FACTSHEET FOR PARTNERSHIP FIELD VALIDATION TEST

Partnership Name	Southwest Regional Partnership on Carbon Sequestration
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Principal Investigator	Brian McPherson; SWP; brian@nmt.edu
Field Test Information: Field Test Name	Paradox Basin, Utah: Aneth EOR-Sequestration Test
Test Location	Near Bluff, Utah
Amount and Source of CO_2	Tons; Source: 150,000 tons/year for 2 years; CO2 sourced from McElmo Dome, CO
Field Test Partners (Primary Sponsors)	Resolute Natural Resources Company
	Navajo Nation Oil and Gas Company

Summary of Field Test Site and Operations

General Geology and Target Reservoirs: The Aneth oil field, discovered in 1956, is one of the largest in the nation. Because the field is Navajo Nation land, mineral royalties go to the Navajo Nation and are utilized in many ways, including a broad scholarship fund. Aneth is located on the McElmo-Cortez CO_2 pipeline system, and the sheer size of the field makes it a possible target for larger-scale sequestration operations. Petroleum production interests were recently purchased from ChevronTexaco and ExxonMobil, and now these interests are jointly owned by Resolute Natural Resources Company (Resolute) and the Navajo Nation Oil and Gas Company. Both companies operate the field together, and the SWP is pleased to partner with Resolute and the Navajo Nation OGC in a combined EOR – sequestration pilot test.

The Aneth Unit is part of the greater Aneth field and is located in the Paradox Basin of southeastern Utah (Fig. 1). Aneth is a stratigraphic trap with fractures and minor faults. The Aneth Unit covers about 16,800 acres of the northern section of greater Aneth and has produced about 149 million barrels of an estimated 421 million barrels of oil in place (Fig. 2). Secondary recovery by waterflood started in 1962. The planned CO2 flood will begin in early 2007 at the rate of 400 tons/day or 25 million cubic feet of gas per day.

The pilot test site is located within the Aneth mound complex (Fig. 3), which formed on a weak structural nose. The present-day structural relief of about 150 feet is largely the result of differential compaction. The primary CO_2 sequestration target is the Pennsylvanian Desert Creek and overlying Ismay members of the

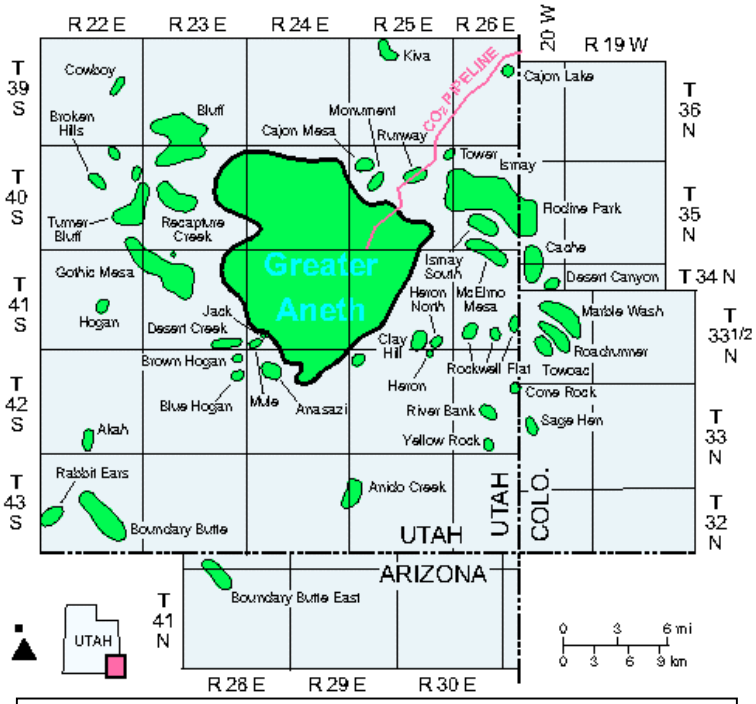

Figure 1. Location of greater Aneth and surrounding oil fields of the Paradox Basin.

