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APPLICATION OF INTEGRATED RESERVOIR MANAGEMENT AND RESERVOIR CHARACTERIZATION TO OPTIMIZE INFILL DRILLING

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FINA OIL AND CHEMICAL COMPANY

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MASTER

QUARTERLY TECHNICAL PROGRESS REPORT

"APPLICATION OF INTEGRATED RESERVOIR MANAGEMENT AND RESERVOIR CHARACTERIZATION TO OPTIMIZE INFILL DRILLING"

INSTRUMENT NO. DE-FC22-94BC14989

NORTH ROBERTSON UNIT DEPARTMENT OF ENERGY CLASS II OIL PROGRAM PROJECT

REPORTING PERIOD: 12/13/95 TO 3/12/96

This Quarterly Progress Report summarizes the technical progress of the project from 12/13/95 TO 3/12/96.

ACTIVITY I.1 - MANAGEMENT AND ADMINISTRATION

PROJECT MANAGEMENT AND ADMINISTRATION - *TASK I.1.1*

The main emphasis on the project during the last Quarter has been developing the Field Demonstration recommendation and submission of the Continuation Application. Assimilation of all the reservoir characterization and performance analysis data with the simulation and geostatistics was conducted to determine the specific well locations for the Field Demonstration. Necessary preparations to implement the field demonstration were also completed. These aspects are discussed in this Quarterly Report.

Project Status: This project has used a multi-disciplinary approach employing geology, geophysics, and engineering to conduct advanced reservoir characterization and management activities to design and implement an optimized infill drilling program at the North Robertson Unit (NRU). The activities during the first Budget Period, which is now complete, consisted of developing an integrated reservoir description from geological, engineering, and geostatistical studies, and using this description for reservoir flow simulation. Specific reservoir management activities have been identified and tested. The geologically targeted infill drilling program to be implemented during Budget Period II is a result of this work.

Project Objectives and Overall Accomplishments: The overall thrust of this project has been Geologically Targeted Infill Drilling. Specifically, in Budget Period I it has been shown that it is possible to optimize economics for each and every new well in an infill drilling program. Blanket

drilling in shallow-shelf carbonate (SSC) reservoirs is neither prudent nor warranted with the modern reservoir characterization tools and techniques available to operators. The key is reservoir characterization. Operators need to recognize its importance and how it can help in optimizing and maximizing recovery economics.

Summary Project Results: The economics are significantly better for a geologically targeted infill drilling pattern which employs a direct line drive, where new producers and injectors are drilled, rather than utilizing a five-spot pattern where existing producers are converted to injectors and new wells are drilled as producers only. In the case of North Robertson, development costs are nearly 25% less for equivalent or improved recoveries with the direct line drive configuration than for the five spot pattern. In addition, the development risk in realizing the expected reserves are significantly reduced with the line drive pattern due to suspected directional fracture and flow trends within the reservoir. An additional reason for this is that good existing producing wells are retained as producers in the line drive development configuration. With the five spot pattern, the risks in realizing the expected reserves are higher due to the inherent unpredictable nature of the "small scale" heterogeneity in the Glorieta/Clearfork. Good geologically targeted infill drilling at North Robertson is expected to reduce development costs by nearly 50% over blanket drilling.

Finally, without reservoir characterization, it is impossible to identify all areas which have extremely poor development potential. Some of these poor areas can be identified with relative ease, such as those lacking sufficient quantity and quality of pay rock. The difficulty arises in assessing potential of poor development areas which have performed well in the past. Such areas in North Robertson are thought to be characterized by good continuity in which the waterflood sweep efficiency has been fairly high. Some of these areas were effectively drained on 40- or 20-acre nominal spacing. The future development for these areas, however, is relatively poor because most of the incremental recovery is accelerated oil rather than additional or incremental recovery. Only through reservoir characterization and studies can these areas be identified and avoided.

Project Continuation: During Budget Period II 18 new infill wells, comprised of producers and injectors, will be drilled and completed. These wells are located in areas of the Unit which appear to have good 10-acre infill potential (Sections 362, 329, and 327) as shown in **Fig. 1**.

