



ZAMA ACID GAS EOR, CO₂ SEQUESTRATION, AND MONITORING PROJECT Steven A. Smith,* James A. Sorensen, Edward N. Steadman, and John A. Harju

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Abstract

A comprehensive monitoring, verification, and accounting (MVA) plan is critical to the success of any geological carbon storage project utilized as a method of reducing CO₂ emissions to the atmosphere. From October 2005 through September 2009, the Zama oil field in northwestern Alberta, Canada, has been the site of acid gas (approximately 70% CO₂ and 30% H₂S) injection for the simultaneous purpose of enhanced oil recovery (EOR), H₂S disposal, and storage of CO₂. The Plains CO₂ Reduction (PCOR) Partnership has conducted MVA activities at the site throughout this period while Apache Canada, Ltd., has undertaken the injection and hydrocarbon recovery processes. This project has been conducted as part of the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) Regional Carbon Sequestration Partnership Program and has been recognized by the Carbon Sequestration Leadership Forum as being uniquely able to fill technological gaps with regard to geological storage of CO₂.

Acid gas has been obtained as a by-product of oil production in the Zama Field and a subsequent fluid separation process at the on-site facilities. During the separation process, oil and gas are sent to market while acid gas is redirected back to the field for utilization in EOR operations. Previously, CO₂ was vented to the atmosphere, and sulfur was separated from the H₂S and stockpiled in solid form on-site. This project has enabled the simultaneous beneficial use of each of these "waste" products and effective mitigation of two environmental concerns. The acid gas is injected into the pinnacle reef reservoirs in the Devonian Keg River Formation. The pinnacle reefs are typically approximately 40 acres at their base, 400 ft tall, and essentially encased in anhydrite.

The Zama project has been designed to address the issue of monitoring CO₂ sequestration at EOR sites in a cost-effective and reliable manner. The primary issues that were addressed include 1) determination of CO₂ and/or H₂S leakage, or lack thereof, from the pinnacle; 2) development of reliable predictions regarding long-term fate of injected acid gas; and 3) generation of data sets that will support the development and monetization of carbon credits associated with the geologic sequestration of CO₂ at the Zama oil field. To address these issues, a variety of research activities has been conducted at multiple scales of investigation in an effort to fully understand the ultimate fate of the injected gas. Geological, geomechanical, geochemical, and engineering work has been used to fully describe the injection zone and adjacent strata in an effort to predict the long-term storage potential of this site.

Through these activities, confidence in the ability of the Zama oil field to provide long-term containment of injected gas has been achieved. While this project has been focused on one of the hundreds of pinnacles that exist in the Zama Field, many of the results obtained can be applied not only to additional pinnacles in the Alberta Basin, but to similar structures throughout the world.

