

Southwest Regional Partnership on Carbon Sequestration

Quarterly Progress Report

Reporting Period: July 1–September 30, 2013

Reid Grigg, PI, Brian McPherson, PI, and Robert Lee, Project Manager

DE- FC26-05NT42591

Recipient: New Mexico Institute of Mining and Technology
801 Leroy Place
Socorro, New Mexico 87801

Table of Contents

Table of Contents	2
List of Figures and Tables	3
Executive Summary	5
TASK 2 Public Outreach and Education	5
Subtask 2.2 Project Website	6
SWP VELO	6
Task 4 Site Characterization and Modeling	7
Subtask 4.1 Existing Data Gathering and Interpretation	7
Subtask 4.3 Initial Reservoir Model Development	8
Farnsworth Field Simulation	8
STOMP-EOR	8
Velocity Data Model	9
Application of General Risk Analysis Workflow to Identify High Permeability Zones	9
Leakage Detection in Homogeneous Domain	11
Generalized/Fundamental Impacts of Chemical Reactions on Injectivity	32
Subtask 4.4 Initial Risk Assessment	41
Subtask 4.5 Site Work Plans	46
Task 5 Well Drilling and Completion	47
Task 6.0 Operational Monitoring and Modeling	47
Eddy Covariance Flux Tower	48
Methane/CO ₂ Flux Chamber	53
Sample Analyses from the Farnsworth Unit	58
Modeling Software	61
Subtask 6.4 Reservoir Modeling	62
STOMP-EOR	62
Task 8 Project Management and Oversight	63
Subtask 8.1 Project Management Plan	64
Subtask 8.2 Project Planning and Reporting	64
Subtask 8.3 SWP Project Meetings	64
Other Management/Oversight Activities	64
Software Contract	64
3D Seismic Data Processing	65
Core Sampling	65
Cost Status	66
Schedule Status	67
Summary of Significant Accomplishments	72
Anticipated Delays	72
Technology Transfer	72
APPENDICES	72

List of Figures and Tables

Figure 1. (a) Schematic of model of multiple formations with leakage pathway and (b) schematic of specified leaky well or leakage pathway (not to scale).	12
Figure 2. Pressure anomalies at monitoring wells in the overlying formation of the generalized inverse analysis model.	14
Figure 3. Generalized 2-dimensional model domain for inverse analysis.....	15
Figure 4. Estimated leaky well location from objective function in case 1.....	17
Figure 5. Pressure drifts among 10^{-15} , $10^{-14.5}$ and $10^{-15.5}$ m ² permeability of overlying formation.	19
Figure 6. Estimated leaky well location based on the objective function for the simulation with overestimated permeability $10^{-14.5}$ m ²	21
Figure 7. Estimated leaky well location based on the objective function for the simulation with underestimated permeability $10^{-15.5}$ m ²	22
Figure 8. Estimated leaky well location from objective function in case 3.....	23
Figure 9. Residuals between measured and calculated pressures in the storage formation in each simulation case for (a) Case 1, (b) Case 2 (permeability $10^{-14.5}$ m ²), (c) Case 2 (permeability $10^{-15.5}$ m ²) and (d) Case 3.....	28
Figure 10. Residuals in the overlying formation in each simulation case for (a) Case 1, (b) Case 2 (permeability $10^{-14.5}$ m ²), (c) Case 2 (permeability $10^{-15.5}$ m ²) and (d) Case 3.	30
Figure 11. Estimated leaky well location from objective function (a) using measurements in the overlying formation and (b) using measurements in the storage formation.	31
Figure 12. Framework or conceptual model for fundamental injectivity analysis with reactive transport.	33
Figure 13. Supercritical CO ₂ saturation in fundamental injectivity model at different timesteps.	35
Figure 14. Total dissolved CO ₂ concentration at different time steps.	35
Figure 15. Changes of pH at different time steps.	36
Figure 16. Changes in chlorite abundance at different simulated time steps.....	37
Figure 17. Changes in oligoclase abundance at different simulated time steps.....	38
Figure 18. Changes in ankerite abundance at different simulated timesteps.....	38
Figure 19. Changes in dawsonite abundance at different simulated time steps.....	39
Figure 20. CO ₂ sequestered by mineral precipitation (kg/m ³), at different simulated time steps.....	40
Figure 21. Changes of porosity for different simulated time steps.....	40
Figure 22. Simplified illustration of a five-spot CO ₂ -EOR pattern and the model permeability distributions.....	43
Figure 23. Global sensitivity analysis of the objective functions to eight uncertain parameters using MARS method.	45
Figure 24. Relative locations of Flux Tower locations on campus with respect to selected sewer maintenance covers (manholes).....	50

Figure 25. Photograph of initial flux tower deployment on UU campus. Note ringdown spectrometer (Picarro ©) in wagon.51

