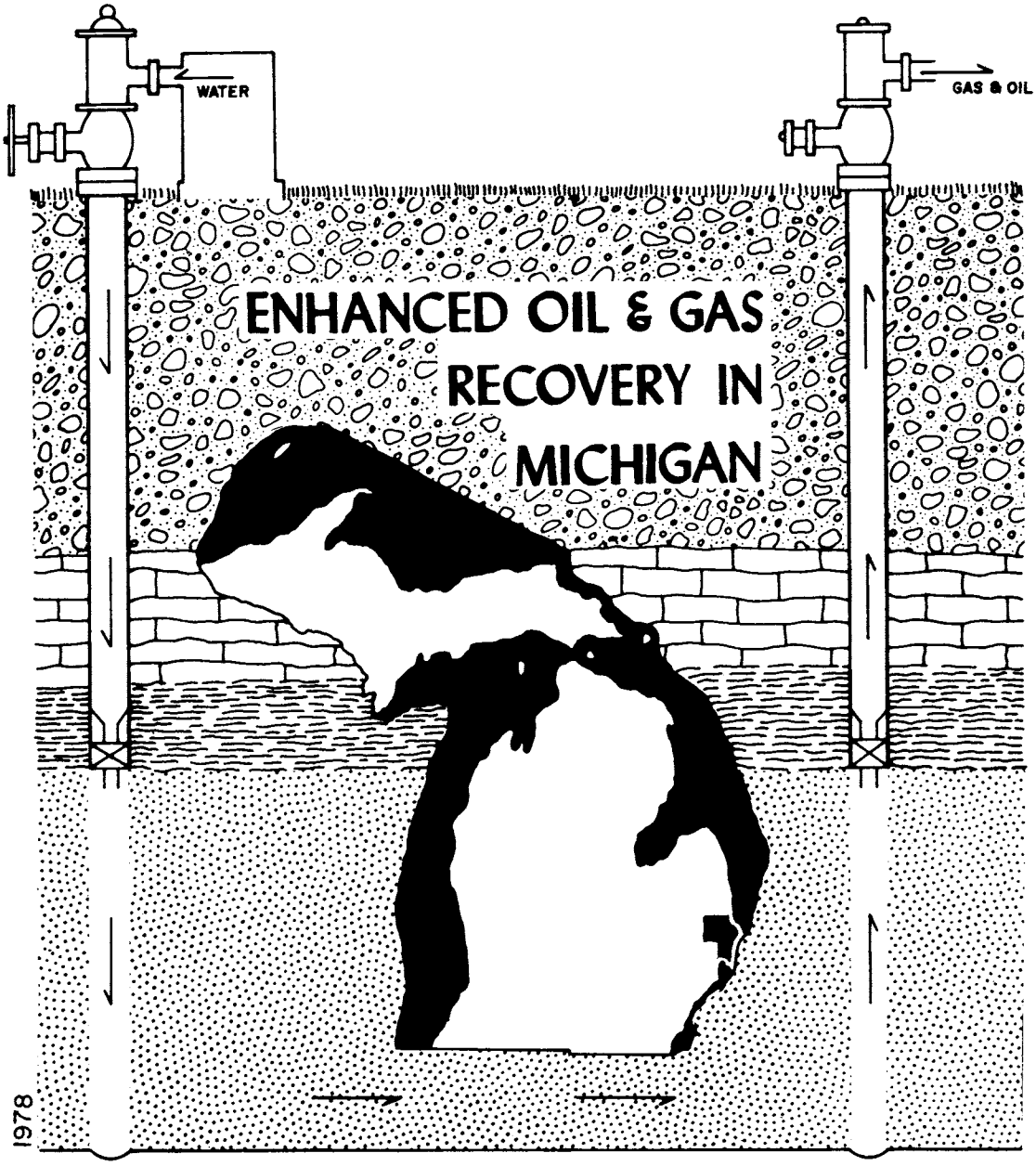
Columbus 3 Unit



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GEOLOGICAL SURVEY
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SECONDARY RECOVERY REPORT NO. 7

Columbus 3 Unit

ENHANCED OIL & GAS RECOVERY IN MICHIGAN

BY
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LANSING, MICHIGAN 1978

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PREFACE

The Columbus 3 Unit report is the third report in this series on Salina-Niagaran reservoirs. The Onondaga 10 Unit report (Number 5 in series), Aurelius 35 Unit report (Number 6 in series), and this report demonstrate the advantages to be gained by implementing either pressure maintenance or secondary recovery projects in Salina-Niagaran reefs. Like the Onondaga 10 Unit and the Aurelius 35 Unit, this project is a pressure maintenance operation and is to be distinguished from a secondary recovery project. The advantage to be gained by initiating a pressure maintenance project rather than utilizing secondary recovery methods is the resultant greater ultimate oil recovery. Secondary recovery methods are initiated after primary production has been depleted. Pressure maintenance operations are begun while primary production remains in the reservoir.

