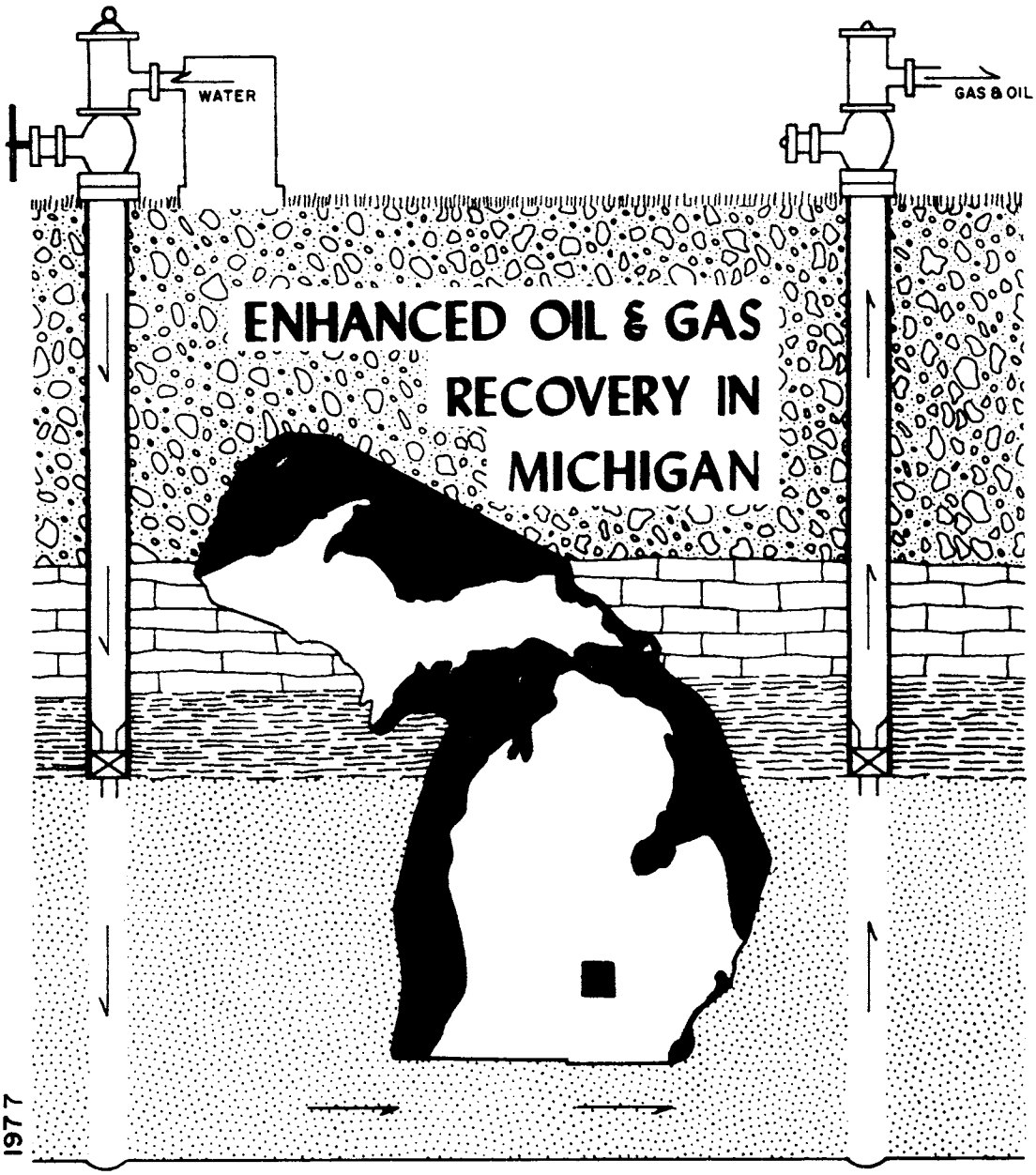
Onondaga 10 Unit



DEPARTMENT OF NATURAL RESOURCES
GEOLOGY DIVISION

PRODUCTION AND PRORATION UNIT
SECONDARY RECOVERY REPORT NO. 5

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GEOLOGY DIVISION

SECONDARY RECOVERY REPORT NO. 5

Onondaga 10 Unit

ENHANCED OIL & GAS RECOVERY IN MICHIGAN

BY
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JAMES S. LORENZ, ARTHUR D. MATZKANIN
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LANSING, MICHIGAN

PREFACE

The Onondaga 10 Unit is the first Salina-Niagaran reservoir reported in the Secondary Recovery Report series and is the first waterflood pressure maintenance project in Michigan. The term *pressure maintenance* as used in this report is not synonymous with the term *secondary recovery*. A secondary recovery operation is initiated some time near the depletion of estimated primary reserves for the purpose of recovering residual oil in place. In contrast, a pressure maintenance operation is begun before the reservoir pressure has dropped to a level requiring secondary recovery. In a given reservoir, ultimate oil recovery will be greater when pressure maintenance is used rather than secondary recovery.

