AN INTEGRATED MODEL FOR ASSESSMENT OF CARBON STORAGE RISK PERFORMANCE IN THE CLOVERLY FORMATION, WESTERN NEBRASKA, USA

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INTRODUCTION

The Energy & Environmental Research Center (EERC) at the University of North Dakota conducted a prefeasibility study for a commercial-scale carbon dioxide (CO_2) geologic storage complex in western Nebraska. The goal of the study was to determine the feasibility of integrating commercial-scale CO_2 capture of industrially sourced CO_2 emissions from Gerald Gentleman Station (and/or other facilities) with subsequent geologic storage in Nebraska safely, permanently, and certifiably.

As part of the objectives for achieving this goal, the EERC created the Integrated Model for Assessment of Carbon Storage Risk Performance at the Cloverly Formation in western Nebraska. This work presents a summary of the results obtained under Task 5.0, "NRAP Validation." The goal was to test the validity of applicable tools developed through the U.S. Department of Energy's (DOE's) National Risk Assessment Partnership (NRAP).

OBJECTIVES

Three main objectives were delineated for the testing efforts:

- Select NRAP tools compatible with data collected from the Nebraska Integrated Carbon Capture and Storage Pre-Feasibility Study.
- Simulate long-term leakage and calculate CO_2 and pressure plumes through time.
- Use other NRAP tools if applicable.

Four NRAP tools were selected for their greatest applicability to the data collected under Task 4.0 ("Subbasinal Analysis"). Both the **Reservoir Reduced-Order Model Generator (RROM-Gen)** and the **Reservoir Evaluation and Visualization (REV)** were used to calculate CO_2 and pressure plumes. The **Well Leakage Analysis Tool (WLAT)** was used for the estimation of long-term leakage potential. Finally, the **NRAP Integrated Assessment Model–Carbon Storage (NRAP-IAM-CS) Tool** was used in performance and quantitative risk assessment of geologic sequestration of CO_2.

MODEL INPUTS

Geologic information, well settings, and reservoir simulation results were the key inputs used for the NRAP tools.

Geologic background including stratigraphy, geothermal, and physical information of formations above target formation were collected for the assessment of CO_2 leakage and effect of leakage on aquifers with WLAT and NRAP-IAM-CS. Five shale intervals and five aquifers were found above target formation (Table 1). Well settings were used as input parameters with WLAT (Table 2).

Table 1. Stratigraphic Information

Formation	TVD (m)	Elevation (m)	Thickness (m)	Properties	Comment
High Plains Aquifer	0.00	1074.72	129.84	Aquifer	Ground surface aquifer
Pierre	129.84	944.88	559.00	Shale	
Niobrara	688.85	385.88	96.01	Aquifer	These two aquifers were counted as one for leakage calculation
Fort Hays	784.86	289.86	8.84	Aquifer	
Carlile	793.70	281.03	47.55	Shale	
Greenhorn	841.25	233.48	17.37	Aquifer	
Belle Fourche	858.62	216.10	22.25	Shale	
Gurley D	880.87	193.85	3.96	Aquifer	
Huntsman	884.83	189.89	13.41	Shale	
Cruise	898.25	176.48	66.75	Aquifer	
Skull Creek	965.00	109.73	26.82	Shale	
Cloverly	991.82	82.91	97.23	Aquifer	Target formation

Reservoir simulation results obtained in Task 4.0, which were conducted to assess the prefeasibility of storing 50 million tonnes (Mt) of CO_2 over 25 years in the Cloverly Formation (Dakota group) in Nebraska, were used to for testing both RROM-Gen and REV tools.

	MODEL	PROJECT
Zone	Depth (m)	TVD (m)
Upper Shale	0.0	0.0
Shallow Aquifer	11.2	129.8
Thief Zone	683.1	688.9
Reservoir	991.8	991.8
Zone	Thickness (m)	Thickness (m)
Upper Shale	11.2	559.0
Shallow Aquifer	19.2	129.8
Thief Zone	22.4	104.9
Reservoir	51.2	97.2
Cement Permeability	Perm. (m^2)	Perm. (m^2)
Average	1.00E-14	5.9E-17
Minimum	1.00E-14	8.9E-18
Maximum	1.00E-14	1.1E-16

Table 2. Input Parameters Used for the Cemented Wellbore Model

INTEGRATED ASSESSMENT MODEL

A key parameter required to predict the wellbore leakage is the effective wellbore cement permeability. The potential impacts of various wellbore cement permeability values on both CO_2 and brine leakage. All of the other factors were kept equal. The range chosen for the effective wellbore cement permeability is based on reported values found in the open literature (Viswanathan and others, 2008; Um and others, 2011; Gasda and others, 2013).

