Final Report

Design Specifications for Seismic Survey

SECARB Phase III Work Product 4.2.2.a

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National Energy Technology Laboratory

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Executive Summary

A test site and anthropogenic CO_2 source have been selected for a large-scale demonstration of carbon dioxide separation, capture and sequestration in southwestern Alabama as part of the Southeastern Regional Carbon Sequestration Partnership's (SECARB) Phase III initiative. The James M. Barry Generating Plant, a major coal-fired power plant in southwestern Alabama, is the selected anthropogenic CO_2 source for the project. The proposed storage test site is located in the Southeast Unit of the Citronelle oil field, which lies at the crest of the Citronelle Dome about 10 miles to the west of the power plant. The proposed storage site appears to be suitable for deep underground injection of CO_2.

An evaluation of the storage capacity and geological integrity of the proposed injection and confining intervals is a critical step in the assessment of the test site. This evaluation is important for several reasons, including project planning, permitting of injection wells, and the design and execution of injection and monitoring operations. Accordingly, the Geological Survey of Alabama (GSA) will conduct a detailed geological evaluation of the Southeast Citronelle Unit that emphasizes the acquisition, interpretation, and analysis of seismic reflection data. The goals of this work are to characterize the geologic structure of the area, verify that no faults are present, determine and analyze the seismic expression of sandstone and shale bodies in the Paluxy target interval, and to assist in the Underground Injection Control (UIC) permitting process.

Due to its lack of hydrocarbons, the proposed injection interval, the Paluxy formation, has not been fully studied in the Citronelle oil field. However, the formation lies above a working oil field resulting in the availability of spontaneous potential and resistivity logs for most well penetrations in and surrounding the test site. Due to the presence of lower-lying hydrocarbons, the field and surrounding region have been well-studied, indicating no faulting has occurred through the oil-bearing sands and shallower

depths. Because of this, there is little need to design and implement a new seismic data acquisition program. Instead, the Project Team will augment the geologic characterization by purchasing and processing existing 2-dimensional seismic data across the planned storage site. This analysis will be merged with the geophysical well logs that are available at nearly 40-acre well spacing. Therefore, the acquired seismic will be more than sufficient to indicate faulting and will add to the geologic characterization of the storage horizon and the confining units.

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1.0 Introduction

Phase III of the Southeastern Regional Carbon Sequestration Partnership (SECARB) will focus on large-scale demonstration tests of carbon sequestration technology. One goal of Phase III is to conduct a demonstration test in which carbon dioxide is separated, captured, and sequestered from an anthropogenic source, such as a coal-fired power facility. The anthropogenic CO_2 source will be the James M. Barry Generating Plant (Plant Barry), a major coal-fired power plant that is located along the eastern margin of the Mississippi Interior Salt Basin in southwest Alabama (**Figure 1**). Based on a geological evaluation of the Plant Barry area, the best opportunity for a large-scale sequestration test lies to the west of Plant Barry in an area that includes the Citronelle oil field (Esposito, Pashin and Walsh., 2008; Pashin, McIntyre, Grace and Hills, 2008). Accordingly, a test site has been designated in the Citronelle Field and the test will target saline reservoirs in the Lower Cretaceous-age Paluxy Formation within the Southeast Citronelle Unit.

The storage capacity and geology of potential geologic sinks in the Paluxy Formation will be characterized to ensure the reservoirs suitability and integrity for carbon sequestration. This evaluation is important from several reasons, including project planning, permitting of injection wells, and the design and execution of injection and monitoring operations. Accordingly, the Geological Survey of Alabama (GSA) will conduct a detailed geological evaluation of the Southeast Citronelle Unit that emphasizes the acquisition, interpretation, and analysis of seismic reflection data. The goals of this work are to characterize the geologic structure of the Southeast Citronelle Unit, verify that no faults are present, determine and analyze the seismic expression of sandstone and shale bodies in the Paluxy target interval, and to assist in the Underground Injection Control (UIC) permitting process.

