Pilot Waterflooding In the Langlie Mattix Pool -- Lea County, New Mexico

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INTRODUCTION

The Langlie Mattix Pool is located in southeast Lea County, New Mexico, as shown in Fig. 1, and contains approximately 1200 wells drilled on 60,000 acres. Discovered some 30 years ago, it is now essentially depleted of primary oil. Waterflood potential appears excellent and there are at present 10 water injection projects in operation and several more in various stages of development. One of the earliest of these is the Woolworth Unit, operated by Amerada Petroleum Corporation.

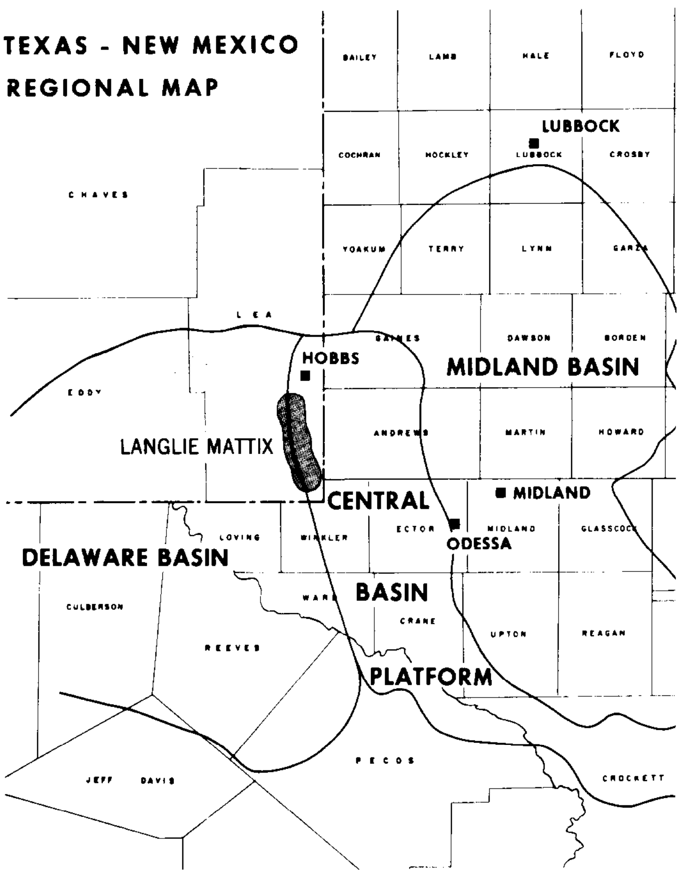

FIGURE 1

West Texas-New Mexico Regional Map Showing Langlie Mattix Field.

The Woolworth Unit was formed in late 1962 and began pilot water injection in early 1963. A pilot project was considered essential at that time for the following reasons:

(1) The unknown floodability of the reservoir.

(2) The lack of reservoir definition (virtually no logs or core analyses).

(3) The questionable condition of well bores (open holes shot with nitroglycerine).

(4) The nearness of the injection interval to an overlying gas reservoir.

The operation of the pilot and unit, performance to date under water injection, and related topics are discussed in the following sections.

GEOLOGY AND RESERVOIR DESCRIPTION

Langlie Mattix Pool

The Langlie Mattix Pool is located regionally on the west flank of the Central Basin Platform. It is one of a series of fields along this feature which produces from the Yates, Seven Rivers, and Queen formations. In the immediate area the Yates and Upper Seven Rivers are gas productive and are included in the Jalmat Gas Pool. The Langlie Mattix Pool, as defined by the New Mexico Oil and Gas Conservation Commission, is the lower 100 ft of the Seven Rivers and all of the Queen.

The Seven Rivers and Queen formations consist of alternating layers of dolomite, sandy dolomite and sandstone. The sandstones, which comprise the reservoir, are lenticular and form strati-