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COLUMBUS 3 UNIT

Enhanced Oil and Gas Recovery in Michigan

Abstract

The Columbus 3 Unit located in St. Clair County is an example of a successful pressure maintenance project. The success of such a project most often is realized through the maintenance of reservoir pressure by the injection of gas and/or water into the reservoir. However, in the case of the Columbus 3 Unit, the incremental gain of 64 percent in excess of anticipated primary production is generally the result of more efficient production of the field, achieved through selective production of the best wells as permitted through the unitization agreement.

INTRODUCTION

Wildcat drilling by Sun Oil Company led to the discovery of the Columbus 3 field in December 1968 through the application of the most modern geophysical technology available at the time. The risks associated with the application of gravity anomaly data to the discovery of oil and gas are illustrated by the fact that two dry holes were drilled into the perceived Columbus 3 structure prior to the actual discovery of the field. The field spans approximately 460 reservoir acres and is located in Sections 3 and 10 of Columbus Township, T5N, R15E, and Section 34 of Wales Township, T6N, R15E, in St. Clair County.

The Columbus 3 field, now unitized, produces from a Niagaran reef developed during Silurian time. The reef extends in a north-south direction and contains a structural saddle in the southern portion which results in two gas caps in the reservoir. The gas-oil contact in the northern gas cap is located at 2352 feet subsea level, while in the southern gas cap it is located at 2390 feet subsea level. The oil-water contact is constant throughout the reservoir with a subsea elevation of 2464 feet. The average reservoir oil pay per well is approximately 51 feet. At the present time the gas being injected into the reservoir is that gas which is produced with the oil.

SALINA AND NIAGARAN RESERVOIR ROCKS

In the Michigan Basin, Salina and Niagaran rocks of the Silurian period contain highly productive oil and gas reservoirs in reef and associated structures.

Niagara rocks in the subsurface are predominantly dolomites and limestones with scattered regional occurrences of cherty zones and thin shale beds. These rocks range in thickness from less than 100 feet in the basin interior to more than 1000 feet at the basin margin. Oil, condensate, and gas production are found primarily in pinnacle reef complexes a few miles basinward from the thick carbonate bank.

Reefs, reef associated sediments, and biostromes occur at various stratigraphic levels within the Salina-Niagara Group. Reefs range in size from small isolated masses 10 feet in diameter to large complexes several hundred acres in extent and vary in height from a few feet to more than 500 feet. Most reefs in the subsurface appear to be coral-algal-stromatoporoid mounds with occurrences of brecciation and a variety of fossil debris from shelly organisms. "Pay zone" porosity appears to be developed by preferential solution of coral skeletons and invertebrate remains from the fossiliferous rock by groundwaters. Dolomitization of limestone reefs frequently plays an important role in the development of porosity. Occasionally evaporite infilling destroys potentially productive porosity.

The Salina Group contains evaporite, carbonate, and shale stratigraphic units. The A-1 Evaporite, A-1 Carbonate, A-2 Evaporite, and A-2 Carbonate units are of particular interest where Niagaran reefs are present. While the A-1 Evaporite is a clean salt over most of the Michigan basin interior, the unit grades laterally into an anhydrite that thins and pinches out against the flanks of reef complexes. The A-1 Carbonate is essentially a dark colored limestone, dolomite, or both in non-reef locations. In the vicinity of reefs, the A-1 Carbonate may be completely or partially dolomitized and exhibits depositional thinning over the reef and margin reef complexes. The A-2 Evaporite is nearly a pure salt in the deeper parts of the basin, while near reefs the unit is generally represented entirely by anhydrite. Partial dolomitization and some depositional thinning occur in the A-2 Carbonate where it overlays reef complexes.

Other Salina Group units have been shown to be capable of oil and gas production in limited areas of Michigan. For example, small anticlinal structures where the A-1 and A-2 Carbonates are draped over Niagaran reefs have been known to produce oil and gas when porosity in these units is sufficiently developed.

GENERAL HISTORY OF THE COLUMBUS 3 UNIT

The Columbus 3 field was discovered on December 11, 1968, with the completion of the H. H. Winn #1 located in the NE¼ NE¼ SW¼ of Section 3, T5N, R15E, Columbus Township, St. Clair County. By April 1970 the entire extent of the field had been delineated with the completion of 22 additional productive wells. Since that date no other wells have been drilled in the reservoir.

A spacing order dated December 19, 1968, was adopted to establish 20-acre drilling units and well spacing patterns for the Columbus Section 3 Salina-Niagaran Formation Pool. The drilling units, rectangular in shape,

are formed by dividing a governmental surveyed quarter-quarter section of land into an east half and a west half. This spacing order designated the Columbus 3 Pool to span a tract of 1360 acres. An amended spacing order was issued on May 22, 1969, to include an additional 360 acres. A Proration Order was issued, effective February 1, 1970, which established an allowable of 75 barrels of oil and/or 100,000 cubic feet of gas per day per well.