Phased Program

The drilling of the eighteen wells in the Field Demonstration will be implemented in a two phase program which consists of eleven wells in Phase I followed by seven wells in Phase II. The phased implementation will allow flexibility in geologically targeting the final seven wells in the Field Demonstration based on the performance and data obtained from the first eleven wells. The specific areas in which the Phase I wells will be drilled are shown in **Figs. 2 and 3**. The flexibility and options available to drill the final seven wells in Sections 329 and 327 are shown in **Fig. 3.** The development in Section 362 consists of only one well to be drilled during Phase I.

Maintaining some flexibility in the final configuration of the well placement for the Field Demonstration is important because we recognize that there are uncertainties in our evaluation tools and methodologies, such as reservoir modelling and interpretative geology. We feel that independent producers, who are one of the key targets in the DOE Class II Program for transferring the technologies and approaches used in the project and Field Demonstration, would also want to maintain flexibility when drilling a relatively large infill drilling program such as North Robertson which consists of eighteen wells. All of the options available to us for the second phase of the Field Demonstration have been studied with reservoir simulation models. Early performance data from the first 10 wells to be drilled in Phase I in Sections 329 and 327 will allow for an early first pass validation of the models and reservoir description projected for these areas. Core and other data will also be taken in Phase I. This will be useful for confirming the results of our reservoir quality studies, and to better define interwell continuity within the Unit. Final selection of the seven Phase II well locations which are directly adjacent to the Phase I areas will then be made.

Reserves

Our analysis indicates that this project will recover approximately 2.2 Million Barrels of additional oil over a 20-year period. These reserves and associated economics are sufficient to warrant implementation of the Field Demonstration during Budget Period II. We believe that other operators which utilize the advanced recovery technologies employed in this project would follow a similar course of action.

The reserves expected in each of the areas of the Field Demonstration are as follows:

Area	Total No. Wells, Phase I & II	Estimated Reserves, (MBO)	
		Per Well	For Area
High Potential Areas:			
Section 362	1	150	150
Section 329	9	130	1,140
Moderate Potential Area:			
Section 327	8	115	920
Total	18	123	2,210

Specific Locations

The locations for the Phase I and II wells in each of the Field Demonstration areas are described below:

Section 362, High Potential: A single producing well will be drilled in an undrained, approximately 20-acre well location area surrounded by expected banked oil from 3 injectors as shown in **Fig. 4**. By drilling this well, we expect to demonstrate how to increase production in areas where there has been incomplete pattern development in the past. Geologically targeted infill drilling opportunities on a single well basis, such as this, exist in many shallow-shelf carbonate reservoirs in the Permian Basin. These opportunities can be identified by other operators by utilizing historical performance studies, pattern balance analyses, or by applying advanced characterization tools such as material balance decline type curve analysis. We identified this location for the Field Demonstration by using these specific technologies. The geological reservoir characterization and other performance analyses also supported this development approach for the Section 362 well location.

Section 329, High Potential: The Phase I program in this area consists of drilling a line drive pattern where one injector and 4 producers are drilled (**See Figs. 5-8**). Both geostatistical and deterministic reservoir simulation models (encompassing 320 surface acres) were completed in this area of Section 329. These results, along with performance analysis and geological knowledge, support the Phase I area as one of relatively low risk and high reward.

There are many options available for drilling three additional wells in Phase II drilling for the Section 329 area. Some of these outcomes are shown in **Figs. 5-8** and are discussed below.

Scenario A is shown in **Fig. 5** and entails extension of the Phase I line drive to the central section of Section 329. This is a relatively low risk approach which completes another pattern in the direct line drive development scheme by drilling an additional injector and two producers. The advantage of this approach is that "smaller," lower risk reserves in the section 329 area can be captured. The disadvantage is that implementing this scenario in Phase II will not allow us to evaluate the higher risk, higher reward possibilities which exist directly to the east of the Phase I wells, as shown in **Fig. 6** and discussed next as ***Scenario B***.