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ONONDAGA 10 UNIT

Enhanced Oil and Gas Recovery in Michigan

Abstract

The Onondaga 10 Unit is the first waterflood pressure maintenance project in the State of Michigan. The project, begun in August 1973, is monitored through a computerized field instrumentation system to assure maximum production efficiency. The field has produced 4.5 million barrels of oil through June 1977, a quantity far in excess of the original primary production estimates of 2.7 million barrels.

INTRODUCTION

The Onondaga 10 field is located in sections 2, 3, 4, 10, 11 and 14 of Onondaga Township, T1N-R2W, Ingham County in the south-central flank of the Michigan Basin. The Onondaga 10 Unit covers 1,760 surface acres and is productive from rocks of the Salina and Niagara groups.

The Onondaga 10 Unit produces oil from two distinct anomalies which are believed to be connected through a common water zone. Each anomaly produces from a separate pressure system, as indicated by bottom-hole pressure survey results. Pressures in two wells in the southeast reservoir (the Edgar #1 and the Richards #1) have been historically lower than pressures in other field wells in the northwest reservoir. The energy mechanism for the field is a gas solution drive with a gas cap. The average pay thickness per well is 61 feet with the productive pay located approximately 2900 feet below sea level.

In order to maximize oil production, Mobil Oil Corporation has computerized field instrumentation through its Denver Regional Office to provide both the field office in Mason and the Denver office with up-to-the-minute field information. The field is operated through the Mason office although the computer in Denver is able to control the choke setting on a producing well or shut-in a particular producing well if a predetermined abnormal condition occurs. The computer reports daily such monitored parameters as: producing or shut-in status for each well; bottom-hole pressures on selected wells; tubing pressure; daily oil, gas, and water production figures; fluid levels in stock tanks; and injected-water figures. Five producing oil wells have been equipped with bottom-hole pressure transducers which continuously monitor reservoir pressures. A computer printout showing all of the monitored parameters is automatically printed in the Mason office once a day. By means of the pressures reported in the printout records, production is then modified to reflect optimum field performance.

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 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 ONONDAGA 10 FIELD HISTORY

The Onondaga 10 field was discovered in March of 1971 when Mobil Oil Corporation drilled the Lenore Davis #1 well located in the SE NE NE quarter of section 10, Onondaga Township, Ingham County. By August 1971, five additional oil producers and four dry holes had been drilled which generally identified the extent of the reservoir.

A spacing order dated May 27, 1971 was adopted to establish designated 80-acre drilling units. This order also defined the reservoir as 1,520 surface acres. A temporary proration order was established on June 1, 1971 that limited the production in the field to 200 barrels of oil per day and/or 200,000 cubic feet of gas per day per well. This temporary proration order became a permanent order effective September 1, 1971.

The May 27, 1971 Spacing Order was amended September 23, 1971 to include additional acreage. This increased the reservoir area to 2,240 surface acres. The June 1, 1971 Proration Order was then amended on September 28, 1971 to include the additional acreage.

By May 1972 a total of 13 oil wells had been drilled in the field. In September 1972 Mobil Oil Corporation petitioned the State of Michigan for unitization of the field as a waterflood pressure maintenance project. At this time approximately 550,000 barrels of oil and 475,000 Mcf of gas had been produced, with an average production of 2,150 barrels of oil per psi pressure loss. Following public hearings the plan was approved and unitization was made effective April 1, 1973. The Onondaga 10 Unit as defined in this order covers 1,760 surface acres as illustrated in Figure 2.

