TECHNICAL PROGRESS REPORT
for
JULY TO SEPTEMBER 2005
NOVEL CONCEPTS RESEARCH IN GEOLOGIC
STORAGE OF CO₂
PHASE III

THE OHIO RIVER VALLEY CO₂ 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 CO₂ 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, and Schlumberger. The main objective of the project is to demonstrate that CO₂ 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 CO₂ disposal in deep saline formations.

The current technical progress report summarizes activities completed for the July through September 2005 period of the project. As discussed in the report, the field activities focused on preparations for reservoir testing in the Copper Ridge "B-zone" in the AEP #1 well. In addition work continued on development of injection well design options, engineering assessment of CO₂ 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. 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 July through September 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 technical activities focused on preparations for reservoir testing in the Copper Ridge “B-zone” in the AEP #1 well, development of injection well design options, engineering assessment of CO₂ 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.

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 CO₂ 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

Activities undertaken during the reporting period include preparations for reservoir testing in the Copper Ridge “B-zone” in the AEP #1 well, development of injection well design options, engineering assessment of CO₂ 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. In addition, work has progressed on NEPA environmental assessment and the risk assessment tasks. Major accomplishments were related to the following topics:

- Preparations were completed for reservoir testing in the Copper Ridge “b-zone” in the AEP #1 test well. A reservoir testing plan was completed to assess storage potential in the Copper Ridge dolomite and confirm long-term storage capacity of the Rose Run sandstone. Personnel and equipment were assembled for the testing, which started October 7, 2005.
- Remaining STOMP-CO₂ reservoir simulations were determined in meetings held with PNNL. A suite of scenarios were decided upon to support the system design, permitting, and risk assessment. Simulations include such issues as hydraulic fracturing, lateral well completion, full-field injection, and stochastic simulations. The simulation parameters are based on the final set of field data. Scenarios are specifically chosen to address field application issues (e.g. evaluate the increase in short and long-term injection rates with horizontal wells).
- Discussions were held with several companies regarding the feasibility of building a pilot-scale CO₂ capture system. Battelle staff and Trimeric, an engineering contractor, continued development of the cost and basic design for the small-scale capture system. Battelle representatives also met with Mitsubishi Heavy Industry (MHI) carbon capture team at their Yokohama office in July to discuss the current status and develop plans for further collaboration including developing the confidential disclosure agreements. Similar discussions are being conducted with Fluor, the second major supplier of capture technologies. These discussions are also focused on identifying new advances that can lead to cost reduction in capture processes.
- 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.
- A draft NEPA Environmental Assessment document was completed for the potential injection phase of the project, except for some information on the final injection system scenario. Overall, no significant potential environmental impacts has been identified for the pilot-scale system.
- A comprehensive review of CO₂ storage monitoring technologies was completed as they apply to the Mountaineer site. A practical monitoring plan tailored for the site is under development.

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 CO₂ 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. As a result of the work completed by WesternGeco and Battelle, a technical note describing modifications to the basic equation used for modeling seismic monitoring of CO₂ in the reservoir has been submitted to Journal of Geophysics for publication.

Task 3 – Borehole Drilling and Testing

As part of the Design Feasibility phase, one of the objectives is to conduct additional reservoir testing in the high permeability “B-zone” in Copper Ridge Dolomite at about 8,100 ft depth. The field work plan initially included flowmeter tests, packer tests, and extended injection test so as to properly evaluate the continuity of these carbonate injection targets at the site. Much of the effort in the later portion of this reporting period focused on assembling the equipment, personnel, and materials for this work. As of the end of September the equipment requirements, vendor selection, and procurement for this field effort have been finalized. Because conducting the extended injection test with brine would have been too costly, required permitting from the state, and may have complicated future geochemical monitoring, it was decided to conduct the same analysis with an extraction test. This decision also partly mitigates the cost impact of increased field services prices due to the higher oil prices and related demand for drilling services in the region. The mobilization into the field began October 7 and a 2-3 week field effort is anticipated.