Figure 26. The first set of flux measurements (CO₂ only) from the new Eddy Covariance Flux tower, plotted versus time-of-day on that first day (blue and yellow trends). Corresponding chamber flux measurements indicated by red trend.52

Figure 27. Summary map of CO₂ flux chamber measurements made during the quarter. All measurements in PPM.54

Figure 28. Summary map of CH₄ flux chamber measurements made during the quarter. Data shown are ppm.55

Figure 29. Methane concentrations measured with the ringdown spectrometer, the core or “engine” of the new flux chamber.56

Figure 30. CO₂ concentrations measured with the ringdown spectrometer, the core or “engine” of the new flux chamber.56

Figure 31. Sample of flux measurements yielded by the new flux chamber; all units in ppm. Measurements surveyed on September 10, 2013.58

Figure 32. Locations of soil collars for flux measurement at the Farnsworth Unit.59

Figure 33. Locations selected for USDW sampling at the Farnsworth Unit.60

Figure 34. Seismicity at Farnsworth Field near the planned CO₂ injection well for Phase III.61

Table 1. Location Points of Five Monitoring Wells in Generic Inverse Analysis Model13

Table 2. Objective Function Values in Case 118

Table 3. Objective Function Values of Case 2 (a) and (b).22

Table 4. Objective Function Values of Case 3.24

Table 5. Statistics of Estimated Parameters in Each Simulation Case24

Table 6. Uncertain Parameters and Objective Functions for the Farnsworth Site42

Table 7. Budget and Expenditures for the Quarter July 1–September 30, 201367

Table 8. Milestone Plan/Status*68

Executive Summary

Tasks addressed in this quarter were Tasks 2, 4 5, 6, and 8.

In Task 2–Public Outreach and Education, the SWP-Velo framework was adopted as the working platform for sharing documents and data, and communicating progress. During this period the research team requested four new capabilities for the framework. A beta version of the project management tools was implemented and an Alfresco file syncing application was temporarily implemented and demonstrated in the SWP-Velo framework, but the SWP research team has not decided whether to fully implement this capability until protocols for collaborative syncing of files are established.

In Task 4–Site Characterization and Planning, a number of objectives were accomplished. In *Initial Reservoir Model Development*, researchers conducted a review of Farnsworth Unit core at the CGG Core Repository, Schulenburg, TX and completed a report on their findings (attached). A master database was constructed identifying wells that penetrated the Arbuckle Group throughout Oklahoma, the principal CO₂ sequestration "sink" in Oklahoma. A geologic model for FWU was constructed to predict miscible displacement and researchers developed the founding equation of state algorithms for STOMP-EOR. A baseline velocity model was created Schlumberger's Petrel 2013 software and interval velocity data, which allows conversion of TWT seismic data to the depth domain. This velocity model will also be useful for generating synthetic seismograms. Researchers developed a protocol for inverse analysis to detect potential high permeability zones and used inverse analysis for estimation of a leakage pathway in a homogeneous domain, with multiphase flow. A generalized/fundamental analysis of impacts of chemical reactions on injectivity was performed using several CO₂ sequestration scenarios, and chemical reactions of minerals, with the goal of developing a template for analysis of the FWU site using monitoring data. In *Risk Assessment*, researchers developed an integrated framework to optimize CO₂ sequestration in the FWU. *Work Plans* for MVA, Characterization, Risk, and Simulation were completed and an overall Gantt chart was created.

In Task 5–Well Drilling and Completion, planning moved ahead in this quarter for the drilling of the three characterization wells with the first planned to be spudded in November.

In Task 6–Operational Monitoring and Modeling, great progress was achieved with respect to surface monitoring preparations. Both the new eddy covariance flux tower and the new flux chamber – both capable of measuring fluxes of CO₂, methane and water vapor – were completed and testing, calibration and initial field surveys using both rigs began with the University of Utah campus as the “field laboratory.” About 80 soil collars were installed on site at the FWU, and water sample collection sites were selected and samples taken. In *Seismic Activities*, researchers presented a poster on the seismicity near the Farnsworth field at the DOE Carbon Storage R&D Project Review Meeting. Research results showed that there is no recorded earthquake within a region of approximately 30 km in radius from the planned CO₂ injection well. In *Reservoir Modeling*, researchers installed equation of state algorithms for STOMP-EOR, and processed seismic volumes were delivered to SWP researchers.

In Task 8–Project Management, the most significant achievement was finalization and signing of the contract between New Mexico Tech, the prime, and CELLC. In addition, the FWU site PMP was submitted to NETL, the Partnership Meeting was set for November 19–20, the software contract was finalized with Schlumberger, and interpretation of the 3D surface seismic data began. A core sampling strategy was also developed.