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FOSSIL ENERGY

COMMERCIAL SCALE DEMONSTRATION, ENHANCED OIL RECOVERY BY MICELLAR-POLYMER FLOODING

Initial Report, October—December 1976

January 1977

Work Performed Under Contract EY-77-C-02-4208

Marathon Oil Company
Findlay, Ohio

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

MASTER

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Initial Report for the
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Under Contract No. E(49-18)-2242

PREPARED FOR
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

MASTER

MARATHON OIL COMPANY
Findlay, Ohio 45840

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ABSTRACT

A contract was executed between The United States Energy Research and Development Administration and Marathon Oil Company, Findlay, Ohio, on September 30, 1976, for the purpose of a commercial scale test of enhanced oil recovery by the Maraflood™ process.

This commercial scale test will be known as the M-1 Project; it is located within Sections 15, 16, 21, and 22, T6N, R13W, Crawford County, Illinois. The M-1 Project area encompasses approximately 407 acres of Robinson Sand reservoir developed in the first decade of the century. The area covers portions of several waterfloods that were developed on 10-acre spacing in the 1950's and are now approaching their economic limit.

The Robinson Sand reservoir is a stream channel sandstone deposition of Pennsylvanian Age at a depth of approximately 950'. Extensive reservoir studies of this area were conducted during 1974 to define the area and to determine flooding patterns to be developed in order to conduct the enhanced recovery project. Ultimately, a five-spot pattern configuration was selected with patterns of 2.5-acre spacing and 5.0-acre spacing to be developed in order to better analyze system performance and economics.

The M-1 Project area is shown in Figure 1. Development was initiated during October, 1974, with a total of 245 wells being prepared for utilization. The 2.5-acre spacing area covers approximately 248 acres and contains 176 wells, while the 5.0-acre spacing area covers approximately 159 acres and contains 69 wells. In both spacing patterns a typical well was completed by setting surface casing at a depth of approximately 150' and cementing it to surface. A 4-1/2" OD long string was then set at the top of the Robinson Sand section and cemented to surface. The open hole Robinson Sand interval was shot with a solid explosive.

This report covers the interim from contract execution, September 30, 1976, through December 31, 1976. Limited additional information and data obtained prior to September 30, 1976, are also included in this first report to add continuity. These additional data will also be reported in detail within the reservoir engineering portion of a special Design Report, to be submitted to ERDA on or before April 1, 1977. Details of all project facilities will be reported in a special Facilities Report, also to be submitted by April 1, 1977.

Within this initial technical report will be found information under WBS No. 1100 (Site Evaluation) dealing with an analysis of a lower sand stringer, injectivity testing, a stimulation program for injection wells, and a stimulation program for producing wells. Under WBS No. 2300 (Performance Monitoring) information regarding pressure monitoring and a description of the data processing techniques and equipment that will be utilized to analyze project performance has been discussed. This and future reports will break down all appropriate data according to their application in the 2.5-acre and 5.0-acre spacing patterns.

TM Trademark of Marathon Oil Company, Findlay, Ohio

EVALUATION OF LOWER SAND STRINGER

Introduction

In January, 1976, during the course of reservoir engineering studies conducted in the M-1 Project, the presence of a lower sand stringer was recognized under approximately 55 acres of the A. Riker, Bassom and Siler, and R. A. Siler leases located on the west side of the project (see Figure 2). Since oil saturations determined by available core analyses from this stringer were abnormally low, and since waterflood development had been limited in the area, it was hypothesized that a saturation problem existed that would make process application uneconomic in the area.

In order to evaluate this area the following work was accomplished:

1. Transient tests were run on four injection wells and their surrounding producers.

2. Three core tests were drilled, analyzed and logged.

3. Maraflood process performance in the subject reservoir area was simulated by computer.

4. Actual oil well production tests were taken during water injection.

A detailed analysis of this program will be presented in the Design Report to be submitted to ERDA by April 1, 1977.

Transient Testing

Interference testing was accomplished during March, 1976, at four locations within the area of concern. The tests were conducted by injecting water into the injection well and observing the fluid buildup in the offset production wells. Analysis of the pressure data was accomplished through conventional techniques, whereby calculated values of reservoir properties are obtained which best explain observed transient test data. Results of this testing are summarized below and detailed in Table 1.

Test Area	Mobility K/μ, md/cp	Storage ϕc, psi^{-1}
SS-3	5	6×10^{-7}
Q-3	21	6×10^{-6}
U-5	6	1×10^{-6}
S-7	12	1×10^{-6}

The data reported for SS-3 are of questionable quality due to erratic injection rates into SS-3 and the corresponding low level of response in the observation wells. The data from Q-3, U-5, and S-7 appear to be of reasonable quality and are in agreement with other data from this area. Storage factors (Øc) indicate little or no free gas saturation.

Core Tests

Three core tests were drilled within the area of concern during April, 1976, to permit definition of the lower sand stringer, which heretofore had only been defined by control from gamma-ray logs. Qualitative results of the core test program are presented below with the detailed information presented in attached Tables 2, 3, and 4.

Test	Sands Present	Permeability	Oil Saturation
CT-1	Main	Low	Good
	Lower	Low	Good
CT-2	Main	Good	Good
	Lower	Fair	Low
CT-3	Main	Good	Good
	(Lower sand not present)		

Analyses of data from the core tests indicate that the boundary between the main and lower sand is generally composed of a zone of interbedded shale and sand about one to three feet thick. This boundary is judged to be impermeable where the interbedding zone exists and where it is not fractured. The data further indicate that the lower sand body has shaled out south of the "R" row of producing wells, eliminating the R. A. Siler lease from any further concern. However, that acreage under the Bassom and Siler lease does contain the lower sand body.

Computer Modeling

During April, 1976, a two-layer conceptual model was used to determine if oil banked in the more permeable, higher oil saturated upper sand stringer would flow down into the lower sand stringer. To approximate the Maraflood process displacement, a stabilized oil bank was simulated at the injection well by simultaneously injecting oil and water into the upper sand only. At breakthrough of the stabilized oil bank at the producing well, model predictions for oil saturations, pressures, and oil migration were monitored. Effects of vertical permeability between the two layers, injection rate, oil cut of injection fluid and capillary pressure were also observed.

The modeling work indicates that banked oil, and probably injected slug and/or polymer, will migrate to the lower sand stringer. Since the Maraflood displacement process was not precisely simulated by this work, it is not known whether the migrating oil will be recovered within the time frame of field operations.