Task 4 – Reservoir Simulations

During early September extended discussion on the status and strategy for reservoir simulations was held in meetings between Battelle Columbus and Pacific Northwest National Laboratory (PNNL) staff. This included definition of scenarios for pilot-scale injection, full-scale injection capacity, horizontal well, and multiple injection zones. All input parameters were reviewed and optimum approach for conducting stochastic simulations was determined. Based on these discussions, a large number of 2-D radial and a smaller number of 3-D rectangular grid simulations are being conducted using the STOMP code. A combination of the well log data and geostatistical methods are being used to ensure that the sandstone-dolomite interlayering observed in the well is preserved in the model while the geologic heterogeneities within these rock types are also addressed. The stochastic simulations should provide a “level-of-

comfort” in injectivity estimates even if the reservoirs are somewhat different than observed in the AEP#1 well. Currently defined simulations are likely to be completed by December 2005.

Task 5 – Design the Future Injection and Monitoring Facility and Prepare Regulatory Permits

Battelle continued assessment of various aspects of the design of capture and injection system in collaboration with AEP. Battelle staff and Trimeric, an engineering contractor, continued development of the cost and basic design for the small-scale capture system. A draft summary of the capture issues and a cost range for various components was prepared for a typical amine-based system based on a site visit to identify possible location and logistics for the pilot tests system. A draft CDA on capture technology from Mitsubishi Heavy Industry (MHI) received in September has been reviewed by Battelle and is in review at AEP. Similarly, CDA negotiations with Fluor are in final stages of review. The most difficult issue in these negotiations has been the extended period of secrecy in required by the vendors and the need to ensure that any DOE contract requirements or AEP site-specific requirements are addressed. This process has been relatively slow and once the final CDA's are approved, an expedited effort on capture system design will be required to complete the work on schedule.

A draft Environmental Assessment document was prepared to address the NEPA requirements. This will be completed once the capture system information has been finalized and submitted to NETL and project sponsors for review. An assessment of monitoring options for CO₂ storage has been completed. The next step is to select technologies that are relevant to Mountaineer project objectives. Preliminary draft for UIC permit application has also been prepared. These will be finalized as information from other tasks becomes available during the next six months.

A manuscript on the in-situ stress analysis in the AEP well and its implication for reservoir stimulation, horizontal wells, and induced seismicity was submitted by Amie Lucier of Stanford for the special issue of Environmental Geoscience journal. Initial review comments on this manuscript have been received and addressed and the manuscript is now in the second review stage. Amie Lucier also visited Battelle during late August to discuss the Stanford effort so far and meet with the regional geologists before starting a new task on evaluating the induced seismicity issues for the region.

Task 6 – Risk Assessment and Stakeholder Interactions

A systematic screening was completed using a FEP (Facilities, Events, and Processes) database to determine the risk assessment pathways that may be applicable in the Ohio River Valley Region and eliminate those that are clearly not applicable. Several items were identified that will be addressed in system design and monitoring. In addition, a new module was added to the STOMP code to address CO₂ movement in the vadose zone. This module will help evaluate impact of any leakage into shallow zones for the risk scenarios that allow CO₂ leakage through artificially high leakage rates. During meetings at PNNL in Richland, the scenarios for risk calculations were finalized. These are based partly on the FEP (Facilities, Events, and Processes) database assessment conducted earlier to determine the risk assessment pathways applicable to the Region. The scenarios are linked with the ongoing STOMP reservoir simulations and with additional processes being incorporated into the code to evaluate any impact on shallow water or atmospheric leakage. Battelle participated in an expert workshop on CO₂ storage risk assessment organized by U.S. EPA and Groundwater Protection Council in Portland Oregon. A preliminary design for the project website was prepared for internal review. This website will be used to present results to stakeholders, the scientific community, and the public.

Figure 1. 3-D block diagram showing AEP#1 well (in blue) and nearby wells created for the UIC permit. The next deepest well is over 3 miles away and completed in the Tuscarora (Clinton) Sandstone at a total depth of 5089 ft, over 2500 ft shallower than the target storage reservoirs.

Task 7 – Project Briefings and Meetings

- Neeraj Gupta presented an update on the project status at a meeting with EPRI executives hosted by AEP.
- Presented Mountaineer project status in briefings at CRIEPI and MHI offices in Japan during a visit related to the CRIEPI funded project.
- Bruce Sass presented the findings of brine analysis and Phil Jagucki presented the geologic framework effort during the AAPG Eastern Section Meeting in Morgantown, West Virginia.
- Neeraj Gupta attended the expert workshop on CO₂ storage risk assessment organized by U.S. EPA and Groundwater Protection Council in Portland Oregon.
- An overview of the carbon sequestration work with specific emphasis on the Mountaineer project and the modeling issues was presented to a team from Mexican Petroleum Institute (IMP) as part of Battelle conducted workshop on reservoir and groundwater modeling.