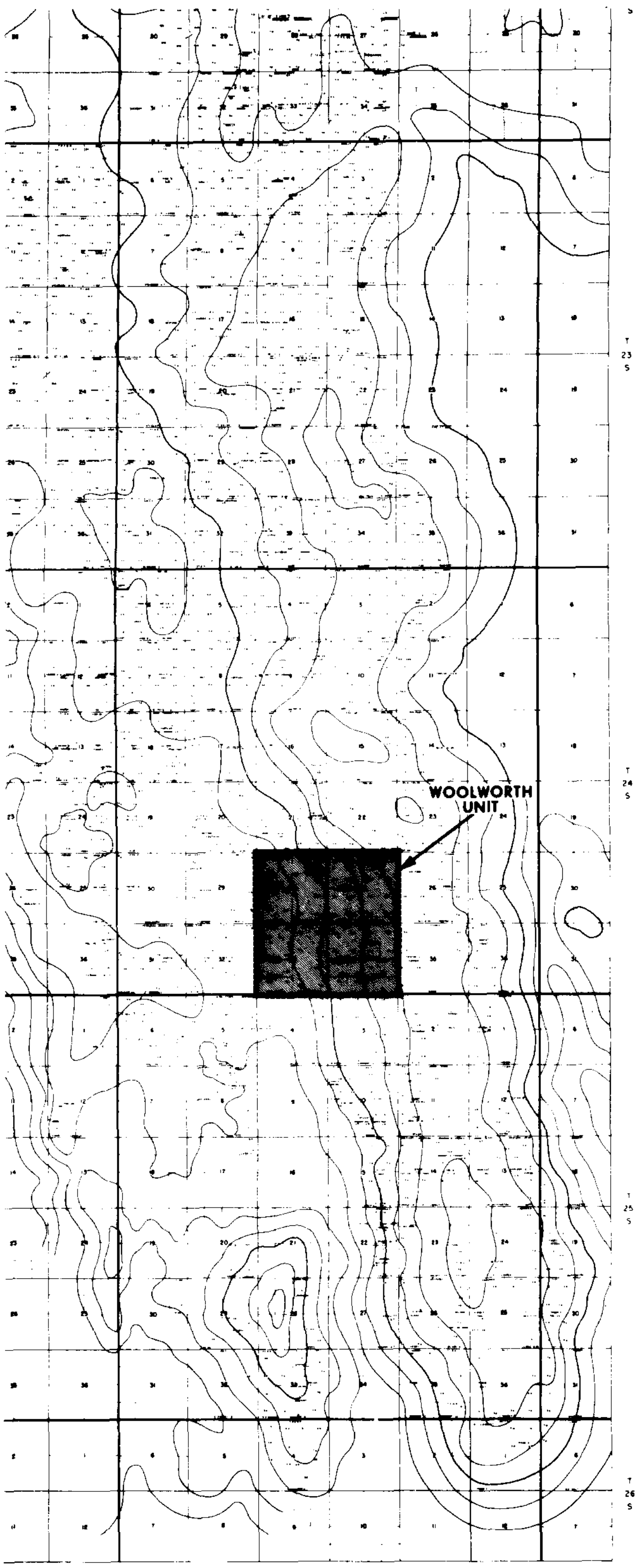

FIGURE 2

Location of Woolworth Unit in the Langlie Mattix Field, Lea County, New Mexico.

graphic traps. Production is limited by sand development and/or gas-oil and oil-water contacts. These were originally assumed to be 150 and 350 ft subsea, respectively. The latter datum is not firm, particularly in the Woolworth area where it is thought to be lower.

A structure map of the field, drawn on the top of the Yates formation, is shown in Fig. 2. The producing formations, gas-oil contact and water-oil contact are illustrated in Fig. 3, a cross section across the Woolworth Unit area.

Woolworth Unit

The principal producing interval is the Queen found at a depth of 3500 ft. Production is limited to the Lower Seven Rivers on the west side of the unit, however. The Queen is subdivided locally into two members, the Stuart and the Penrose. These are illustrated in Fig. 4, which shows a Gamma-Ray Sonic log and core graph from well 3-8, drilled after the unit was formed. The Stuart section has a gross thickness of approximately 130 ft, and is above the Penrose. The remainder of the section is the Penrose. As may be noted from Fig. 4, the productive interval consists of a number of noncommunicating (or poorly communicated) layers. Lateral distribution of these layers is shown in Fig. 5, which is an east-west log cross section through the unit. Again, these logs (with one exception) were obtained after the unit was formed.

As shown on the structure map, the Woolworth Unit lies on the west flank of a north-south trending anticlinal feature. Beds dip from east to west at an average rate of 170 ft per mile, as illustrated in Fig. 3.

Rock Properties

Porosity and permeability distribution for well 3-8 are shown in Fig. 4. These data yield averages (based on all samples with measurable permeability and residual oil saturation) as follows:

Zone	Porosity, Percent	Permeability, md	Net Thickness, Ft
Stuart	15	3.02	23
Penrose	17	4.08	8

HISTORY AND DEVELOPMENT

The field was discovered in 1935 and developed in the late 1930's and early 1940's. Wells were drilled generally on 40-acre spacing, and completed in "open-hole". In most wells, casing was set at or near the top of the Langlie Mattix interval but in some cases was set in the Jalmat zone. After pipe was set, the well was drilled into the pay and shot with a large charge of nitroglycerine. Very few old wells were logged and fewer were cored. Recent caliper surveys in the old holes indicate hole diameters in excess of 36 in. in the interval shot with nitroglycerine.

Initial potentials varied widely from several hundred to several thousand BOPD. Initial GOR's also showed wide variations, reflecting in many cases communication with the primary gas cap. The produced oil had an API gravity of 35° and was saturated with gas at the original reservoir conditions of 1450 psig and 87° F.

In the period of early development, an oil-water contact was established in some areas at 350 ft subsea. This was considered uniform over the field and most wells were completed at a total depth above this datum. As a result, the west side wells in the Woolworth Unit, where the beds dip to the west, penetrated only the uppermost portion of the Langlie Mattix interval. Some of these wells have since been deepened and have found oil-saturated sections below the 350 ft datum. The oil-water contact in this area remains, as yet, to be adequately defined.

UNITIZATION

The Woolworth Unit consists of Sections 27, 28, 33 and 34 in Township 24 South, Range 36 East, as shown in Fig. 6. The desirability of installing a pilot led to unitization after one operator originally proposed to start a cooperative waterflood.

