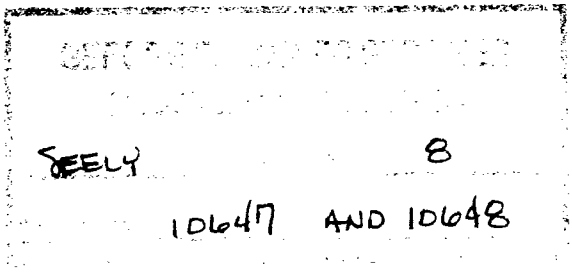
SEELY OIL COMPANY
815 WEST TENTH STREET
FORT WORTH, TEXAS 76102

WATERFLOOD STUDY

CENTRAL E.K. QUEEN AREA

E-K YATES-SR-QUEEN FIELD

LEA COUNTY, NEW MEXICO



Submitted by: C. W. Seely

CONCLUSIONS

1. Two previous waterfloods in the E.K. Queen Field, the Mobil EK Queen Unit and the Murphy Baxter North EK Queen Unit, have been very successful.

2. Little or no secondary oil has been produced from the Central E.K. Queen Area.

3. Ultimate recovery from the Upper Queen can be increased significantly by water flooding.

4. Using a peripheral water injection pattern and by drilling six new injection wells and four new producers, reserves can be increased by 786,000 barrels.

5. Capital expenditures required to develop a waterflood program over a 3-1/2 year program is $2,375,000.

6. For waterflooding operations to be efficient it is necessary to unitize the Upper Queen formation.

RECOMMENDATIONS

1. Proceed with unitization of the Upper Queen formation in the Central E.K. Queen Area as soon as possible.

2. Initiate a waterflood development program in the Central E.K. Queen Area as soon as approval is obtained from the New Mexico Oil Conservation Division of the Energy and Minerals Department.

LIST OF FIGURES

LIST OF TABLES

WATERFLOOD PROSPECT
PROPOSED CENTRAL EK QUEEN UNIT
E-K YATES-SR-QUEEN FIELD
LEA COUNTY, NEW MEXICO

Location and Geology

The E.K. Queen Field is located about 25 miles west of Hobbs, New Mexico, and is situated in one of the best locations of past and present Queen Sand waterfloods. The Queen sand is a member of the Guadalupian series of Permian age. The main oil sand is grey and fine to medium grained and a very friable quartz sandstone. The oil bearing reservoir sand appears to be a wedge or bar sand deposit, with red silty sandstones having calcerous or anhydritic cementation, both overlying and underlying the productive interval. The thickness varies from a few feet to fourteen feet. The main pay zone in the E.K. Queen Field is in the Upper Queen which normally has a total development of about fifty feet, and in almost all cases the continuous pay zone throughout the field is located about 30-35 feet below the top of the Queen formation.

As can be seen from the structure map (Figure 1), the E.K. Queen Field shows minor structural relief with regional dip to the south at the rate of 100-125 feet per mile in the center of the field. Accumulation in the Upper Queen sand is controlled mainly by porosity-permeability pinchout updip, and localized static water tables to the south and east. The primary depletion recovery mechanism is solution gas drive with no evidence of any significiant water encroachment in the proposed Center E.K. Queen Unit Area ("Central Unit"), either by water drive or from the two prior waterfloods in the field. See primary production curve for "Central Unit", (Figure 2).

Radioactivity logs are available on most of the older wells in the field. A few redrilled wells and some wells drilled for deeper production have modern Dual Laterol and Density Neutron logs. Several cores have been taken in the field; detailed analyses were available on two wells and a summary of average data on five more wells in the "Central Unit". In addition a summary of average data on 24 additional wells located in the Santa Fe Exploration Co. (Mobil) E.K. Queen Unit were available (Mobil Unit).

E.K. Queen Field Production

The Carper Drilling Company Carper Sivley #1 was the discovery well and was completed on December 5, 1954, for an initial potential of 60 BOPD. Rapid development of the field resulted in 64 Queen sand producing wells by the year 1957.

Expansion then occurred at a slower rate so that as of the effective date of unitization for Mobil Oil Company's E.K. Queen Unit in the southern part of the field during 1966, there were 81 wells that had been completed in the Queen sand.

