FACTSHEET FOR PARTNERSHIP FIELD VALIDATION TEST

Partnership Name	Southwest Regional Partnership on Carbon Sequestration
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Field Test Information: Field Test Name	Permian Basin, Texas: SACROC EOR-Sequestration Test
Test Location	Near Snyder, Texas
Amount and Source of CO_2	Tons: 300,000 tons/year for 3 to 5 years; Source: CO_2 sourced from McElmo Dome, CO
Field Test Partners (Primary Sponsors)	KinderMorgan CO_2 Company, L.P.

Summary of Field Test Site and Operations

General Geology and Target Reservoirs**:** The SACROC oil field unit, the main part of the Kelly-Snyder field, lies along a trend of fields described by Galloway et al. (1983) as the Horseshoe Atoll Play (Figure 1). Hydrocarbons are produced from Pennsylvanian-age strata, including the Cisco and Canyon formations, which represent an isolated platform depositional environment (Figure 2). The Cisco and Canyon formations are carbonates that vary in observed facies, including interbedded pellet, crinoid, algal, and intraclast grainstones and boundstones.

Seal Strata: The section overlying the productive oil zone are Permian-age strata, the Triassic age Dockum formation, and the Paloecene/Eocene Ogallala Formation (Figure 2). Permian strata include cyclic shallow-water ramp carbonates sequences bracketed by cycle-base shales, and evaporite tops. The carbonate mudstones and evaporite beds are very low permeability. Immediately overlying the injection zone, the Wolfcamp formation within the Wichita-Albany Group is a high-stand sea level rise flooding surface composed of marine shales. Thus, there are both primary and secondary seals between the injection zone and potable water zones above.

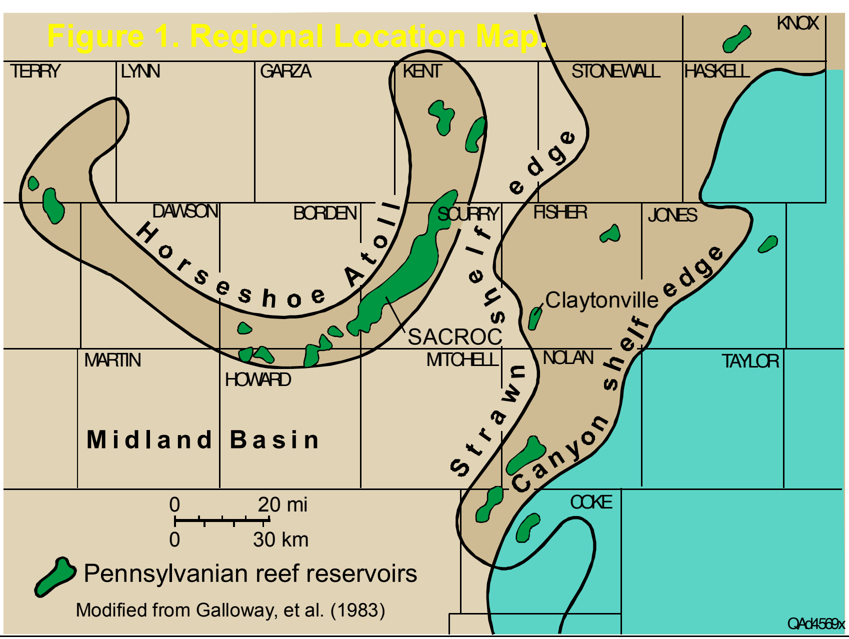

Figure 1. Regional Location Map.