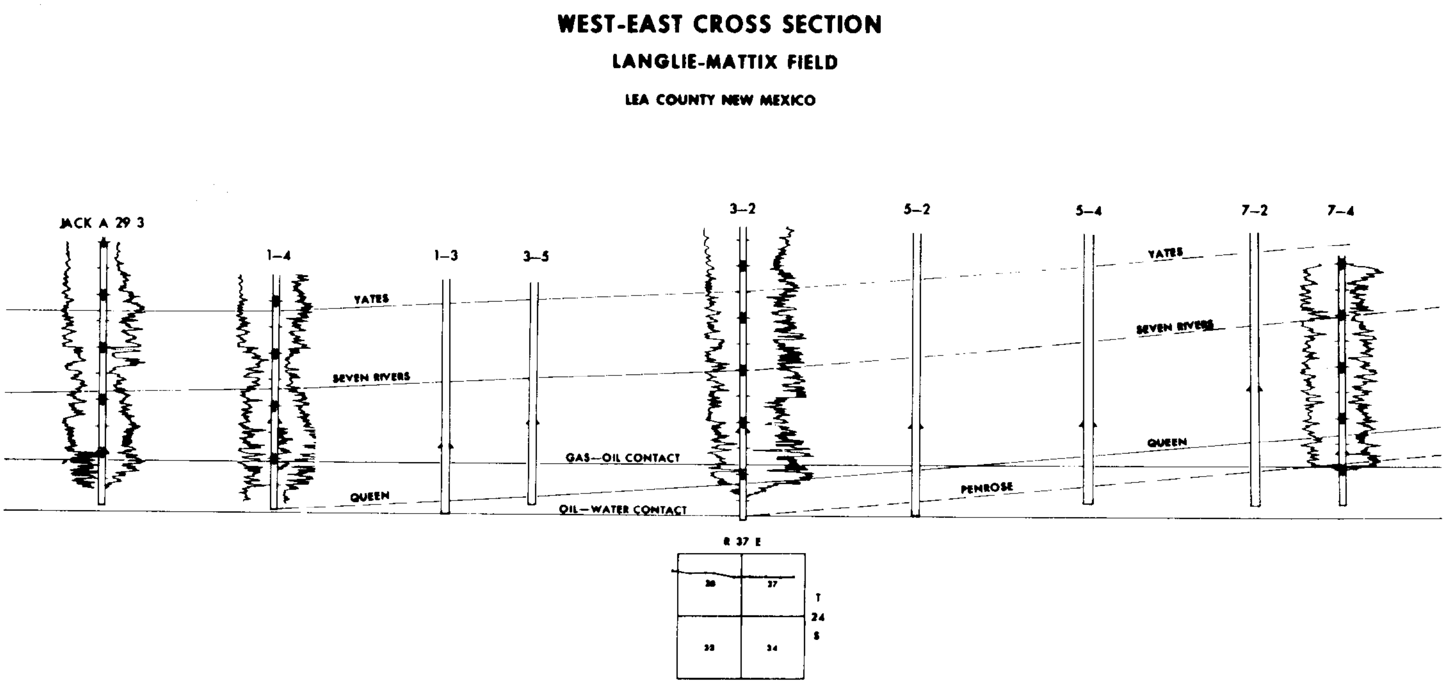

FIGURE 3

West-East Cross Section, Langlie Mattix Field, Lea County, New Mexico.