Scenario B **(Fig. 6)** entails drilling one injector, one conversion of an existing producer to injection, and drilling three new producers. The simulation results and other analyses indicate potential for higher reward than for Scenario A, but the geological risks are expected to be greater due to the lack of abundant data on the edge of the Unit. The conversion is necessary to add needed injection support in the northeast area of Section 329, in which sweep efficiency is felt to be rather low in the existing waterflood configuration since it is lacking injection support because of its proximity to the lease line. Recognizing that injection support could also be beneficial in other areas of Section 329 led to development of two additional development scenarios for Phase II (***Scenarios C*** and ***D***).

Scenarios C and D, shown in **Figs. 7 and 8,** respectively, focus on adding needed injection in various areas of Section 329. These areas are adjacent to the Phase I development area. Core obtained during the Phase I drilling will be analyzed and the resulting interwell continuity study

will allow us to make a more informed decision on whether or not we should pursue the development schemes shown in these infill drilling scenarios.

Additional infill drilling scenarios which are variations of those described above, or ones which entail some other locations near the Phase I wells, are possible and will continue to be evaluated for Phase II drilling as we obtain results from the Phase I performance and data acquisition programs. An informed choice, weighing the risks and rewards for the Phase II wells in the Section 329 area will then be made. Refinements will continue to be made to the simulation models and other tools available to us will be utilized when choosing one of the scenarios (or variations thereof) for the final selection of Phase II wells.

Section 327 (Moderate Potential): It is important that areas other than just the high potential areas be included in the Field Demonstration so that the characterization completed in Budget Period I can be validated in parts of the reservoir where different factors are at play in the subsurface geology, and areas where different dynamic forces impacting the waterflood performance exist. It is for these reasons that this area of moderate potential for geologically targeted infill drilling was selected.

We recognize that this is not the very best area of the Unit available to us with regard to geologically driven reservoir quality estimates, however, reducing nominal well spacing to 20-acres during the previous infill program resulted in a substantial reserves addition in this area due to previously uncontacted oil. Future operations in this area of the Unit have been considered more on the basis of historical performance, decline curve analysis, and reservoir surveillance activities. The reservoir rock in this area is of lower quality compared to that found in Section 329, but is more homogeneous. It is important to note that this area of moderate potential is economic at North Robertson and would also be economic in fields for other operators, including independents. In addition, not all operators will have geologically-driven targets which are characterized as high potential areas. In this case, operators would be left to evaluate and pursue opportunities on the basis of previous production performance and engineering calculations.

Fig. 9 shows the details of the Phase I and available Phase II development areas for Section 327 in the Field Demonstration. As in Section 329, Phase I entails drilling one injector and four producers in a direct line drive configuration. All of the three potential Phase II areas involve extending the line drive pattern either in a north/south direction or directly west of the Phase I wells. Flow simulation results indicate some quantifiable differences in the three different options for Phase II. Our judgment, however, is that the simulation reservoir description may not capture all of the heterogeneity and compartmentalization present in this complex reservoir. For this reason, we do not want to rely on simulation alone in prematurely selecting all the locations for the Section 327 area. It is prudent to leave flexibility in selection of some locations and base these locations on results from the first five wells. Thus, a phased development plan was developed for Section 327. The options for Phase II drilling in Section 327 are somewhat simpler than Section 329 since we are not on the periphery of the Unit, and do not need to consider the need for injection support on "boundary wells."

Summary on Selection of Well Locations

We have used all the information from the geological, engineering, and reservoir performance analyses to geologically target the Field Demonstration well locations. We recognize that flow simulation is a good tool for targeting wells, but like any tool its limitations as well as strong points must be considered. Constructive discussion of the simulation studies and their input parameters was a high priority for the project team. Significant judgment using all the collective knowledge was applied to the final decisions for the Field Demonstration plan.

For SSC reservoirs, reservoir heterogeneity and compartmentalization is a day to day reality which impacts operators' field operations and subsequent well performance, and may result in "untapped" oil. We have focused on utilizing reservoir characterization tools and techniques which allow us to better deal with this producibility problem. With respect to reservoir simulation, especially deterministic modelling, which cannot capture this heterogeneity and compartmentalization, we recognize that results from these conventional simulations predict more acceleration rather than additional recovery which may actually exist and be closer to "reality." We believe our efforts in geostatistical reservoir description and flow simulation can improve on the shortcomings of conventional simulation. The validation exercise in Budget Period II will allow us to determine the value of geostatistics in quantifying future reservoir performance.