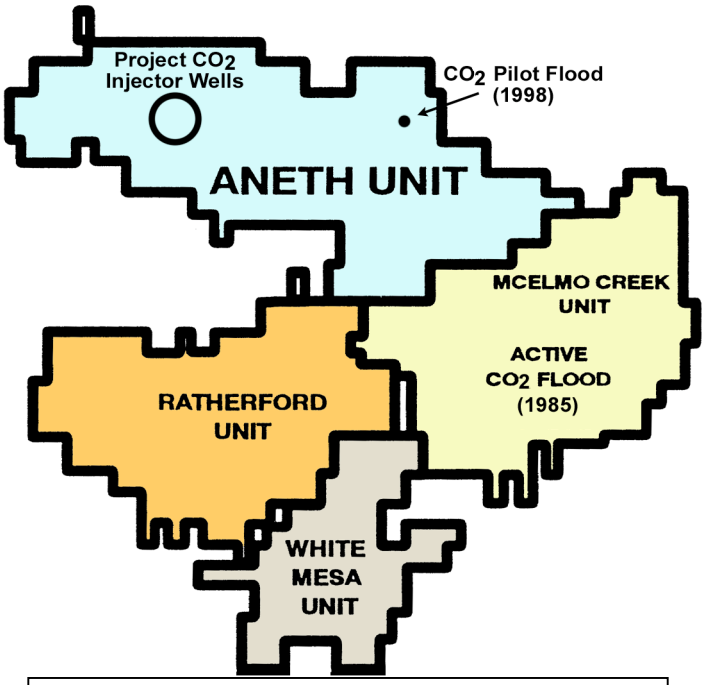

Figure 2. Units within the greater Aneth field.

Paradox formation, the primary producers in the Greater Aneth Field. These carbonate strata were deposited on the southwestern flank of the Paradox evaporite basin, and are laterally equivalent to the more basinward anhydrites and salts.

The Aneth Unit was originally developed with vertical wells drilled on 80-acre spacing. The field was infill drilled in the 1970s to 40 acre spacing. The field has been managed with water injection that began with unitization in the early 1960s. In 1996 Texaco drilled 43 multi-lateral horizontal wells (23 producers and 20 injectors). In 1998, the injectors in section 14 were converted to a CO_2 WAG project to pilot the possibility of a field wide CO_2 injection program. Thus, monitoring of horizontal CO_2 injection is an added attraction offered by this pilot test site.

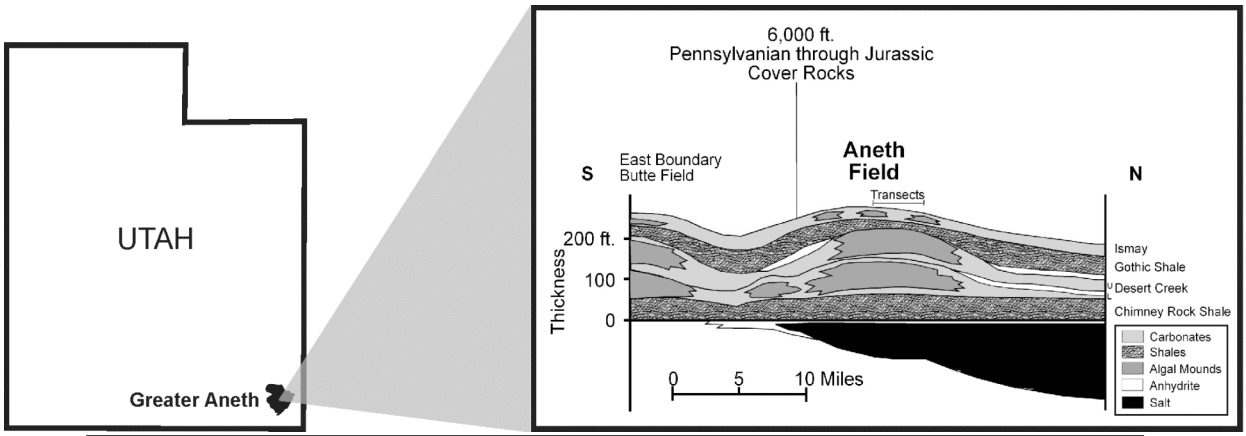

Figure 3. Location map of Aneth field and pilot site (left) and representative cross-section (right). The area indicated by "transects" is the location of a profile of CO_2 flux measurements the Partnership conducted in

Brief Summary of Target Reservoirs and Seals:

- **Producing Formations:** Desert Creek and Ismay Zones of the Paradox Formation (Pennsylvania). Depth to top approximately 5600 to 5800 ft. Bottom hole temperature – 125 degrees F (Fig. 3).
- **Deepest fresh water aquifer**: Navajo Sand (Jurassic) 500 to 1000 ft.
- **Lithology:** limestones, both oolitic and algal.
- **Type of trap and reservoir geometry:** stratigraphic, partly dolomitized algal carbonate mound on a weak structural nose (Fig. 4).
- **Seal and source rocks:** The "seal" unit above the sequestration target is the low-permeability Gothic Shale, and

the underlying seal is an organic-rich mud deposit, the Chimney Rock Shale (Figs. 3 and 4). Both shales are seals as well as original oil source rocks. Oil generation began during the Cretaceous as these strata were buried to depths greater than 10,000 feet. Later tectonic uplift and gentle structural development had only minor effects on redistribution of the accumulation.

