

Monitoring Methods Optimization: Pioneering Design for CCUS

Project Description

GCCC has participated in the design of monitoring programs where CO₂ captured from industrial or power-plant sources is sold for CO₂ enhanced oil recovery (CO₂ EOR). Uncertainty remains in what monitoring should be done so that such projects can receive full value as carbon capture and storage (CCS) matures. The U.S. Environmental Protection Agency (EPA) has developed regulations

(known as Class VI) for CO₂ storage under the Underground Injection Control (UIC) Program that are more comprehensive in terms of reporting and monitoring than those that have long been in place for CO₂ EOR. Further, EPA under the Clean Air Act (CAA) has developed greenhouse gas reporting rules that are linked to Class VI for saline storage but leave some uncertainty for EOR.

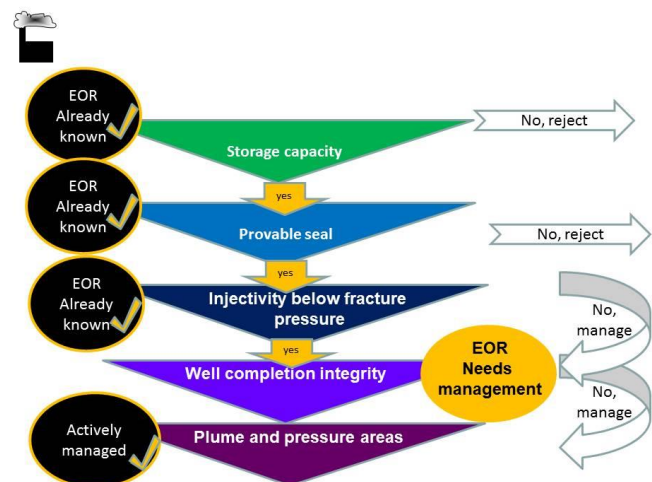
The Challenge

CO₂ EOR has a very different uncertainty profile compared with saline storage. The greatest uncertainties in saline storage are greatly reduced at an EOR setting.

- (1) the quality of the confining system to effectively limit vertical flow is demonstrated,
- (2) the ability of the reservoir to accept fluids at the planned rate for the planned duration is known, and
- (3) the ultimate stabilized fluid geometry is well defined by the hydrocarbon trapping and operational history.

Another set of important uncertainty reductions are provided by the EOR operation, in which injection and production well patterns are effective in limiting the area of CO₂ migration and the area and magnitude of pressure increase. The number of wells in an EOR project, however, creates an increased risk of loss of containment because of the possibility of failure of well engineering. The potential for monitoring at EOR sites is also

different from that at saline sites because abundant wells provide opportunities not available in saline sites, but natural and operational history creates complexities that may limit monitoring options (Wolaver and others, 2013).



Characterization and monitoring geologic systems for CO₂ retention, comparing saline needs to EOR needs

Solutions and Deployment

Working closely with operators, GCCC has designed two plans for monitoring CO₂ EOR. One plan has been deployed; the other is awaiting a final investment decision.

Because the reservoir and seal properties are well known at EOR sites, and the flood is

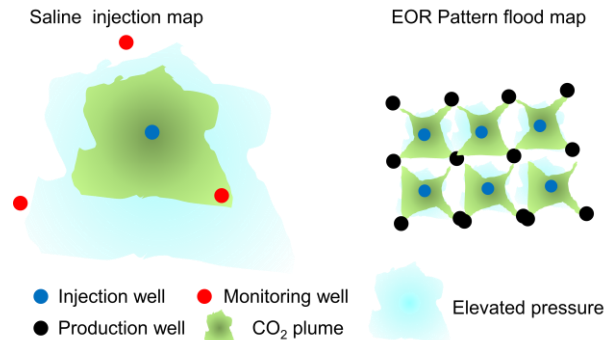
actively managed, risks and uncertainties at EOR sites are quite different from those at saline aquifer sites. Most uncertainty lies in the performance of wells in isolation of the reservoir as pressure is increased by injection.

