QUARTERLY TECHNICAL PROGRESS REPORT
(Fourth Quarter)

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**ADVANCED OIL RECOVERY TECHNOLOGIES FOR IMPROVED
RECOVERY FROM SLOPE BASIN CLASTIC RESERVOIRS,
NASH DRAW BRUSHY CANYON POOL, EDDY COUNTY, NM**

DOE Cooperative Agreement No. DE-FC-95BC14941

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OBJECTIVE

The overall objective of this project is to demonstrate that a development program based on advanced reservoir management methods can significantly improve oil recovery. The demonstration plan includes developing a control area using standard reservoir management techniques and comparing the performance of the control area with an area developed using advanced reservoir management methods. Specific goals to attain the objective are: (1) to demonstrate that a development drilling program and pressure maintenance program, based on advanced reservoir management methods, can significantly improve oil recovery compared with existing technology applications, and (2) to transfer the advanced methodologies to oil and gas producers in the Permian Basin and elsewhere in the U.S. oil and gas industry.

SUMMARY OF TECHNICAL PROGRESS

This is the fourth quarterly progress report on the project. Results obtained to date are summarized.

MANAGEMENT AND PROJECT PLANNING

Geological, engineering, geophysical, and simulation teams continue compiling and analyzing data. To provide communication and coordination between the team members located in a diverse geographic areas requires the use of state-of-the-art communication systems. Reporting and coordinating of five subcontractors uses advanced technologies to communicate and coordinate efforts. The combination of E-mail, the Internet, and high capacity data transfer are used successfully to exchange data and conclusions between each group.

GEOLOGY

The initial stratigraphic framework geological model was developed, and the maps were put into the Landmark's Stratamodel program. The top and bottom of each of the primary reservoir sands - the "K", "K-2", and "L" sands- were added to the model as well as the top of the underlying Bone Spring Formation. The layers for the uppermost sand, the "J" interval, were added to the model. The process was complicated by the fact that the maps were based on only 23 data points in the area. As layers were added to the model, correcting problems in the model was an ongoing requirement. The most persistent problem encountered dealt with intersections between the horizons in between the data points. In some cases, significant portions of the maps needed to be re-contoured in order to eliminate the problem. After much revision, the final result was a three-dimensional model that satisfied the needs of the reservoir simulation group as well as the conforming to the geological model interpretation.

After the stratigraphic framework was developed, the sub-unit isopach layers for the "K", "K-2", and "L" sands were added. Like the other maps integrated into the model, these maps were modified where needed and put into the three-dimensional framework without violating the constraints of the

model. The next step was for the simulation group to begin to distribute the various reservoir attributes throughout the model. It is anticipated that additional geological refinement will be required as this process evolves.

Refinement of the geological model will be affected by the results of the 3-D seismic survey that has been shot over the Unit. Initial results indicate a reasonable correlation between porosity development and seismic attributes. Work is continuing on the data volume, and the interpretation will greatly enhance the accuracy of the geological model. The 3-D seismic data will be integrated into the framework model as well.

The drilling of the Nash Draw #12 has added an important data point to the model. The structural and stratigraphic mapping data from Well #12 have been integrated into the stratigraphic model as well as the other reservoir maps.

ENGINEERING

Data Acquisition Well

One data well, the Nash Draw # 12, has been drilled at a location 918' FSL and 2153' FEL of Section 12-T23S-R29E. This well exhibited good "L" zone development and exhibited fair "K" zone development. Of interest was the correlation of porosity in the "K" and "L" sands with the high intensity seismic reflection amplitudes for the respective intervals in the 3-D seismic data volume. This correlation presents positive information that seismic attributes may be used for determining the distribution of the best quality reservoir rocks in the Nash Draw Unit.

The well is presently being completed and tested. Production information should be available by the end of the next quarter.

