# Southeast Regional Carbon Sequestration Partnership

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| Report Type: | Completion of Drilling Injection Wells into Brine-bearing Lower Tuscaloosa Sandstones<br><br>(Work Products 5.1.1.a and 5.1.2.b) |
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# Abstract

Three $CO_2$ injection and observation/monitoring wells were drilled at the SECARB Early Test Detailed Area of Study. This report documents completion of these wells in support of Task 5.1, Subtasks 5.1.1 and 5.1.2.

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# Executive Summary

For the Early Test, The Bureau of Economic Geology (BEG) at the University of Texas at Austin has partnered with Denbury Resources, Incorporated, to take advantage of ongoing $CO_2$-EOR efforts by the field operator. Following release of a Finding of No Significant Impact (FONSI) March 17, 2009, Phase III injection started April 1, 2009, in three downdip Phase III wells CFU 26-1, 27-1, and 28-1. Additional drilling to achieve the 1 million metric ton down-dip injection rate was completed.

# Report Details-Experimental

Due to the nature of the project, no experimental methods, materials or equipment are necessary.

# Results and Discussion

## Task 5.0: Well Drilling and Completion

### *Subtask 5.1: Early Test Site Well Drilling and Completion*

*Injection well CFU 31F-1*

The DAS injection well CFU-F31-1 that spudded on May 29 was logged on June 6 and completed on June 9. Figure 1 and Figure 2 show photograph of the rig drilling this well. This well was drilled with a field-standard 8 ¾ inch borehole to accommodate a 5½ inch steel casing. Denbury drilled it 200 ft deeper than normal and cemented it to the base of surface casing to accommodate seismic monitoring with VSP and cross well, at no additional cost to the project. Casing completion is 60 ft 16 inch surface conductor, 2019.11 ft 9.625 inch surface casing, and drill depth is 10,700 ft. Well is vertical with bottom hole location tracked via Telledrift. Stuart Coleman observed logging on behalf of SECARB. An acoustic log was collected at the base of surface casing to support VSP design and interpretation. Figure 3 shows the reservoir interval of the logs.

Denbury interprets that the reservoir is 74 ft of clean gamma ray sand, 60 ft of clean SP sand, of which 10,430 to 10,483 is defined as D with 25 ft of porosity and 10,485 to 10,508 and has 19 ft of porosity (in excess of 25%).

