TECHNICAL PROGRESS REPORT

for

OCTOBER TO DECEMBER 2005
NOVEL CONCEPTS RESEARCH IN GEOLOGIC STORAGE OF CO_2
PHASE III

THE OHIO RIVER VALLEY CO_2 STORAGE PROJECT

Contract No. DE-AC26-98FT40418

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ABSTRACT

As part of the Department of Energy's (DOE) initiative on developing new technologies for storage of carbon dioxide in geologic reservoirs, Battelle has been investigating the feasibility of CO_2 sequestration in the deep saline reservoirs in the Ohio River Valley region. In addition to the DOE, the project is being sponsored by American Electric Power (AEP), BP, The Ohio Coal Development Office (OCDO) of the Ohio Air Quality Development Authority, Schlumberger, and Battelle. The main objective of the project is to demonstrate that CO_2 sequestration in deep formations is feasible from engineering and economic perspectives, as well as being an inherently safe practice and one that will be acceptable to the public. In addition, the project is designed to evaluate the geology of deep formations in the Ohio River Valley region in general and in the vicinity of AEP's Mountaineer Power Plant in particular, in order to determine their potential use for conducting a long-term test of CO_2 disposal in deep saline formations.

The current technical progress report summarizes activities completed for the October through December 2005 period of the project. As discussed in the following report, the main field activity was reservoir testing in the Copper Ridge "B-zone" in the AEP #1 well. In addition reservoir simulations were completed to assess feasibility of CO_2 injection for the Mountaineer site. These reservoir testing and computer simulation results suggest that injection potential may be substantially more than anticipated for the Mountaineer site. Work also continued on development of injection well design options, engineering assessment of CO_2 capture systems, permitting, and assessment of monitoring technologies as they apply to the project site. Overall, the current design feasibility phase project is proceeding according to plans.

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EXECUTIVE SUMMARY

This is a Quarterly Technical Progress Report for Contract DE-AC26-98FT40418. It has been prepared in accordance with the requirements of the National Energy Technology Laboratory (NETL). The reporting period for the current document is October through December 2005.

The purpose of this project is to evaluate the geology of deep formations in the Ohio River Valley region and to conduct a long-term test of carbon dioxide injection/storage in deep saline formations at an active power plant site. As discussed in the report, the main field activity was reservoir testing in the Copper Ridge "B-zone" in the AEP #1 well. In addition reservoir simulations were completed to assess feasibility of CO_2 injection for the Mountaineer site. These latest reservoir tests and computer simulations intimate that injection potential may be substantially more than first expected for the Mountaineer site. Work also continued on development of injection well design options, engineering assessment of CO_2 capture systems, permitting, and assessment of monitoring technologies as they apply to the project site. Overall, the current design feasibility phase project is proceeding according to plans.

1.0 INTRODUCTION

The main objective of this project is to evaluate the geology of deep formations in the Ohio River Valley region and if decided by the project sponsors conduct a long-term test of carbon dioxide injection/storage in deep saline formations at an active power plant site. This work supports the overall project objective of demonstrating that CO_2 sequestration in deep formations is feasible from engineering and economic perspectives, as well as being an inherently safe practice and one that will be acceptable to the public.

2.0 EXPERIMENTAL

The main activities undertaken during the reporting period were field reservoir testing in the Copper Ridge "B-zone" in the AEP #1 well and reservoir simulations of injection of CO_2. In addition, work continued on development of injection well design options, engineering assessment of CO_2 capture systems, reservoir simulations, work on a Class V Underground Injection Control permit, and assessment of monitoring technologies as they apply to the project site. Major accomplishments were related to the following topics:

- Reservoir testing was completed in the Copper Ridge "b-zone" in the AEP #1 test well at depth interval of approximately 8100-8300 ft. A well workover rig and testing equipment were mobilized to the site in October. Well testing consisted of dynamic flowmeter tests, slug and extraction drill-stem testing, sequential extraction testing, and extraction testing. All equipment was demobilized by early November. Initial processing and analysis of the tests results shows that the Copper Ridge "b-zone" has CO_2 injection/storage potential similar to Rose Run sandstone.