Early in the production history of the Columbus 3 field, Sun Oil Company conducted a pressure maintenance feasibility study and summarized the findings in a November 1971 report. The report contained the recommendation that a gas-plus-water pressure maintenance project be initiated for the field to include the injection of approximately 200 Mcf gas per day or approximately 80% of the produced gas plus about 500 barrels of water per day. This decision was based upon the fact that an incremental gain of 2,100,000 barrels of additional oil was forecast if the proposed pressure maintenance project was implemented.

To process the gas a 2500 MCFGPD refrigeration-type gas processing plant with a suction pressure of 300 psig and a discharge pressure of 1600 psig was recommended. The reservoir was evaluated by means of two computerized simulation models that matched historical performance of the field with model parameters and accordingly projected future recovery. By using the models, future performance was evaluated through analysis of bottom-hole pressure data, production data, isopach information, reservoir geometry, and physical properties of the oil and gas. From this data the determination was made that the reservoir contained an estimated original stock tank volume of 11,375,000 barrels of oil with 7,055 MMcf of solution gas plus a gas cap containing 3,623 MMcf of gas.

Much of the original porosity has been destroyed by the presence of salt throughout the reservoir. Salt-filled porosity is especially present in the top of the reservoir structure and in the west flank of the reef, and to a lesser extent the upper portion of the reef along the eastern flank is salt plugged. Porosity in the remainder of the reef was found to depend upon the degree of dolomitization caused by the movement of formation waters during lithification.

An initial attempt at the unitization was made on March 20, 1973, when the Sun Oil Company filed a petition with the Supervisor of Wells requesting an order providing for the unitized management, operation, and pressure maintenance of the Columbus 3 Field. The findings, as a result of a hearing held May 15, 1973, specified approval of the plan on June 20, 1973, contingent upon Sun Oil Company obtaining written approval of 75 percent of the interests which are free of costs, as stipulated in Act 197, Public Acts of 1959 (Unitization Act). The unitization agreement did not take effect as scheduled and the gas, which was produced from the field in excess of that used for lease fuel requirements, continued to be flared.

This gas flaring led to a show cause hearing held on March 20, 1974, to explore the opinion of the Supervisor of Wells issued on February 22, 1974, that "...based on the data of record, the opinion that the venting and flaring of gas without beneficial use is unnecessary and unwarranted

waste and that a gas gathering system and facilities should be installed capable of processing and marketing all gas produced." At this time estimated volumes of gas being vented and flared totaled approximately 500 Mcf per day. At the time of the March hearing, unitization of the field had not yet been accomplished because 75% of the interests which are free of costs had not approved the plan. The determination of the Supervisor of Wells dated April 13, 1974, stated that in the interest of maximum hydrocarbon production from the reservoir all produced gas from the Columbus 3 field should be recycled "...for pressure maintenance or marketed prior to July 1, 1974" or that "...all wells in the pool are to be immediately closed in and remain closed in until such time the gas is either utilized in pressure maintenance of the reservoir or gas connections and market facilities have been achieved."

In response to this action, the necessary 75% of the interests which are free of costs signed the unitization agreement and a supplemental hearing was held on June 25, 1974, on which date the unitization order was issued for the Columbus 3 Unit. The order became effective June 30, 1974, and supersedes the proration order for the field. At the time of unitization, two gas wells in the field were converted into gas injection wells and an oil well was converted into a water injection well. The source of gas and water injected into the field is that gas and brine associated with the production of oil from the field.

Through June 30, 1978, a total of 4,360,000 barrels of oil has been produced, with no gas sales from the field. Estimated primary production of 3,275,000 barrels of oil was exceeded in the third quarter of 1976. As of May 1978 the Columbus 3 Unit has 10 pumping wells, 6 flowing wells, one temporarily abandoned well, 3 wells shut-in for high gas-oil ratios, 1 water injection well (brine disposal well), and 2 gas injection wells. Most of the wells in the field could be flowed without the use of a pump, but to minimize paraffin problems pumping units with scrapers on the pump rods have been installed. At the present time a vapor recovery unit recovers approximately 60 to 100 Mcf of gas per day, which is reinjected into the field.

With the unitization of the field, the Columbus 3 Unit has been produced with greater efficiency than when the wells were produced at the prorated allowables. Without unitization all high GOR and gas wells would be produced with a loss of ultimate oil recovery from the reservoir. This results from the fact that energy contained within the reservoir which could have been used to produce oil would have imprudently been used to produce gas from the reservoir. Production efficiency was increased by the selective production of the best oil wells as permitted in the unitization order. This fact, more than any other, has led to the projected incremental gain of 2,100,000 barrels of oil for the project.