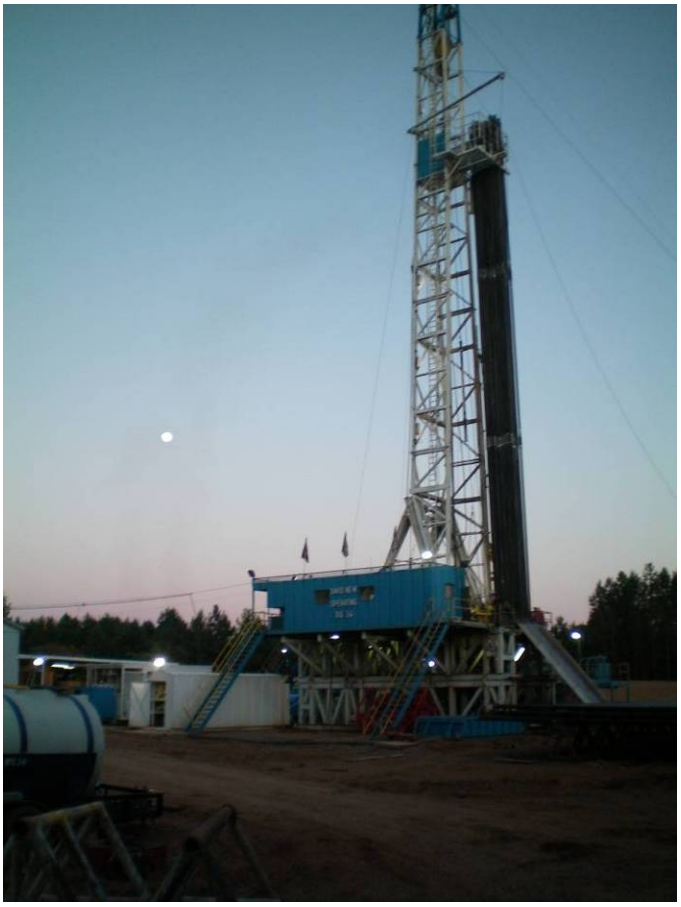

**Figure 1. Rig New David #16 drilling injection well CFU 31F-1 from well pad.**

**Figure 2. Rig drilling injection well CFU 31F-1 from distance showing setting.**

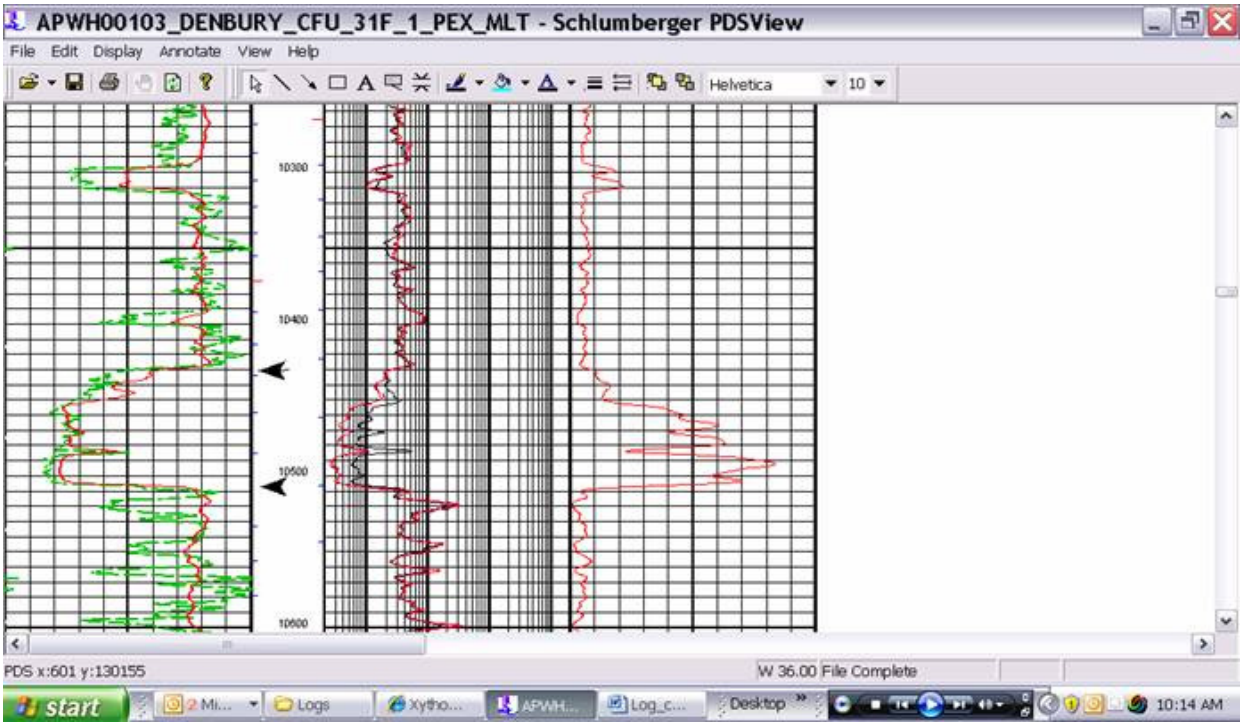


**Figure 3. Wireline log of reservoir interval in the DAS injection well CFU31-F1.**

*Observation well CFU 31F-3*

After completing the injector CFU 31F-1, Denbury began drilling the DAS observation wells, starting with CFU 31F-3, the easternmost observation well. This well was spudded June 12, and drillers cemented surface casing, installed wellhead, and tested BOPs on June 14. Teledrift was used to ensure that the well was adequately straight and to reduce the cost of having hole deviation controlled. Teledrift output is shown in Figure 4.