- STOMP-CO_2 reservoir simulations were completed to investigate various injection scenarios to support system design, permitting, and risk assessment. Eleven different simulations were performed to address such issues as hydraulic fracturing, lateral well completion, full-field injection, and stochastic simulations. Results indicate that up to several hundred ktonnes CO_2/year per well may be injected in the Rose Run Sandstone at the Mountaineer site. Sensitivity runs were also completed to validate modeling results given uncertainty regarding some hydrogeologic parameters. A summary report was prepared for the reservoir modeling; although, additional modeling runs are planned for the Copper Ridge "b-zone" once reservoir test results are analyzed.

- A comprehensive review of CO_2 storage monitoring technologies was completed as they apply to the Mountaineer site. An objective survey of monitoring methods was completed for CO_2 storage sites around the world to see whether they would be applicable at the Mountaineer site given its specifications. A practical monitoring plan tailored for the site is under development.

- A gas well location was identified in northeastern Ohio for regional geologic framework exploration. Preliminary plans were developed to characterize this well to increase information on CO_2 storage potential in the NE Ohio/NW Pennsylvania/W New York area.

- Continued work on developing a draft Underground Injection Control injection permit under the assumption that a Class V experimental well status is viable, should it be decided to proceed to injection phase. Most sections of the permit document are complete, expect for the final injection and monitoring plans, which are in progress.

3.0 RESULTS AND DISCUSSION

The following sections summarize the major activities and their outcomes for the reporting period under each task of the project.

Task 1 – Geologic Data Assessment

Task 1 includes subsurface geologic assessment in the vicinity of the field site based on pre-existing information. All activities under Task 1 of the Statement of Work have been completed, and Battelle has developed a thorough understanding of the geologic framework for the site for deep saline reservoirs, caprock formations, and coal seams. An Interim Topical Report on the findings was submitted to NETL on August 3, 2003.

Task 2 – Seismic Survey

The main tasks related to the seismic survey have been completed including: design of a survey through injection well site, acquisition of 11 miles of seismic reflection data, processing of the data, interpretation of the results, analysis of the feasibility of seismic monitoring of CO_2 in the region, and reporting. Remaining elements of task 2 pursued during this quarter were continued evaluation of 4-D seismic monitoring costs and logistics. In addition, related monitoring methods such as vertical seismic profile were reviewed to see if they are applicable to this site.

Task 3 – Borehole Drilling and Testing

The main activity during this quarter was the second round of reservoir testing, following up on the initial round in spring 2004. The primary objective of this testing was to evaluate the high permeability zone in Copper Ridge Dolomite at about 8,100 ft depth. The field mobilization started during the second week of October and the testing was completed at the end of October. After the initial set-up and borehole fluid circulation, flowmeter tests were conducted in the borehole under static and dynamic conditions with a somewhat greater resolution and inducted pressure difference than in the spring 2004 tests. This was followed by the detailed drill stem test and an extended extraction test in the Copper Ridge Zone (Figure 1). The initial results indicate that there is promising injection potential in this zone, however, detailed analysis of data are being conducted at this time. Several additional zones in the borehole were tested to determine if there is any other flow potential and also to validate caprock integrity. The test zones were selected based on previously collected wireline data and the flowmeter testing programs. Finally, an additional set of drill stem test and a mini-fracture test in the Rose Run Sandstone were conducted. An additional mini-fracture test planned for Copper Ridge zone could not be completed due to packer failure.

Figure 1. Copper Ridge reservoir testing in the AEP#1 well.

Testing and demobilization was completed in November. All equipment from the site was demobilized and final site walk completed with AEP plant personnel to ensure that no further site restoration is needed

at this time. The well head has been reinstalled in its normal configuration and all testing fluids and other waste have been removed. Processing of the reservoir testing data was started in December. Final analysis for hydrologic and geochemical parameter is anticipated in the coming months. Preliminary assessment indicates that the Copper Ridge B zone is a promising reservoir with capacities and permeability at least as good as those of the Rose Run zone. With this work completed the main remaining activity in Task 3 is to complete the site characterization report.

Task 4 – Reservoir Simulations

A series of eleven 2-D radial reservoir simulations were run using geostatistical realizations of porosity/permeability. Reservoir simulations focus on evaluating the range of injection rates and resulting CO_2 behavior (pressure build-up, spreading, dissolution etc) in the Rose Run zone, which is an inter-layered sandstone and dolomite zone. A combination of the well log data and geostatistical methods were used to ensure that the sandstone-dolomite interlayering observed in the well was preserved in the model while the geologic heterogeneities within these rock types are also addressed. After 3 years of simulated injection, injection rates between 56 and 589-ktonne/year were observed, with a mean value of 315-ktonne/year for a singe vertical well scenario (Figure 2). A base case was selected from this series that showed an injection potential close to the mean value for the series. Based on this, sensitivity cases were run to examine the effect of varying the well pressure gradient, sandstone permeability, and sandstone unsaturated flow characteristics. Injection rate is sensitive to the permeability of the sandstone layers, varying almost linearly with that parameter. For example, Figure 2 shows the injection rates for the base case permeability and for permeabilities that are 10 and 0.1 times the base case. The change in moisture characteristics between Berea and Hygiene sample based values do not show much effect on the injectivity.