Special Fluid Swelling Tests

Instead of obtaining a second full core as originally planned, additional reservoir fluid swelling tests were performed to determine possible injectant parameters. Lean gas, carbon dioxide and nitrogen were studied as possible injection fluids for a possible pressure-maintenance project. From the fluids tested, carbon dioxide exhibits the most favorable characteristics and separator gas exhibiting satisfactory results. Nitrogen exhibited limited solubility in the Nash Draw crude oil and provided only approximately half of the oil viscosity reduction that CO₂ and separator gas provided.

Frac Treatment Optimization

Using data from the bottomhole pressure analysis, the frac treatment design was evaluated, and the presently used design parameters were confirmed. The design used to frac-treat the Brushy Canyon uses a fracture half-length of 400 ft and a frac height of approximately 200 ft, which includes the "K", "K-2", and "L" zones. Using the Delaware Model to predict the ultimate recovery from the wells and an average recovery factor of 12%, the drainage area is estimated to be 50 to 60 acres. This represents an area approximately 600 ft surrounding the indicated fracture geometry. The drainage area is described as a rectangle approximately 1200 ft wide and 2000 ft long. These assumptions will be further verified using the reservoir simulation model. Larger designs are being considered to

extend the frac length, but the concern over frac-height growth has curtailed these plans until a quantitative model can be found to predict frac heights with frac lengths of 600 to 800 ft.

Decline Curves

Historical production data have been updated through August 1996. The decline curves have been compared to the Delaware Model to evaluate production trends.

Pilot Area

The pilot area has been proposed around Well #1. The spacing in this part of the field is very close, and interference has been observed between Wells #1, 6, 14, 5, 9, and 10. Preliminary calculations of water injection rates indicates that the water injection rates would be 150 to 200 barrels of water per day, which would be too low to obtain response in a reasonable length of time. Pressure maintenance will be investigated with a low viscosity injectant that can be injected at sufficiently high rates to effect response in a timeframe adequate for economic success of the project.

In the pilot area, detailed flow-unit maps have been prepared. Each of the sub-units of the three main sands has been mapped individually. Maps prepared for each sub-unit are isopach maps for log-derived net pay and isopach maps for gross sub-units. These maps have been put into the initial geologic model for the simulation study in the pilot area.

E. Loving Analogy

The logs on the sixteen (16) wells in Section 14-T23S-R28E, selected as an analogy to the Nash Draw Unit, have been digitized. These digitized logs will be used to determine the productive zones and to arrive at an OOIP number for the entire section (640 acres). Using decline curves to predict primary recovery, an estimate of the recovery efficiency based on 40-acre spacing will be predicted.

Calibration

Using core and log data, each well has been calibrated to match production, net pay, and transmissibility. By calculating a transmissibility value for each interval, production rates and cumulative production were allocated to each interval. The transmissibility for each layer, along with saturation data, will be used as input into the reservoir simulation model to determine the producing characteristics of each layer.

3-D SEISMIC

Acquisition and processing of the 3-D seismic volume was performed during this quarter. Because of the extensive pre-survey testing and planning, high quality data were obtained. The rigorous processing sequence that was applied to the 3-D field records produced a valuable image volume of the heterogeneous turbidite reservoirs that are the focus of the Nash Draw study.

The interpretation of the 3-D seismic image was initiated late in the quarter, and preliminary structure, isochron, and seismic attribute maps have been produced. Seismic amplitude attributes appear to be quite valuable for identifying productive reservoir facies, with high reflection amplitudes occurring at the better producing wells and low reflection amplitudes at the poorer producers.

RESERVOIR CHARACTERIZATION/RESERVOIR SIMULATION

Activities of the Reservoir Characterization/Simulation Team this quarter were focused on the completion of the petrophysically-derived geological model, that is, the geological model based on log and core measurements. Although seismic data was acquired, processed, and partially interpreted during the quarter, it is not represented directly in the present model.