Production Tests

Water injection was begun into all injection wells on the 55-acre area during April, 1976, at 5 barrels per day per net foot of sand (B/D/NF) at maximum 600 psi injection plant pressure. The oil wells were also started at this time. After approximately one week of operation, oil well testing commenced and was continued until the completion of the 55-acre test. Production tests for the oil wells within the contested area are shown in Table 6. Well T-2 was not completed at this time and no test is shown. Of particular note is well RR-4 with a 95% oil cut and wells L-6 and V-2 which produced only "traces" of oil. Both upper and lower sand zones were open during the testing.

The production tests gave an indication of the presence of oil saturation at each oil well location. Detailed information regarding this test program will be included in the Design Report to be submitted to ERDA by April 1, 1977.

Conclusions

Based on analysis of the core data, interference testing, computer modeling and actual oil well production, the following conclusions were drawn:

1. Fifteen producing wells and twelve injection wells located on the Bassom and Siler lease should be plugged back to prevent loss of fluids to the lower sand zone.

2. The main sand zone underlying the 55-acre area investigated should be included in the project.

A plugback program for the lower sand zone in 27 wells on the Bassom and Siler lease was initiated during late September, 1976, and completed in early December, 1976. Affected wells are listed in Table 5. This work was accomplished by filling the wellbore with sand to within two feet of the base of the main sand body. In order to eliminate sand problems in the producing wells, a tamped lead wool seal was placed on top of the sand plug.

INJECTIVITY TESTING

Introduction

During the course of development of the M-1 Project reservoir, it became evident that adverse wellbore and/or reservoir conditions could possibly present difficulties in the injection of Maraflood process fluids into the reservoir. In order to identify and correct any injectivity problems that might exist prior to slug injection, a program of injection well and oil well testing was initiated in the entire project area.

Discussion

In order to facilitate operations and data collection, the M-1 Project acreage was divided into four test segments. Refer to Figure 3 for a map of these

segments. Segments 1, 2, and 3 encompass the 2.5-acre spacing area, while Segment 4 includes the entire 5.0-acre portion of the project.

During the injectivity tests in each segment, the desired injection rate of filtered water was 5 B/D/NF at a maximum injection plant pressure of 600 psig. All oil wells in a segment were operational during the segment test.

With data gathered from the injectivity testing program, it was judged that any well accepting less than 4.0 B/D/NF was substandard and should be considered for stimulation. The data presented below summarize the results of the injection well performance tests within both the 2.5-acre and 5.0-acre spacing areas. Tables 7 and 8 summarize injection rates for the injection wells during the segment tests.

Summary of Injection Well Performance

	Injection Rate Range (B/D/NF)				
No. of Wells	0-1.0	1.0-2.0	2.0-3.0	3.0-4.0	Greater than 4.0
2.5-Acre					
Segment 1	3	1	4	8	19
Segment 2	14	6	3	2	7
Segment 3	0	0	0	1	16
5.0-Acre					
Segment 4	14	0	2	3	10
Total	31	7	9	14	52

As a result of the injectivity testing program, 61 injection wells were classified as substandard performers. A program of stimulation was outlined for the injection wells to be completed prior to slug injection. The oil wells will be stimulated in the future after further evaluation, since results from the initial testing were not definitive due to the many substandard injectors.

INJECTION WELL STIMULATION PROGRAM

Introduction

As a result of the previously mentioned injectivity program and subsequent evaluation, fifty-nine wells were stimulated. This stimulation program was initiated August 25, 1976. Fifty-six substandard injection wells were hydraulically fractured and three wells were acidized. Initial fracture treatment design was based on a maximum radius of fracture of 35' to minimize the possibility of reduced sweep efficiency. Utilizing this preselected fracture radius and core data, computerized treatment programs were requested from service companies. Two procedures were selected. One procedure was for a normal fracturing treatment in this area using a 35 cp viscosity gelled water with 20/40 mesh sand as the propping agent and 10/20 mesh sand as a tail-in. The second procedure utilized a cross-linked polymer to gell the water to approximately 2200 cp. Initially 8/12 mesh sand was used as the propping

agent; however, this was reduced to 10/20 mesh sand to prevent screen-outs. Treating volumes were altered on each well in relation to reservoir sand thickness and open hole diameter.

Following fracturing treatment, each well was placed on injection until a stabilized rate was achieved. Observation of the injection behavior showed some wells treated with low viscosity fluid had a greater decline before stabilizing than those treated with higher viscosity fluid. This, plus the high instantaneous shut-in pressures, suggested limited vertical height of the fracture or horizontal fractures. Three radioactive tracer surveys were run on wells treated with low viscosity fluids. The surveys indicated limited zone treatment. Due to this fact, and indications from service companies' laboratory data that high viscosity fracturing fluids offer a better chance for vertical fracturing, it was decided to treat the remaining wells with high viscosity fluid. Following this decision, radioactive beads were added to the treatment. Survey results showed a high percentage of the zone was fractured. Additional surveys are being obtained to determine an average percentage of the zone fractured with each type of treatment. An analysis of this information will be reported in a subsequent report when the work is complete.

Stimulation Results - 2.5-Acre Spacing Pattern

Twenty-four wells were treated using 2200 cp gel and 16 wells were treated using 35 cp gel. (See Tables 9 and 10 for individual well results. Injection potential is based on a maximum surface pressure of 600 psig.)

Stimulation results on the 40 wells treated showed an average injectivity, with filtered water, of 1.65 B/D/NF prior to treatment and a potential injectivity, at 600 psig surface pressure, of 6.73 B/D/NF after treatment. The following is a summary of present injectivity potential:

Number of Wells	Well Potential, B/D/NF
11	Greater than 10.0
1	8.0 to 10.0
12	6.0 to 8.0
10	4.0 to 6.0
6	Less than 4.0

Six wells remained substandard following hydraulic fracturing treatments. Due to the presence of clay in the reservoir, which is soluble in hydrofluoric (HF) acid, four of these six substandard wells fractured were stimulated using an atomized HF acid treatment. Nitrogen was used as the atomizing agent as well as displacing fluid.

The data presented below compare the injectivity potential, at 600 psig surface pressure, of these wells before and after the atomized acid treatments.

Well	Previous Treatment	Injection Rate, B/D/NF Prior	Injection Rate, B/D/NF Current
W-3	Shot/Frac.	0	7.8
A-11	Shot/Frac.	0	3.9
C-5	Shot/Frac.	0	3.7
C-7	Shot/Frac.	0	0

Stimulation Results - 5.0-Acre Spacing Pattern

Thirteen wells were treated using the 2200 cp gel and three wells were treated using the 35 cp gel. (See Table 11 for individual well results.) Treatment volumes were increased in the 5.0-acre area to achieve a fracture radius of 49'. That radius is comparable to a 35' radius in a 2.5-acre spaced well when considering the ratio of radius of fracture to distance between unlike wells.