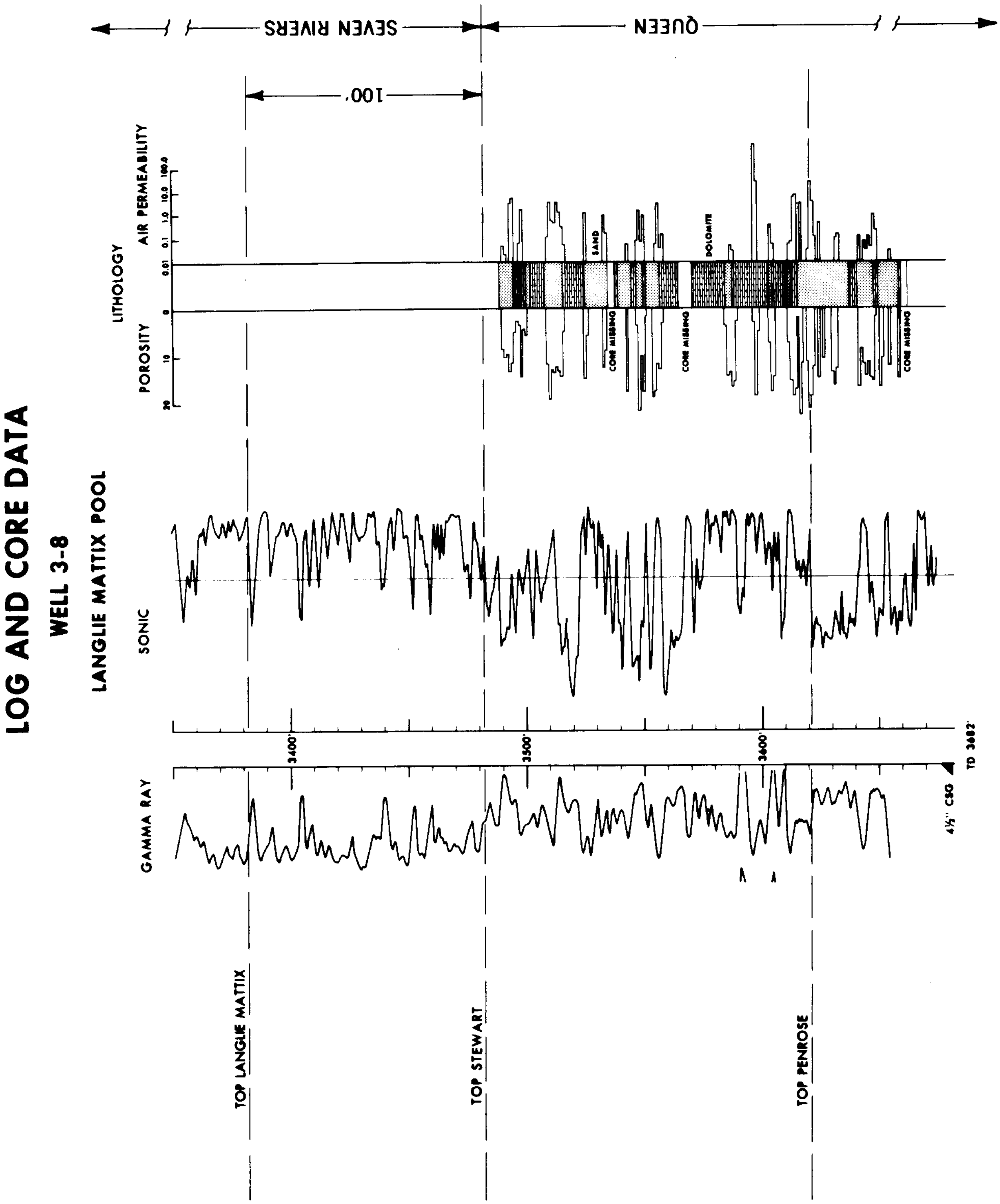

FIGURE 4

Log and Core Data, Well 3-8, Langlie Mattix Pool.

EAST - WEST LOG CROSS SECTION
LANGLIE MATTIX WOOLWORTH UNIT
LEA COUNTY, NEW MEXICO

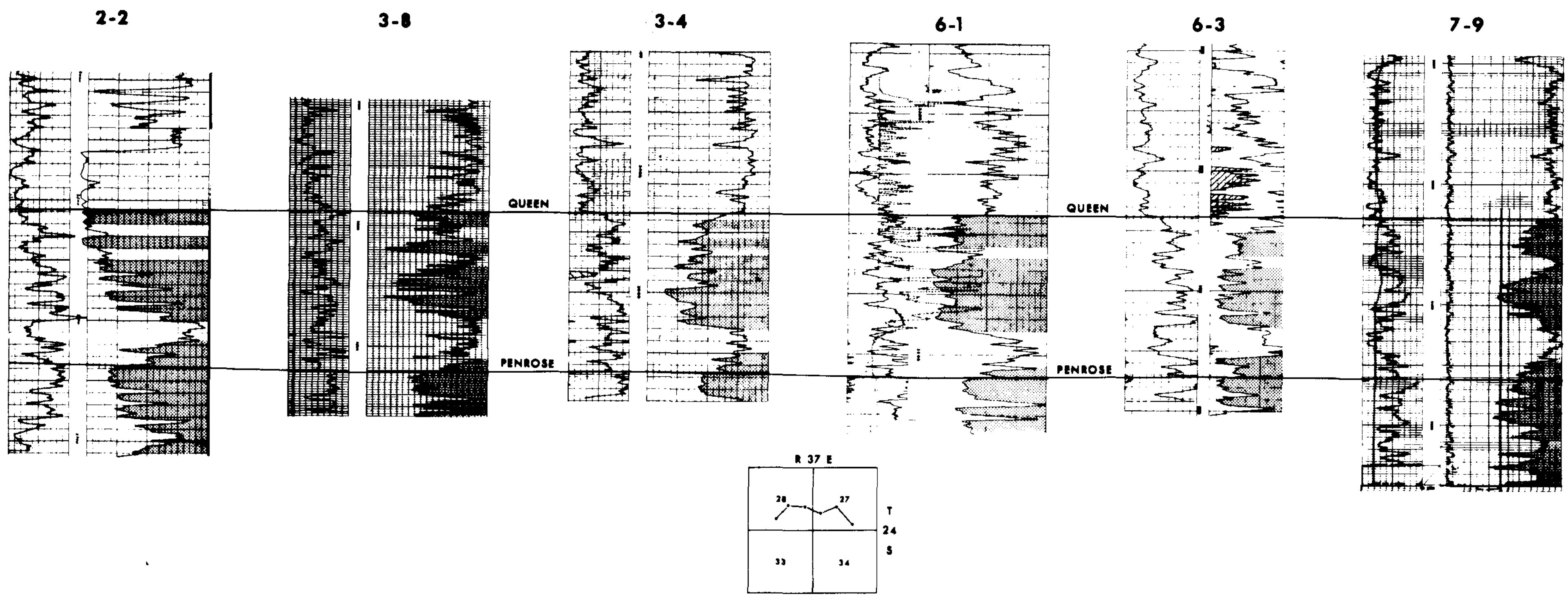

FIGURE 5

East-West Log Cross Section, Langlie Mattix Woolworth Unit, Lea County, New Mexico.