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. We are currently looking at SW New York/NW Pennsylvania/NE Ohio area where drilling is active. Several opportunities are under consideration, and we hope to participate in up to two tests during this fall. Battelle met with Knox Energy geologist to discuss their planned drilling activities and explore collaboration options.

Collaborative Risk Assessment Research with CRIEPI, Japan

Battelle and CRIEPI (Japan's Central Research Institute for Electric Power Industry) have been working on a joint project funded by the Japanese Government. The objective the effort is to obtain data from Mountaineer site and surrounding area for research on CO₂ behavior in rocks shallower than 3000 ft, where CO₂ may move into a gas phase. During July, Battelle and CRIEPI held a 2-day meeting at CRIEPI facility in Abiko Japan to discuss the project findings including field data, laboratory tests, reservoir and leakage modeling, and outline of the final report. MHI also presented the results of the laboratory pilot testing of coal samples from Ohio and an initial evaluation of the trace metal leaching into groundwater. Several abstracts based on this effort are being submitted to GHGT-8 conference for consideration.

4.0 CONCLUSION

The project remains on track to complete all major tasks. 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 CO₂ capture and injection demonstration at 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

During the first quarter of fiscal year 2006, the major focus of the project will continue on design of an integrated CO₂ capture test facility, development of a site-specific monitoring strategy, injection well design, and the remaining permitting requirements. We anticipate that the modeling and risk assessment tasks will be by and large complete in the next quarter. Site testing and field information will be used to develop a program for the injection phase of the project and discussion of the future pathways with the project sponsors.

5.0 REFERENCES

No references cited.

Planned Quarterly % Completion based on DOE Funding starting in October 2005 Only Does not include Budget and spending prior to October 2005 (pre Mod 17) or non-DOE cash or in-kind cost share													
		Quarters After FY 2005 Start of Mod 17											
Task No.	Title	FY05Q1	FY05Q2	FY05Q3	FY05Q4	FY06Q1	FY06Q2	FY06Q3	FY06Q4	FY07Q1	FY07Q2	Total %	Total \$
Task 1	Preliminary Geologic Assessment	0	0	0	0	0	0	0	0	0	0	0	0
Task 2	Seismic Survey	1	0	17	9	20	15	9	15	10	2	100	98000
Task 3	Borehole Drilling, Sampling, and Testing	9	1	4	13	63	6	3	2	0	0	100	396000
Task 4	Reservoir Simulations	1	3	7	24	30	17	10	4	3	0	100	148000
Task 5	Capture, Injection, Monitoring Design	4	7	17	15	12	12	13	10	9	2	100	680000
Task 6	Risk Assessment and Stakeholder Outre:	1	2	3	9	15	17	17	17	16	4	100	446000
Task 7	Project Management and Briefings	5	3	6	13	13	13	13	13	13	6	100	227438
Task 8	Development of Regional Framework	7	0	1	3	43	38	5	3	0	0	100	106500
												Total Post October 2005 Budget	2101938

Task 1 was completed before Oct 2005, therefore projected budgets for this are zero.

In the EV tables below EV is calculated as actual % completion/Planned % completion*Planned Value. Actual % completion is based on \$ spent
% Numbers are rounded to nearest %

Earned Value after FY05-Q1

		Current Quarter				Cumulative Since October 2005			
		Planned %comp	PV	Actual %comp	EV	Planned %comp	PV	Actual %comp	EV
Task 1	Preliminary Geologic Assessment	0	0	0	0	0	0	0	0
Task 2	Seismic Survey	1	1000	0	431	1	1000	0	431
Task 3	Borehole Drilling, Sampling, and Testing	9	34000	10	38069	9	34000	10	38069
Task 4	Reservoir Simulations	1	2000	3	4557	1	2000	3	4557
Task 5	Capture, Injection, Monitoring Design	4	25000	6	40192	4	25000	6	40192
Task 6	Risk Assessment and Stakeholder Outre:	1	5000	0	606	1	5000	0	606
Task 7	Project Management and Briefings	5	12000	6	12552	5	12000	6	12552
Task 8	Development of Regional Framework	7	7000	5	5632	7	7000	5	5632
Totals for Chart			86000	5	102040		86000	5	102040