Stimulation results on the 16 wells treated showed an average injectivity, with filtered water, of 0.88 B/D/NF prior to treatment and a potential injectivity, at 600 psig surface pressure, of 7.74 B/D/NF after treatment. The following is a summary of present injectivity potential:

Number of Wells	Well Potential, B/D/NF
5	Greater than 10.0
4	8.0 to 10.0
3	6.0 to 8.0
3	4.0 to 6.0
1	Less than 4.0

Three wells were stimulated using atomized HF acid treatments with nitrogen as the atomizing agent. The data presented below compare the injectivity potential at 600 psig surface pressure of these wells before and after atomized acid treatment.

Well	Previous Treatment	Injection Rate, B/D/NF Prior	Injection Rate, B/D/NF Current
SS-7	None	2.7	5.0
QQ-15	Shot	0	8.0
GG-17	Shot	2.4	7.8

Work in Progress

In order to evaluate the effect of hydraulic fracturing, a transient test program is underway to determine skin factor and transmissibility data before and after the treatments. Seven of ten wells have now been surveyed. Results of this program will be reported upon completion.

A radioactive tracer survey program is also underway to determine the affected interval of the hydraulically fractured wells. Forty-three of the fifty-five wells in this program have now been surveyed. To date, no tracers have shown fluid entering any zone other than the Robinson Sand reservoir. Results of this program will also be reported in detail upon completion.

POLYMER INJECTIVITY TESTING PROGRAM

Introduction

A program was conducted during the interim November 4, 1976, through December 10, 1976, to determine the injectivity of Dow 700 and Dow 500 series PUSHER™ polymers.

Discussion

This program consisted of injecting 1100 ppm Dow 500 polymer into four wells, and 1100 ppm Dow 700 polymer into another four wells. Phase 1 of the program utilized four wells that had previously been injectivity tested with micellar solution. Phase 2 of the program utilized four wells previously untested. Micellar solution manufactured in a pilot plant at Marathon's Denver Research Center was injected and followed by polymer.

All wells in the program were selected so that permeability and completion procedure were as near equivalent as possible. Tracer logs were run in all wells to insure that fluid was being distributed over the entire open hole section. Results of this program are shown in Table 12 and readily indicate that little difference can be seen between the injectivity of Dow 500 and 700 polymers. As a result of this program and laboratory oil displacement data, it was concluded that Dow 700 polymer will be utilized in the M-1 Project.

PRODUCING WELL STIMULATION REQUIREMENTS

A well testing program has been initiated to identify producing wells requiring stimulation. This program was segmented exactly as were the prior segment tests. Testing is currently underway in Segment 2 (2.5-acre spacing) and will follow immediately in Segment 4 (5.0-acre spacing). This program is necessary because results obtained from the original segment tests were clouded by the many poor injectors, thus making the original oil well tests unreliable.

TM -Trademark of The Dow Chemical Company, Midland, Michigan

PRESSURE MONITORING

Twelve wells have been selected for pressure monitoring in accordance with contract requirements. Six injection wells (C-3, I-7, O-13, S-7, GG-13, and QQ-13) will be monitored quarterly and six producing wells (D-4, H-8, P-12, T-8, HH-12, and PP-12) will be monitored annually.

These wells were selected utilizing the following criteria:

1. Good geologic distribution in both spacing patterns.
2. A wide distribution of isogeometric permeability.
3. Both new wells and conversions to be represented.
4. Wells to encompass a range of prior stimulation techniques.
5. Wells to encompass a wide range of injectivities.

Transient testing of these wells has been initiated and is scheduled for completion prior to startup of micellar solution injection.

DATA PROCESSING AND ANALYSIS

A Datapoint 1100 (Model 1133) computer terminal is located in the Northeastern District Office of Marathon Oil Company and will be utilized to service the requirements of the M-1 Project.

This terminal has considerable data processing and computing capabilities and is also directly linked to Marathon Oil Company's computer facilities in Findlay, Ohio and Littleton, Colorado.

A suite of computer programs, developed for previous Maraflood field projects, will be utilized during the M-1 Project. These programs will be used on a regular basis to monitor and control the injection and production of Maraflood process fluids.

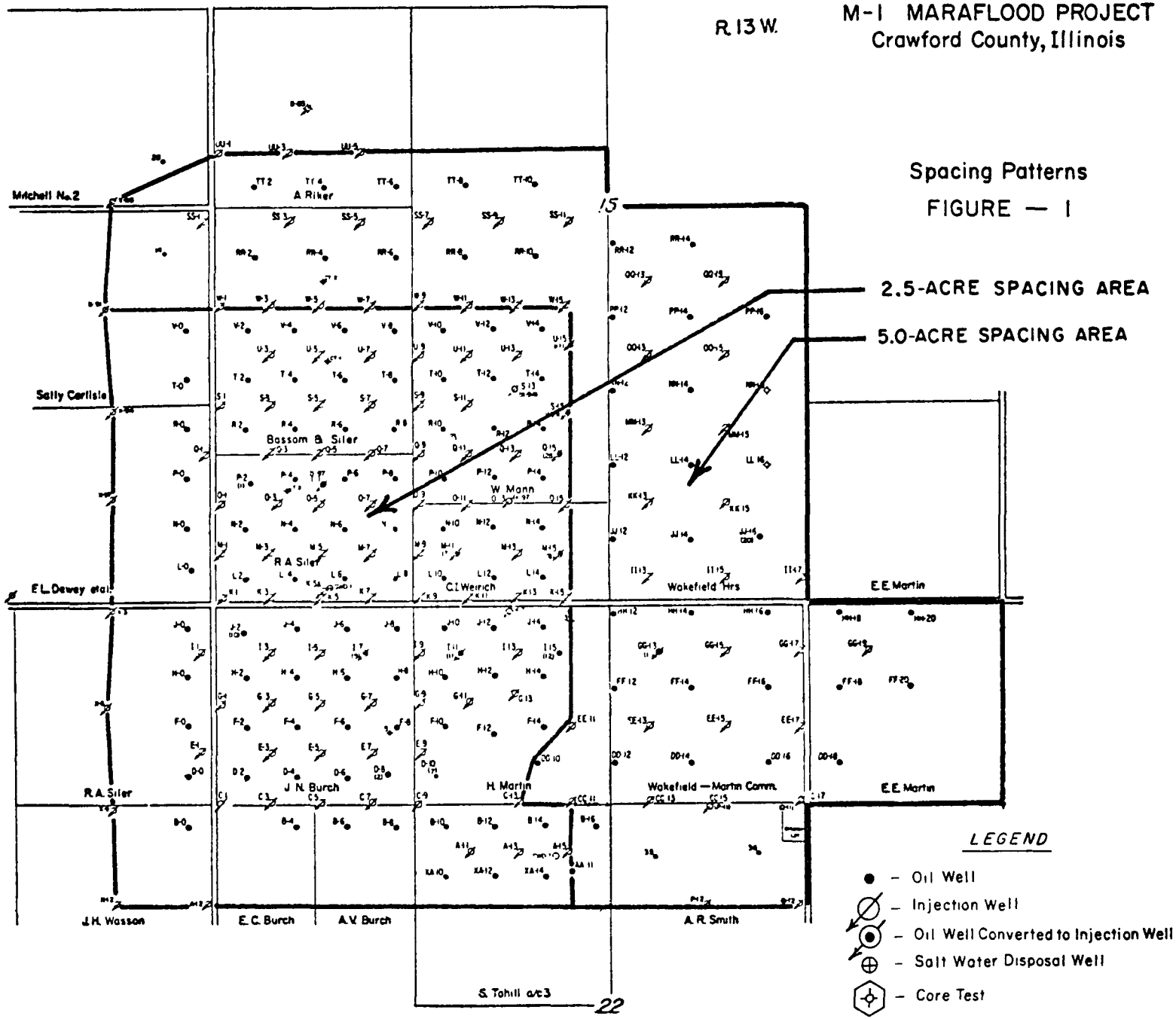
All production, injection, and fluid analysis data from the M-1 Project will be processed through a computer program called PRIDAP (Production-Injection Data Analysis Program). This program facilitates rapid documentation and automatic analysis of single elements and/or groups of data. The program has been made operational for the M-1 Project.