Sensitivity analysis results include rate of CO_2 leakage to atmosphere and the total mass of CO_2 leakage to groundwater. Maximum values after 25 years were 2.5 tons for the shallow aquifer and 58 tons for the groundwater.

Maximum values for the total mass of brine leakage were 60.9 tons reach into the shallow aquifer and 20.6 tons reach into the groundwater.

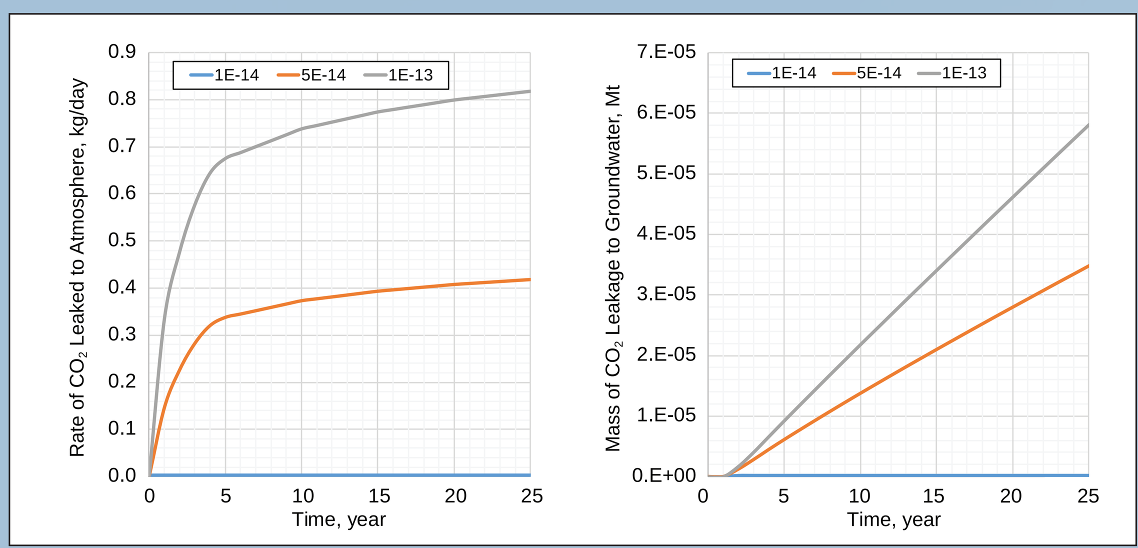

Figure 6. Sensitivity analysis of wellbore cement permeability on CO_2 leakage: a) rate of CO_2 leakage to atmosphere and b) total mass of CO_2 leakage to the groundwater.

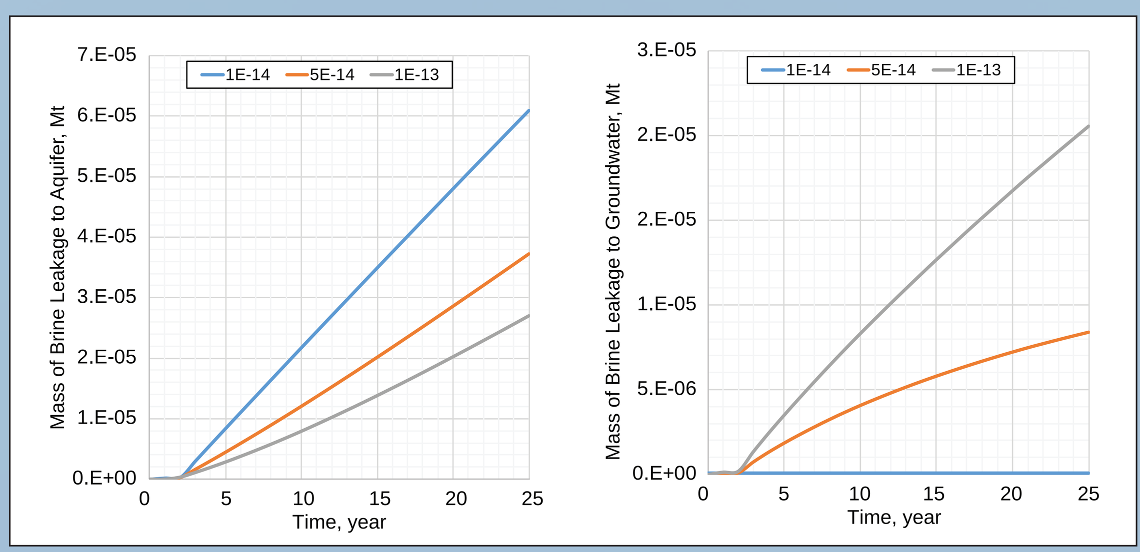

Figure 7. Sensitivity analysis of wellbore cement permeability on brine leakage: a) rate of brine leakage to the shallow aquifer and b) total mass of brine leakage to the groundwater.