Earned Value after FY05-Q2

		Current Quarter				Cumulative Since October 2005			
		Planned %comp	PV	Actual %comp	EV	Planned %comp	PV	Actual %comp	EV
Task 1	Preliminary Geologic Assessment	0	0	0	0	0	0	0	0
Task 2	Seismic Survey	0	0	1	0	1	1000	1	431
Task 3	Borehole Drilling, Sampling, and Testing	1	2000	1	3461	9	36000	10	41531
Task 4	Reservoir Simulations	3	5000	4	6059	5	7000	7	10616
Task 5	Capture, Injection, Monitoring Design	7	50000	7	50161	11	75000	13	90353
Task 6	Risk Assessment and Stakeholder Outre:	2	9000	2	7577	3	14000	2	8183
Task 7	Project Management and Briefings	3	7500	3	7665	9	19500	9	20216
Task 8	Development of Regional Framework	0	0	0	0	7	7000	5	5632
Totals for Chart			73500	4	74923		159500	8	176963

Earned Value after FY05-Q3

		Current Quarter				Cumulative Since October 2005			
		Planned %comp	PV	Actual %comp	EV	Planned %comp	PV	Actual %comp	EV
Task 1	Preliminary Geologic Assessment	0	0	0	0	0	0	0	0
Task 2	Seismic Survey	17	17000	17	16720	18	18000	18	17151
Task 3	Borehole Drilling, Sampling, and Testing	4	15000	4	15783	13	51000	14	57314
Task 4	Reservoir Simulations	7	11000	4	6281	12	18000	11	16897
Task 5	Capture, Injection, Monitoring Design	17	115000	18	120262	28	190000	31	210615
Task 6	Risk Assessment and Stakeholder Outre:	3	12000	2	9036	6	26000	4	17219
Task 7	Project Management and Briefings	6	14500	7	15259	15	34000	16	35476
Task 8	Development of Regional Framework	1	1500	1	1330	8	8500	7	6962
Totals for Chart			186000	9	184670		345500	17	361634

Earned Value after FY05-Q4

		Current Quarter				Cumulative Since October 2005			
		Planned %comp	PV	Actual %comp	EV	Planned %comp	PV	Actual %comp	EV
Task 1	Preliminary Geologic Assessment	0	0	0	0	0	0	0	0
Task 2	Seismic Survey	9	9000	0	0	28	27000	18	17151
Task 3	Borehole Drilling, Sampling, and Testing	13	50000	13	49529	26	101000	27	106842
Task 4	Reservoir Simulations	24	35000	23	33311	36	53000	34	50207
Task 5	Capture, Injection, Monitoring Design	15	100000	13	87354	43	290000	44	297969
Task 6	Risk Assessment and Stakeholder Outre:	9	40000	9	40326	15	66000	13	57545
Task 7	Project Management and Briefings	13	30000	5	11371	28	64000	21	46846
Task 8	Development of Regional Framework	3	3000	0	501	11	11500	7	7463
Totals for Chart			267000	11	222391		612500	28	584025

Earned Value after FY06-Q1

		Current Quarter				Cummulative Since October 2005			
Tasks		Planned %comp	PV	Actual %comp	EV	Planned %comp	PV	Actual %comp	EV
Task 1	Preliminary Geologic Assessment	0	0			0	0		
Task 2	Seismic Survey	20	20000			48	47000		
Task 3	Borehole Drilling, Sampling, and Testing	63	250000			89	351000		
Task 4	Reservoir Simulations	30	45000			66	98000		
Task 5	Capture, Injection, Monitoring Design	12	80000			54	370000		
Task 6	Risk Assessment and Stakeholder Outre:	15	65000			29	131000		
Task 7	Project Management and Briefings	13	30000			41	94000		
Task 8	Development of Regional Framework	43	46000			54	57500		
Totals for Chart			536000				1148500		