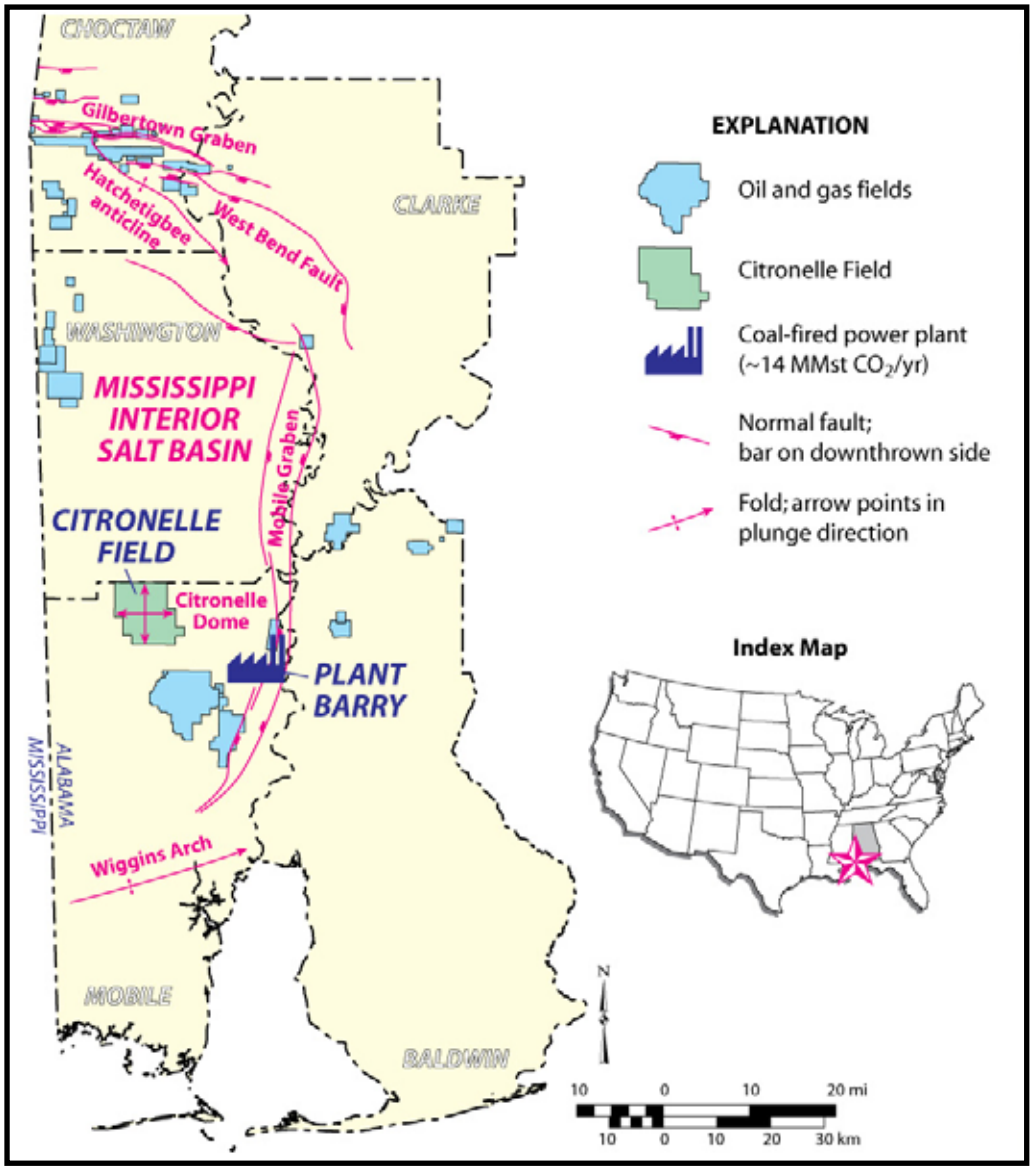

Figure 1: Map Showing Location of Plant Barry and the Citronelle Oil Field along the Eastern Margin of the Mississippi Interior Salt Basin in Southwest Alabama

2.0 Scope of Work

The implementation of this work will be carried out in four tasks: 1) Data Acquisition; 2) Data Loading; 3) Depth Conversion and Correlation; and 4) Data Analysis and Interpretation. Task 1, Data Acquisition, will focus on obtaining available seismic reflection data and geophysical well log data. Task 2, Data Loading, will focus on loading the geophysical data into the Petra® and PetraSeis® software programs.[1]

Task 3, Depth Conversion and Correlation, will center on using the available sonic log data to depth convert the seismic reflection data in order to correlate well logs and the seismic reflection data. Task 4, Data Analysis and Interpretation, will focus on interpreting the results of Tasks 1 through 3, preparation of materials to support the Underground Injection Control (UIC) permitting process, and making recommendations regarding geological integrity, development strategies, and future work.

Task 1: Data Acquisition

The principal data sources needed to perform the proposed study are geophysical well logs and seismic reflection data. Geophysical well logs for the Southeast Citronelle Unit and the surrounding area are available through the State Oil and Gas Board of Alabama and from Denbury Resources. These logs are already on file at the GSA and all of the well logs are available as TIFF images. The primary logs of interest will be the sonic, gamma-density, and SP-resistivity logs. These logs are required for velocity analysis, depth-conversion of seismic profiles, and correlating reflection seismic data to stratigraphic data. Other types of relevant geological data, such as core analyses, will be gathered and transmitted to the project team as part of this task.