A summary of field data is presented in Data Sheet No. 1. Historical oil production is listed in Table 1, with gas and water injection data listed in Table 2. Figure 5 illustrates bottom-hole pressure drop versus reservoir cumulative oil production for the Columbus 3 Unit. As of May 1978 the field is producing at a bottom-hole pressure of 1020 psig with a 20 psig pressure decline for the last twelve months. Total field production per 1 psig pressure drop has been 10,300 barrels of oil.

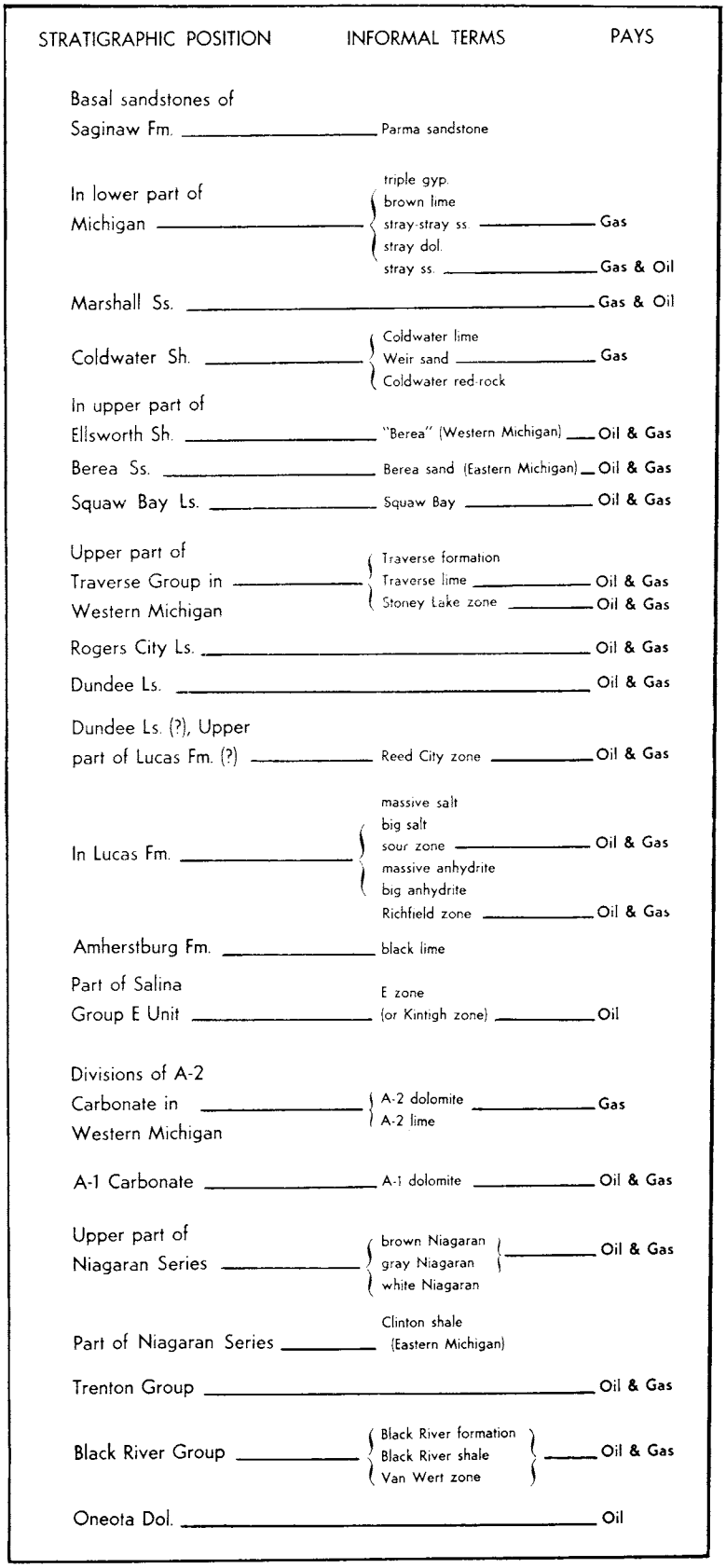

Figure 1. Principal oil and gas pays and informal terms used in petroleum exploration applied to parts of formations or groups of formations in the subsurface of the Michigan Basin.