RESERVOIR–SEAL INTERFACE LAYER

Results from the reservoir–seal interface layer are shown below (Figures 1 and 2) at selected times (prior to starting the injection and after 25 years of injection) with the GEM outputs corresponding to Geological Realization 1 (P10). Results after 25 years of injection are shown in terms of 1) the pressure plume (Figure 1) and 2) the CO_2 plume.

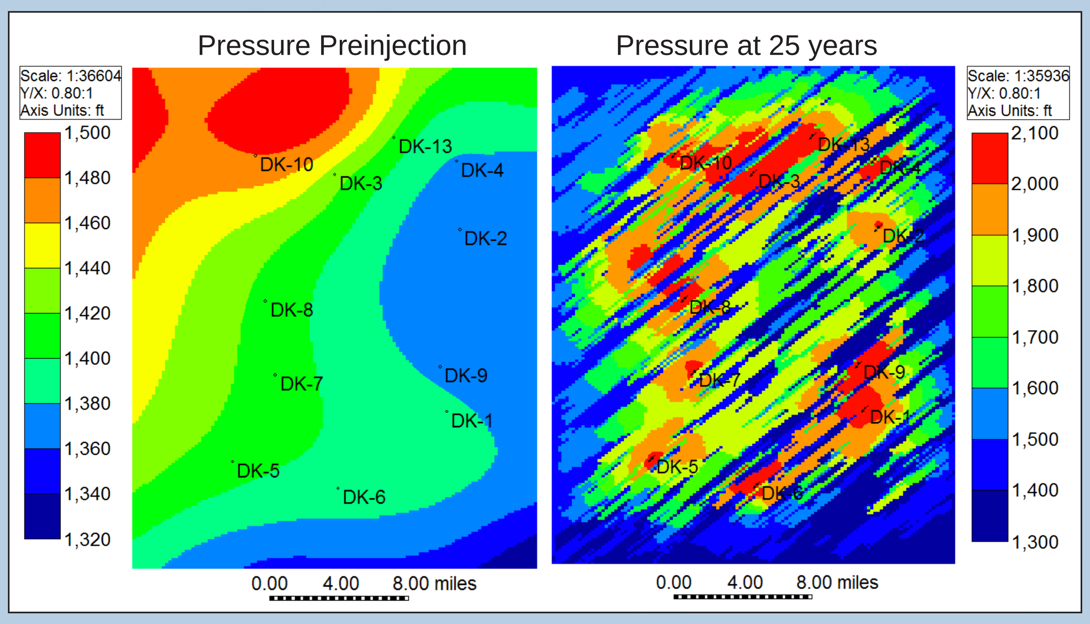

Figure 1. Maps showing a top view (XY plane) of the pressure plume for Geological Realization 1 (P10) at a) before starting the CO_2 injection (left) and b) after 25 years of injection (right).

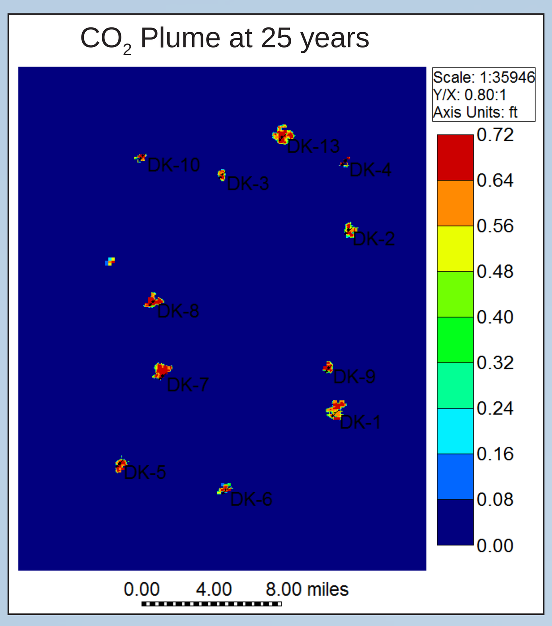

Figure 2. Maps showing a top view (XY plane) of the CO_2 saturation plume for Geological Realization 1 (P10) after 25 years of injection.