Two other computer programs will provide necessary information regarding injection and production data for inclusion in the monthly technical report. The injection program will provide documentation by well of the monthly injection statistics, cumulative injection statistics, a projection of the desired injection rate, and an analysis of wells deviating from the desired

injection rate. The five-spot analysis program will be used to document production and injection information by individual five-spot pattern on a daily average, monthly, and cumulative basis. It also shows the ratio of produced fluid to injected fluid for each five-spot pattern element.

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
Crawford County, Illinois

Spacing Patterns
FIGURE — 1



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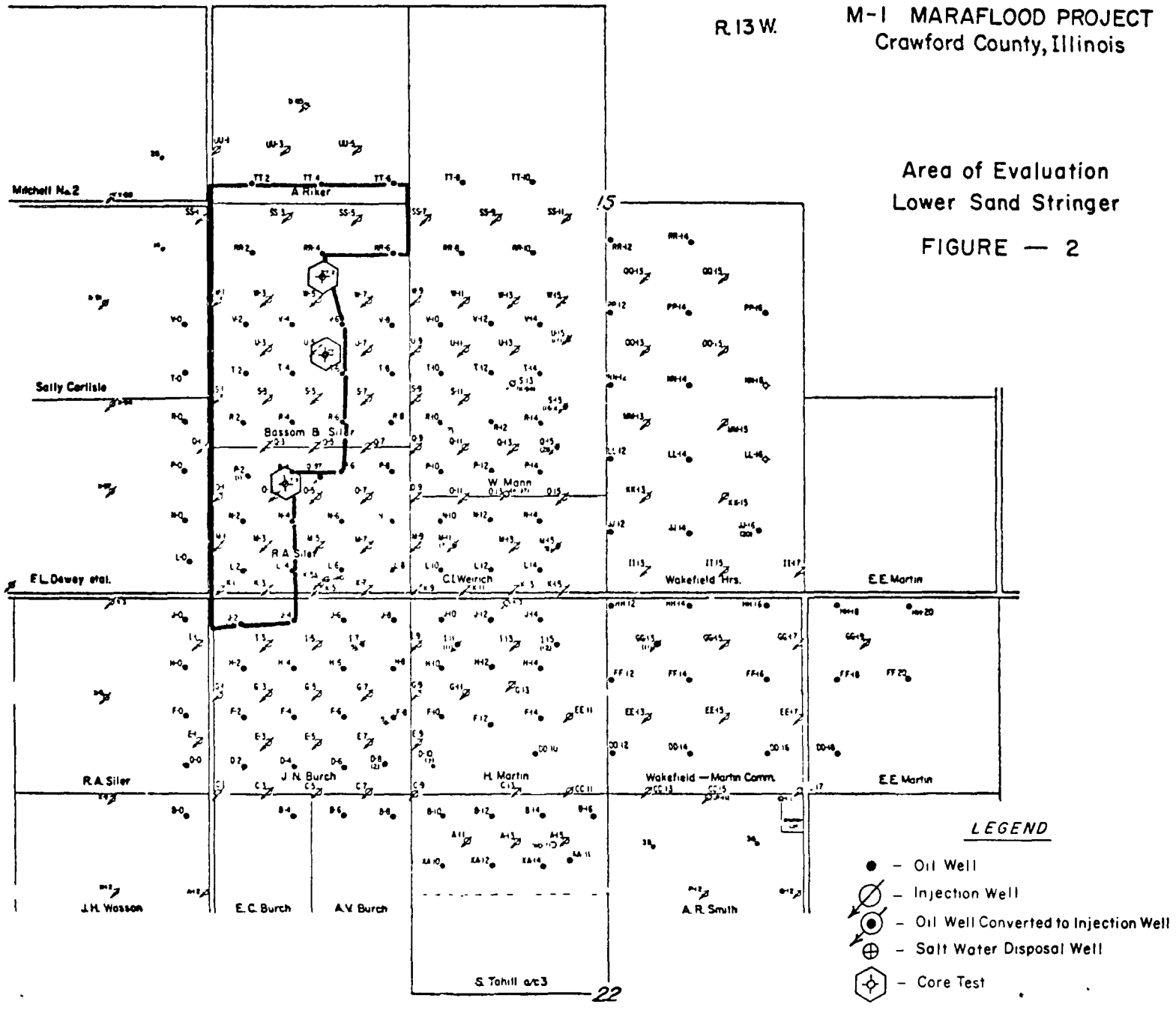
Crawford County, Illinois