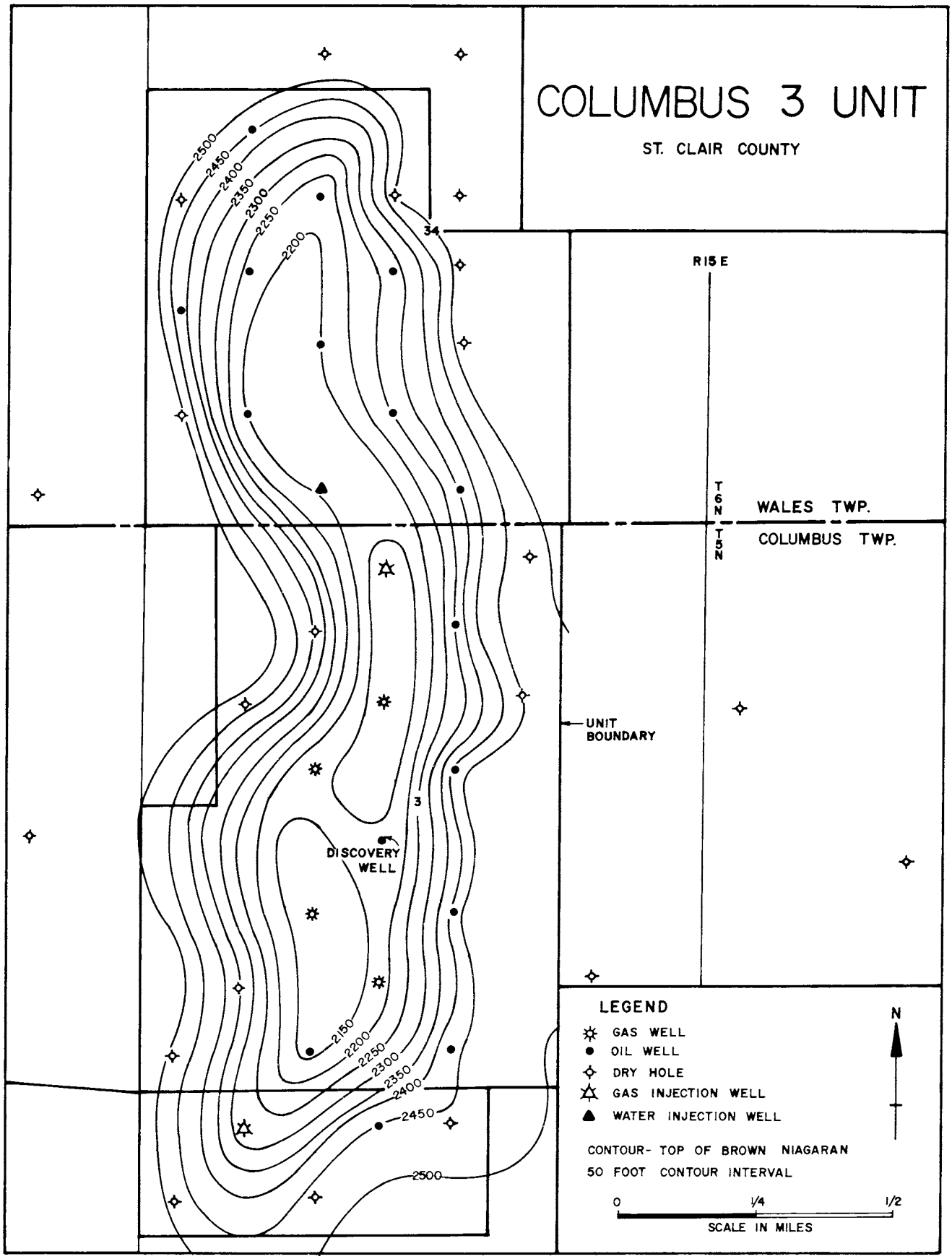

Figure 2. Structure of the Columbus 3 Unit.

Data Sheet No. 1

Columbus 3 Unit

Salina-Niagaran Pressure Maintenance
Gas Injection and Waterflood Project

GENERAL POOL DATA

Location	St. Clair County, Columbus Township (T5N, R15E), Sec. 3, 10, Wales Twp. (T6N, R15E), Sec. 34
Date of pool discovery	December 11, 1968
	Sun Oil Company, H. H. Winn #1
	Permit Number 27691
Producing formation	Salina-Niagaran
Pay lithology	Brown dolomite, dolomitized carbonate
Type of trap	Reef
Drilled acres	460
Unit acres	860
Reservoir area, estimated acres	460

ENGINEERING DATA

Type of reservoir energy	Gas cap
Original reservoir pressure	1447 psia
Reservoir temperature	72° F
Viscosity of original reservoir oil	.95 cp
Bubble point pressure	1447 psia
Formation volume factor	1.281 Reserve bbl./stock tank bbl.
API oil gravity	40.2°
Original solution gas-oil ratio	615 c.f.p.b.
Average porosity	10% gas zone, 12% oil zone
Average permeability	80 md. gas zone, 150 md. oil zone
Connate water, estimated	12% gas zone, 14% oil zone
Net oil pay thickness	51 feet*
Acre feet of oil pay	23460*

RECOVERABLE HYDROCARBON DATA

Estimated original stock tank oil in place	11,375,000 bbls.
Estimated original recoverable stock tank oil	3,275,000 bbls.
Calculated recoverable stock tank oil per acre foot	140 bbls. primary; 229 bbls. primary and secondary
Original gas in solution	7055 MMcf, 3623 MMcf gas cap
Estimated additional recoverable oil due to secondary recovery methods	2,100,000 bbls.

