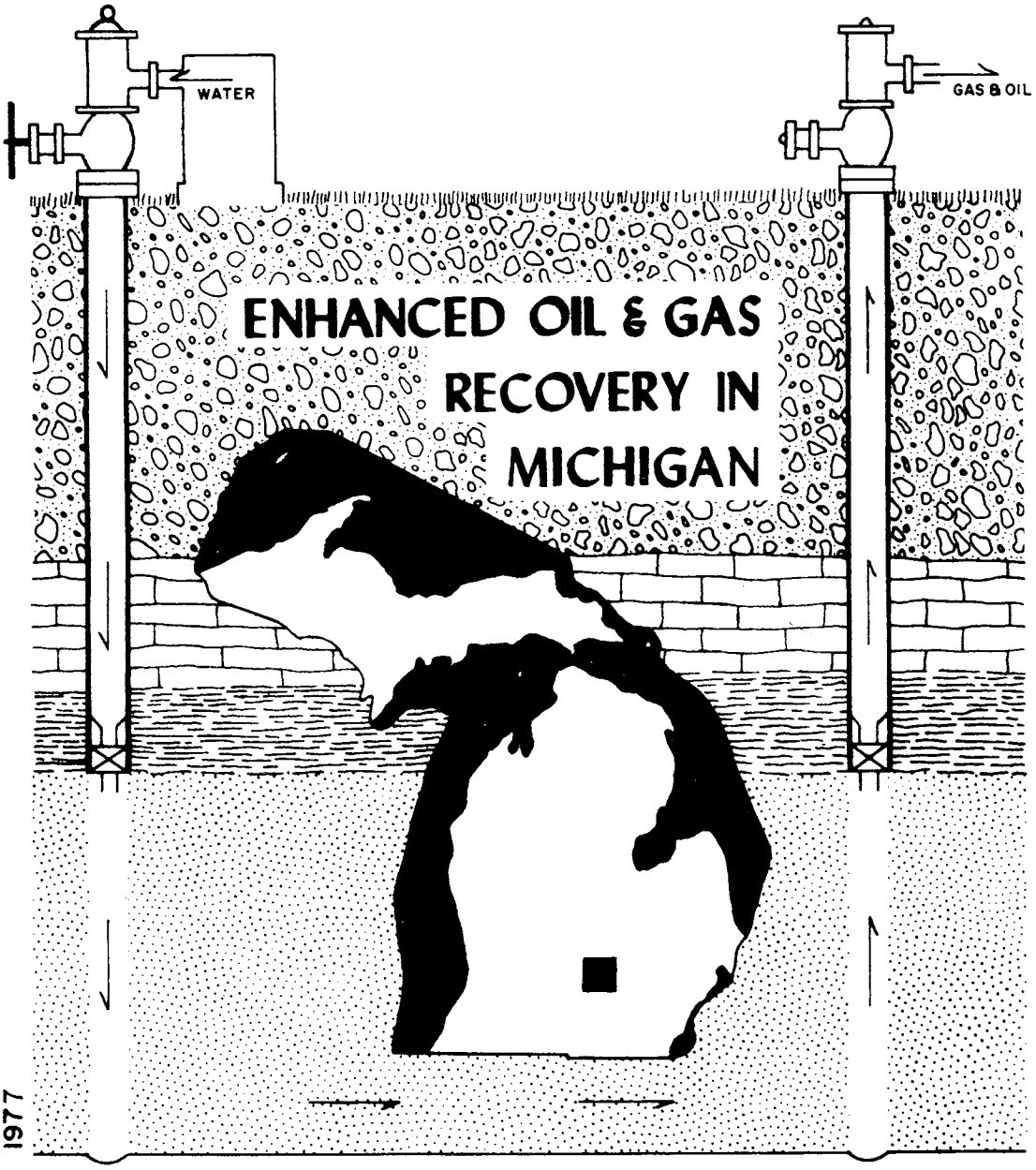
# Aurelius 35 Unit




DEPARTMENT OF NATURAL RESOURCES
GEOLOGY DIVISION

PRODUCTION AND PRORATION UNIT
SECONDARY RECOVERY REPORT NO. 6

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GEOLOGY DIVISION

**SECONDARY RECOVERY REPORT NO. 6**

# Aurelius 35 Unit

## ENHANCED OIL & GAS RECOVERY IN MICHIGAN

BY
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LANSING, MICHIGAN

# PREFACE

The Aurelius 35 Unit Waterflood report is the second report in this series on a Salina-Niagaran reservoir. Like the Onondaga 10 Unit this project is a pressure maintenance operation and is to be distinguished from a secondary recovery project. The advantage to be gained through a pressure maintenance operation is greater ultimate oil recovery than that achieved through a secondary recovery project. Secondary recovery methods are instigated after primary production has been depleted. Pressure maintenance operations are begun while primary production remains in the reservoir.

CONTENTS

# AURELIUS 35 UNIT

## Enhanced Oil and Gas Recovery in Michigan

*Abstract*

*A successful pressure maintenance program began in June, 1974, on the Aurelius 35 field in Aurelius Township of Ingham County, Michigan. The implementation of pressure maintenance is expected to enhance ultimate production from the field to 32 percent of recoverable original oil in place as compared to a primary recovery of 10.5 percent or 805,000 barrels. Through the second quarter of 1977 total oil production has exceeded 1,280,000 barrels.*

## INTRODUCTION

Exploratory drilling by Mobil Oil Corporation led to the discovery of oil in the Aurelius 35 field in December, 1971. With the completion of four oil wells and two dry holes within one year, the extent of the field had been delineated. In 1976 a fifth oil well was drilled into the reservoir. Seismic data and successfully completed wells show the field to be beneath portions of sections 26, 35, and 36 of Aurelius Township in Ingham County.

Oil and gas production is obtained from a Salina-Niagaran 200-acre reef composed of recrystallized and dolomitized carbonates. Based upon log evaluations, the wells in the field have been determined to contain various hydrocarbon pays 78 to 210 feet thick in the interval between the top of the A-1 carbonate and the oil-water contact at 3090 feet subsea level in the Niagaran formation. Unitized production is defined, by the agreement of November 1973, to be that production obtained from the interval between the top of the A-1 carbonate and the base of the Niagaran formation.