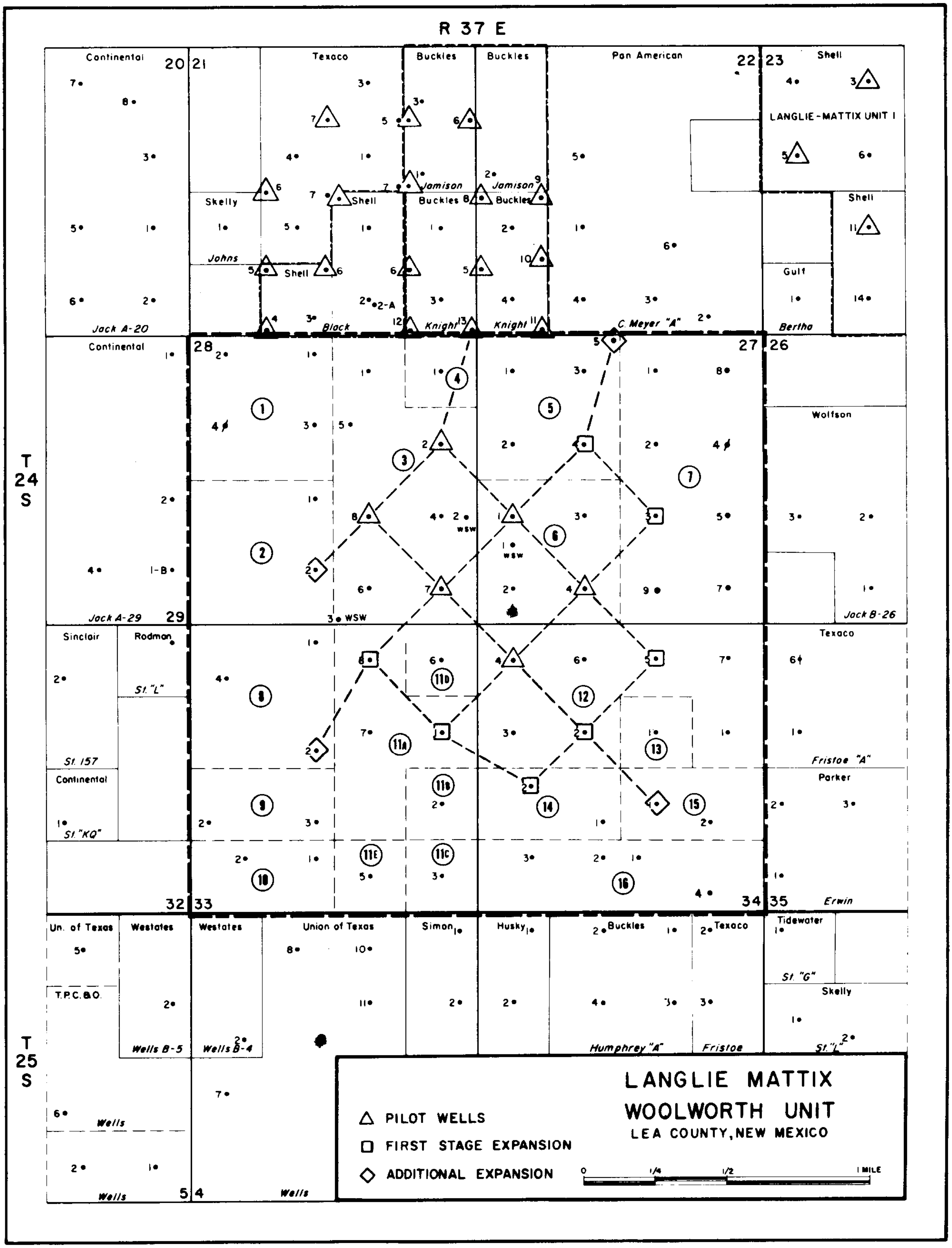

FIGURE 6

Langlie Mattix Woolworth Unit, Lea County, New Mexico.

An Engineering Committee was formed to develop unitization parameters and a plan of operation. It is interesting to note that the Engineering Committee was requested to provide specific information on surface acres, usable wells, current production, and cumulative production as parameters for unitization. These parameters involve little interpretation and thus, in themselves, are not controversial.

The engineering report was finished in September 1957, but since current production was chosen as a parameter, some of the operators sand-fraced their wells to gain an advantage. This forced all operators to do the same and thereby delayed unitization for at least three years or possibly longer. The effects of these treatments may be seen in Fig. 7.

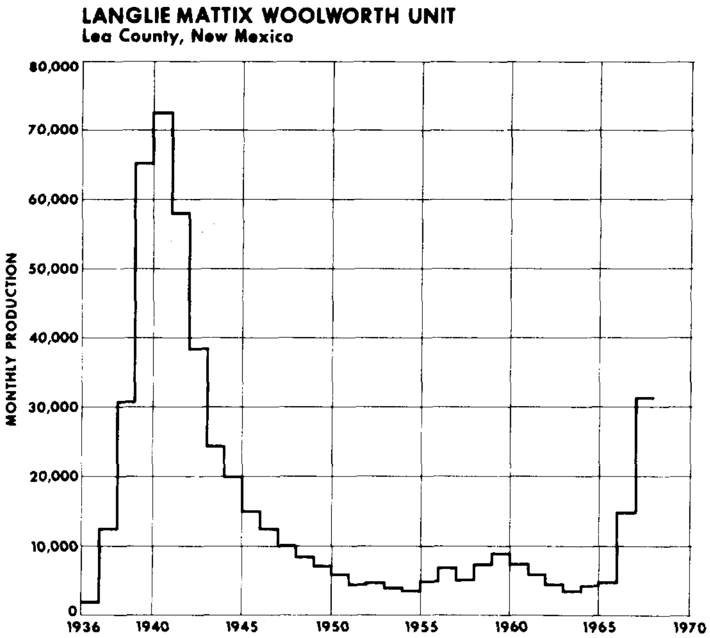

FIGURE 7

Monthly Production vs. Time, Langlie Mattix Woolworth Unit, Lea County, New Mexico, Effects of Sand-Frac Treatments.

The unit was finally formed and became effective in October 1962. A two-phase formula was selected. Phase I was based on 50 per cent current oil production, 25 per cent surface acres, and 25 per cent usable wells and was in effect until 250,000 barrels of oil had been produced after January 1, 1961. Phase II gives equal credit to acreage, usable wells and cumulative production, and will be in effect for the remainder of the operation.

The Oil Conservation Commission granted permission to conduct waterflood operations under Statewide Rule 701, which allows for expansion only after response had been noted adjacent to the wells proposed for injection.