During the quarter, the Engineering and Geology Teams developed a new interpretation of the Nash Draw based on the logs and well test data. In this interpretation, the Nash Draw Brushy Canyon Unit is divided into three non-communicating "lobes". The central lobe supports production in the pilot area. This segment of the reservoir was re-interpreted and re-digitized. The resulting files were imported into SGM (Stratigraphic Geocellular Model) to build a new 3-D representation of the lobe. Figure 1 illustrates the structure of top of the uppermost horizon, the "J" sand (displayed only for the eastern half of the reservoir), and locates the proposed pilot area (the boundaries are slightly different from before). Figure 2 outlines the lobe which supports the pilot. Figure 3 illustrates the relationship between the five major producing horizons in this new interpretation. In this model we have enforced the well picks in each zone and subzone (of the "K" and "L" sands).

Using the Well Attribute Model developed last quarter, the following attributes were imported into the stratigraphic framework model for the pilot lobe:

- interpreted porosity and interpreted permeability
- perforated interval and fractured interval
- net pay
- water saturation

In some instances, these attributes were available on a foot-by-foot basis for one or more of the producing zones. Not all of the attributes were available for each well. The distribution of reservoir attributes like conductivity and storage capacity within the producing zones of the Nash Draw Brushy Canyon Unit will be based on the well attribute model. Within SGM these distributions are interpolated deterministically, that is, weighted by the reciprocal of the square of the distance between the location of interest and nearby wells within the reservoir model. Figure 4 illustrates the distribution of porosity calculated in this manner; Figure 5 illustrates the distribution of net pay.

The present model is adequate to represent the geological characterization of the Nash Draw Brushy Canyon Pilot for reservoir simulation. The simulator itself will calculate the storage capacity and hydraulic conductivity of the oil lobe supporting the pilot from the porosity and permeabilities displayed the previous two figures.

Work will begin in October to develop the input needed to perform the simulations of the immiscible enhanced recovery cases (dry gas injection and water injection). These cases should be finished by the end of the calendar year.

TECHNOLOGY TRANSFER

The transfer of technical information generated during the course of this project is one of the prime objectives of the project. Toward this objective, Strata has participated in several meetings and workshops to promote the dissemination of information generated during this quarter of the project. A summary of these activities is outlined as follows:

Liaison & Technical Committee Meeting August 1996

A liaison and technical committee meeting was held on August 16, 1996. There were fourteen (14) participants including Nash Draw partners, BLM representatives, OCD representatives, and industry group representatives. The status of the project was discussed, and findings to date presented for review.

Characterization Workshop August 1996

A workshop sponsored by the Petroleum Recovery Research Center at New Mexico Tech, titled "Integration of Advanced Reservoir Characterization Techniques" was held in Roswell, NM on August 22 and 23, 1996. Strata Production Company presented an update of the status and findings at the Nash Draw Project.

DOE Outreach Meeting July 1996

A poster was presented at the DOE Outreach Program meeting in Roswell on July 25 and 26, 1996. Several area producers attended the meeting, and there was considerable interest in the activities being conducted at the Nash Draw Unit.

FRAC Design Workshop September 1996

A conference titled: "Stimulation Design and Monitoring -Delaware Mountain Group Formations" was held on September 19, 1996 at the New Mexico Junior College in Hobbs, New Mexico. Sponsors of the Conference included the PRRC and the Petroleum Technology Transfer Council. Strata Presented the findings and conclusions of the fracture stimulation design and evaluation scenario used to determine effectiveness of the stimulation program.

Internet Home Page

An Internet homepage went online in September 1996. The page is located at <http://baervan.nmt.edu/prrc/homepage.html>. At this page, go to "Research Divisions," then "Reservoir Evaluation and Advanced Computational Technologies (REACT)" and then go to "DOE CLASS III PON Slope Basin Reservoir Characterization: Nash Draw Field." After reviewing the homepage, click on "NASH DRAW" to view project and field data. This site will be updated as new information becomes available.

Nash Draw Project Top of "J" Sand

Figure 1

Figure 2

Nash Draw Project Stratigraphic Framework Model

Figure 3

Figure 4

Figure 5