A good response occurred within a year on the Mobil unit and the waterflood operation on this unit was successfully continued until the mid 1970's at which time many of the wells were plugged and abandoned so that by the year 1983 there were only 6 Queen sand producing wells remaining and a few water injection wells utilized for salt water disposal. Utilizing twenty-five water injection wells in a five-spot water injection pattern the Mobil waterflood peaked at approximately 60,000 barrels per month as shown on Figure 3.

The Murphy Baxter North E.K. Queen Unit (Baxter Unit) waterflood was initiated during February, 1971, and response to water injection occurred within a year. A peripheral water injection pattern consisting of 9 water injection wells was utilized on the Baxter unit. Because of this wider spaced water injection pattern, response to water injection occurred over a longer period of time with a peak oil production rate of 10,000 barrels per month. A primary-secondary oil production curve for the Baxter unit is attached as Figure 4.

The Baxter unit waterflood has been abandoned, and most of the wells were plugged during 1988 and 1989.

Primary Production History Proposed Central E.K. Queen Unit

There are sixteen (16) 40-acre locations in the "Central Unit" area that have had wells produce Queen sand oil. Wells on thirteen (13) of these locations were among the original Queen sand completions during the 1950's. Two (2) wells were drilled and completed in 1963 and were later used as water injection wells in the Murphy Baxter Unit. The other location on the east end of the Central Unit was drilled in 1981. Only three (3) of the original thirteen (13) wells have produced continuously.

The other ten were plugged and abandoned at an early time. At the time of abandonment, these ten wells had a combined producing rate of 41 BOPD (Table I). All of the plugged wells were plugged prior to any water injection into the E.K. Queen reservoir with the exception of the Marathon State EKA #3 which was plugged in 1969.

The early abandonment of ten (10) of these original thirteen (13) wells was probably the primary reason that the oil productive Queen sand under the Central Unit was not included in the Mobil and/or Baxter waterflood units. Cumulative primary oil recovery (Np) as of 1/1/91 from the proposed Central Unit is 444,562 barrels, which is 65 barrels per acre-foot, or 11.2% original oil in place, N. The recovery when considering the developed area only is 93 barrels per acre-foot and 16.0% N. An Iso-Cumulative Map contoured on cumulative primary oil production for the E.K. Queen Field is shown as Figure 5.

Performance Offset E.K. Queen Field Waterfloods

A detailed study of the two E-K Queen Field Queen sand waterfloods operated by Mobil Oil Company and Murphy Baxter respectively was made.

The combined primary oil production from the Mobil and Baxter waterflood units was 2,250,000 barrels and the combined secondary recovery by waterflood was 2,842,000 barrels resulting in recovery ratio of 1.26 to 1. The Queen sand under the Central Unit is similar to both the Mobil and Baxter units in following ways:

(1) Correlative oil productive porosity within the Upper Queen sand development. (See cross-sections Figures 6 and 7).
(2) Similar initial oil production potential.
(3) Little to no primary water production.
(4) Comparable primary oil production decline rates.
(5) Same porosity log characteristics.
(6) Same type structure (Figure 8).

Due to the excellent performance of the Mobil and Baxter waterfloods, there is little doubt as to the waterflood potential of the Queen sand under the proposed Central E.K. Queen Unit.

Further evidence of the waterflood potential of the Queen sand under the proposed Central E.K. Queen Unit is supported by response on General Operating Company's State BC lease during 1989 as a result of salt water disposal in the Queen sand at a location in the NW/4 SW/4 Section 9 (Tract 6) diagonally offsetting the State BC lease (Tract 2). Permission to use the well for salt water disposal in the oil productive Queen sand was granted in the latter part of 1987. Time of initiation of salt water disposal in the Queen sand and volumes injected are not known. Salt water disposal in this well has been discontinued, and the production increase from the State BC lease has also been lost.

Determination of Secondary Reserves

Reserves from waterflooding were estimated two ways - volumetric and from performance of two adjoining floods in the same field. The reservoir volume inside the peripheral waterflood pattern was determined to be 6048 acre-feet as determined from the Isopachous Map of Net Upper Queen Sand shown as Figure 9. A secondary recovery factor of 130 barrels per acre-foot was calculated based on data presented in Tables II and III, and the following:

The primary production recovery factor for the total unit is 65 barrels per acre-foot; however, it increases to 93 barrels per acre-foot when considering developed area only. The larger figure was used in calculating secondary recovery. Thus 6048 acre-feet times 130 B/A-F results in an estimated secondary recovery of 786,000 barrels.