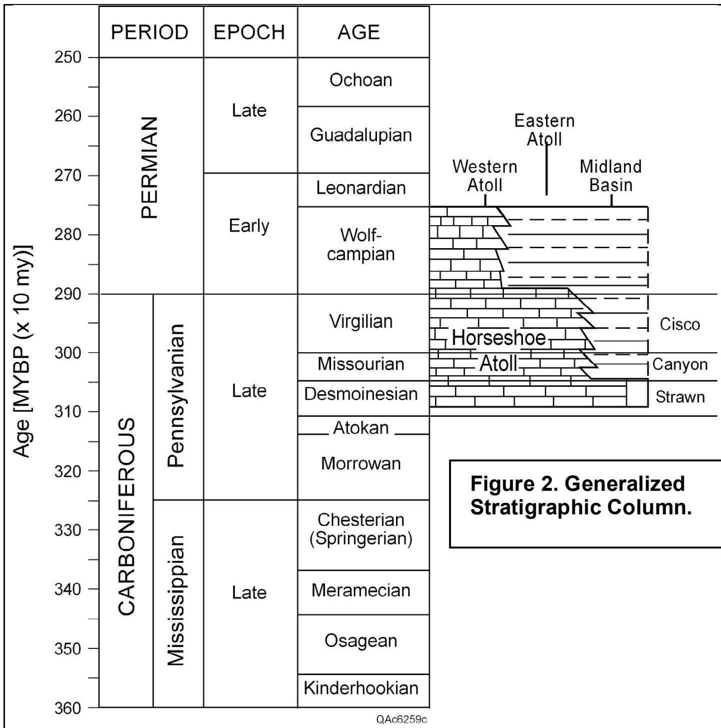

Figure 2. Generalized Stratigraphic Column.

Potential Leakage Areas: The Pennsylvanian Reef strata at SACROC (Figure 2) have low leakage potential. The structural closure is not formed by faulting and no major faults are mapped in the area. Fracturing is prevalent within the injection zone, but because the origin of fractures is non-tectonic, the fractures seem to be confined to the injection interval and do not result in potential leakage paths. Fractures are a result of paleo low-stand exposures that formed karsts of varying sizes. SACROC is highly developed, with numerous wellbores and production-related infrastructure. Potential leakage from wellbores is a field -management issue that can be addressed by robust engineering practices. Well -drilling in these fields is documented and indicates little potential for unknown wellbores.

Reservoir Properties: The geology of the injection zone is comparable to a large class of potential brine storage reservoirs. Depth of the flooded zones range from ~6300–7100 ft (1900–2200 m) with average reservoir pressures of ~2600 psig. The Wolfcamp shale is extremely low permeability, but the reservoir units approach 10s of millidarcies with porosity ranging from ~2 to ~15%. The oil residing in the field is of high quality. Some free gas was most likely released into the reservoir during initial production, as inferred by increasing producing gas-oil ratios. Pore types include vugs, interparticle, intercrystalline, and fractures. Because the relationship between porosity and permeability is dependent on the pore type, it can be quite variable. Although storage and flow capacity is low, the reservoir has been interpreted to be in fairly good vertical and horizontal communication, based on the consistency of bottom-hole pressure measurements.

In sum, the target reservoir physical properties and character of its oil make the Pennsylvanian carbonates (Figure 2) a good candidate for CO_2 enhanced oil recovery as well as concomitant storage of CO_2. Good injectivity is also observed by the field operator, and elucidation of potential injectivity reduction following CO_2 injection is among SWP goals.

Data Quality: Formation characterization is ongoing at SACROC. The field was discovered in the early 1950's and quickly developed. Thus, much of the well data and wireline logs are quite old. Newly acquired data have increased the quality of subsurface characterization.