Budget Period II Workplan

During the second Budget Period, the recommendations for geologically targeted infill drilling will be implemented, new data collected, and reservoir performance monitored. The new data and observed performance will be critically evaluated to determine the validity of the predictions and conclusions of the first Budget Period. Technology transfer is also a critical component of the second Budget Period.

Specific activities during the Field Demonstration (Budget Period II) are included below. The second Budget Period is scheduled to last 39 months, beginning March 13, 1996 and ending June 12, 1999. A summary of the specific activities are:

- **Implement the Field Demonstration:** Drill a total of 18 infill wells and convert up to 16 wells to injection. Obtain 3,600 feet of core, well log, pressure transient, and additional well test data in the new infill wells. Make all tie-ins to gathering and injection system for all new and converted wells.

- **Integrated Reservoir Management Program, Field Operations and Surveillance:** Performance of all wells in the Field Demonstration areas will be closely monitored. Reservoir surveillance and data acquisition programs will continue with follow up surveys recorded on new wells and in the areas of the previous surveillance surveys. Specific focus on

analysis will include considering injection volumes and pressures, production volumes, fluid sampling, production logging, and pressure transient testing. The effectiveness of the waterflood in the infill areas will be evaluated.

- **Integration and Validation:** The validation activities are a very important aspect of Budget Period II. All of the data acquired during the Field Demonstration, along with the data and analysis from the first Budget Period, will be integrated and analyzed. One goal of this effort is to evaluate the validity of the analyses performed during Budget Period I. This effort will first involve validation of the reservoir characterization. A large part of this effort will be integration of the analyses from the newly acquired core, and from the special core analysis. Another important aspect of this effort will be validation of the reservoir management and reservoir performance analysis activities, such as material balance decline type curve analysis. As during Budget Period I, geostatistics and reservoir simulation will also complement the geological and reservoir performance analysis efforts. The geostatistical and deterministic reservoir simulation models will be revised and continually updated to monitor performance. One goal will be to use reservoir simulation as an operational tool so that we can be proactive to operational and reservoir issues as they arise in the field.

- **Technology Transfer:** For Budget Period II, we have built upon our knowledge from the first Budget Period. This knowledge in the areas of reservoir characterization and reservoir management for shallow-shelf carbonates (SSC) reservoirs, with the Clearfork in particular, will be refined. The experience of the Field Demonstration will validate this knowledge. More insight into the cost/benefit of various approaches and technologies will be developed. This information will be extremely helpful to the industry and will be conveyed using the same technology transfer components used during Budget Period I. These components include technology transfer workshops, publications, newsletters, and report writing.

ACTIVITY I.5 - TECHNOLOGY TRANSFER

PUBLICATIONS AND PRESENTATIONS - *TASK I.5.3*

Technology transfer activities for the project this Quarter were:

Published Papers and Professional Meeting Presentations:

Permian Basin SPE Section Presentation, "Reservoir Characterization and Management - A Synergistic Approach To Development Optimization and Enhancing Value," February 21, 1996, Midland, Texas.

TECHNICAL WORKSHOPS - *TASK I.5.5*

The first Technology Transfer workshop is scheduled to be held in Midland, Texas on April 25-26, 1996. A second workshop is scheduled for June 13-14, 1996 in Houston, Texas. The "technology transfer packages" are designed to describe the results and methodologies of the project and will be distributed as part of the workshops.

The workshop agenda is a one and one half day format. The first day will cover an introduction to the project, historical perspective, geology, and geophysics. This will be followed by detailed discussions of reservoir performance analysis and reservoir surveillance and monitoring activities in the previously defined reservoir management areas. The second day focuses on geostatistics and reservoir flow simulation. Information on resource requirements and lessons learned will be emphasized.

The target audience for the workshops are independent and major operators. The workshop planning is being coordinated with the University of Tulsa Continuing Education Department.

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