Area of Evaluation
Lower Sand Stringer

FIGURE — 2



MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 1

Results of Interference Testing

Well	Mobility k/μ, md/cp.	Storage ϕc, psi^{-1}
U-5 Injector		
V-4	7.41	7.16×10^{-7}
V-6	4.83	10.00×10^{-7}
T-4	9.31	1.20×10^{-6}
T-6	3.59	2.64×10^{-6}
U-5 Group Avg.	5.83	1.34×10^{-6}
Q-3 Injector		
T-4	13.05	2.94×10^{-6}
R-2	30.26	1.54×10^{-5}
R-4	10.52	4.34×10^{-6}
P-2	40.73	2.14×10^{-6}
P-4	25.43	1.43×10^{-5}
Q-3 Group Avg.	20.78	5.77×10^{-6}
SS-3 Injector		
TT-2	3.50	4.49×10^{-7}
RR-2	5.15	2.09×10^{-6}
SS-3 Group Avg.	4.78	6.47×10^{-7}
S-7 Injector		
S-5	10.50	1.24×10^{-6}
R-6	10.57	1.06×10^{-6}
R-8	20.32	9.81×10^{-7}
T-6	7.32	2.03×10^{-6}
T-8	14.76	8.70×10^{-6}
S-7 Group Avg.	12.34	1.66×10^{-6}

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 2

Core Test #1
Bassom & Siler Lease

Depth, ft.	Permeability md.	Helium Porosity, %	Fluid Saturation, % Oil	Water
909.7-.9	2.9	15.0	29.3	30.7
910.2-.3	.87	12.7	31.1	54.3
911-915 Drilled				
915.3-.5	1.6	12.9	36.4	61.2
916.5-.7	24.0	18.3	24.6	59.0
917.5-.7	41.0	18.9	26.5	60.3
918.4-.6	124.0	20.4	34.4	46.6
919.2-.4	21.0	17.8	29.3	48.3
920.3-.6	15.0	18.1	24.8	49.7
921.6-.8	21.0	15.9	30.2	51.6
922.3-.5	29.0	17.5	23.4	56.6
923.2-.5	19.0	16.7	31.6	58.2
924.3-.5	8.1	16.0	27.5	49.4
925.4-.6	9.0	16.2	27.8	50.6
926.3-.5	69.0	20.1	32.9	40.8
927.5-.65	1.6	14.5	33.1	53.1
Averages	25.8	16.8	29.5	51.4
928.5-.7	SHALE			
929.3-.5	4.4	21.5	25.6	44.6
930.3-.6	3.5	18.9	29.1	47.6
931.6-.8	.08	8.8	10.2	90.9
932.7-.9	.56	11.7	28.2	65.8
933.2-.5	31.0	18.1	32.6	37.6
934.5-.7	.03	2.6	0	96.2
935.2-.5	51.0	17.7	28.2	39.0
936.3-.5	.87	12.5	24.0	60.4
937.4-.6	.45	11.8	11.9	60.2
938.7-.8	15.0	16.4	30.5	46.9
939.4-.6	12.0	16.6	30.1	52.4
940.4-.6	57.0	19.3	32.6	38.8
Averages	14.7	14.7	23.6	56.7

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 3

Core Test #2
Bassom & Siler Lease

Depth, ft.	Permeability md.	Helium Porosity, %	Fluid Saturation, % Oil	Water
922.4-.6	.49	12.9	27.9	41.1
924.6-.9	53.0	13.7	35.0	59.1
925.6-.8	81.0	17.4	29.4	57.5
926.5-.7	173.0	20.2	35.2	45.0
927.4-.6	206.0	21.2	37.2	38.2
928.4-.6	140.0	20.1	30.8	41.8
929.5-.7	186.0	20.9	30.6	39.0
930.4-.6	87.0	18.5	26.0	36.8
931.5-.7	44.0	18.0	32.3	39.5
932.1-.4	61.0	18.4	35.9	39.1
933.4-.6	129.0	20.6	21.4	29.6
934.3-.6	2.0	14.2	29.6	52.8
935.4-.6	21.0	18.0	30.9	47.6
936.6-.7	28.0	17.7	32.7	49.6
937.5-.7	95.0	20.2	32.9	36.2
938.3-.6	15.0	16.7	31.1	46.0
939.3-.6	21.0	17.9	28.4	41.9
940.3-.6	17.0	16.9	29.2	46.6
941.3-.5	8.6	16.3	39.2	44.8
Averages	72.0	17.9	31.4	43.8
942.5-.7	1.7	4.3	5.6	100.0
943.3-.6	1.3	15.5	20.2	64.7
944.4-.6	3.5	15.5	25.6	60.0
945.3-.5	9.3	15.3	22.0	58.7
946.5-.8	10.0	23.9	26.3	46.4
947.5-.7	7.2	17.9	21.1	51.5
948.6-.8	6.8	15.7	20.4	56.1
949.3-.6	4.4	14.6	24.0	62.3
950.4-.6	1.2	13.9	26.0	86.5
951.5-.7	.58	12.0	30.1	100.0
953.3-.6	.94	13.1	16.8	74.0
954.2-.4	16.0	14.6	15.1	64.3
955.4-.6	1.6	14.5	17.3	66.2
956.2-.5	.56	11.0	10.0	15.8
957.4-.7	.40	12.7	11.8	59.0
958.4-.6	59.0	19.3	26.4	30.0
959.4-.7	139.0	21.7	16.1	62.3
960.5-.7	131.0	21.1	15.7	66.8
961.6-.7	156.0	22.1	14.0	66.0
962.6-.8	95.0	18.0	18.4	82.7
Averages	32.3	15.8	19.1	67.9

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 4

Core Test #3
R. A. Siler Lease

Depth, ft.	Permeability md.	Helium Porosity, %	Fluid Saturation, % Oil	Water
886.6-.8	52.0	18.5	29.2	48.7
887.5-.8	312.0	22.7	18.7	60.9
888.4-.7	190.0	22.2	22.1	52.2
889.2-.5	154.0	22.4	26.2	29.1
890.2-.5	468.0	24.1	13.3	35.5
891.4-.6	127.0	21.7	21.6	39.2
892.4-.8	157.0	21.7	30.1	38.1
893.2-.5	22.0	17.8	36.1	56.7
894.4-.6	30.0	18.6	26.5	41.2
895.5-.7	49.0	18.8	32.3	43.0
896.6-.9	63.0	19.7	28.9	42.2
897.6-.8	59.0	19.3	42.3	58.7
898.4-.6	65.0	20.2	34.9	45.8
899.4-.6	127.0	20.8	46.2	50.5
900.3-.5	52.0	16.1	49.1	57.9
901.4-.6	148.0	20.1	41.6	42.6
902.3-.6	175.0	19.8	49.7	45.1
903.5-.7	15.0	16.8	46.9	43.4
904.3-.5	20.0	15.7	27.4	52.3
905.5-.7	46.0	18.5	32.1	47.5
906.4-.7	18.0	16.6	32.6	52.9
907.7-.9	94.0	20.9	29.2	41.8
908.5-.7	46.0	18.4	30.1	40.9
909.3-.5	45.0	18.2	36.3	44.5
910.2-.4	9.0	16.7	32.4	42.2
911.5-.7	78.0	20.1	21.9	48.2
912.2-.4	171.0	21.9	32.7	40.8
913.2-.4	50.0	20.4	34.7	54.2
914.2-.5	74.0	19.7	25.6	37.7
Averages	100.6	19.6	32.1	46.0