* Geological Survey estimate based upon Sun Oil Company's oil isopach map

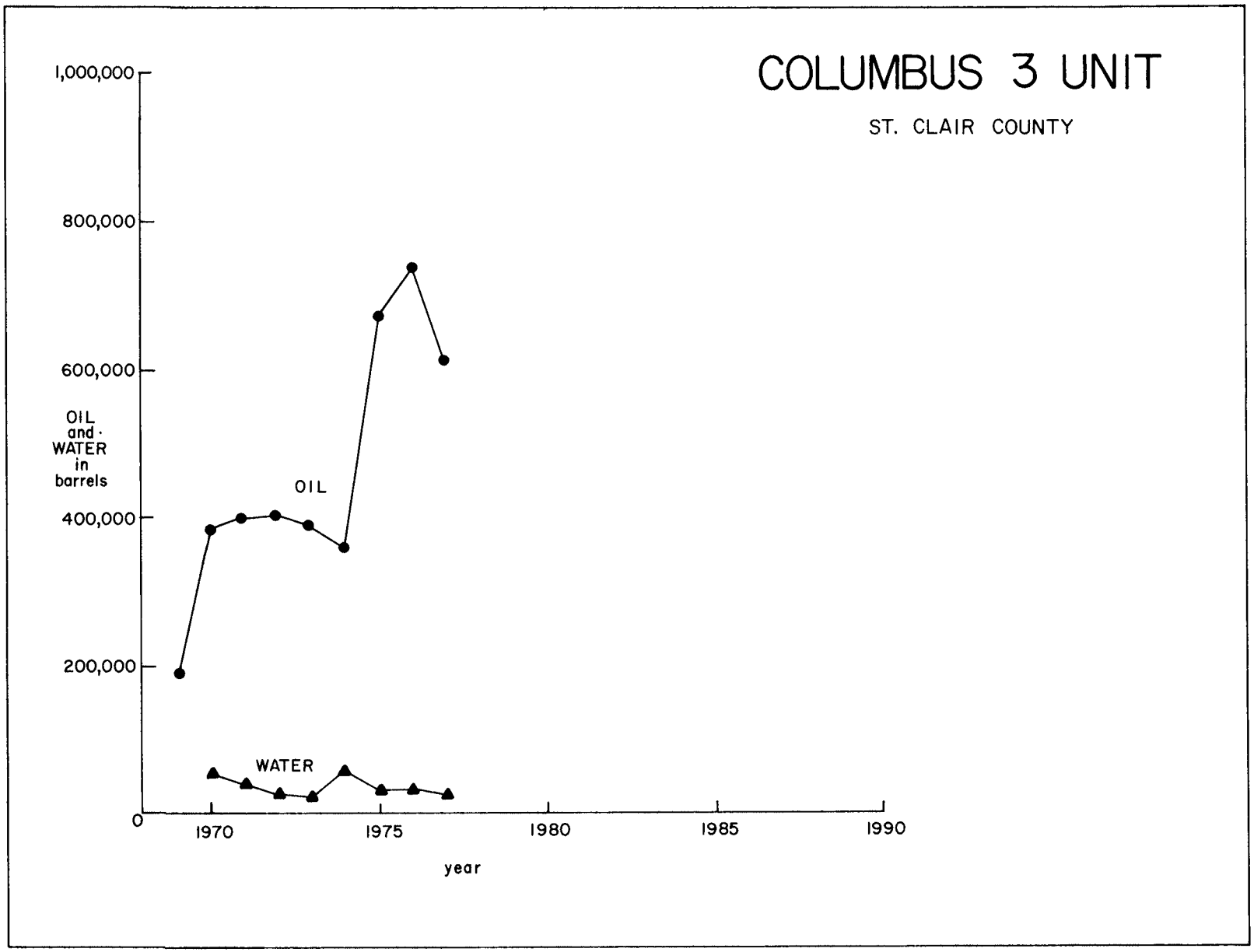

Figure 3. Oil and water production from the Columbus 3 Unit.

Columbus 3 Unit, St. Clair County							
Year	Production Data						Remarks
	Gas		Oil		Water (estimated)		
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	
1969			180,820	180,820			
1970			382,202	563,022	53,655	53,655	
1971			398,152	961,174	40,880	94,535	
1972			401,631	1,362,805	24,455	118,990	
1973			387,750	1,750,555	19,710	138,700	
1974			360,473	2,111,028	55,480	194,180	Unitization effective June 30, 1074
1975			669,880	2,780,908	29,930	224,110	
1976			737,938	3,518,846	30,660	254,770	
1977			612,163	4,131,009	26,100	280,870	

Table 1. Oil, gas, and water production from the Columbus 3 Unit. Oil and water production figures are shown in barrels. Gas production figures are shown in thousand cubic feet (Mcf).