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Workflow Process

The workflow for EOR monitoring follows the process defined by site-specific monitoring design:

1. Identify the goals of key stakeholders.
2. Perform site characterization, merging reservoir characterization from wireline logs and any available seismic data with production history. Additional data are needed to characterize the overburden, including geologic characterization and history of utilization—for example, for production, storage, or disposal.
3. Assess risks and uncertainties that would lead to not achieving goals of key stakeholders.
4. Combine steps 1 to 3 to create analytical or geocellular models of failure scenarios—for example, failure of one or more well constructions to isolate the injection zone or out-of-pattern migration.
5. On the basis of steps 2, 3, and 4, design monitoring strategies to provide timely indication that the goals are being met. Because the project timeframes were relatively short, we focused our monitoring near the injection zone in above-zone monitoring intervals. In addition, we connected characterization of the groundwater and soil gas to establish its variability and because some stakeholders (e.g., Railroad Commission of Texas [RRC] guidance on incidental storage) recommended it.



Comparison of the CO₂ distribution and pressure elevation of a saline injection to EOR pattern flood

Selected Citations

Hovorka, S. D., Nicot, J.-P., Zeidouni, M., Sava, Diana, Yang, Changbing, Sun, A. Y., and Remington, R. L., 2014, Workbook for developing a monitoring plan to ensure storage permanence in a geologic storage project, including site-specific tool selection: Bureau of Economic Geology, Jackson School of Geosciences,

The University of Texas at Austin, contract report conducted under Funding Opportunity Number EPA-G2008-STAR-H1, Integrated Design, Modeling, and Monitoring of Geologic Sequestration of Anthropogenic Carbon Dioxide to Safeguard Sources of Drinking Water and with funding from the Carbon Capture Project, 65 p.

Wolaver, B. D., Hovorka, S. D., Smyth, R. C. 2013, Greensites and brownsites: implications for CO₂ sequestration characterization, risk assessment, and monitoring: International Journal of Greenhouse Gas Control, v. 19, p. 49–62, doi:<http://dx.doi.org/10.1016/j.ijggc.2013.07.020>.

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Monitoring Methods Optimization: Time-Lapse Compressibility

Project Description

Demonstrating safe and long-term storage of CO₂ presents several monitoring challenges. We proposed a methodology that uses well-known interference well testing for monitoring the above-zone monitoring intervals (AZMI).

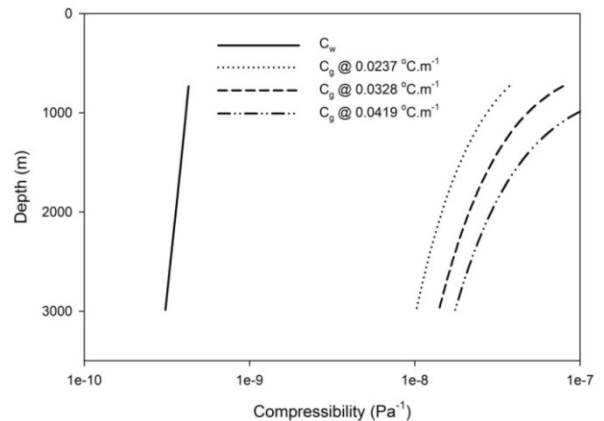
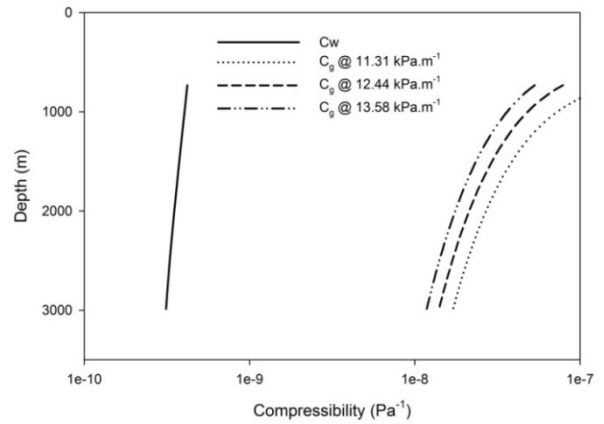
Impact

- ◆ Development of the new method helps to distinguish between the brine and CO₂ leakage.
- ◆ The method can be used to detect low-rate/long-term leakages that may not have a noticeable pressure signal as leakage starts.
- ◆ The method is designed in a time-lapse form, so inherently many uncertain reservoir parameters cancel out in the calculations.

