austin
  - Schlumberger Carbon Management Services
  - Computer Modeling Group

- ✓ **Endorsements**
  - Scott Angelle, Secretary, Louisiana Department of Natural Resources
  - Ken Nemeth, Executive Director, Southern States Energy Board

Project Timeline



Publications

- ✓ **None to date**