Project Location

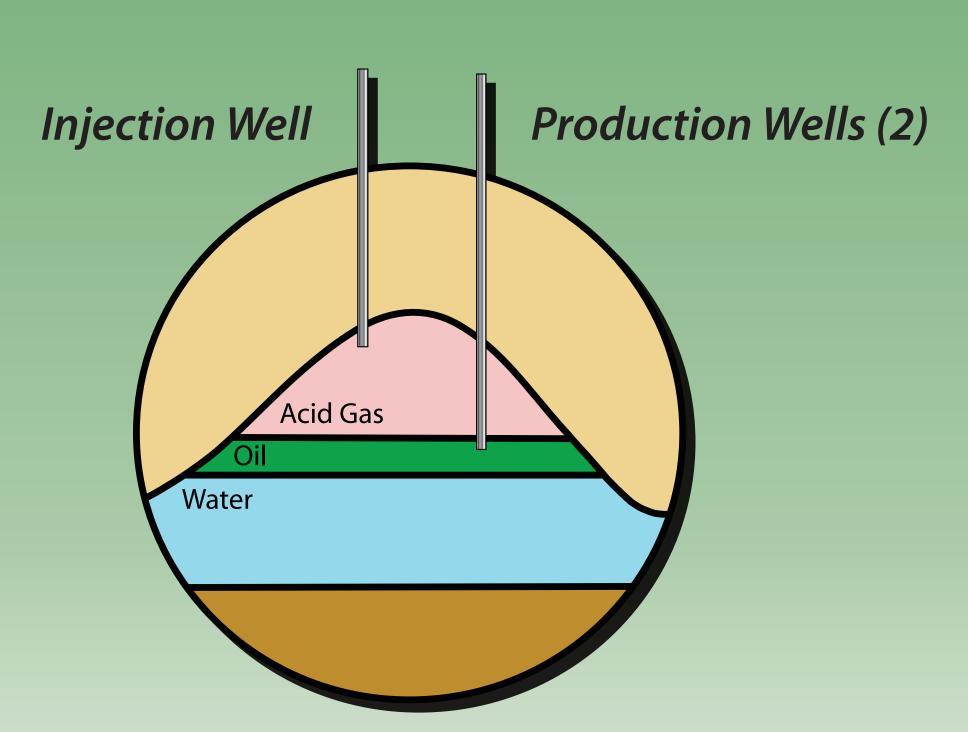


Zama is located in the northwestern corner of Alberta, Canada. The PCOR Partnership region comprises nine states and four provinces in the central interior of North America.

Zama Acid Gas EOR



Acid gas is obtained from an on-site gas-processing facility.



Acid gas is injected into the top of pinnacle reef structures in an effort to "push" oil to the producing well at the bottom of the structure.

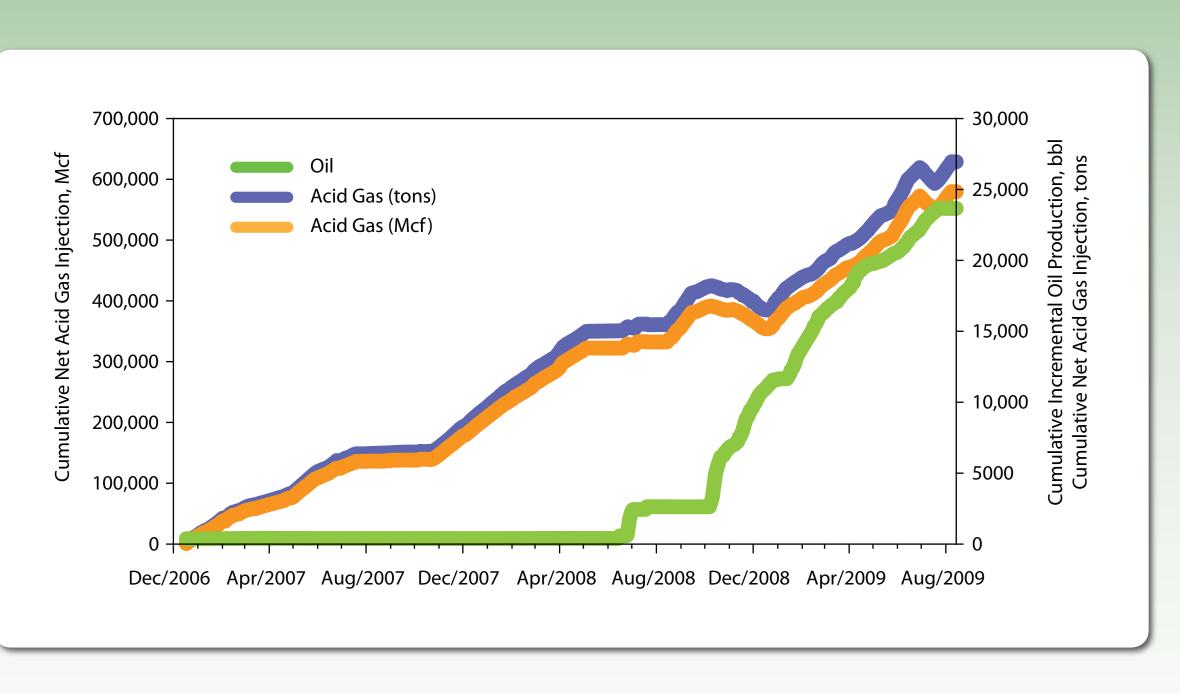
Benefits of Using Acid Gas for EOR

- Significant economic savings in plant operating costs
- Incremental oil production
- Lower miscibility pressure compared to CO₂
- Significant reduction in venting to the atmosphere

CO₂ Sequestration

Benefits

- Substantial volumes of acid gas could be sequestered in over 800 similar structures in the field.
- Eliminate the need for sulfur blocking.
- Minimize the use of disposal wells.