A separate approach as to recovery was made by Mobil, Figure 10, using a permeability capacity distribution of the Queen formation based on available core data for the total E.K. Queen Field which came from twenty-four (24) wells in the Mobil Unit and from seven (7) wells in the Central Unit. Then based on an estimated relative permeability ratio of water to oil, a water-cut recovery relationship was developed and is shown as Figure 11. This shows a water-cut of 96.5% for a secondary recovery of 130 barrels per acre-foot which is in good agreement with the volumetric calculation.

As mentioned above, excellent secondary performance was obtained from both the Mobil Unit and the Baxter Unit. There is little question as to the similarity of the Queen formation of the Central Unit compared to the other two units. The main difference is in the primary production as shown by the comparison with the Mobil Unit below:

	Central Unit	Mobil Unit
Primary Rec., bbls.	444,562	1,737,000
Primary Rec., B/A-F	65	90.5
Primary Rec., % N	11.2	18.3

By applying the Mobil primary recovery factor to the Central Unit, the primary recovery would have been 617,000 barrels. By using the combined overall flooding efficiency of the two Units, Mobil and Baxter of 1.26, the Central Unit secondary reserves would be 777,000 barrels which is in good agreement with the 786,000 barrels from the volumetric method.

The secondary reserves of 786,000 barrels is a recovery of 130 barrels per acre-foot and 22.3% of the original oil in place.

This results in an ultimate recovery of 1,230,000 barrels which is 180 barrels per acre-foot or 30.9% of the original oil in place, which is well within the performance range of most of the Queen sand floods in the area.

Unitization Proposed Central E.K. Queen Unit

A formula consisting of ninety percent for cumulative primary oil recovery as of 1/1/91 including an adjustment of 5,000 barrels of oil per usable well and ten percent acreage is recommended for the unitization formula.

A tabulation of unit participation utilizing this formula is attached as Table IV.

Waterflood Development Plan Proposed Central E.K. Queen Unit

It is recommended that a peripheral waterflood injection pattern, shown on Figure 12, similar to the one utilized in the Baxter waterflood be utilized for the Central Unit. This plan would utilize two previous water injection wells on the Baxter waterflood, conversion of existing producing wells to water injection, and the drilling of six new water injection wells.

In addition to the existing producing wells to be utilized for waterflood production from the Queen sand, it will be necessary to drill four new producing wells.

For the details of the proposed waterflood development plan, reference is made to Table V.

WATERFLOOD STUDY
CENTRAL E-K QUEEN AREA
E-K YATES-SR-QUEEN FIELD
LEA COUNTY, NEW MEXICO

TABLE I

PRIMARY OIL IN CENTRAL E.K. QUEEN AREA
LEFT IN GROUND
DUE TO PREMATURE ABANDONMENTS

d WELLS

Well	Location		Date Completed	Date P&A or Last Prod.	Prod. Rate When P&A or Last Prod. BOPD	Cum. as of Last Prod. Bbls.	Actual Production from Redrilled Locations (One Re-Entry)	Cum. Prod. when Other Wells were P&A As of 1-1-67	Cum. Prod. As of 1-1-91	Primary Oil Made After 10 Wells Were P&A	Time Inte Produce (Years)
Sunray DX											
St. "G"	1m	7-18-34	6-55	8-66	1	20,551					
St. "G"	2n	7-18-34	7-55	8-66	1	29,270					
St. "H"	1o	7-18-34	9-55	8-66	1	28,393					
St. "H"	2m	8-18-34	5-56	8-66	1	38,696	Redrilled GOC Amoco St. #1 - 8-83			13,109	7
Bass											
New Mexico St.	1p	7-18-34	12-55	5-62	2	16,672					
Arco											
State AJ	2b	17-18-34	5-57	4-62	3	6,546					
State AJ	1d	17-18-34	4-56	4-62	3	22,133	Re-entered GOC St. AJ #1 - 4-86			3,897	5
Ohio Oil Co.											
State EKA	2b	18-18-34	10-55	12-56	20	12,316					
	3a	18-18-34	3-56	3-69	3	19,096	Redrilled by GOC Santa Fe St. #2 - 8-86			17,394	5
	6c	17-18-34	10-56	6-58	6	9,284	Redrilled by GOC Santa Fe St. #1 - 11-85			5,790	6
										Average 40,190 divided by 4 =	