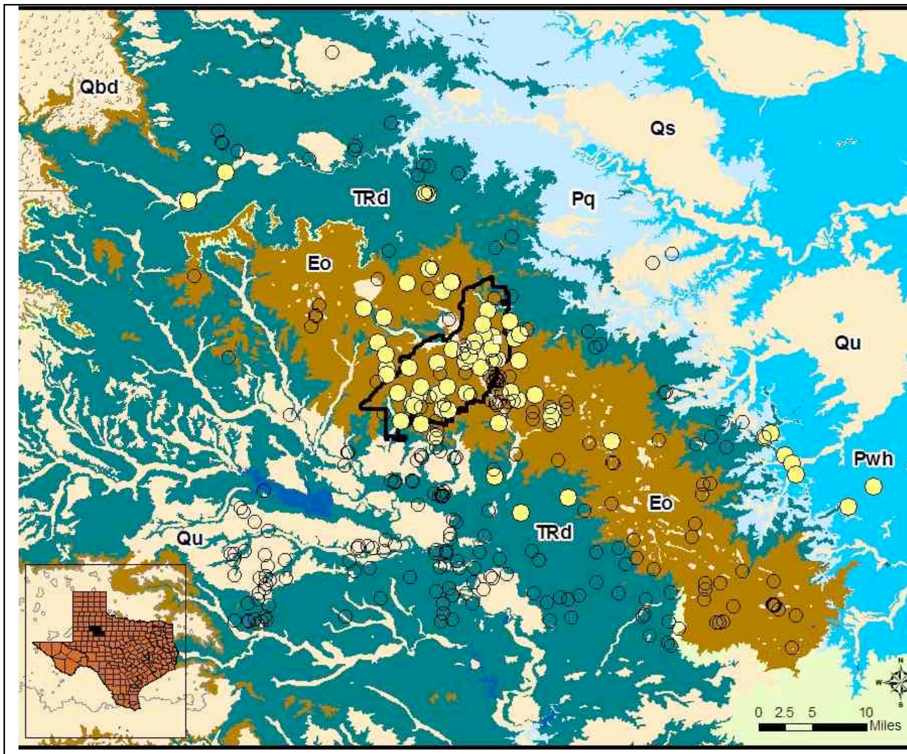

Figure 3. BEG Geologic Atlas of Texas maps showing surface geology within the multicounyt area on index map insert. SACROC oilfield (black outline in center) located in central Scurry County. SWP groundwater sample (yellow circles) and Texas Water Development Board database (open circles) locations for sources of groundwater geochemical data analysis in progress. Key to geologic units: Quaternary grouped (Qbd, Qs, Qu); Paleocene/Eocene Ogallala Fm. = Eo; Triassic Dockum Fm. = TRd.

Surface Description and Land Use: The Ogallala Formation (Figure 3, Eo) is present at the surface over most of the SACROC unit. Presence of the Ogallala overlying the Dockum Formation (Figure 3, TRd) results in slightly different chemistry of Dockum groundwater because in this case, precipitation seeps downward through Ogallala before recharging the Dockum. The Permian units (Figure 3, Pq, Pwh) have been grouped in a geographic information system (GIS) project for simplicity of presentation. A surface water divide bisects the Ogallala outcrop. Regional groundwater analyses indicate a possible groundwater divide at the same location. These divides are a potential complication for analysis of regional groundwater variability because there are likely changes in groundwater chemistry along flow-paths to the northeast toward the Double Mountain Fork of the Brazos River and to the southwest toward the Colorado River.

Surface topography is relatively flat compared to other SWP pilot areas, with only gentle hills and mild terraces associated with surface water erosion. As such, land-usage in the area is dominated by farming and oilfield infrastructure with some residential areas.

Nearest Underground Drinking Water Source: Drinking water over this area is present from ~100 to 500 ft depths throughout the region. Drinking water sources in this area (Figures 3) are a combination of groundwater and surface water piped from reservoir southwest of SACROC oilfield. Where the Ogallala and Dockum formations are absent, shallow Permian drinking water lies at relatively shallow depths. Most of the water wells over SACROC and in Scurry County are defined as producing from the Dockum Formation but they are likely also completed in the Ogallala formation. Water wells in Fisher County are completed primarily in Permian units (Blaine and other aquifers), the Triassic Dockum, or Quaternary Seymour units.

Injection Operation: Injection of CO_2 is ongoing in the SACROC Unit. Total CO_2 injection exceeds approximately 300,000 tons per year. A new stage of injection that the SWP will specifically monitor will begin in late 2008; this includes a WAG (water injection alternating with gas injection) period where CO_2 injection will be partially offset by water.

Research Objectives

The SACROC Unit in the Texas Permian Basin is the oldest CO_2-EOR operation in the United States, with CO_2 injection dating from 1972—only one CO_2-EOR project in Hungary is older, dating from ~1969. SACROC continues to be flooded by the current owner/operator, Kinder Morgan CO_2 Company, L.P. (KinderMorgan). Current operations inject ~13.5 MtCO_2/yr and withdraw/recycle ~7 MtCO_2/yr, for a net storage of ~6.5 MtCO_2/yr. In total, the site has accumulated more than 55 MtCO_2.