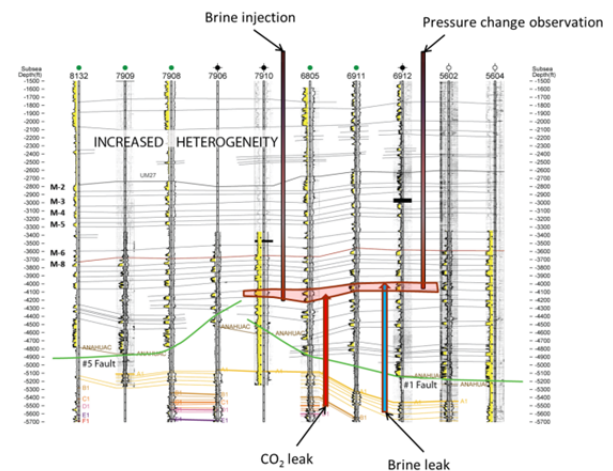
Methods

The proposed methodology works on the premise that at any given depth brine and CO₂ have different compressibility. In a monitoring zone initially filled with brine, any leakage of CO₂ changes the total compressibility of the zone. For the method to work, the cumulative amount of the leaked CO₂ has to be sufficient to change the total compressibility of the system.

Assuming that the fluids within the area of investigation have not been changed, then calculated transmissibility and storativity should remain reasonably constant in repetitive tests. Any noticeable change in transmissibility and storativity of the reservoir indicates that the nature of the fluids in the area of investigation of the test has been changed and that the brine has been replaced with more compressible CO₂.



The difference between brine compressibility at different depths at various geopressure and geothermal gradients.

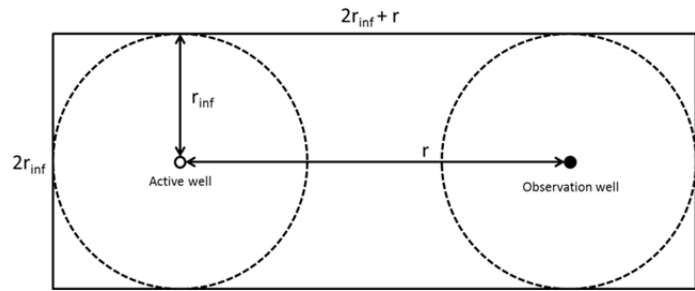


When brine or CO₂ leaks to the AZMI it increases the pressure and in the case of CO₂ leakage changes the average compressibility and viscosity of the leaked zone.

Monitoring Methods Optimization: Time Lapse Compressibility

Methods (continued)

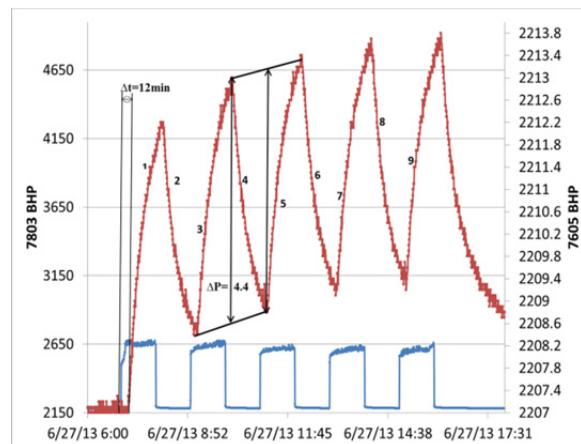
We used an interference test because the area investigated is much larger than that of a single well drawdown or buildup test. The minimum area investigated by an interference test between two wells located a distance r apart is obtained by constructing two circles centered on each well. This construction is based on the principle of reciprocity, which states that the results of the interference test will be the same if the active well and observation well are interchanged. Because there is interference between the wells, the radius of investigation of each well is at least equal to the distance between the wells. The approximate area investigated is $6r^2$.



Area of coverage of an interference well test. Time-lapse monitoring of the compressibility would show if any CO₂ has been leaked if the leakage is big and close enough.

Accomplishments

We successfully deployed the proposed idea in Miocene sands of the Texas Gulf Coast. Results suggest this methodology can be successfully deployed for monitoring with minimal added cost to the whole monitoring plan. Field pulse tests were reasonably repeatable, and our calculations found leaks as small as 1 to 2% of the size of the whole area of coverage are detectable.



Pulses were 1 hour injection to 1 hour shut in (pulse ratio = 0.5). The test was repeated three times to ensure repeatability.

Citation

Hosseini, S. A., 2014, Pressure transient analysis for monitoring of CO₂ leakage in brine aquifers: 6th International Conference on Porous Media & Annual Meeting of the International Society for Porous Media, May 27–30, Milwaukee, Wisconsin.

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