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 5

Wells Plugged Back
to Isolate Lower Sand Stringer

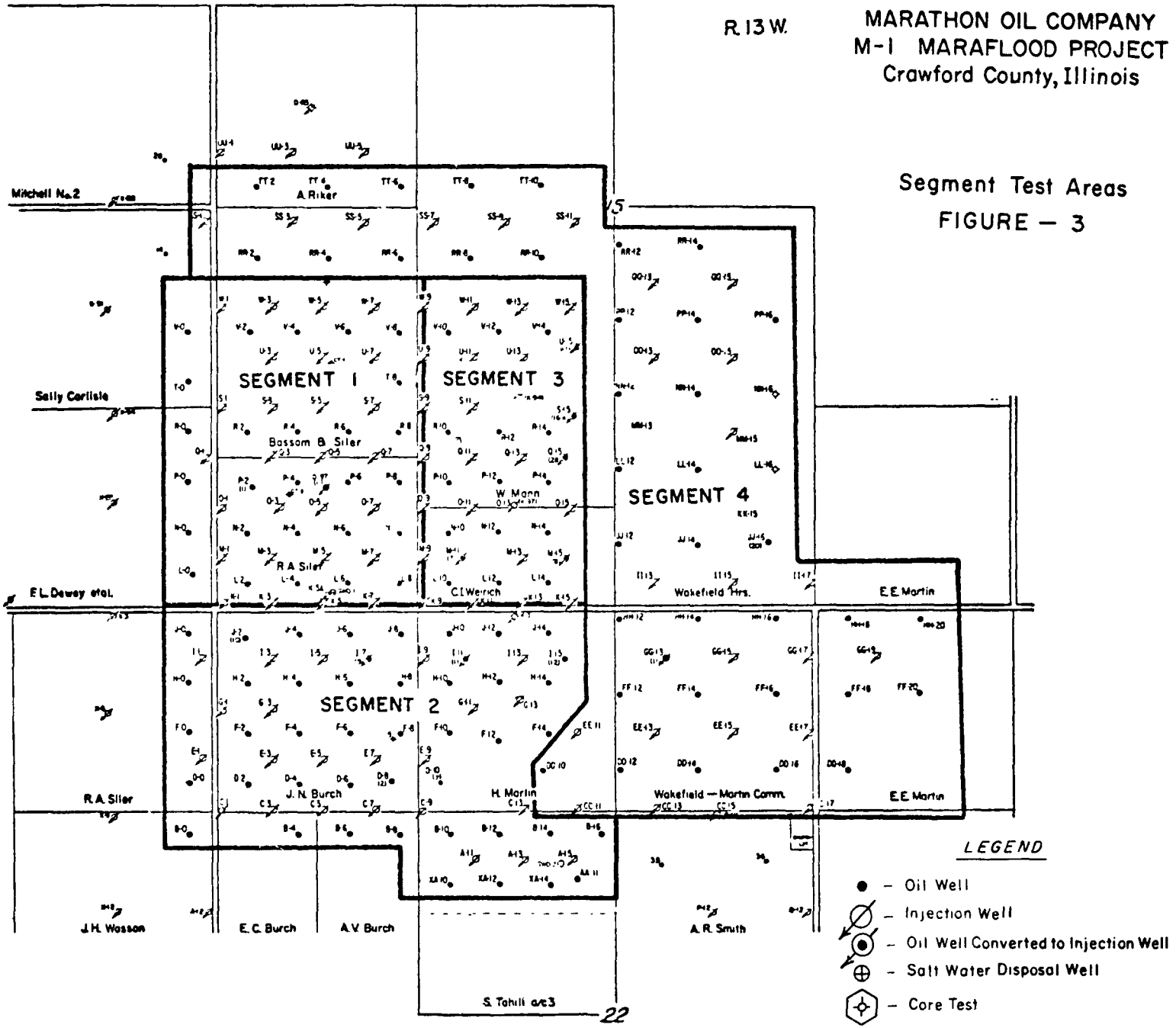
Well	Wellbore Status	Total Depth, Ft.	Plug Back Depth-Ft. Recommended	Plug Back Depth-Ft. Actual
Injectors				
Q-1	Shot	945	914	914
Q-3	Shot	945	917	917
S-1	Shot	945	916	916
S-3	Shot	955	922	922
U-1	Shot	950	926	926
U-3	Shot	942	920	920
U-5	Shot	943	924	923.5
W-1	Shot	950	936	936
W-7	Shot	952	931	930.5
SS-3	Gauge	960	948	948
SS-5	Gauge	960	938	938
SS-7	Gauge	952	930	930
Producers				
R-0	Gauge	945	912	912
R-2	Gauge	945	918	912
R-4	Gauge	950	921	921
T-0	Gauge	955	919	919
T-4	Gauge	940	929	929
V-0	Gauge	955	930	930
V-2	Gauge	950	930	930
V-4	Gauge	950	931	931
V-6	Gauge	950	927	927
RR-2	Gauge	957	942	942
RR-4	Gauge	951	940	940
RR-6	Gauge	960	934	934
TT-2	Gauge	958	938	938
TT-4	Gauge	960	944	944
TT-6	Gauge	966	946	946

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 6

Well Test Data
Bassom & Siler - R. A. Siler Lease
April 1976

Well	Pump Time On-Off, Min.	BOPD	BWPD	BTFPD	Oil Cut %
RR-2	100% on	5.14	68.30	73.44	7
RR-4	15-15	19.00	1.00	20.00	95
RR-6	15-45	0.15	14.85	15.00	1
V-2	100% on	Tr	77.52	77.52	Tr
V-4	45-15	0.33	33.27	33.60	1
V-6	45-15	2.73	33.39	39.12	7
V-8	45-15	0.66	65.58	66.24	1
T-2					
T-4	15-15	0.61	60.59	61.20	1
T-6	15-15	1.23	23.49	24.72	5
T-8	100% on	0.56	80.32	80.88	0.7
R-2	100% on	0.48	48.24	48.72	1
R-4	30-30	1.56	20.76	22.32	7
R-6	30-30	1.66	39.86	41.52	4
R-8	100% on	3.36	63.84	67.20	5
P-2	45-15	1.88	92.45	94.33	2
P-4	100% on	0.95	94.09	95.04	1
P-6	100% on	0.95	94.09	95.04	1
P-8	100% on	0.67	66.53	67.20	1
N-2	20-30	0.49	48.71	49.20	1
N-4	100% on	13.89	78.75	92.64	15
N-6	100% on	.75	75.09	75.84	1
N-8	100% on	0.88	87.20	88.08	1
L-2	45-15	0.04	4.76	4.80	1
L-4	100% on	0.96	95.04	96.00	1
L-6	100% on	Tr	53.30	53.30	Tr
L-8	45-15	3.50	84.10	87.60	4