CO_2 AND PRESSURE PLUME THRESHOLDS

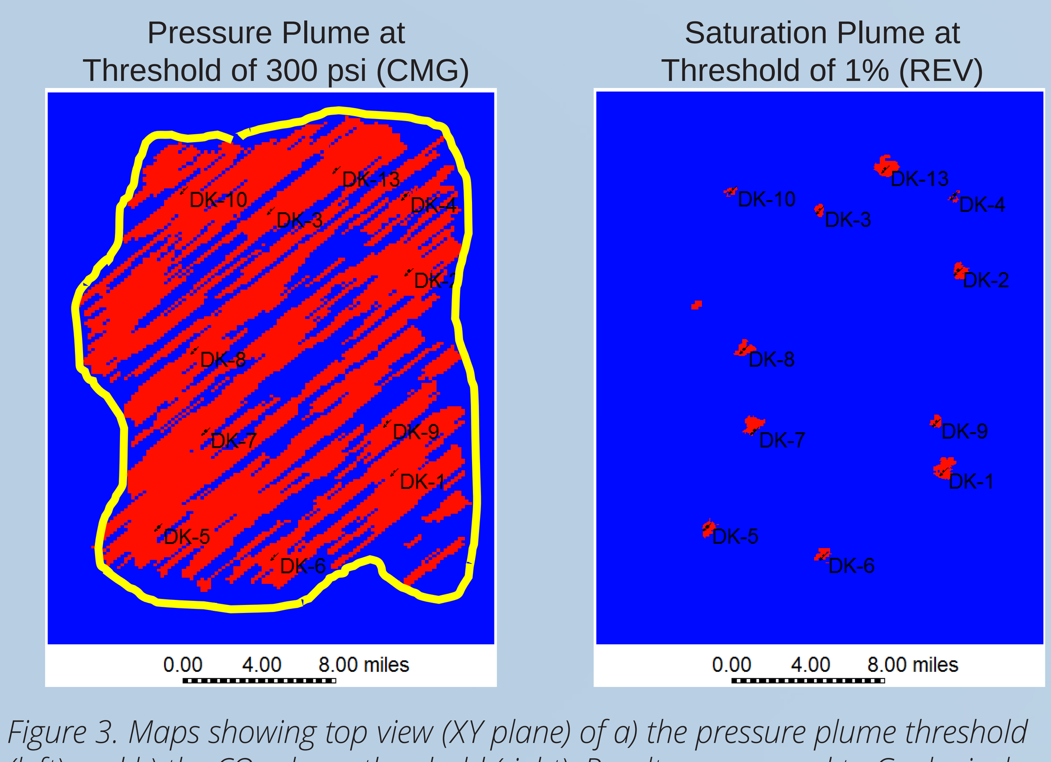

Figure 3. Maps showing top view (XY plane) of a) the pressure plume threshold (left) and b) the CO_2 plume threshold (right). Results correspond to Geological Realization 1 (P10) after 25 years of injection.

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WELL LEAKAGE ANALYSIS

Two wellbore models were tested: the Cemented Wellbore Model and the Multisegmented Well Model.

As no historical records of wells exhibiting CO_2 leakage existed in the area under study, the remainder of this section should be seen as a theoretical exercise that could not be validated using any field data.