Drilling a 12¼ inch diameter long string borehole to accommodate 7-inch casing with instrumentation was significantly slower than expected, and a number of engineering parameters had to be determined by trial and error. On June 16, at drill depth of 5,445 ft, an episode of over torque resulted in parting the drill string. To correct this, the drillers reduced the mud weight and reduced the fins; however this proved to be insufficient. On June 22 at a drill depth of 7,134 ft, the drillers had a second episode of over torque and twist off of the drill string and had to fish 4 separate drill string pieces, which spun apart. The engineering solution was to replace the 4½ inch drill string with a new 5 inch drill string to give it more momentum. The new 5 inch drill pipe required replacing rig equipment, including new bigger pipe rams for the blow out preventers. To install them, the BHP was picked up and rotated, and new pipe rams installed, rotated back, lowered, re-installed and tested.

In addition, drilling was slower than normal, because about twice as much rock has to be removed for a 12½ inch hole as for an 8½ inch hole. Low drilling rate was especially marked in the seal intervals, Austin Chalk, and Washita-Fredericksburg below the injection zone. We estimate 13 days rig time was required beyond what was budgeted because of these issues. We expect that experience will allow improved well speed, which will bring the second well

to TD faster, as the 5 inch drill pipe and blowout preventers will be used from the start. Drillers will attempt to find a better bit for the carbonate intervals. We expect to stay budget-neutral because $CO_2$ injection will be delayed, reducing this expense.

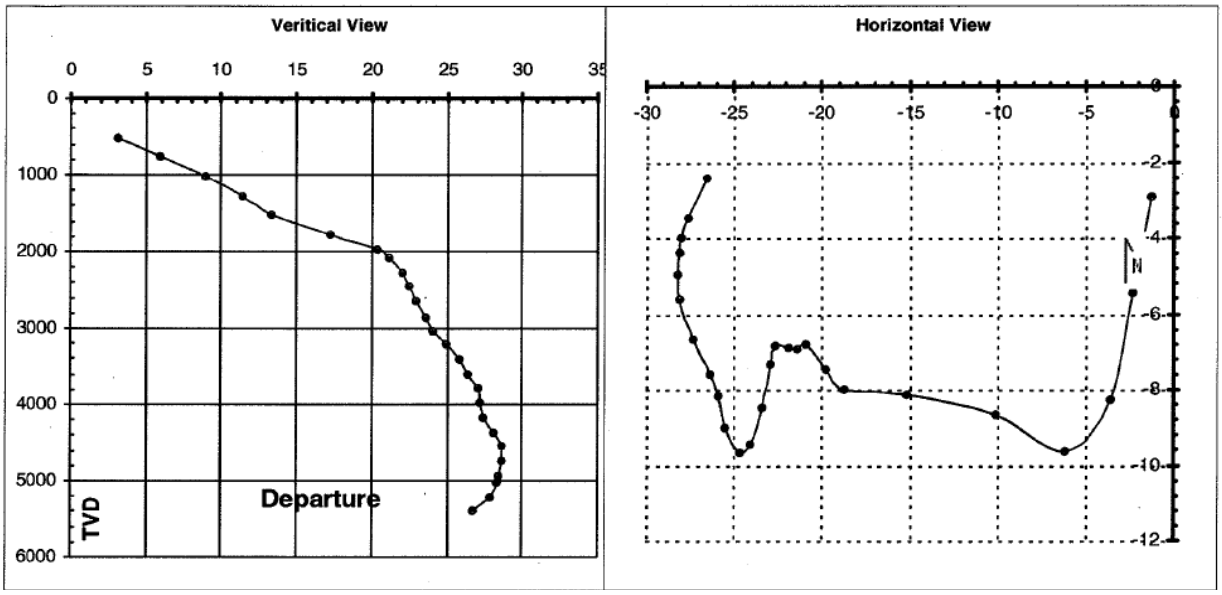


**Figure 4. Teledrift output during drilling. After casing, we will run deviation surveys to TD to determine precise well location to support the cross-well surveys.**