PRODUCING WELLS (Only 3 of original 13 wells are still producing)

Bass											
New Mexico St.	2n	8-18-34	6-56					45,567	80,334	34,767	24
Gen. Oper. Co.											
State BC	1o	8-18-34	2-57					26,953	57,853	30,900	24
	2p	8-18-34	4-57					15,711	35,866	20,155	24
										Average 85,822 divided by 3 =	

Primary Oil in Ground Due to Prematurely Abandoned
Between 10,000 - 29,000 per well

Estimate 20,000

TABLE II

SUMMARY OF BASIC DATA

Upper Queen Formation

Central EK Queen Unit
E-K Yates-SR-Queen Field
Lea County, New Mexico

Oil Production and Wells

Cumulative Oil Production to 1-1-91, Barrels	444,562
Monthly Oil Production - December 1992, Barrels	521
Number of Producing Oil Wells - December 1992	8

Fluid and Rock Characteristics

Average Porosity - Percent	13.4
Average Permeability - Millidarcys	35.0
Connate Water Saturation - Percent	30.0
Formation Volume Factor - Barrels Reservoir Space/Stock Tank Barrel	1.25
Original Oil Viscosity - Centipoise	1.4
Oil Viscosity January 1993 - Centipoise	3.2
Original Solution Gas Oil Ratio - Cubic Feet per Barrel	500
Reservoir Temperature - °F	100
Original Reservoir Pressure - psig @-400'	1,541
Residual Oil Saturation-Sor-Percent	23.5

Oil Reservoir Volumes

Productive Area, Acres	951
Productive Reservoir Volume - Acre-Feet	6,820
Average Productive Thickness - Feet	7.2
Developed Area - Acres	632
Developed Reservoir Volume - Acre-Feet	4,800
Average Developed Thickness - Feet	7.6
Floodable Reservoir Volume Within Pattern - Acre-Feet	6,048
(1) Developed Area - Acre-Feet	4,441
(2) Undeveloped Area - Acre-Feet	1,607

TABLE II

SUMMARY OF BASIC DATA

Upper Queen Formation

Central EK Queen Unit
E-K Yates-SR-Queen Field
Lea County, New Mexico

Stock Tank Oil In Place

Productive Reservoir Volume -	
Barrels per Acre-Foot	582
Barrels	3,969,200

Oil Recovery

Cumulative Oil Production to 1-1-91, Barrels	444,562
Barrels Per Acre-Foot (Total Area)	65
Barrels Per Acre-Foot (Developed Area Only)	93
Percent N - OIP (Total Area)	11.2
Percent N - OIP (Developed Area Only)	16.0
Secondary Recovery - Barrels	786,000
Barrels Per Floodable Acre-Foot	130
Percent N - OIP	22.3
Ultimate Recovery Primary & Secondary - Barrels	1,230,562
Barrels per Productive Acre-Foot	180
Percent N - OIP	30.9

TABLE III

Sample Calculations

Central EK Queen Unit
E-K Yates-SR-Queen Field
Lea County, New Mexico

1. Estimated N (original oil in place)

$$N = \frac{7758(\emptyset)(1-Sw)}{Bo_1}$$

$$= \frac{7758(.134)(1-.30)}{1.25}$$

$$= 582 \text{ B/A-F}$$

Where:

$\emptyset$ is weighted average porosity from seven core anaylyses from Central Unit Area.

Sw is average interstitial water saturation based on log calculations from General Operating Company's Amoco State No. 1 and Santa Fe State No. 1.

Bo_1 is original formation volume factor based on initial solution GOR of 500/1, BHT of 100° F., gas gravity of 0.86 and oil gravity of 36.4° API.

2. Calculation of Secondary Reserves

$$Np \text{ sec} = \frac{E}{Bo_2}\left[\left\{7758(\emptyset)(1-Sw)-(N_p)(Bo_1)\right\}\frac{Bo_2}{Bo_1} - 7758(\emptyset)(Sor)\right]$$

$$= \frac{.5}{1.07}\left[\left\{7758(.134(1-.7)-93(1.25)\right\}\frac{1.07}{1.25} - 7758(.134)(.235)\right]$$

$$= 130 \text{ B/A-F}$$

Where:

Np sec = Estimated Secondary Recovery, B/A-F

E = Overall Flooding Efficiency, %

Horizontal 84%, Vertical 60%

$\emptyset$ = Porosity, %

Sw = Interstitial water saturation, % pore space

Np = Primary recovery, B/A-F

Bo_1 = Original formation volume factor, bbl/bbl

Bo_2 = Present formation volume factor, bbl/bbl

Sor = Residual oil saturation, % pore space. Sor is based on the weighted average residual oil saturation from seven core analyses from Central Unit Area.