The waterflood project began in August, 1973 with the injection of water into two wells drilled for that purpose. By September, 1974, a total of 6 injection wells drilled in a random pattern were in operation. Original plans called for injection water to be obtained from the Dundee Formation. This formation and parts of the Traverse Group were tested and found to contain inadequate water supplies for injection purposes. However, a sufficient quantity of water was found in the Marshall Formation. Four water supply wells were completed in the Marshall Formation and equipped with submersible Reda pumps. These water wells inject water through a header system into the producing oil zone through the injection wells.

An order dated March 25, 1974 supersedes all prior spacing and proration orders for the field. With the completion of two oil wells in July 1976 and one oil well in March 1977, the field contains 15 oil wells, 4 water supply wells, and 6 water injection wells.

Total field production through June 1977 was 4,517,000 barrels of oil and 4,040,000 Mcf of gas, which exceeds by 1.8 million barrels the primary oil production estimate of 2.7 million barrels. Total recoverable stock tank oil attributable to pressure maintenance is estimated at 5.6 million barrels. Reservoir pressure in mid-1977 for the unit was approximately 1900 psig as compared to 1556 psig when the project began.

STRATIGRAPHIC POSITION	INFORMAL TERMS	PAYS
Basal sandstones of Saginaw Fm.	Parma sandstone	
In lower part of Michigan	triple gyp. brown lime stray-stray ss.	Gas
	stray dol. stray ss.	Gas & Oil
Marshall Ss.		Gas & Oil
Coldwater Sh.	Coldwater lime Weir sand	Gas
	Coldwater red-rock	
In upper part of Ellsworth Sh.	"Berea" (Western Michigan)	Oil & Gas
Berea Ss.	Berea sand (Eastern Michigan)	Oil & Gas
Squaw Bay Ls.	Squaw Bay	Oil & Gas
Upper part of Traverse Group in Western Michigan	Traverse formation Traverse lime	Oil & Gas
	Stoney Lake zone	Oil & Gas
Rogers City Ls.		Oil & Gas
Dundee Ls.		Oil & Gas
Dundee Ls. (?), Upper part of Lucas Fm. (?)	Reed City zone	Oil & Gas
In Lucas Fm.	massive salt big salt sour zone	Oil & Gas
	massive anhydrite big anhydrite Richfield zone	Oil & Gas
Amherstburg Fm.	black lime	
Part of Salina Group E Unit	E zone (or Kintigh zone)	Oil
Divisions of A-2 Carbonate in Western Michigan	A-2 dolomite A-2 lime	Gas
A-1 Carbonate	A-1 dolomite	Oil & Gas
Upper part of Niagaran Series	brown Niagaran gray Niagaran white Niagaran	Oil & Gas
Part of Niagaran Series	Clinton shale (Eastern Michigan)	
Trenton Group		Oil & Gas
Black River Group	Black River formation Black River shale Van Wert zone	Oil & Gas
Oneota Dol.		Oil

Table 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.