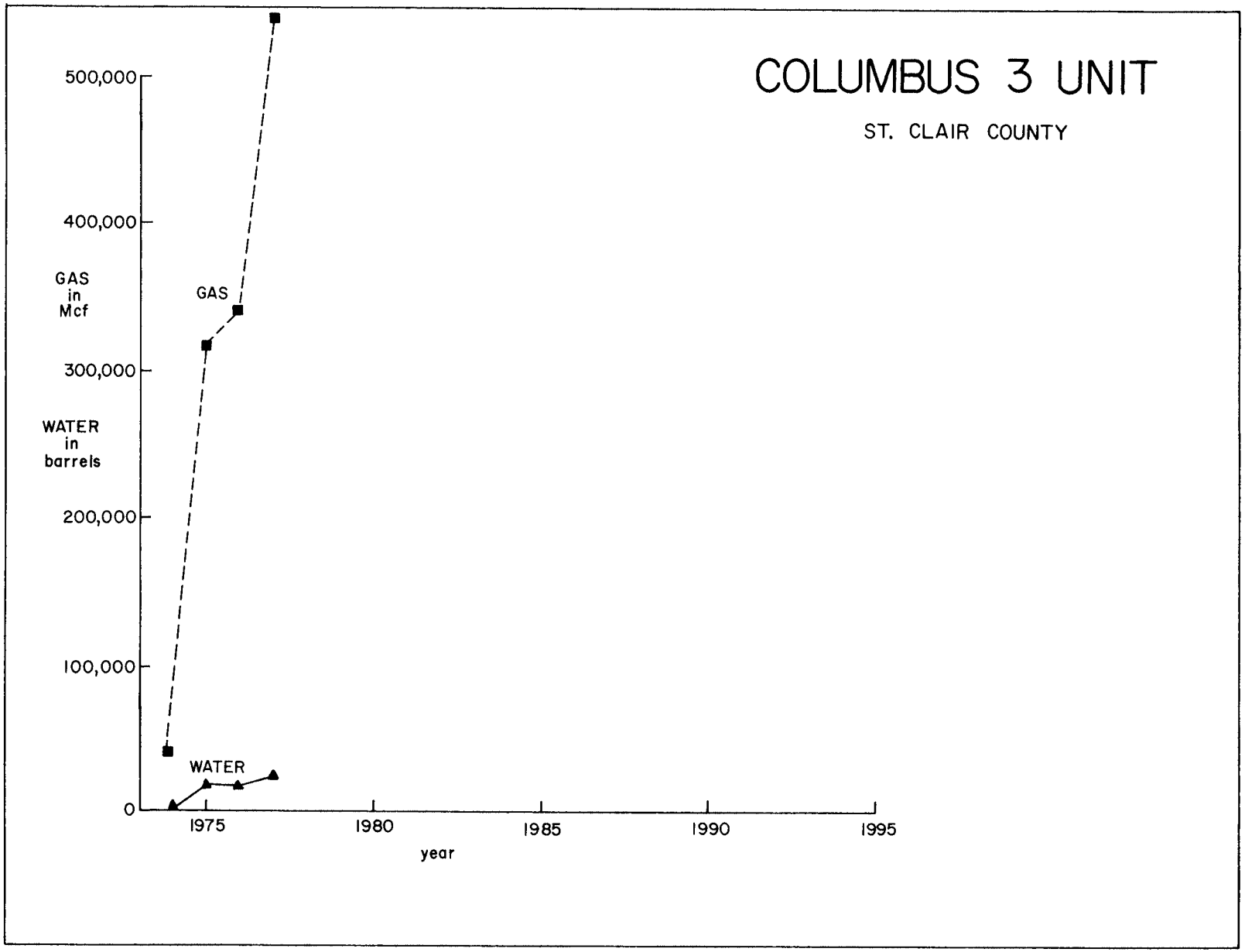

Figure 4. Water and gas injected into the Columbus 3 Unit.

Columbus 3 Unit, St. Clair County								
Year	Injection Data							
	Gas			Water			Pressure	
	No. Wells	Annual	Cumulative	No. Wells	Annual	Cumulative	Gas	Water
1974	2	40,414	40,414	1	559	559	1070	Vacuum
1975	2	318,263	358,677	1	18,382	18,941	1100	Vacuum
1976	2	340,759	706,264	1	18,677	37,618	1100	Vacuum
1977	2	580,638	1,286,902	1	25,906	63,524	1100	Vacuum

Table 2. Water injection data for the Columbus 3 Unit. Water figures are in barrels.