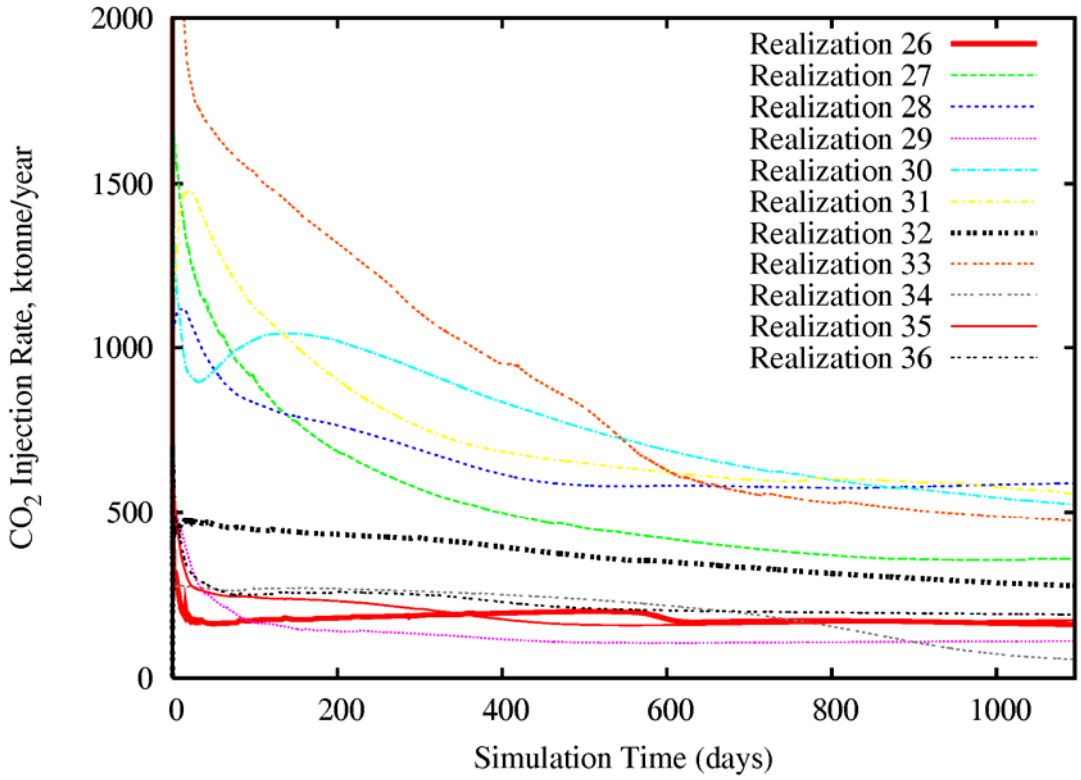

Figure 2. Comparison of CO_2 injection rates into the Rose Run Formation for 11 geostatistical realizations of porosity and permeability. The base case is shown as "realization 32". These simulations show that injectivity is fairly sensitive to hydraulic input parameters but stays over 200 ktonne/yr.

Pilot scale simulations were also performed with fixed injection rates of 30 tonnes/day and 100 tonnes/day to simulate potential rates for the pilot-scale field experiments. For the injection rate of 30 tonnes/day most of the injected CO_2 can be found within 1000 ft of the injection well after 3 years (Figure 3). The same is true for the injection rate of 100-tonnes/day but more vertical spreading is evident. These simulations will be useful in preparing injection well permits and developing a monitoring strategy for the field injection tests. Simulations for the Copper Ridge "b-zone" are pending analysis of the recent round of reservoir testing.