[1] Petra and PetraSeis are registered products of IHS Inc. 321 Inverness Drive South, Englewood, CO 80112

Since the majority of the geophysical well logs already exist and are available to the Project Team through the GSA, the primary goal of Task 1 will be to identify and purchase useful seismic profiles that traverse the Southeast Citronelle Unit and at least one seismic profile that will traverse the Citronelle oilfield. Data within the Southeast Citronelle Unit will be instrumental for determining structural geometry and geological integrity within the storage target area, whereas lines traversing the field will verify the structural integrity of the reservoir and sealing units.

Seismic reflection data for the Citronelle Field are available principally through Seismic Exchange Incorporated[2] (SEI) which has been contacted regarding the availability and pricing of data. The first step under Task 1 will be to work with SEI and other vendors to determine what data are available and in what form. Prior to purchase, sample printouts of parts of the profiles will be obtained and screened for quality and depth penetration. After quality has been assessed, decisions will be made regarding what data should be purchased so that project goals can be met.

Task 2: Data Loading

As seismic data are acquired, they will be loaded into the Petra® software system at the GSA. A separate Petra project (i.e., geologic model) is being developed by the Project Team for subsurface characterization and will be transmitted to GSA in order to augment their seismic characterization. Selected sonic and density logs, required for depth conversion and attribute analysis, will be digitized using Neuralog software[3] and other logs will be digitized as needed.

Seismic reflection data will be loaded into PetraSeis, a module of Petra that is fully compatible with the geologic model and will accept TIFF images generated from paper copies as well as digital data. For paper data, seismic profiles will be scanned to TIFF format and imported into PetraSeis, which will then be used to calibrate and depth-

[2] Seismic Exchange Inc., 1776 Yorktown Street, Houston, TX 77056-4182
[3] Neuralog, Inc., 4800 Sugar Grove Blvd, Suite 200, Houston, TX 77477

register the TIFF images. Editing of the headers and layout of these files is sometimes required for successful import into seismic interpretation software.

Task 3: Depth Conversion and Correlation

Seismic data must be depth-converted through analysis of velocity data to ensure that seismic events are properly correlated with geologic structure and stratigraphy. Sonic and density logs will provide the necessary information required for depth conversion. These logs and seismic data will be analyzed to determine the regional velocity field using standard geophysical procedures. If possible, a wavelet will be extracted from purchased digital seismic data and used along with the sonic log data to develop a synthetic seismogram. This seismogram will provide a definitive correlation between stratigraphic markers and seismic events.

Major stratigraphic units, and particularly markers that correspond with seismic reflections, will be identified in all available geophysical logs and correlated using Petra® software. In addition, mappable sandstone bodies will be delineated in the geologic model created by the Project Team and included in the GSA Petra project. The GSA's experience in the region indicates that discontinuous reflections are common in the Lower Cretaceous siliciclastic section (including the Paluxy formation). Therefore, correlating seismic and well data in the Paluxy Formation may be instrumental for constraining the extent and geometry of reservoir sandstone bodies and seals.

Task 4: Data Analysis and Interpretation

Time-structure maps of major seismic reflections, and isochron maps showing the time-thickness of major stratigraphic intervals will be created. After seismic data have been fully tied to stratigraphic control and depth conversion is complete, seismic and well data will be used to make true-depth structural contour maps of key

stratigraphic markers, including the top of the Ferry Lake Anhydrite and any other widespread seismic reflections in the Cretaceous section. True-thickness isopach maps will also be made of key stratigraphic intervals. If possible, seismic control will be used to refine isopach and isolith maps of reservoir sandstone and sealing shale units where significant sequestration potential appears to exist.

Seismic profiles will be interpreted to identify faults which may affect the containment of CO_2. Key attributes that may indicate faulting include quarter-wavelength or greater offset of seismic reflections, as well as localized amplitude anomalies. The Ferry Lake Anhydrite is the strongest and most widespread seismic reflector near the Paluxy section. Therefore, particular attention will be paid to offset and amplitude variation associated with the Ferry Lake event.

The final step in the study will be assessing all project results to make recommendations regarding future work. Analysis of geological integrity will help verify that operations can be conducted safely and will also help identify which sandstone bodies provide the best sequestration targets. Recommendations will further be made regarding paths forward for site development and future work that will contribute to a safe and successful field test.

3.0 References

1. Esposito, R. A., Pashin, J. C., and Walsh, P. M.; “Citronelle Dome: A Giant Opportunity for Multi-Zone Carbon Storage and Enhanced Oil Recovery in the Mississippi Interior Salt Basin of Alabama: Environmental Geosciences”, v. 15, p. 53-62, 2008.

2. Pashin, J. C., McIntyre, M. R., Grace, R. L. B., and Hills, D. J.; “Southeastern Regional Carbon Sequestration Partnership (SECARB) Phase III”, Final Report prepared for Advanced Resources International, 57 p, 2008.