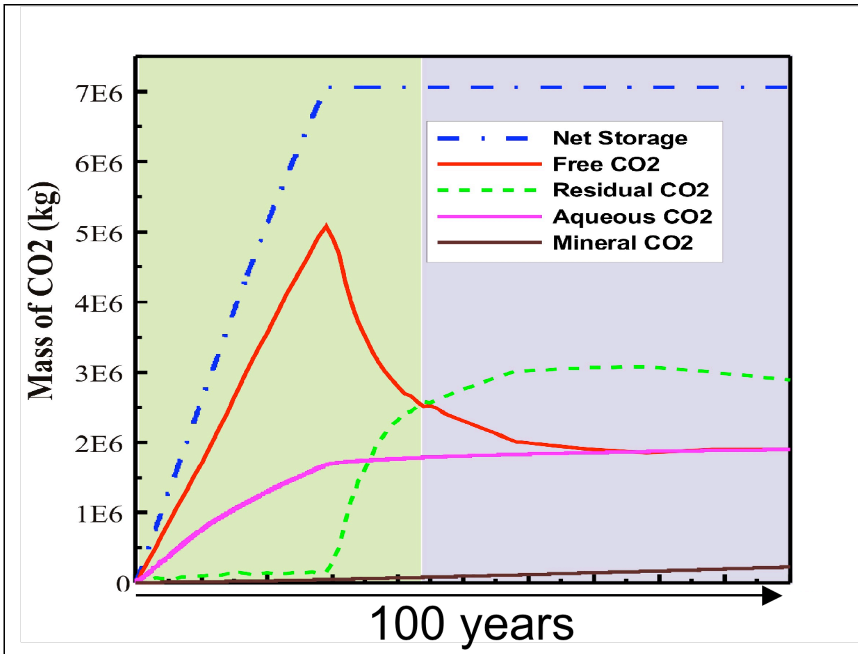

Figure 4. Results of an extensive history-match analysis to evaluate trapping mechanisms at SACROC for 100 years starting in 1972.

Our first effort at SACROC was an intensive post-audit modeling analysis to understand the fate of the CO_2 injected over 30 years' time, including a forecast of decades to follow. Results suggest that during injection, hydrostratigraphic trapping dominates, but for the 70 years to follow, residual-gas trapping is the dominant mode of CO_2 storage (Figure 4). KinderMorgan maintains a vast database of CO_2 injection/production data that facilitated this analysis. The SWP also began extensive MMV studies at SACROC during its ongoing injection operations. The SACROC pilot represents an unprecedented opportunity for CO_2 storage history-matching in tandem with large-scale MMV operations.

EOR-Sequestration Testing: The CO_2 at SACROC is sourced from the McElmo Dome. The SWP will monitor the new stage of CO_2 injection for a period of at least 18 months. State-of-the-art reservoir modeling will be used to simulate flow and chemical processes and orecast ultimate CO_2 storage capacities. Given the historical success of EOR in this and other southern U.S. basins, our primary research objective of the EOR-sequestration test is to evaluate and maximize efficacy of CO_2 subsurface monitoring technologies, and to improve our ability to track the fate of injected CO_2 and to calculate ultimate storage capacity. A particular focus will be the efficacy of 2-D and 3-D seismic imaging methods and investigation of ways to optimize interpretation using other geophysical data. Finally, another major goal is to develop a rigorous risk assessment framework that will help identify optimum storage sites in this and other similar oilfield reservoirs located throughout the southwestern U.S.

Summary of Modeling and MMV Efforts:

Table 1 summarizes our ongoing and future monitoring activities for the SACROC EOR–-sequestration testing. Data from these monitoring activities are being used to parameterize state-of-the-art basin reservoir models that include coupling of multiphase CO_2-groundwater flow with rock deformation and chemical reactions. These models are being used to conduct continuing post-audit (history match) simulations of SACROC and to evaluate ranges of residence times, migration rates and patterns. We are also examining the effects of CO_2 injection on fluid pressures and rock strain (e.g., potential reactivation of fracture permeability). Model simulations are being conducted to examine potential reservoir diagenesis to follow CO_2 injection, including variations in solubility, dissolution, and precipitation. Seismic models, including 3-D reflection, vertical seismic profiling, passive seismic monitor, and repeat borehole geophysical logging are helping us evaluate different geophysical methods for imaging CO_2 in the subsurface.