R.13 W.
MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
Crawford County, Illinois
Segment Test Areas
FIGURE — 3
T.6 N.
SEGMENT 1
SEGMENT 2
SEGMENT 3
SEGMENT 4
Mitchell No.2
Sally Carlisle
E.L. Dewey etal.
R.A. Siler
J.H. Wasson
E.C. Burch
A.V. Burch
S. Tahill a/c3
A.R. Smith
E.E. Martin
Wakefield Hrs.
Wakefield — Martin Comm.
H. Martin
J.N. Burch
C.I. Weirich
W. Mann
Bassom & Siler
A. Riker
15
22
LEGEND
– Oil Well
– Injection Well
– Oil Well Converted to Injection Well
– Salt Water Disposal Well
– Core Test

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 7

(Page 1 of 2)

2.5-Acre Spacing
Injectivity Test Results

Segment 1 Injection Rate			Segment 2 Injection Rate		
Injection Well	B/D	B/D/NF	Injection Well	B/D	B/D/NF
K-1	89	4.5	A-11	11	0.6
K-3	104	3.3	A-13	87	3.1
K-5A	16	0.1	A-15	204	5.5
K-7	87	2.4			
K-9	51	1.9	C- 1	110	3.3
			C- 3	6	0.4
M-1	86	3.0	C- 5	0	0.0
M-3	152	5.1	C- 7	0	0.0
M-5	208	4.7	C- 9	0	0.0
M-7	142	3.0	C-13	85	4.1
M-9	212	4.2			
			E- 1	4	0.2
O-1	109	4.7	E- 3	0	0.0
O-3	74	3.2	E- 5	0	0.0
O-5	197	4.9	E- 7	120	4.0
O-7	197	4.2	E- 9	40	1.7
O-9	190	3.7			
			G- 1	0	0.0
Q-1	114	5.4	G- 3	11	0.2
Q-3	107	5.4	G- 5	71	2.6
Q-5	124	4.6	G- 7	142	4.7
Q-7	193	4.4	G- 9	8	0.4
Q-9	205	4.4	G-11	0	0.0
			G-13	0	0.0
S-1	125	5.7			
S-3	113	6.3	I- 1	26	1.4
S-5	32	2.1	I- 3	42	1.8
S-7	83	2.4	I- 5	46	1.5
S-9	150	3.3	I- 7	61	2.1
			I- 9	47	1.7
U-1	120	6.0	I-11	46	2.0
U-3	107	6.3	I-13	0	0.0
U-5	46	3.1	I-15	170	5.3
U-7	14	0.7			
U-9	124	3.5	K-11	27	1.0
			K-13	121	4.0
W-1	124	5.6	K-15	144	4.6
W-3	4	0.2			
W-5	81	4.8			
W-7	43	2.9			
W-9	103	4.9			

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 7

(Page 2 of 2)

2.5-Acre Spacing
Injectivity Test Results

Injection Well	Segment 3 Injection Rate B/D	B/D/NF
M-11	220	4.9
M-13	242	4.4
M-15	177	4.5
O-11	219	4.1
O-13	269	5.0
O-15	226	4.8
Q-11	207	4.5
Q-13	128	3.1
Q-15	197	4.6
S-11	197	4.3
S-13	176	4.3
S-15	179	4.5
U-11	202	4.6
U-13	182	4.3
U-15	138	4.2
W-11	162	5.1
W-13	144	4.1
W-15	122	3.8

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 8

5.0-Acre Spacing
Injectivity Test Results

Injection Well	Segment 4 Injection Rate B/D	B/D/NF
CC-11	0	0.0
CC-13	138	4.5
CC-15	83	4.6
CC-17	67	4.5
EE-11	140	4.7
EE-13	155	3.9
EE-15	186	5.2
EE-17	85	4.3
GG-13	155	4.6
GG-15	204	5.8
GG-17	93	2.4
GG-19	0	0.0
II-13	0	0.0
II-15	116	4.8
II-17	0	0.0
KK-13	0	0.0
KK-15	78	3.9
MM-13	0	0.0
MM-15	59	3.9
OO-13	0	0.0
OO-15	0	0.0
QQ-13	0	0.0
QQ-15	0	0.0
SS- 1	108	5.7
SS- 3	0	0.0
SS- 5	0	0.0
SS- 7	46	2.7
SS- 9	0	0.0
SS-11	0	0.0

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 9

2.5-Acre Spacing
Fracture Treatment Results
35 cp Gel

(Page 1 of 2)

Well	Treatment Date	Injection Rate, B/D/NF		Treatment Size			
				Gelled Water, Gals.		Sand	
		Initial	Present Potential	Pre-flush	Body	Pounds	Mesh
W- 3	8/27/76	0.20	0.00	1,000	800	1,000	20-40
					400	800	10-20
C- 9	8/27/76	0.00	0.00	1,000	600	750	20-40
					300	600	10-20
G- 1	9/ 3/76	0.00	7.70	1,000	700	875	20-40
					350	700	10-20
G- 3	9/ 3/76	0.20	7.30	1,000	700	875	20-40
					350	700	10-20
G-11	9/ 3/76	0.00	5.10	1,000	500	625	20-40
					250	500	10-20
E- 3	9/ 3/76	0.00	5.30	1,000	400	500	20-40
					200	400	10-20
I-13	9/13/76	0.00	6.80	1,000	500	625	20-40
					250	500	10-20
I- 3	9/13/76	1.80	6.70	1,000	800	1,000	20-40
					400	1,600	10-20
M- 7	9/13/76	3.00	7.80	1,000	1,200	1,500	20-40
					600	2,400	10-20
W- 7	9/13/76	2.90	>10.00	1,000	400	500	20-40
					200	800	10-20
U- 5	9/13/76	3.10	>10.00	1,000	400	500	20-40
					200	800	10-20
I- 7	9/14/76	2.10	6.20	1,000	700	875	20-40
					350	1,400	10-20
C- 1	9/14/76	3.30	>10.00	1,000	900	1,125	20-40
					450	1,800	10-20