OPERATIONS AND PERFORMANCE

Initial

At the effective date of the unit, practically all wells were at or near the economic limit. Of the 56 unit wells, 30 were pumping, 13 were produced by gas-lift, 1 was flowing, and 12 were temporarily abandoned. Oil production from these wells amounted to 142 BPD, or an average of 3 BPD per well. Average gas-oil ratio was near 8000 cu ft per bbl. At that time, cumulative production from the unit area was 5.5 million bbls out of the 59.9 million bbls produced from the field. This was a recovery of approximately 2140 bbls per acre from the unit area.

The first operational step was to evaluate each well and close in those which were at or below the economic limit. Pumping units and associated equipment were moved from the closed-in wells to the better gas-lift wells and the gas-lift system was gradually phased out. Obsolete pumping units were abandoned and the remaining equipment was moved to the better wells. As a result, very few wells other than those in or adjacent to the pilot area were left on production. This procedure lowered daily unit production only a small amount while substantially reducing lifting costs.

Due to the uncertainty as to whether or not the Langlie Mattix interval would respond to water injection, it was agreed by the operators that a minimum amount of money should be spent. Therefore, no new equipment for w ll tests or other data-gathering purposes was p *chased. Most of the old tank batteries were not equipped for selective well testing, so to test a* particular well, other wells had to be closed in. This made individual production tests difficult to obtain, and consequently, there was a minimum of good data.

By May 1, 1963, when injection began, 21 wells were closed-in. The remaining wells produced a total of 125 bbls oil and 26 bbls water per day. GOR was 6338 cu ft per bbl.

Pilot

Six wells, forming two adjacent 80-acre normal 5-spots, were chosen for pilot injection. These were wells 3-2, 6-1, 6-4, 12-4, 3-7, and 3-8, with the latter being drilled for this purpose, as shown in Fig. 6. At that time, the producing rates of the two center wells, 3-4 and 6-2, were 1 and 4 BOPD, respectively.

Initial injection rates amounted to 300 BPD per well. All wells took water on vacuum except 3-8 which required 475 psig. This newly drilled well had injection through casing perforations, whereas the other injection wells were depleted oil wells with open holes shot with nitroglycerine.

Since some of the injection wells had casing set above the unitized interval, the Oil Conservation Commission required tracer surveys be run, and if necessary, packers set to prevent entry of water into the Jalmat zone.

An attempt was made to evaluate the injection intervals by the use of a standard bottomhole temperature survey. Surveys were taken as soon as the injection was stopped and additional surveys were run for as long as 48 hours thereafter. Since formation temperature was approximately 82° F, and the supply water was approximately 78° F, temperature surveys did not define zones of water entry. This method was abandoned in favor of regular radioactive tracer surveys which provided much better data. Surprisingly enough, the injection profiles were very good with each major zone taking some water.

After a few months injection rates were increased to 500 BPD per well. All wells except 3-8 continued to take water on vacuum until late 1964 when well 6-4 began pressuring up. The last well began to pressure up in September 1967. *Present injection pressures range from 740 to 1000 psig.*

Initial oil response occurred some seven months after first water injection. At that time, well 2-2 increased from 4 to 31 BOPD and later to near 100 BOPD. This proved to be short-lived, however, as the well soon began to produce large volumes of water. Since well 2-2 was the west offset to injection well 3-8, injection into 3-8 was restricted and immediately water and oil production dropped in 2-2. Injection profiles were run in well 3-8 in an attempt to locate the offending layer or layers. Nothing conclusive was established so normal operation was resumed.

After approximately two years of pilot water injection, well 2-2 was all but watered out. Significant response was occurring in the center producers and in other nearby wells, however. Lifting problems which either preceded or were associated with this response included the following:

1. Due to the extremely low BHP, sand constantly caved into the well bores causing a severe problem with fill. Wells had to be cleaned out often in order for response, if any, to be recognized.
2. This need to recognize response made it also necessary to keep all wells pumping off at all times. This naturally caused excessive rod breaks. A regular program of dynamometer and well sounder tests was initiated.
3. Just prior to oil response, each well produced a mixture of thick oily sand and drilling mud which would plug pump intakes and cut plungers in the downhole pumps. Several pulling jobs in a period of two weeks were necessary before each well would return to clean oil production. After this situation would clear up, the wells would increase in oil production very rapidly. The appearance of this sludge, therefore, is a significant indicator of response in this project.

Response In The Pilot Area

Performance graphs of the two center producers, 3-4 and 6-2, are shown in Fig. 8. As stated above, the average daily oil rates for these wells prior to water injection were 1 and 4 BPD, respectively. These rates continued for about two years before moderate increases were noted. Large increases followed and the rates eventually exceeded 350 BPD per well which, with the produced water, was about the capacity of the lift equipment.

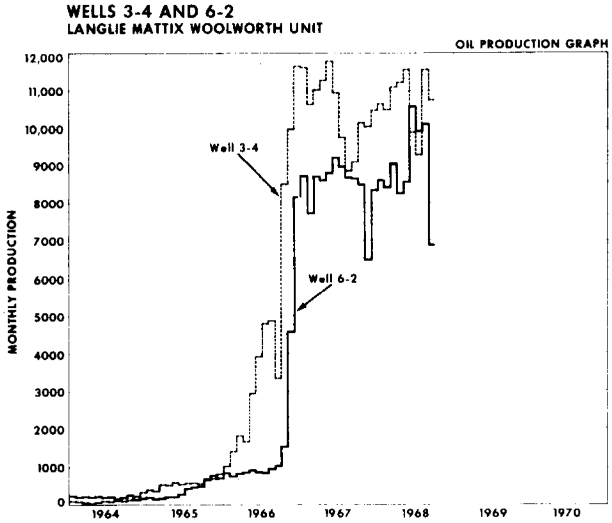

FIGURE 8

Oil Production vs. Time, Wells 3-4 and 6-2, Langlie Mattix Woolworth Unit, Lea County, New Mexico, Oil Rate Performance.