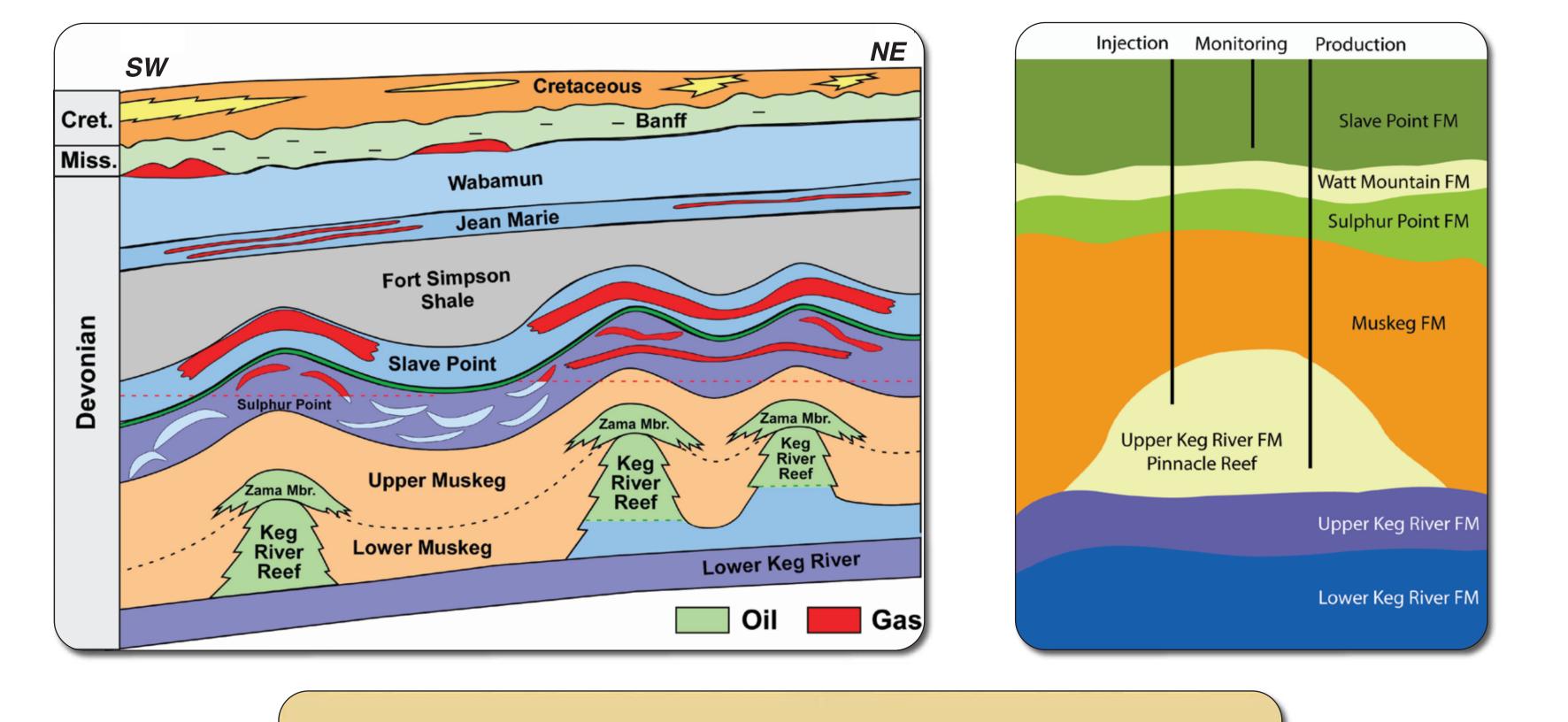


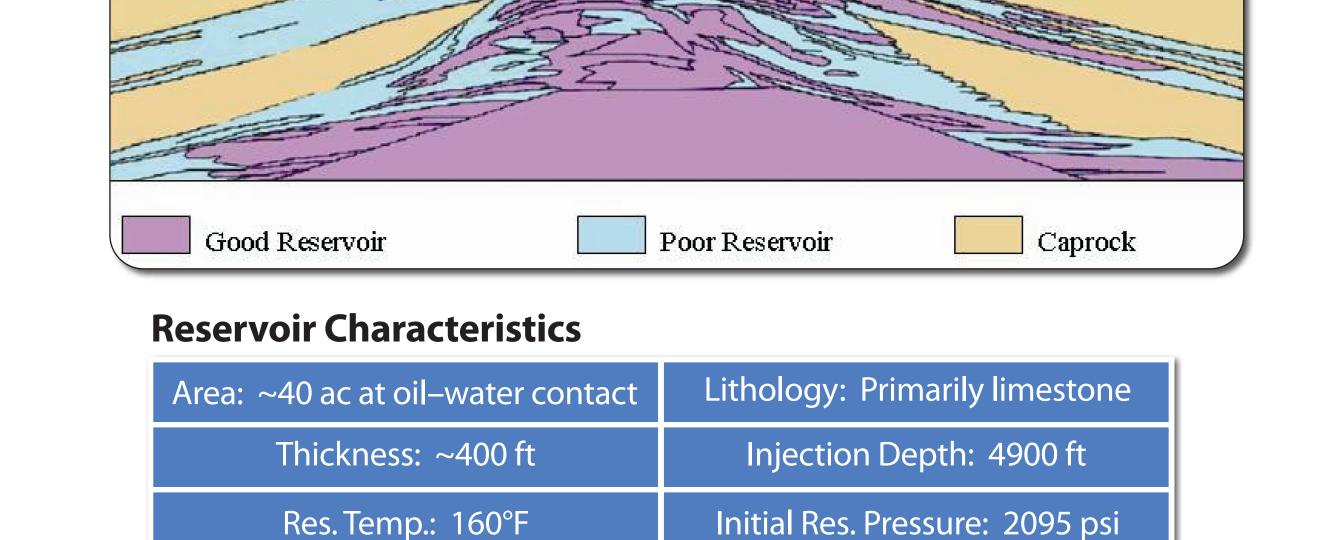
- Cumulative injection through January 2009 27,000 tons acid gas (19,000 tons CO₂ [70%])
- Cumulative oil production 12,956 bbl



Injection activities at Zama have eliminated the need to add to this sulfur pile.

Geological Setting





OOIP: 3.5 million stb

Permeability: 100–1000 mD

Philosophy

- Maximize the use of existing data sets to develop background and baseline conditions.
- Minimize the use of invasive or disruptive technologies to acquire new data.
- Coordinate MMV data acquisition with routinely scheduled operational data acquisition activities.
- Use resources to target the best sites for EOR and secure sequestration.

Research Activities

- Geological characterization
- Geomechanical characterization
- Geochemical evaluation
- Fluid sampling and analysis

Cap Rock Failure Wellbore Leakage

Spillpoint Breech

To be ensured of containment, the system is being monitored with regard to cap rock integrity, wellbore integrity, and injection pressures as to not induce leakage from the base of the reservoir.

Monitoring

Application Tracing movement of CO₂ in the storage Quantifying solubility trapping Quantifying solubility and mineral trapping **Trace elements** Quantifying CO₂-water-oil-rock interaction Control of formation pressure below fracture Groundwater aquifer Wellbore and injection tubing condition Leakage out of the storage formation Tracking CO₂ movement in and above storage Brine salinity Tracking migration of brine into shallow Sonic velocity CO₂ saturation Calibrating seismic velocities for 3-D seismi