In preparation for casing completion of the observation wells, a pre-drilling operation was conducted on June 10, 2009, at the drilling site and in the drilling contractor's office in Natchez, MS. All services involved in drilling, running the casing, and cementing the casing in place were present. The meeting included a site visit where various components of the DTTS, ERT, and casing mounted P/T gauge instrumentation, as well as a sample of the fiberglass casing, were viewed. Afterward, the group traveled to David New Drilling's offices in Natchez to view the components to be deployed below the 7 inch steel casing. All aspects of the drilling, running of the casing, and cementing the casing in place were discussed, including drilling technique and the drilling mud program and cementing program. Risk analysis showed that high probability-high consequence failures during casing completion include failure to get casing to design depth and poor cement job. The mitigation for both of these risks is the mud program. Near the bottom of the well, we requested higher than normal attention by the mud engineer and additives to mud, including graphite, to make it slippery. On June 12, Jeff Martel, Merlin Keown, Dale Barnett (Denbury), David Freeman Donald Stehle, and Dan Collins (Sandia Technologies) and Tip Meckel and Ramon Treviño reviewed contingency plans and made sure that parts were on hand should they be needed.


**Figure 5. DAS well pad in May 2009, showing location of observation wells (M1 and M2) CFU 31F-2 and CFU 31F-3. Composite photograph by Changbing Yang.**

*Observation Well CFU 31F-2*

The second observation well at the DAS was completed on August 28, 2009, through installation of the casing, including on-casing monitoring equipment, cement, and wellhead. Denbury drilled the CFU 31F-2 well to 10,701 feet. Schlumberger wireline equipment was rigged up and open hole wireline logging operations competed. Following completion of logging, the open hole was washed and reamed to total depth, 10,790 ft, and the hole was circulated to clean and condition the drilling fluid for casing installation.

Sandia mobilized concurrently with completion of the well installation and set up to manage running of the casing and casing-deployed monitoring equipment in CFU 31F-3 well. A depth correlation log was run from 10,650 feet to 9,500 feet and the casing was lowered 12 feet for depth correction. Drilling fluid was circulated to condition the open hole section for cementing. The casing was cemented with 465 sacks of 12.8 lb/gal lead slurry and 770 sacks of 16.2 lb/gal tail slurry.

# Conclusion

The SECARB Early Test's injection well (CFU 31F-1) and two observation wells (CFU 31F-2 and CFU 31F-3) have been drilled and completed. This concludes work under Task 5.1.

# References

No references were used for this document.

# List of Graphical Materials



# List of Acronyms and Abbreviations

| | |
|---|---|
| 3-D | Three Dimensional |
| APT | annulus pressure test |
| ARI | Advanced Resources International |
| 3-D | Three Dimensional |
| APT | annulus pressure test |
| ARI | Advanced Resources International |
| AUGUSTA | Augusta Systems, Inc. |
| BEG | Texas Bureau of Economic Geology |
| BWV | bulk water volume |
| CBM | Coal Bed Methane |
| CCS | Carbon Capture and Storage |
| $CO_2$ | Carbon Dioxide |
| COOP | Carbon Offset Opportunity Program |
| CoreLab | Promore Engineering |
| CRDS | Cavity Ringdown Spectrometer |
| DAS | Detailed Area of Study |
| DEM | Digital Elevation Model |
| Department | United States Department of Energy |
| DIAL | Differential Absorption Lidar |
| DOE | United States Department of Energy |
| DOT | United States Department of Transportation |
| DTS | differential temperature survey |
| EA | Environmental Assessment |
| ECBM | Enhanced Coal Bed Methane |
| ECC | Eastern Coal Council |
| EGL7 | Ella G Lees #7 Observation Well (Field Test 1 at Cranfield, MS) |
| EGR | Enhanced Gas Recovery |
| EIA | Energy Information Administration |
| EIV | Environmental Information Volumes |