Cumulative production from these two wells since start of water injection has amounted to 517,000 bbls (3230 bbls per acre). This may be compared to the estimated cumulative of 430,000 bbls (2690 bbls per acre), before water injection, from the area outlined by the original 5-spots.

Water production, as yet, has not become excessive. This is illustrated in Fig. 9, which shows per cent oil in the total well stream versus cumulative oil for each well. As shown here, there is no trend to the data by which ultimate recovery from the two pilot wells can be projected. Recovery and performance of the pilot, however, have confirmed the floodability of the reservoir in this area.

In addition to the response discussed above, all wells immediately adjacent to the 5-spots had substantial increases in production. Well 11-6, for

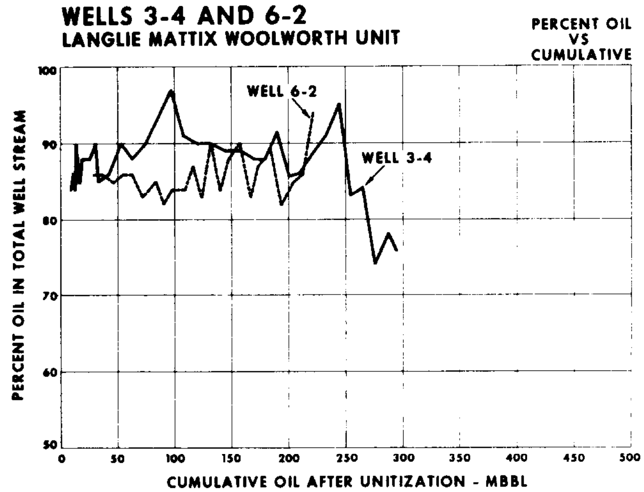

FIGURE 9

Percent Oil in Total Well Stream vs. Cumulative Oil Production after Unitization, Wells 3-4 and 6-2, Langlie Mattix Woolworth Unit, Lea County, New Mexico.

example, increased from 3 BOPD to 50 BOPD as a result of injection into the pilot wells.

A summary of unit performance including results of the expansion, to be discussed below, is shown in Fig. 10. This is a performance graph of the unit illustrating the following:

(1) A sharp decline in GOR.
(2) Two significant increases in oil production.
(3) The absence of large quantities of water production to date.

The unit area produced, during September 1968, a total of 45,568 bbls oil for a daily average of 1518 bbls as compared to 142 bbls at the date of unitization. Cumulative oil production from the unit after unitization was 1,062,684 bbls as of October 1, 1968. At that time, with expansion still incomplete, production was being obtained from 13 wells.

Well 11-6, mentioned above, is now the center well in a recently enclosed 5-spot, and production from this well has increased further from 50 BOPD to in excess of 300 BOPD as a result of adding back-up wells. This recent increase demonstrates the importance of back-up injection.

Expansion

Oil Conservation Commission Rule 701 states that after response in a well outside the original 5-spot, it may be enclosed in a 5-spot by adding additional injection wells. Since all the wells outside the original pilot area were responding, plans were begun to add a new row of injection wells. This would include seven wells and would enclose four more 5-spots. At this point, a problem of ownership of water supply was encountered. This problem was resolved in approximately two years and plans for expansion were resumed.

Early in the planning period, the question of deepening arose. An examination of existing log and core data indicated that most of the porosity in the Penrose section occurred in the top 50 ft. For this reason, the decision was made to insure that all wells penetrated at least this much Penrose. The first few wells were to be deepened by coring, then logged and stimulated. All wells, both injection and producing, were to be completed in the same sections. After the first few wells were cored and it was established that the porous intervals were fairly uniform, other wells were deepened and logged only.

Since all wells near the center of the unit and near the pilot injection wells had the porous zones in the upper part of the Penrose, it was decided to deepen a well on the west side of the