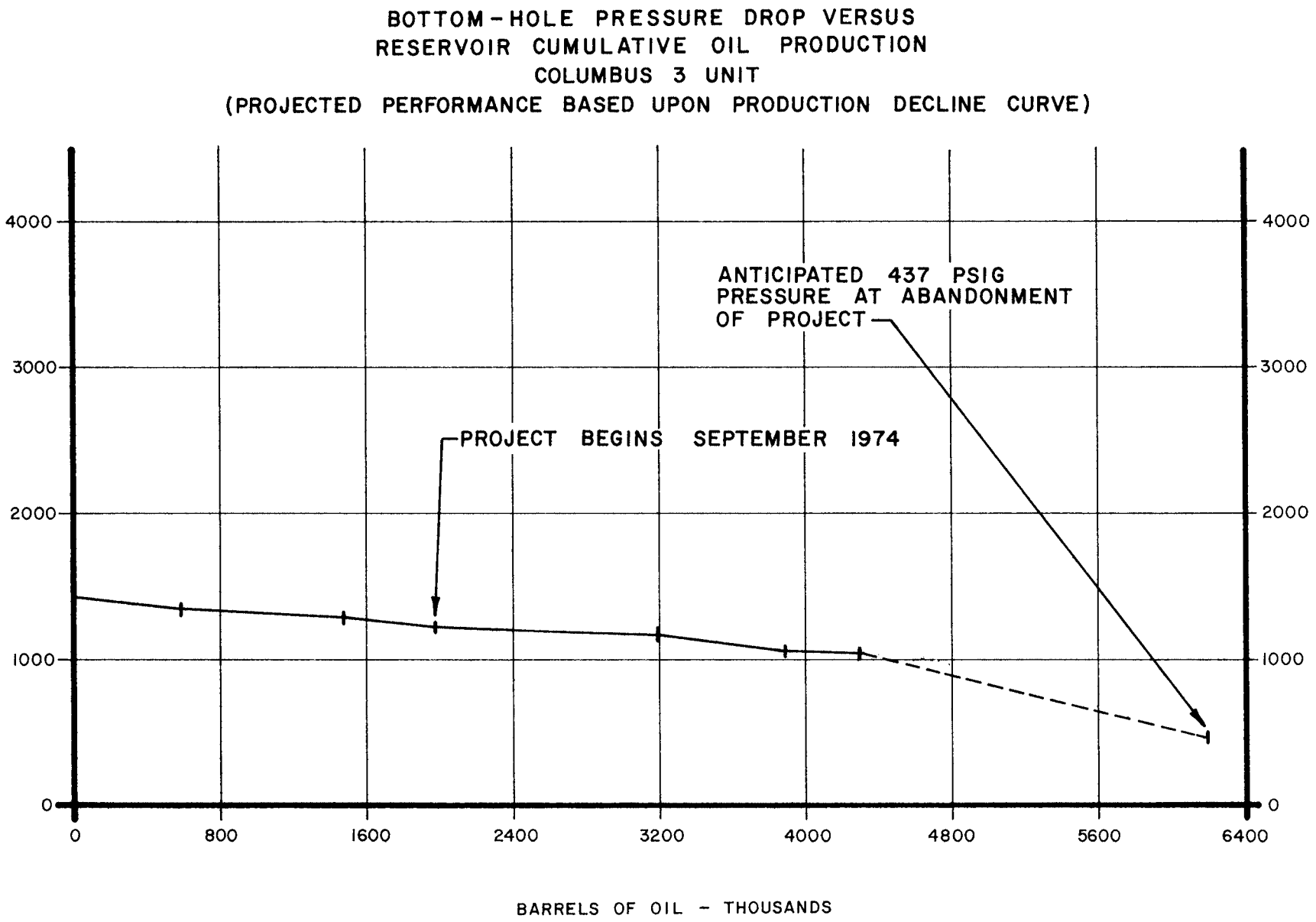

Figure 5. Bottom-hole pressure drop versus reservoir cumulative oil production for the Columbus 3 Unit.

References

Cohee, George V., (1948), Thickness and Lithology of Upper Ordovician, and Lower and Middle Silurian Rocks in the Michigan Basin. U.S. Geological Survey Oil and Gas Investigation, Preliminary Chart No. 33.

Ells, Garland D., (1967), Michigan's Silurian Oil and Gas Pools. Michigan Geological Survey Publication.

Mantek, W., (1973), Niagaran Pinnacle Reefs in Michigan, Michigan Basin Geological Society, Annual Field Conference.

Mesolella, K. J., Robinson, J. D., McCormick, L. M., and Ormiston, A. R., (1974), Cyclic Deposition of Silurian Carbonates in the Michigan Basin. Bulletin American Association of Petroleum Geologists, Volume 58, No. 1, (January, 1974).

Michigan Basin Geological Society, 1968, Symposium on Michigan Oil & Gas Fields: 199 pages.

Michigan Geological Survey, Michigan's Oil and Gas Fields: Annual Statistical Summaries 2 thru 22 (even numbered issues only).

Sun Oil Company, Feasibility Study of Pressure Maintenance, Niagaran Brown Dolomite Reservoir, Columbus Section "3" Field, November, 1971.