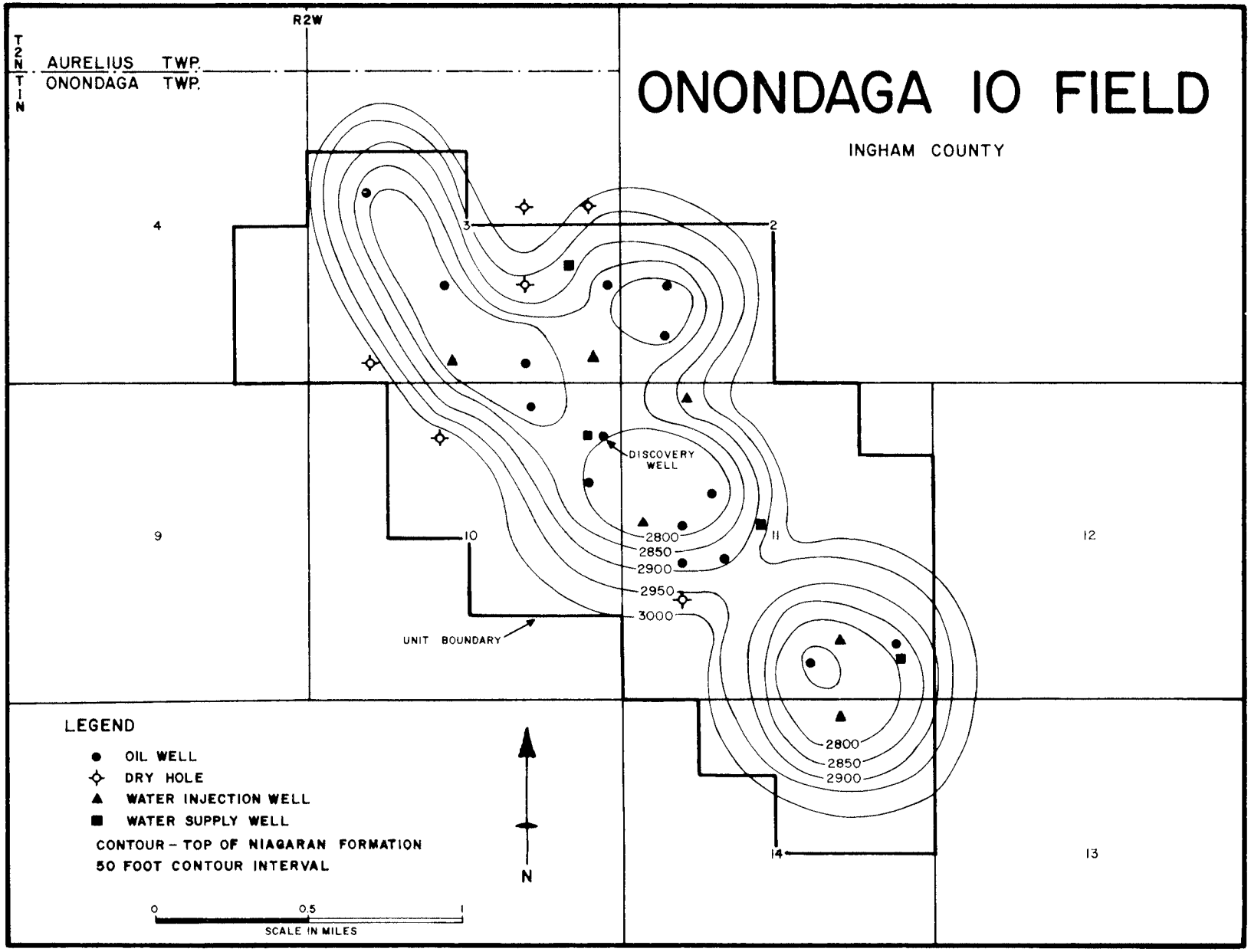

Figure 2: Structure of the Onondaga 10 Unit contoured on top of the Niagaran Formation.

Data Sheet No. 1

Onondaga 10 Unit

Salina Niagaran

Pressure Maintenance Project

GENERAL POOL DATA

Location	Ingham County, Onondaga Twp. (T1N, R2W), Sec. 2, 3, 4, 10, 11, 14
Date of pool discovery	March 25, 1971
Discovery well	Mobil Oil Corporation, Davis #1 Permit Number 28355
Producing formation	Salina-Niagaran
Pay lithology	Dolomitized carbonates
Type of trap	Reef
Drilled acres	1280
Unit acres	1760
Reservoir area, estimated acres	880

ENGINEERING DATA

Type of reservoir energy	Solution gas & gas cap expansion
Original reservoir pressure	1808 Psia
Reservoir temperature	92°F
Viscosity of original reservoir oil	.87 cp
Bubble point pressure	1785 - 1798 Psia
Formation volume factor	1.3372
API oil gravity	34.9°
Original solution gas-oil ratio	670 cfpb
Average porosity	5.9%
Average permeability	30 md horizontal, 6 md vertical
Connate water, estimated	20%
Net oil pay thickness	75 ft.
Acre feet of oil pay	65,956

RECOVERABLE HYDROCARBON DATA

Estimated original stock tank oil in place	18,020,000 bbls.
Estimated original recoverable stock tank oil	2,703,000 bbls.
Calculated recoverable stock tank oil per acre foot	41 bbls. primary; 126 bbls. primary and secondary
Original gas in solution	12,140 MMcf, 3,360 MMcf gas cap
Estimated original recoverable gas	11,098 MMcf
Estimated additional recoverable oil due to secondary recovery methods	5,588,500 bbls.