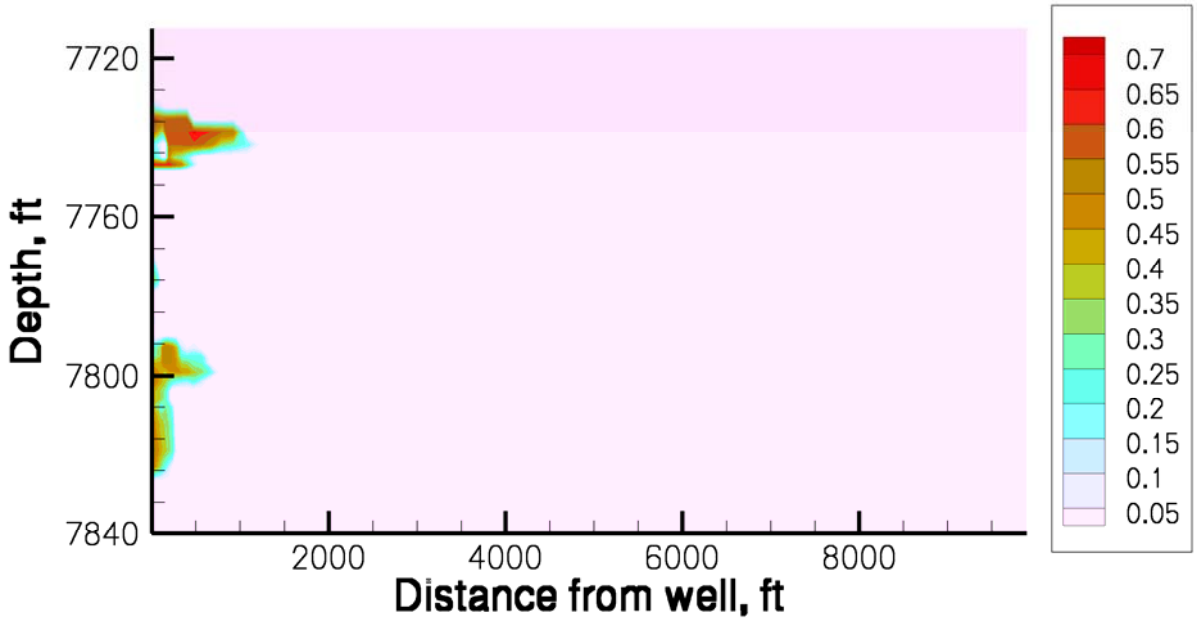

Figure 3. Supercritical CO_2 saturation after 3 years of injection at a rate of 30 tonnes/day into 2-dimensional simulation of the Rose Run formation based on geostatistical realization 29. These simulations suggest that CO_2 front will not extend more than approximately 1,000 ft from the injection well.

<u>Task 5 – Design the Future Injection and Monitoring Facility and Prepare Regulatory Permits</u>

A draft Environmental Assessment document for NEPA purpose and a draft UIC permit document for injection well are nearly complete. However, final completion will be achieved once the design scenarios are finalized. A preliminary injection well design has been prepared jointly with Laurel Oil and Gas. This design incorporates options to either use current vertical well for injection in multiple zones or drill another lateral branch in to the Rose Run Sandstone to evaluate injectivity with horizontal wells, which will be important for large-scale injection.

An assessment of monitoring options for CO_2 storage has been completed. The next step is to select technologies that are relevant to Mountaineer project objectives. As part of this effort, two Battelle team members visited Kentucky Geological Survey (KGS) to discuss the potential for soil gas monitoring with Dr. Ron Kluseman of Colorado School of Mines, who is conducting a joint project on this technology with KGS.

The Confidential Disclosure Agreements (CDA) with Fluor was finally signed by Battelle, AEP, and Fluor. With this we plan to proceed with more detailed discussions and site visit with Fluor during January. Mitsubishi Heavy Industry provided comments on the suggested version of CDA prepared by Battelle. Mitsubishi's comments are being reviewed by AEP and Battelle to prepare the next version of

the CDA. Further progress in developing a more detailed capture system design will be possible after this CDA is also signed.

Task 6 – Risk Assessment and Stakeholder Interactions

Risk and consequence assessment for the Mountaineer geological sequestration project is ongoing, in a phase-wise fashion. For the purpose of this assessment, the injection field is assumed to be the potential source of hazard, and likely CO_2 concentrations and fluxes are calculated as the key measures of risk and consequence to humans, animals, biota, property, agriculture, and water resources. The Mountaineer field drilling and seismic characterization data available to-date is being used as the primary input for this assessment. During October 2005, we have worked on developing a conceptual model of the site including the host formation, cap and bed rock layers, as well as the entire overburden including the vadose zone up to the top soil, and completed implementing the same in STOMP. This effort involved studying the geologic data, well log and CMR data, to match the stratigraphy with suitable input hydrologic parameters for STOMP simulations. Injection simulations using this site model are currently underway and this will be used to evaluate any potential for leakage or other impacts.