- **Potential leakage points**: Not a strongly faulted reservoir, gross structure is depositional (algal mound). Planned 3D seismic survey may provide details of small-scale faulting, if any. Well spacing in the Aneth Unit is generally at 40 acres.
- **Pay zone thickness:** 130 to 195 ft. Net pay average 50 ft.
- **Porosity:** 10.3%
- **Permeability:** 6 to 27 millidarcies
- **Water saturation and water characteristics:** 23.3%, salt water 125,000 to 175,000 ppm NACL concentration

Data Quality: Most geophysical well logs are available from the Utah Division of Oil, Gas and Mining (DOGM) for the Aneth and other units in Greater Aneth field; only a mudlogs have been preserved. They consist of 1950s vintage through 1990s logs both as hard copy and scanned images; LAS files are generally not available. Well log quality is good to very good. An estimate of 70% of logs have coverage along the length of the entire bore hole, with roughly 30% covering the reservoir section only. Correlation of formation tops is achieved by studying the gamma ray and formation density/compensated neutron logs of each well; porosity is also determined from a variety of well logs. The general petroleum geology of Greater Aneth field has been summarized in numerous publications since the field was discovered.

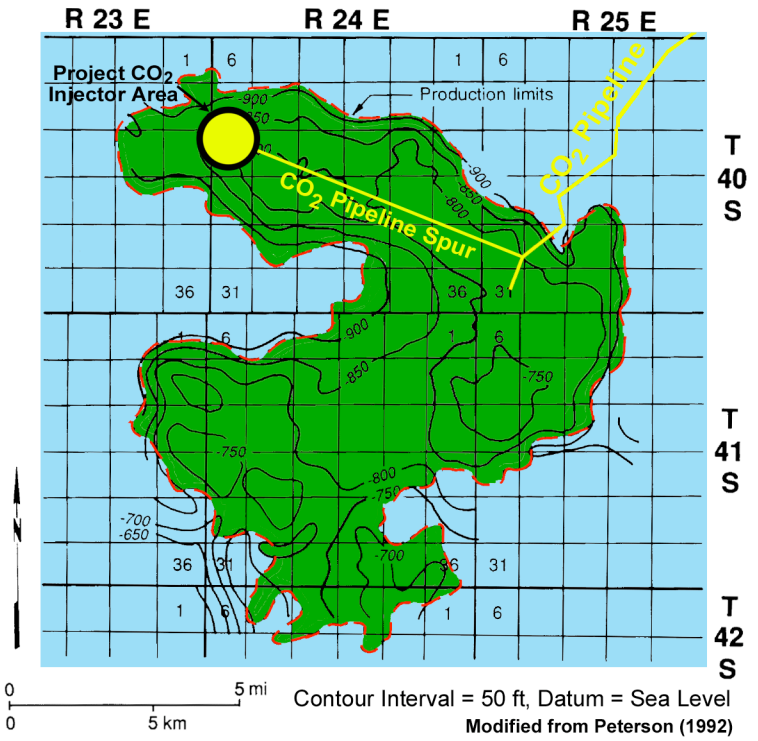

Figure 4. Structure map of top of the Desert Creek zone.

The location of conventional cores through the Paradox Formation reservoir from wells is variable. The UGS has seven cores from Aneth Unit wells. Other cores are either in position of Resolute or unknown. Core-derived porosity and permeability, thin sections, and core descriptions are available from Resolute.

Cumulative production data and completion reports data is available from DOGM's Web site, including old and abandoned producers.

High-quality water well information, ground-water quality, and surface water data is readily available on the Utah Division of Water Rights' Web site and various publications.

Surface Description and Land Use: The topography of the area consists of washes and dissected buttes and mesas formed in response to downcutting by the San Juan River. The surface geology of the area consists of rocks of the Cretaceous Dakota Sandstone and Burrow Canyon Formation, and the upper Jurassic Morrison Formation. Quaternary alluvial deposits occur in valleys, washes, and along the floodplain of the San Juan River. The only perennial tributary to the San Juan River is McElmo Creek; a few springs are also present.

Most of the area is part of the Navajo Indian Reservation although the Aneth Unit demonstration will be conducted on Bureau of Land Management lands. The largest communities in the area are Montezuma Creek and Aneth, with a combined population of about 1000 people. Land use in the area consists of livestock grazing and limited agriculture, which relies on water wells powered by windmills.