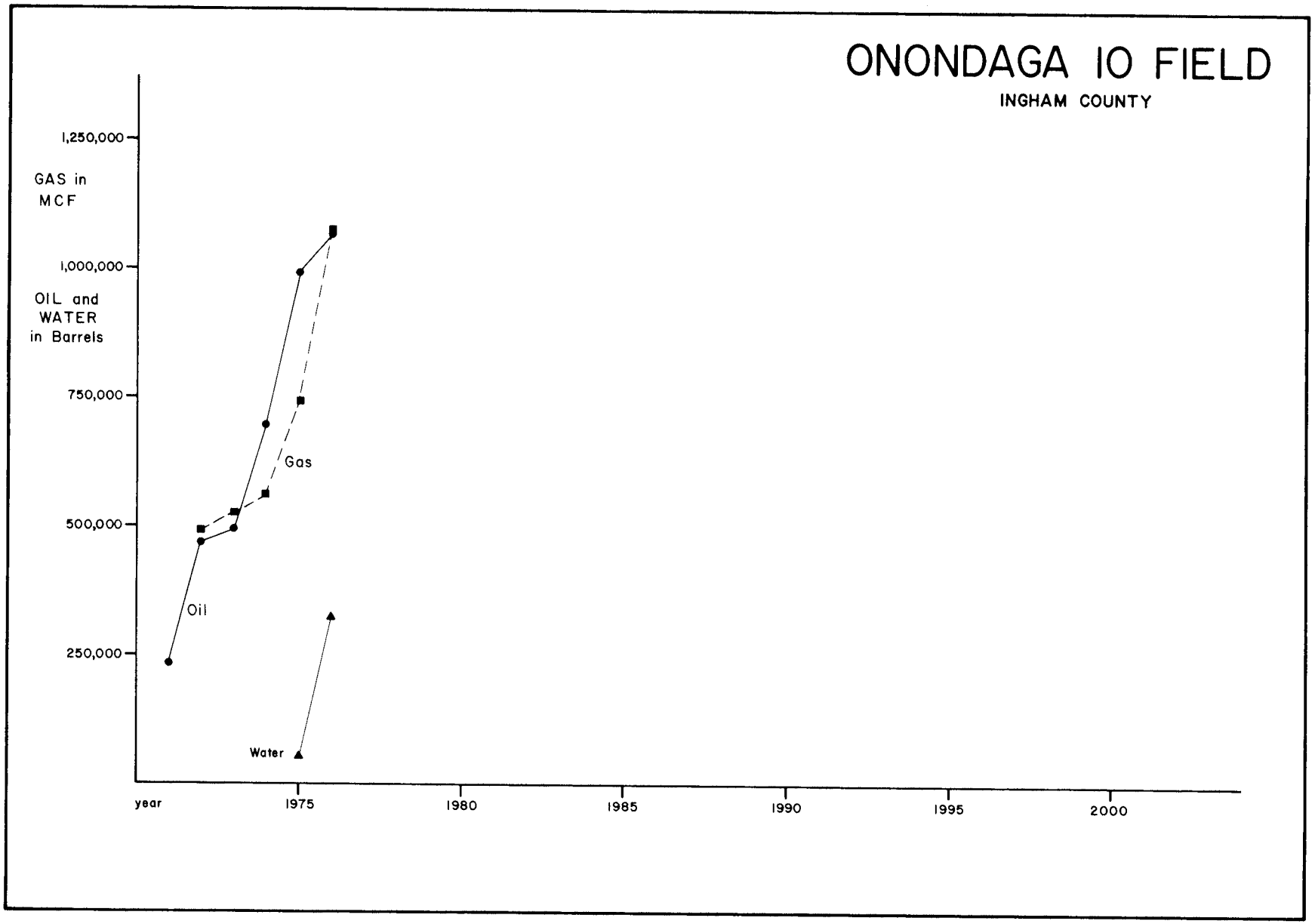

Figure 3. Oil, gas, and water production from the Onondaga 10 Unit. Oil and water production is shown in barrels. Gas production is shown in thousand cubic feet (Mcf).

Onondaga 10 Field, Ingham County							
Year	Production Data						Remarks
	Gas		Oil		Water (estimated)		
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	
1971	0	0	234,646	234,646			
1972	491,028	491,028	469,073	703,719			
1973	525,939	1,030,517	491,735	1,192,510			Waterflood begins
1974	560,311	1,590,828	692,000	1,889,478			
1975	747,723	2,320,843	996,761	2,886,239	52,500	52,500	Oil production surpasses original primary estimates in 1975.
1976	1,071,943	3,392,786	1,067,814	3,954,053	326,000	378,500	

Table 1. Oil, gas, and water production from the Onondaga 10 Field. Oil and water production figures are shown in barrels. Gas production figures are shown in thousand cubic feet (Mcf).