Neeraj Gupta had an extended phone discussion with Ms. Elisa Young, an interested stakeholder near the Mountaineer Plant. Subsequently Ms. Young was also invited to the field location to witness the ongoing reservoir testing and discuss the overall project. We plan to continue responding to her questions to the extent possible.

Neeraj Gupta and Dave Ball also responded to a request for interview with a Toledo Blade journalist.

A preliminary design for the project website has been prepared and it is in internal review now.

Preparation of input file for the STOMP- CO_2 simulations, which include the injection horizon, cap rock, and the entire overburden including the vadose zone, has been completed. This task required gathering and analysis of both saturated and 2 phase (CO_2-water) hydrologic characteristics of the site, with approximately 150 different soil/rock types. Simulation runs using this conceptual model are critical to leakage evaluation and risk assessment. In addition, methods are being developed to model the influence of the number of injection wells (multiple well injection), and geomechanical modeling (i.e., impact of injection pressure on fracturing around the well and near the cap rock interface. Both of these phenomena have a direct impact of the potential for leakage and risk.

Work started on preparing an updated fact-sheet for the project to disseminate information on the project findings and current status to the stakeholders.

Task 7 – Project Briefings and Meetings

- Neeraj Gupta presented an update on the project status and the overall carbon management technology during a discussion with the Japanese Tokyo Electric Power Co. representatives at AEP. This was followed by a trip to the Mountaineer plant to visit the field site and the plant tour.
- Neeraj Gupta also participated in the second international workshop on monitoring of the CO_2 storage in Rome, Italy, at no expense to the DOE funded project.
- A briefing on the project status was presented to Mr. Charlie Byrer and the Mountaineer plant manager during a visit to the plant to view the reservoir testing and the flue gas desulfurization (FGD), which is under construction.

- A presentation on the Mountaineer project was made to Senator **John Glen** during his visit to Battelle on November 22.
- A detailed presentation on the project status and findings was made at the CO_2 Sequestration Advanced Technology Workshop organized by Society of Petroleum Engineers in Galveston.
- Discussed plans for continued work with Schlumberger during a visit to Battelle in November.
- A presentation on the regional geologic framework lessons learned from the Mountaineer well and surrounding region was given at the American Geophysical Union meeting in San Francisco and two presentations, one on regional geology and one on geochemical analysis, were given at the regional meeting of the American Association of Petroleum Geologists.

Task 8 –Building the Regional Geologic Framework

Battelle continues to monitor ongoing or planned drilling activity in the region for opportunities to fill gaps in geologic data for deeper formations with the long-term goal of building a geologic framework for potential storage and containment zones in the Ohio River Valley region. Battelle met with Knox Energy geologist to discuss their planned drilling activities and explore collaboration options. A planned gas well location in NE Ohio was identified for expanded exploration. Preliminary plans were developed to characterize this well to increase information on CO_2 storage potential in the NE Ohio/NW Pennsylvania/W New York area.

4.0 CONCLUSION

The project remains on track to complete all major tasks during 2006 calendar year. Overall, the project is proceeding to pilot demonstration phase, and a strong team has been assembled to accomplish this undertaking. During the reporting period substantial progress was made in the planning and design of a pilot-scale CO_2 capture and injection demonstration at the Mountaineer site. Reservoir testing and computer simulations intimate that injection potential may be substantially more than anticipated for the Mountaineer site. As a first-of-a-kind system, this work involves numerous challenges, but a diverse range of resources are being utilized to meet the challenges.

4.1 Future Activities

With the completion of the reservoir testing, the remaining focus of the project will shift to the capture and injection system design issues. During the next few months the following areas of emphasis are anticipated:

- Expedite finalization of CDAs with capture system vendors and development of detailed design for the capture system and injection well completion options
- Completion of reservoir testing data analysis
- Continued development of injection well design and monitoring system options
- Complete simulations of injection in Copper Ridge and finalize results from Rose Run
- Extending the modeling effort to risk assessment task.

5.0 REFERENCES

No references cited