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 9

2.5 Acre Spacing
Fracture Treatment Results
35 cp Gel

(Page 2 of 2)

Well	Treatment Date	Injection Rate, B/D/NF		Treatment Size			
		Initial	Present Potential	Gelled Water, Gals.		Sand	
				Pre-flush	Body	Pounds	Mesh
				4-stage treatments, following per stage			
A-13	9/15/76	3.10	>10.00	750	250	250	20-40
					250	500	20-40
S- 5	9/15/76	2.10	>10.00	750	250	250	20-40
					250	500	20-40
				6-stage treatment, following per stage			
M- 5	9/15/76	4.70	>10.00	750	250	250	20-40
					250	500	20-40
	avg.	1.66	7.06				

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 10

2.5-Acre Spacing
Fracture Treatment Results
2200 cp Gel

Well	Treatment Date	Injection Rate, B/D/NF		Treatment Size			
				Gelled Water, Gals.		Sand	
		Initial	Present Potential	Pre-flush	Body	Pounds	Mesh
K- 7	8/25/76	2.40	5.30	400	600	2,400	8-12
M- 1	8/25/76	3.00	5.60	1,000	500	2,000	8-12
K-11	8/25/76	1.00	4.10	1,000	500	2,000	8-12
U- 7	8/26/76	0.70	8.80	1,000	500	2,000	10-20
C- 3	8/26/76	0.40	5.90	1,000	300	1,200	10-20
A-11	9/ 8/76	0.60	0.00	1,000	500	2,000	10-20
E- 1	9/ 8/76	0.20	5.10	1,000	450	1,800	10-20
C- 7	9/ 8/76	0.00	0.00	1,000	450	1,800	10-20
C- 5	9/ 8/76	0.00	0.00	1,000	400	1,600	10-20
G-13	9/ 8/76	0.00	4.00	1,000	400	1,600	10-20
E- 5	9/ 8/76	0.00	4.30	1,000	400	1,600	10-20
G- 5	9/ 8/76	2.60	6.00	1,000	600	2,400	10-20
I-11	9/ 8/76	2.00	6.90	1,000	550	2,200	10-20
I- 5	9/ 9/76	1.50	5.60	1,000	600	2,400	10-20
I- 9	9/ 9/76	1.70	2.80	1,000	600	2,400	10-20
I- 1	9/ 9/76	1.40	7,80	1,000	550	2,200	10-20
S- 7	9/ 9/76	2.40	>10.00	1,000	650	2,600	10-20
O- 3	9/ 9/76	3.20	>10.00	1,000	550	2,200	10-20
Q-13	9/20/76	3.10	>10.00	1,600	650	2,600	8-12
K- 3	10/13/76	3.30	>10.00	1,600	800	3,200	10-20
K- 9	10/26/76	1.90	>10.00	1,600	550	2,200	10-20
K- 5A	10/18/76	0.10	6.00	1,600	400	1,600	10-20
G- 9	10/18/76	0.40	7.70	1,600	550	1,600	10-20
E- 9	10/22/76	1.70	4.90	1,600	550	2,200	10-20
	avg	1.40	5.87				

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 11

5.0-Acre Spacing
Fracture Treatment Results
2200 cp Gel

Well	Treatment Date	Injection Rate, B/D/NF		Treatment Size			
				Gelled Water, Gals.		Sand	
		Initial	Present Potential	Pre-flush	Body	Pounds	Mesh
OO-13	9/20/76	0.00	3.40	1,600	550	2,200	8-12
II-13	9/21/76	0.00	9.30	1,600	500	2,000	8-12
KK-13	9/23/76	0.00	5.10	1,600	400	1,600	8-12
SS-11	9/27/76	0.00	>10.00	1,600	550	2,200	10-20
OO-15	9/28/76	0.00	5.50	1,600	550	2,200	10-20
SS- 3	9/30/76	0.00	9.40	800	400	1,600	10-20
SS- 5	9/30/76	0.00	7.60	800	250	1,000	10-20
SS- 9	9/30/76	0.00	8.30	1,600	700	2,800	10-20
MM-15	10/ 1/76	3.90	7.40	1,600	400	1,600	10-20
KK-15	10/ 5/76	3.90	>10.00	1,600	550	2,200	10-20
EE-13	10/ 8/76	3.90	>10.00	1,600	1,200	4,800	10-20
QQ-13	10/ 8/76	0.00	6.20	1,600	600	2,400	10-20
GG-19	10/13/76	0.00	>10.00	1,600	650	2,600	10-20
	avg.	0.90	7.86				
			5.0-Acre Spacing 35 cp Gel				
MM-13	9/14/76	0.00	8.60	1,000	500	625	20-40
					250	1,000	10-20
II-17	9/14/76	0.00	5.40	1,000	600	750	20-40
					300	1,200	10-20
CC-11	9/14/76	0.00	>10.00	1,000	700	825	20-40
					350	1,400	10-20
	avg.	0.00	8.00				

MARATHON OIL COMPANY
M-1 MARAFLOOD PROJECT
CRAWFORD COUNTY, ILLINOIS

TABLE 12

Polymer Injectivity Summary

	Dow 500 - 1100 ppm				Dow 700 - 1100 ppm			
Well	S-11	W-11	I-3	SS-3	W-13	U-9	MM-15*	SS-5
Spacing Pattern	2.5	2.5	2.5	5.0	2.5	2.5	5.0	5.0
Micellar Solution								
Total Injected, Bbls.	138	323	176	169	295	172	170	176
Total Injected, B/NF	3.1	9.2	8.4	8.0	8.0	5.4	8.9	11.7
Polymer								
Total Injected, Bbls.	562	600	376	678	380	388	372	683
Total Injected, B/NF	12.5	17.1	17.9	32.3	10.3	12.1	19.6	45.5
Rate, B/D	98	104	97	99	100	103	96	98
Rate, B/D/NF	2.2	3.0	4.6	4.7	2.7	3.2	5.1	6.5
Max. Pressure, psig	325	225	180	492	325	250	500	504
Calculated Max. Injectivity (@ 600 psig) B/D/NF	3.0	4.7	7.1	5.3	3.7	4.8	5.6	7.2
Well Data								
Sand, Net Ft.	45	35	21	21	37	32	19	15
Isogeometric Permeability, md	75	60	50	60	60	65	50	40
Previously Open Hole Shot	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Previously Fractured	No	No	Yes	Yes	No	No	Yes	Yes
Tracer Log	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*MM-15 is an edge well with only two producers around it.

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