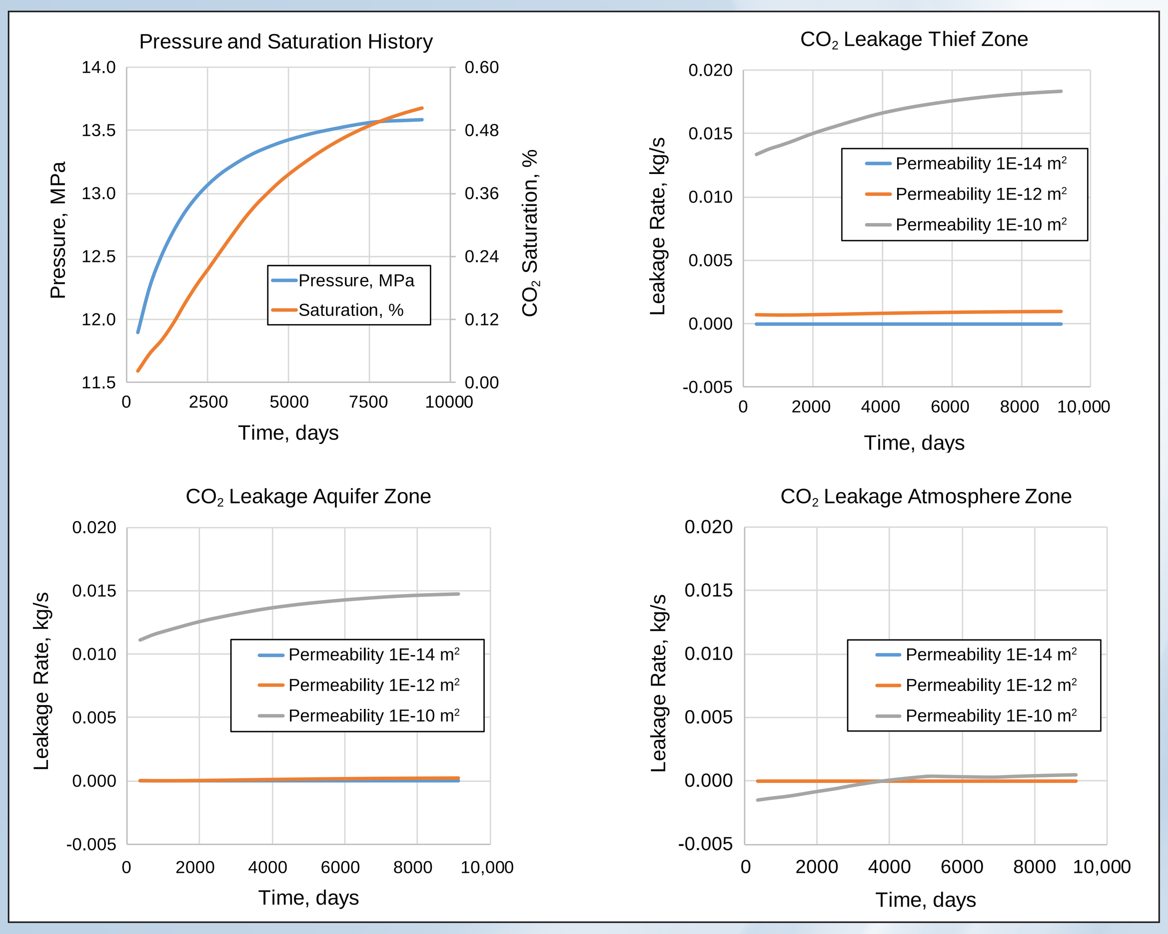

Figure 4. Cemented Wellbore Model inputs and results: a) pressure and saturation history from Computer Modelling Group Ltd. (CMG) results, b) CO_2 leakage rate to the Thief Zone, c) CO_2 leakage rate to the Aquifer Zone, and d) CO_2 leakage rate to the Atmosphere Zone. Note that 1 kg/s is equivalent to 86.4 Mt/day.

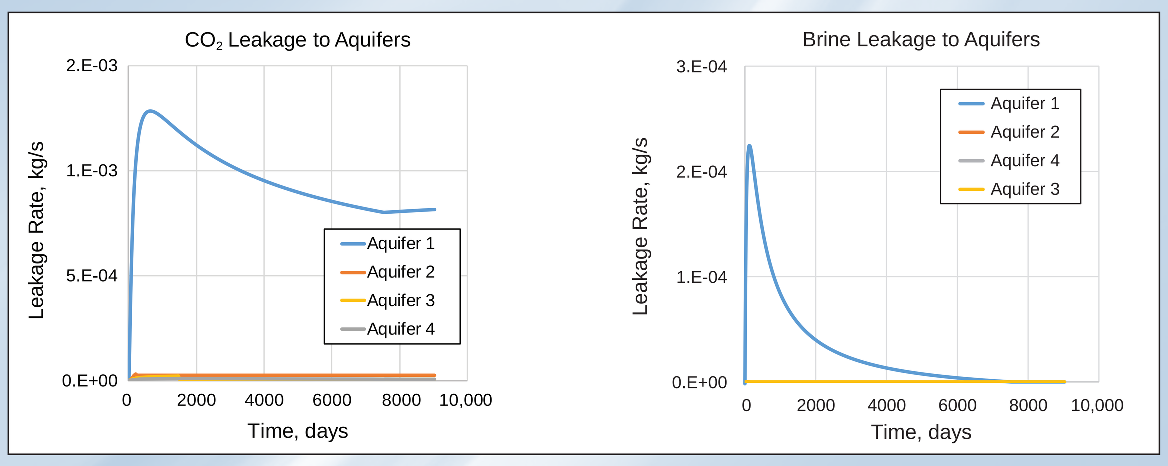

Figure 5. Plots of the results obtained with the Multisegmented Well Model: a) CO_2 leakage to aquifers vs. time and b) brine leakage to aquifers vs. time.

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CMG COMPUTER MODELLING GROUP LTD.
NRAP National Risk Assessment Partnership