Earned Value after FY06-Q2

		Current Quarter				Cummulative Since October 2005			
Tasks		Planned %comp	PV	Actual %comp	EV	Planned %comp	PV	Actual %comp	EV
Task 1	Preliminary Geologic Assessment	0	0			0	0		
Task 2	Seismic Survey	15	15000			63	62000		
Task 3	Borehole Drilling, Sampling, and Testing	6	25000			95	376000		
Task 4	Reservoir Simulations	17	25000			83	123000		
Task 5	Capture, Injection, Monitoring Design	12	80000			66	450000		
Task 6	Risk Assessment and Stakeholder Outre:	17	75000			46	206000		
Task 7	Project Management and Briefings	13	30000			55	124000		
Task 8	Development of Regional Framework	38	41000			92	98500		
Totals for Chart			291000				1439500		

Earned Value after FY06-Q3

		Current Quarter				Cummulative Since October 2005			
Tasks		Planned %comp	PV	Actual %comp	EV	Planned %comp	PV	Actual %comp	EV
Task 1	Preliminary Geologic Assessment	0	0			0	0		
Task 2	Seismic Survey	9	9000			72	71000		
Task 3	Borehole Drilling, Sampling, and Testing	3	13000			98	389000		
Task 4	Reservoir Simulations	10	15000			93	138000		
Task 5	Capture, Injection, Monitoring Design	13	90000			79	540000		
Task 6	Risk Assessment and Stakeholder Outre:	17	75000			63	281000		
Task 7	Project Management and Briefings	13	30000			68	154000		
Task 8	Development of Regional Framework	5	5000			97	103500		
Totals for Chart			237000				1676500		

Earned Value after FY06-Q4

		Current Quarter				Cummulative Since October 2005			
Tasks		Planned %comp	PV	Actual %comp	EV	Planned %comp	PV	Actual %comp	EV
Task 1	Preliminary Geologic Assessment	0	0			0	0		
Task 2	Seismic Survey	15	15000			88	86000		
Task 3	Borehole Drilling, Sampling, and Testing	2	6000			100	395000		
Task 4	Reservoir Simulations	4	6000			97	144000		
Task 5	Capture, Injection, Monitoring Design	10	65000			89	605000		
Task 6	Risk Assessment and Stakeholder Outre:	17	75000			80	356000		
Task 7	Project Management and Briefings	13	30000			81	184000		
Task 8	Development of Regional Framework	3	3000			100	106500		
Totals for Chart			200000				1876500		

Earned Value after FY07-Q1

		Current Quarter				Cummulative Since October 2005			
Tasks		Planned %comp	PV	Actual %comp	EV	Planned %comp	PV	Actual %comp	EV
Task 1	Preliminary Geologic Assessment	0	0			0	0		
Task 2	Seismic Survey	10	10000			98	96000		
Task 3	Borehole Drilling, Sampling, and Testing	0	1000			100	396000		
Task 4	Reservoir Simulations	3	4000			100	148000		
Task 5	Capture, Injection, Monitoring Design	9	60000			98	665000		
Task 6	Risk Assessment and Stakeholder Outre:	16	70000			96	426000		
Task 7	Project Management and Briefings	13	30000			94	214000		
Task 8	Development of Regional Framework	0	0			100	106500		
Totals for Chart			175000				2051500		

Earned Value after FY07-Q2

		Current Quarter				Cummulative Since October 2005			
Tasks		Planned %comp	PV	Actual %comp	EV	Planned %comp	PV	Actual %comp	EV
Task 1	Preliminary Geologic Assessment	0	0			0	0		
Task 2	Seismic Survey	2	2000			100	98000		
Task 3	Borehole Drilling, Sampling, and Testing	0	0			100	396000		
Task 4	Reservoir Simulations	0	0			100	148000		
Task 5	Capture, Injection, Monitoring Design	2	15000			100	680000		
Task 6	Risk Assessment and Stakeholder Outre:	4	20000			100	446000		
Task 7	Project Management and Briefings	6	13438			100	227438		
Task 8	Development of Regional Framework	0	0			100	106500		
Totals for Chart			50438				2101938		

Earned Value Chart for DOE Share of 40418 Since FY05 Q1
Individual Quarter Comparison

Earned Value Chart for DOE Share of 40418 Since FY05 Q1
Cummulative Since October 2005