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|---|---|
| EOR | Enhanced Oil Recovery |
| EPA | United States Environmental Protection Agency |
| EPRI | Electric Power Research Institute |
| ERT | electric resistance tomography |
| FACE | Free Air $CO_2$ Enrichment |
| GCCC | Gulf Coast Carbon Center |
| GCWA | Gulf Coast Well Analysis |
| GHG | Greenhouse Gas |
| GIS | Geographical Information System |
| GM | geomechanical |
| GNIS | Geographic Names Information System |
| gpm | gallons per minute |
| GR | gamma ray |
| GSA | Geologic Survey of Alabama |
| GSWG | Geologic Sequestration Working Group |
| Ho:Tm:YLF | holmium-thalium-yittrium-lithium- fluoride laser |
| ICET | Institute for Clean Energy Technology |
| INS | Inelastic Neutron Scattering |
| InSAR | interferometric synthetic aperture radar |
| IOGCC | Interstate Oil and Gas Compact Commission |
| KGS | Kentucky Geological Survey |
| LBNL | Lawrence Berkeley National Laboratory |
| LIBS | Lazer Induced Breakdown Spectroscopy |
| Lidar | light detection and ranging |
| LLNL | Lawrence Livermore National Laboratory |
| LGS | Louisiana Geological Survey |
| MIT | Massachusetts Institute of Technology |
| MIT | mechanical integrity test(ing) |
| MM&A | Marshall Miller and Associates |
| MMRI | Mississippi Mineral Resource Institute |
| MMscf | Million standard cubic feet |
| MMV (or MM&V) | Monitoring, Mitigation (or Measurement) and Verification |
| MVA | Monitoring, Verification and Accounting |
| Mscf | Thousand standard cubic feet |
| MSU | Mississippi State University |
| NARSAL | Natural Resources Spatial Analysis Laboratory |
| NATCARB | National Carbon Database |
| NEPA | National Environmental Policy Act |
| NETL | National Energy Technology Laboratory |
| NLCD | National Land Cover Dataset |
| NOAA | National Oceanic & Atmospheric Administration |
| NPP | Net Primary Productivity |
| $O_2$ | Oxygen (pure) |
| OPS | Office of Pipeline Safety |
| ORNL | Oak Ridge National Laboratory |
| OSP | The University of Texas Office of Sponsored Programs |

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|---|---|
| P&A | Plugging & Abandonment |
| Partnership | Southeast Regional Carbon Sequestration Partnership |
| PDG | Protocol Discussion Group |
| PEIS | Programmatic Environmental Impact Statement |
| ppm | parts per million |
| ppb | parts per billion |
| ppt | parts per trillion |
| psi | pounds per square inch |
| psia | pounds per square inch absolute |
| PTTF | Pipeline Transportation Task Force |
| RAT | radioactive tracer survey |
| RCSP | Regional Carbon Sequestration Partnership |
| R&D | Research and Development |
| RGGI | Regional Greenhouse Gas Initiative |
| rms | root mean square |
| RMOTC | Rocky Mountain Oil Test Centre |
| RWG | Regulatory Working Group |
| SDWA | Safe Drinking Water Act |
| SECARB | Southeast Regional Carbon Sequestration Partnership |
| SLC | Southern Legislative Conference |
| SP | spontaneous potential |
| SSEB | Southern States Energy Board |
| STATSGO | State Soil Geographic |
| Sw | water saturation |
| TD | total depth |
| TVA | Tennessee Valley Authority |
| TX BEG | Texas Bureau of Economic Geology |
| U.S. DOE | United States Department of Energy |
| U.S. | United States |
| UIC | Underground Injection Control |
| UNFCCC | United Nations Framework Convention on Climate Change |
| USDA | United States Department of Agriculture |
| USDOE | United States Department of Energy |
| USDOT | United States Department of Transportation |
| USDW | Underground Sources of Drinking Water |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |
| UT-BEG | University of Texas Bureau of Economic Geology |
| VCCER | Virginia Center for Coal and Energy Research |
| VRGGP | Voluntary Reporting of Greenhouse Gases Program |
| VT | Virginia Tech |
| WAG | Water After Gas |
| WBCSD | World Business Council for Sustainable Development |
| WRI | World Resources Institute |
| WVONGA | West Virginia Oil and Natural Gas Association |

# Appendices

There are no appendices to this report.