PERFORMANCE GRAPH

LANGLIE MATTIX WOOLWORTH UNIT

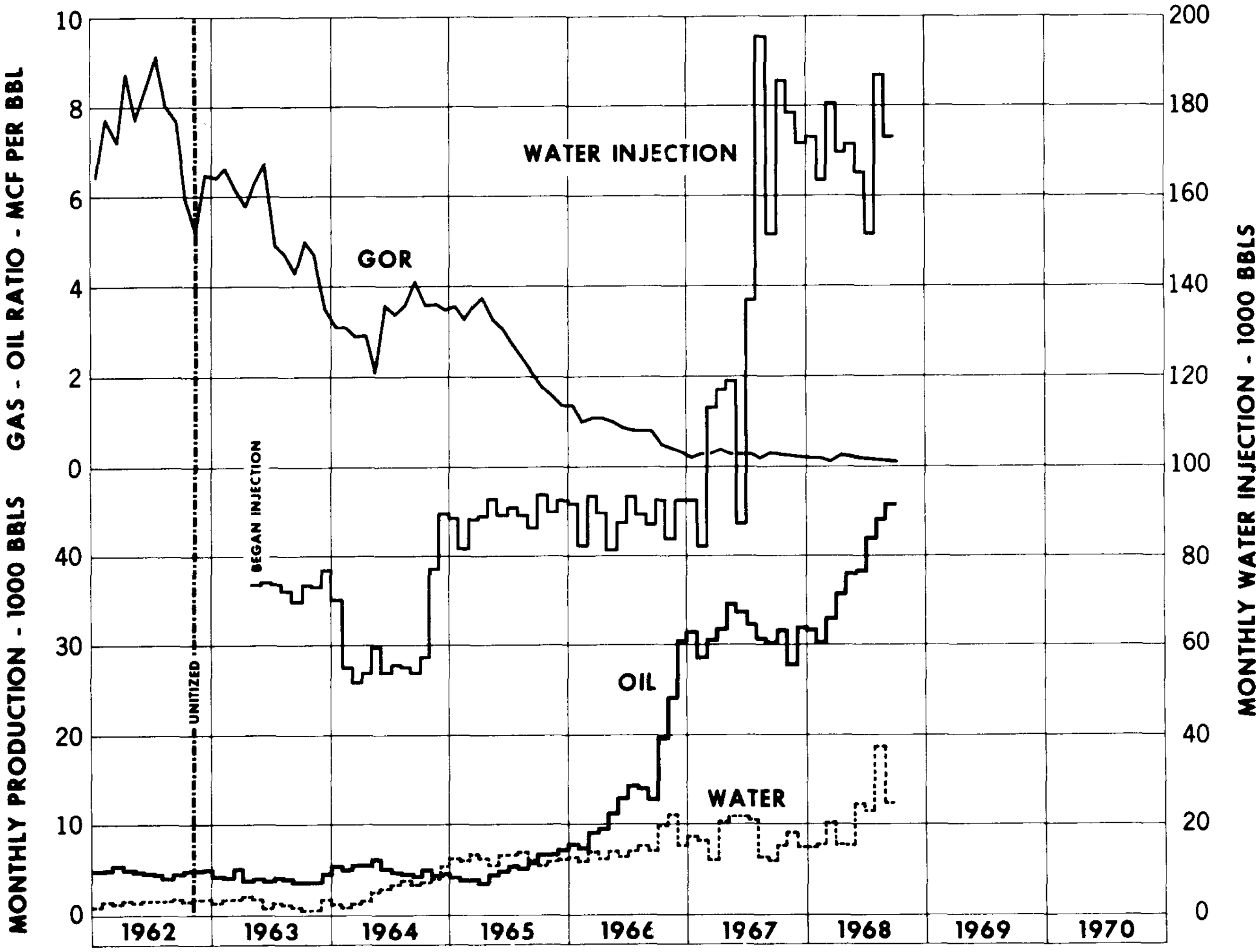

FIGURE 10

Performance Graph, Langlie Mattix Woolworth Unit, Lea County, New Mexico.

unit to evaluate these zones. Well 8-4 was deepened by coring and was logged. It confirmed that the upper part of the Penrose was oil-saturated but tight. Since the well was a future injection well, it was not fraced; therefore, it has produced very little from the new zones. Had it been fraced or shot with nitroglycerin, it might have produced some primary oil. At least it did show the need for additional development on the west side, and several new wells are planned to accomplish this.

After floodability was assured, authorization for larger and more efficient equipment was obtained. Larger pumping units were installed on the two pilot producers. Other wells will also be converted as the capacity of present equipment is exceeded. Dynamometer and well sounder surveys are being continued in order to recognize the earliest need for these changes.

It was determined also that consolidation of batteries and electrification of the system could be justified. A central battery and satellite staions have been installed. The satellite stations consist of separators and liquid meters for well testing, with the data being relayed to the central battery by cables. The central battery contains storage vessels and a LACT unit. These facilities have not only saved money in repairs and labor, but have made available reliable data for use in observing and controlling the performance of the reservoir.

Water Supply Source

Original plans were to use San Andres water as the supply source. In drilling the initial water supply well, however, a thick section of water-bearing Santa Rosa formation was encountered. Since San Andres water is normally corrosive, and Santa Rosa water is normally fresh in this area, it was decided to use the latter if capacity and volumes were adequate. Three wells were drilled and tested, and samples of the water were analyzed. The water was found to be noncorrosive and showed no tendencies to cause formation swelling. Since some of the supply wells produced sand, settling tanks were required. Tests indicated these wells would furnish sufficient water for the pilot operation but would be inadequate for the full-scale flood.

To supplement the above water, an agreement was reached with El Paso Natural Gas Co. to purchase approximately 4000 BPD cooling tower drawoff water from two gasoline plants in the area. Since this water was to be picked up from open pits, it required treatment for removal of oxygen, bacteria, suspended solids, and chemicals added at the plant.

In addition to these two sources, water produced with oil production is being injected. This water is mostly Santa Rosa, since very little true formation water is produced.

Many tests on these waters were run in an attempt to determine the proper way for them to be handled. No concrete conclusion could be reached, so it was decided to mix all the water in a common tank, allow the mixture to settle in another tank then go through the injection pump. This mixture is being monitored at several points before and after being pressured and is being treated for scale and corrosion accordingly.

It is questionable whether or not these supply sources will adequately supply the flood through its peak requirements, and in this event, still another source will be needed.

CONCLUSIONS

1. Lacking adequate reservoir information, the pilot program has successfully provided evaluation of the uncertainties facing the operators prior to unitization.
2. The Langlie Mattix interval in this area can be successfully waterflooded. Secondary oil production from this interval will be more than the often referred to 1 to 1 ratio of secondary to primary recovery.
3. The early date completions, which were made without any thought of secondary recovery, have presented problems but have not prevented a successful operation.
4. Santa Rosa water in this area has usable quality, but volumes are not sufficient for large projects.

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