TABLE IV

SEELY OIL COMPANY
Central EK Queen Unit
E-K Yates-SR-Queen Field
Lea County, New Mexico

Unit Participation by Tracts

Tract Number	Cumulative Queen Oil Recovery as of 1-1-91 Plus Adjustments 90%*	Acreage 10%	Unit Participation 100%
1	18.752558	1.618778	20.371336
2	19.067473	0.809389	19.876862
3	0.000000	0.364326	0.364326
4	2.256792	0.404694	2.661486
5	1.149170	0.404695	1.553865
6	0.919189	0.404694	1.323883
7	3.690360	0.404695	4.095055
8	9.891577	0.809389	10.700966
9	0.000000	0.404694	0.404694
10	10.442906	0.404695	10.847601
11	6.907889	1.214083	8.121972
12	14.378690	2.351174	16.729864
13	2.543396	0.404694	2.948090
Totals	90.000000	10.000000	100.000000

* See Attachments

SEELY OIL COMPANY
Central EK Queen Unit
E-K Yates-SR-Queen Field
Lea County, New Mexico

Unit Participation for Cumulative Queen Oil Recovery Including Adjustment for Usable Wells

Tract Number	Actual Cumulative Queen Oil Recovery as of 1-1-91*	Queen Oil Adjustment for Usable Wells*	Total Queen Oil Recovery Including Adjustment	100% Cumulative Queen Oil Recovery Participation	90% Cumulative Queen Oil Recovery Participation
1	97006	5000	102006	20.836176	18.752558
2	93719	10000	103719	21.186081	19.067473
3	-0-	-0-	-0-	0.000000	0.000000
4	12276	-0-	12276	2.507547	2.256792
5	1251	5000	6251	1.276856	1.149170
6	-0-	5000	5000	1.021321	0.919189
7	15074	5000	20074	4.100400	3.690360
8	48806	5000	53806	10.990641	9.891577
9	-0-	-0-	-0-	0.000000	0.000000
10	51805	5000	56805	11.603229	10.442906
11	32576	5000	37576	7.675432	6.907889
12	78214	-0-	78214	15.976322	14.378690
13	13835	-0-	13835	2.825995	2.543396
Totals	444562	45000	489562	100.000000	90.000000

* See Attachments for Detail of Individual Tract

Seely Oil Company
Central EK Queen Unit
E-K Yates-SR-Queen Field
Lea County, New Mexico

Queen Oil Recovery as of 1-1-91

Tract Number	Wells That Produced Queen Oil	Well Location	Present Well Status	Cumulative Queen Oil Produced as of 1-1-91
1	State of New Mexico #1	P- 7-18S-34E	P & A 1975	16672
1	State of New Mexico #2	N- 8-18S-34E	Producing	80334
			Tract 1 Total	97006
2	State BC #1	O- 8-18S-34E	Producing	57853
2	State BC #2	P- 8-18S-34E	Producing	35866
			Tract 2 Total	93719
4	North EK Queen Unit Tract 7 Well #2	F- 7-18S-34E	P & A 1988	12276
			Tract 4 Total	12276
5	Rhodes State #1	M- 9-18S-34E	Producing	1251
			Tract 5 Total	1251
7	State EKA #6	C-17-18S-34E	P & A 1975	9284
7	Santa Fe State #1	C-17-18S-34E	Producing	5790
			Tract 7 Total	15074
8	State EKA #2	B-18-18S-34E	P & A 1975	12316
8	State EKA #3	A-18-18S-34E	P & A 1975	19096
8	Santa Fe State #2	A-18-18S-34E	Producing	17394
			Tract 8 Total	48806
10	New Mexico H State #2	M- 8-18S-34E	P & A 1973	38696
10	Amoco State #1	M- 8-18S-34E	Producing	13109
			Tract 10 Total	51805
11	State AJ #1	D-17-18S-34E	P & A 1965	22133
11	State AJ #2	B-17-18S-34E	P & A 1965	6546
11	State AJ #1 (Re-Entry)	D-17-18S-34E	Producing	3897
			Tract 13 Total	32576
12	New Mexico G State #1	M- 7-18S-34E	P & A 1968	20551
12	New Mexico G State #2	N- 7-18S-34E	P & A 1968	29270
12	New Mexico H State #1	O- 7-18S-34E	P & A 1973	28393
			Tract 14 Total	78214
13	North EK Queen Unit Tract 4 Well #7	G- 7-18S-34E	P & A 1988	13835
			Tract 15 Total	13835
			Unit Total	444562