Table 1. Measurement Technologies Employed at SACROC, Texas Test Site

Measurement technique	Measurement parameters	Applications
Natural tracers	- Travel time - Partitioning of CO_2 in brine/ oil - Identification sources of CO_2	- Tracing movement of CO_2 - Quantifying solubility trapping - Tracing leakage
Water composition	- CO_2, HCO_3, CO_3^{2-} - Major ions - Trace elements - Salinity	- Quantifying solubility & mineral trapping - Quantifying CO_2-water-rock interactions - Detecting leakage into shallow groundwater aquifers
Subsurface pressure	- Formation pressure - Annulus pressure - Groundwater aquifer pressure	- Control of formation pressure below fracture gradient - Wellbore and injection tubing condition - Leakage out of the storage formation
Well logs	- Brine salinity - Sonic velocity - CO_2 saturation	- Tracking CO_2 movement in and above storage formation - Tracking migration of brine into shallow aquifers - Calibrating seismic velocities for 2-D seismic surveys
Time-lapse 2-D seismic imaging	- P and S wave velocity - Reflection horizons - Seismic amplitude attenuation	- Tracking CO_2 movement in and above storage formation
Time-lapse vertical seismic profiling	- P and S wave velocity - Reflection horizons - Seismic amplitude attenuation	- Detecting detailed distribution of CO_2 in the storage formation - Detection leakage through faults and fractures
Electrical techniques	- Formation conductivity	- Tracking movement of CO_2 in and above the storage formation - Detecting migration of brine into shallow aquifers
CO_2 land surface flux monitoring using flux chambers	- CO_2 fluxes between the land surface and atmosphere Atmosphere	- Detect, locate and quantify CO_2 releases
Soil gas sampling	- Soil gas composition Isotopic analysis of CO_2	- Detect elevated levels of CO_2 - Identify source of elevated soil gas CO_2 - Evaluate ecosystem impacts

Accomplishments to Date

- Baseline surface fluxes measured
- Baseline reservoir groundwater (brine) compositions assessed
- 3-D reservoir model grids assembled
- surface and subsurface structure contour maps and cross-sections refined through new mapping using recently acquired geophysical logs that span the shallow (100 to 3,000 ft) subsurface.
- identification of shallow groundwater flow paths
- identification of regional trends in groundwater chemistry
- identification of impacts to shallow groundwater from old (pre-1975) produced water (brine) evaporation pits
- initial history match simulations completed, and updates continue as data is collected
- obtained 3-D seismic data volume collected by Kinder Morgan in 2003 over the northern section of SACROC for use as baseline for new surface seismic data
- completed pre-injection borehole geophysical logs in multiple monitoring wells within injection pilot site
- completed pre-injection vertical seismic profiling

- CO_2 injection started in first two wells 9/2008, second two well scheduled for 10/2008.

Summary of Target Sink Storage Opportunities and Benefits to the Region

- The SACROC pilot will be an initial high resolution analysis of the potential for CO_2 storage in the broader carbonate "Horseshoe Atoll" system, a huge (area and volume) system with potentially enormous CO_2 capacity (Figure 1). Given that most of the western side of the atoll is below the oil-water contact, it is particularly appealing for large-scale sequestration, as suggested by our Phase I analysis of the region.
- The SACROC field is also representative of many oil/gas fields throughout the southwestern U.S., and results will be applicable to many such fields.
- Typically, EOR with CO_2 is carried out with an objective to maximize re-production and recycling of CO_2 for further EOR. Among the SWP goals is to maximize sequestration, or leaving CO_2 in the ground rather than recycling, while not compromising efficacy of EOR.

Cost:

Total Field Project Cost: Approximately $5.5M

DOE Share: Approximately $4.4 or 80%

Non-DOE Share: Approximately $1.1 or 20%

Field Project Key Dates:

Baseline Completed: January, 2008

Drilling Operations Begin: October, 2007

Injection Operations Begin: September, 2008

MMV Events: September, 2008

Field Test Schedule and Milestones (Gantt Chart):

Major field operations at SACROC have been under way since the start of the project in late 2005. Safety training, initial reservoir model grids, and other essential SWP activities also began during this past year. A general summary of the SWP's schedule is provided in the Gantt chart below.