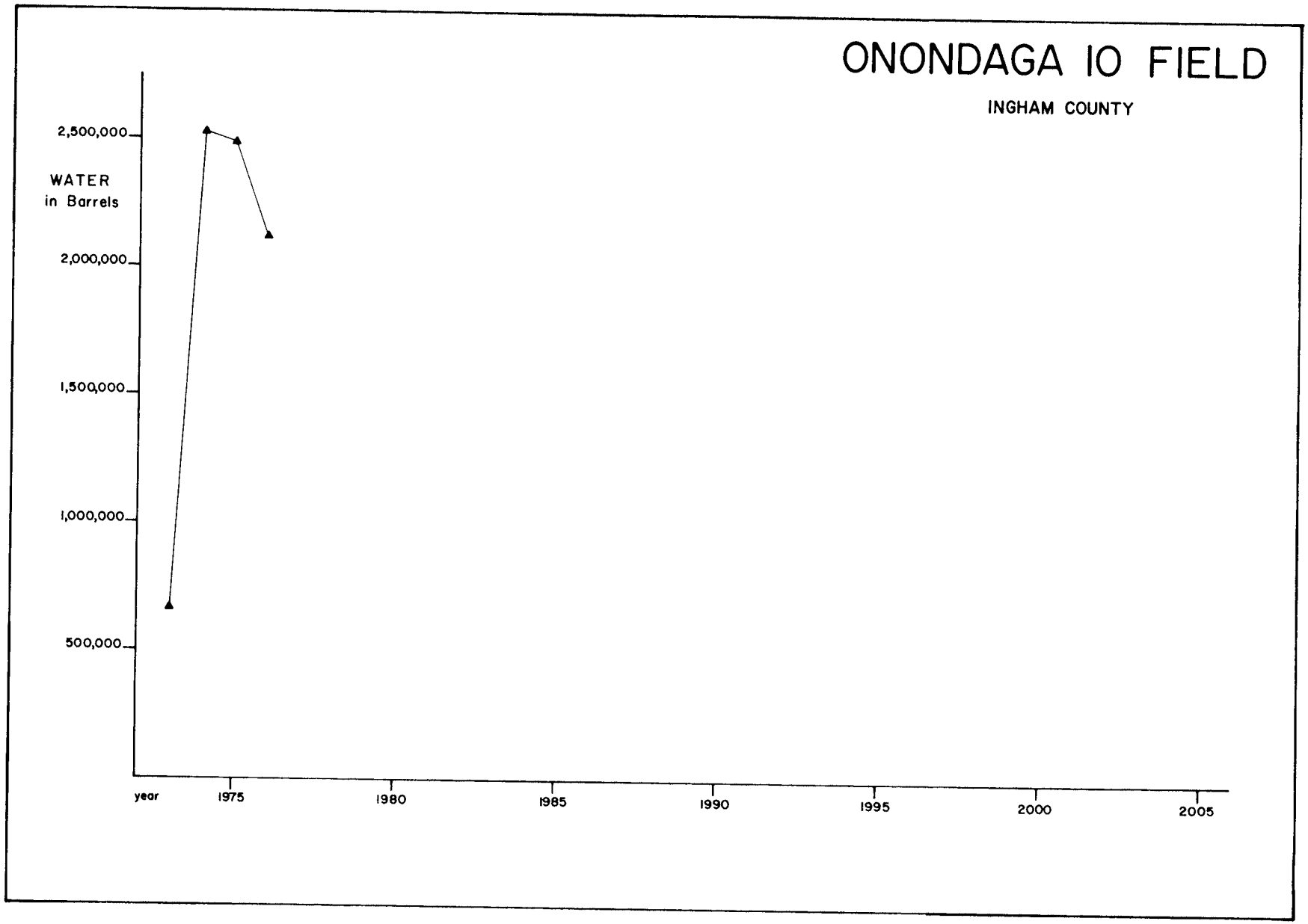

Figure 4: Water injected into the Onondaga 10 Unit. Injected water is shown in barrels.

Onondaga 10 Field, Ingham County								
Year	Injection Data							
	Gas			Water			Pressure	
	No. Wells	Annual	Cumulative	No. Wells	Annual	Cumulative	Gas	Water
1971								
1972								
1973				3	670,415	670,415		780
1974				6	2,525,014	3,195,429		780
1975				6	2,471,688	5,667,117		1,100
1976				6	2,120,902	7,788,019		840

Table 2. Water injection data for the Onondaga 10 Field. Water figures are in barrels.