SEELY OIL COMPANY
Central EK Queen Unit
E-K Yates-SR-Queen Field
Lea County, New Mexico

Queen Oil Adjustment for Usable Wells

Tract Number	Usable Well	Well Location	Present Well Status	Queen Oil Adjustment for Usable Well
1	State of New Mexico #2	N- 8-18S-34E	Producing (Queen)	5000
			Tract 1 Total	5000
2	State BC #1	O- 8-18S-34E	Producing (Queen)	5000
2	State BC #2	P- 8-18S-34E	Producing (Queen)	5000
			Tract 2 Total	10000
5	Rhodes State #1	M- 9-18S-34E	Producing (Queen)	5000
			Tract 5 Total	5000
6	State HS #2	L- 9-18S-34E	Shut-In SWD (Queen)	5000
			Tract 6 Total	5000
7	Santa Fe State #1	C-17-18S-34E	Producing (Queen)	5000
			Tract 7 Total	5000
8	Santa Fe State #2	A-18-18S-34E	Producing (Queen)	5000
			Tract 8 Total	5000
10	Amoco State #1	M- 8-18S-34E	Producing (Queen)	5000
			Tract 10 Total	5000
11	State AJ #1 (Re-Entry)	D-17-18S-34E	Producing (Queen)	5000
			Tract 11 Total	5000
			Unit Total	45000

SEELY OIL COMPANY
Central EK Queen Unit
E-K Yates-SR-Queen Field
Lea County, New Mexico

Unit Participation for Acreage Factor

Tract Number	Number of Acres	100% Acreage Participation	10% Acreage Participation
1	160.00	16.187778	1.618778
2	80.00	8.093889	0.809389
3	36.01	3.643262	0.364326
4	40.00	4.046945	0.404694
5	40.00	4.046945	0.404695
6	40.00	4.046944	0.404694
7	40.00	4.046945	0.404695
8	80.00	8.093889	0.809389
9	40.00	4.046944	0.404694
10	40.00	4.046945	0.404695
11	120.00	12.140834	1.214083
12	232.39	23.511736	2.351174
13	40.00	4.046944	0.404694
Totals	988.40	100.000000	10.000000

TABLE V

SEELY OIL COMPANY

CENTRAL EK QUEEN UNIT

Lea County, New Mexico

PLAN OF DEVELOPMENT

LAST HALF OF 1993

(1)	Develop fresh water supply	$ 25,000
(2)	Install water plant and injection system	50,000
(3)	Re-complete Well No. 301 for water injection	50,000
(4)	Re-enter and complete Well No. 401 for water injection	40,000
(5)	Re-enter and complete Well No. 1301 for water injection	40,000
(6)	Drill, complete and equip Well No. 1201 for water injection	200,000
(7)	Drill, complete and equip Well No. 802 for production	225,000
	TOTAL	$630,000

1994

(1)	Drill, complete and equip Well No. 1202 for water injection	$200,000
(2)	Drill, complete and equip Well No. 1203 for production	225,000
(3)	Drill, complete and equip Well No. 803 for water injection	200,000
(4)	Drill, complete and equip Well No. 901 for production	225,000
	TOTAL	$850,000

SEELY OIL COMPANY

CENTRAL EK QUEEN UNIT

Lea County, New Mexico

PLAN OF DEVELOPMENT

1995		
(1)	Drill, complete and equip Well No. 1102 for water injection	$200,000
(2)	Convert Well No. 501 to water injection	50,000
(3)	Convert Well No. 601 to water injection	20,000
	TOTAL	$270,000
1996		
(1)	Drill, complete and equip Well No. 702 for water injection	$200,000
(2)	Drill, complete and equip Well No. 102 for water injection	200,000
(3)	Drill, complete and equip Well No. 103 for production	225,000
	TOTAL	$625,000
	GRAND TOTAL	$2,375,000