Research Objectives

EOR-Sequestration Testing: The field has the capacity to take delivery of up to 20 MMCF per day of CO_2 and re-injection capacity of a similar amount. The CO_2 comes from McElmo Dome CO_2 and arrives at a pressure of about 2750 psi, which is sufficient to inject it into the wells without compression. For our combined EOR/sequestration program, individual well CO_2 injection rates are planned and expected to be about 300 MCF per day per well. The process of displacing approximately 20% of the reservoir pore volume will take about five to eight years. Carbon dioxide will be injected for a period of several years and to intensely monitor CO_2 movement for 18 to 24 months. Lower-intensity monitoring will be performed for the remaining period of the four-year SWP Phase 2 program. Injection will commence in early 2007. State-of-the-art reservoir modeling will be used to simulate flow and chemical processes and forecast ultimate CO2 storage capacities. Given the previous success of EOR in this and other western U.S. sedimentary basins, our primary research objective of the EOR-sequestration test is to evaluate and maximize efficacy of CO2 subsurface monitoring technologies, and to improve our ability to track the fate of injected CO2 and to calculate ultimate storage capacity. Finally, it is our goal to develop a rigorous risk assessment framework that will help identify the optimum storage sites in this and other similar oilfield reservoirs that are ubiquitous throughout the Rocky Mountain western states.

Summary of Modeling and MMV Efforts

Table 1 below provides a summary of our ongoing and future monitoring activities for the Aneth EOR-sequestration testing. Data from these monitoring activities are being used to parameterize state-of-the-art mathematical reservoir models. These models include coupling of multiphase CO2-groundwater flow and rock deformation and chemical reactions, to evaluate residence times, migration patterns and rates, and effects of CO2 injection on fluid pressures and rock strain, and effects of chemical diagenesis, including variations in solubility, dissolution, and precipitation. We are also developing state-of-the-art seismic models, to assist with optimization of different seismic methods for imaging CO2 in the subsurface. All methods are 2-D, but we are using 3-D data and models to develop optimized 2-D models.

Our first reservoir modeling objective is to elucidate the origin of subsurface brines and the hydraulic communication amo different aquifers required to form those brines. This is intended to provide insight about how pressures induced by CO2 in might "communicate" hydraulically with other units, and to help identify potential migration pathways.

Table 1. Measurement Technologies Employed at Aneth, Utah Test Site

Measurement technique	Measurement parameters	Applications
Introduced and natural tracers	- Travel time - Partitioning of CO_2 into brine or oil - Identification sources of CO_2 - CO_2, HCO_3, CO_3^{2-}	- Tracing movement of CO_2 - Quantifying solubility trapping - Tracing leakage - Quantifying solubility & mineral trapping
Water composition	- Major ions - Trace elements - Salinity	- Quantifying CO_2-water-rock interactions - Detecting leakage into shallow groundwater aquifers
Subsurface pressure	- Formation pressure - Annulus pressure - Groundwater aquifer pressure - Brine salinity	- Control of formation pressure below fracture gradient - Wellbore and injection tubing condition - Leakage out of the storage formation - Tracking CO_2 movement in and above storage formation
Well logs	- Sonic velocity - CO_2 saturation	- Tracking migration of brine into shallow aquifers - Calibrating seismic velocities for 2D 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
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
Passive seismic monitoring	- Location, magnitude and source characteristics of seismic events	- Development of microfractures in formation or caprock - CO_2 migration pathways
Electrical techniques	- Formation conductivity	- Tracking movement of CO_2 in and above the storage formation - Detecting migration of brine into shallow aquifers
Time-lapse microgravity techniques	- Density changes caused by fluid displacement	- Detect CO_2 movement in or above storage formation - CO_2 mass balance in the subsurface
Visible and infrared imaging from satellite	- Hyperspectral imaging of land surface	- Detect vegetative stress
CO_2 land surface flux monitoring using flux chambers or eddycovariance	- 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

Source of Headings: IPCC Special Report on Carbon Dioxide Capture and Storage

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Accomplishments to Date

- Baseline surface fluxes measured
- Baseline reservoir groundwater (brine) compositions assessed
- 3-D reservoir model grids assembled
- Surface and subsurface geologic maps and cross-sections refined through new mapping

Summary of Target Sink Storage Opportunities and Benefits to the Region

- The Desert Creek Formation is representative of many oil/gas fields throughout the Colorado Plateau, and results will be applicable to many such fields.
- Typically, EOR with CO2 is carried out with an objective to maximize re-production and recyling of CO2 for further EOR. Among the SWP goals is to maximize sequestration, or leaving CO2 in the ground rather than recyling, while not compromising efficacy of EOR.

Cost:

Total Field Project Cost:
Approximately $5.5M

DOE Share: Approximately $4.4M or 80%

Non-Doe Share: Approximately $1.1M or 20%

Field Project Key Dates:

Baseline Completed: January, 2007

Drilling Operations Begin: October, 2006

Injection Operations Began: August, 2007

MMV Events: August, 2007

Field Test Schedule and Milestones

Major field operations, including well-drilling, pipeline planning, reservoir engineering and baseline MMV operations, began in winter and spring of 2006. Safety training, initial reservoir model grids, and other essential SWP activities also began during this past year. First injection was originally schedule for September, 2006, but was rescheduled to August, 2007, because of permitting delays. A general summary of the SWP's schedule for the Utah project is provided in the Gantt chart below.