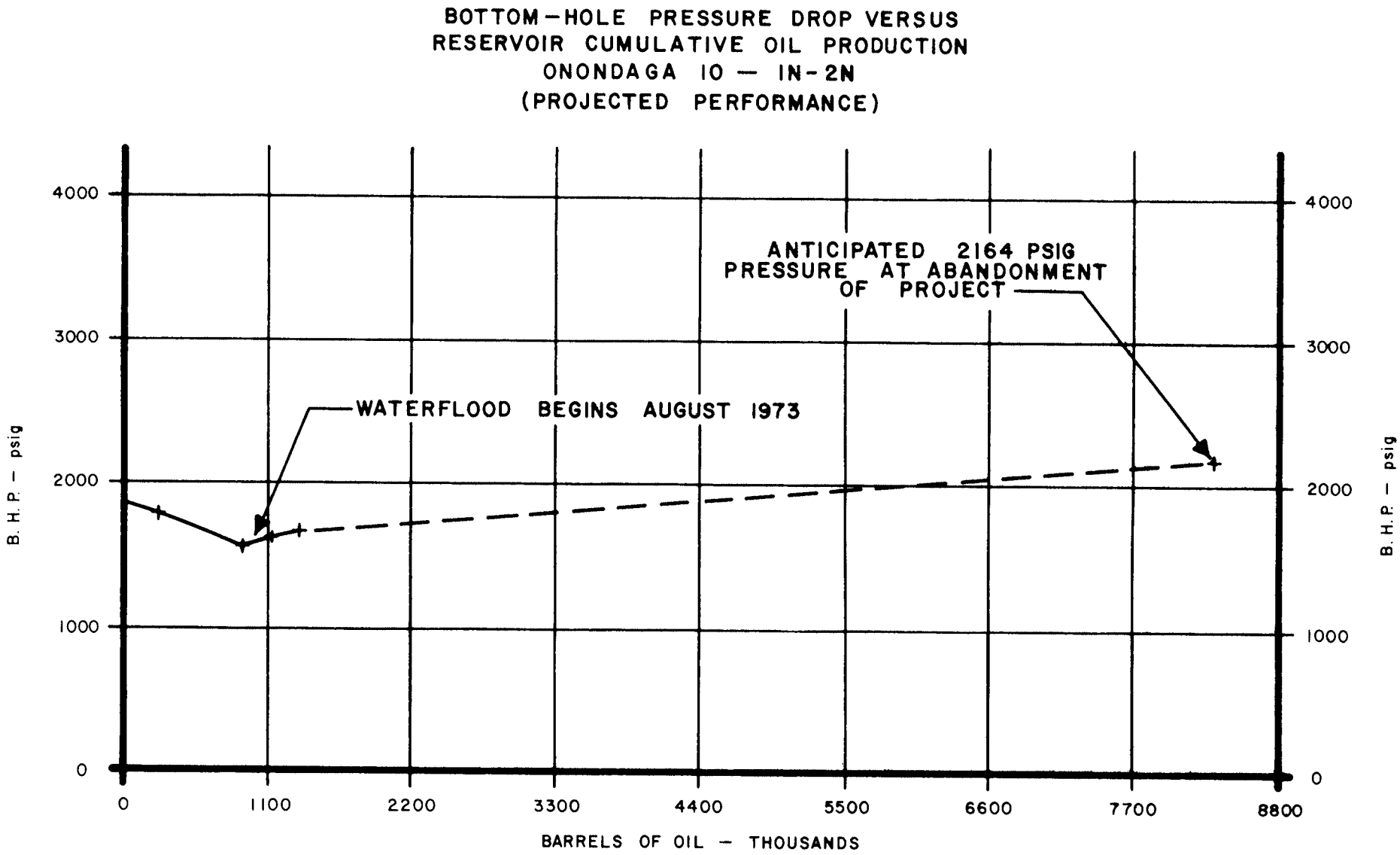

Figure 6. Bottom-hole pressure drop versus reservoir cumulative oil production for the Onondaga 10 Field. Pressure in pounds per square inch (psig) and production in barrels.

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 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 Petroleum Geology, 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).

Mobil Oil Corporation, Improved Recovery Feasibility Study, Proposed Onondaga 10 Unit, Revised August 22, 1972.

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