## 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 reefs 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 HISTORY OF AURELIUS 35 UNIT

The Aurelius 35 pool was discovered in December, 1971 with the completion of the Mobil Oil Corporation Hawkins #1 well in Section 35 of Aurelius Township. On December 15, 1971 a drilling and spacing order was issued by the Supervisor of wells which established the Aurelius 35-2N-2W Salina-Niagaran Formation pool. The order specified 80-acre drilling units in the east one-half and west one-half of a governmental surveyed quarter section of land for sections 26 and 35 and the west one-half of sections 25 and 36. On January 1, 1972 a proration order established a daily production allowable of 200 barrels of oil and/or 200,000 cubic feet of gas per day per well.

A reservoir evaluation in 1972 indicated the Aurelius 35 field could be profitably operated as a pressure maintenance project. This conclusion was determined through the use of a computer simulation model which evaluated geological and rock property parameters associated with the field. The computer model was able to predict ultimate primary recovery after a computer match had been established with actual field performance. The model was also used to determine the location and number of oil and water injection wells to be drilled which would maximize the ultimate recovery from unitized pressure maintenance operations.

After proper administrative procedures were completed, the Supervisor of Wells issued an order approving the unitization of the Aurelius 35 field effective December 1, 1973. The unitization agreement specifies the unit to include the southeast quarter of section 26, the northeast quarter of section 35, and west one-half of the northwest quarter of section 36, Aurelius Township, Ingham County. Injection into the field began in June, 1974 through two water injection wells. Source water for injection purposes is water from the Marshall formation and produced brine from the Salina-Niagaran zone. In June, 1977 the Aurelius 35 Unit contained five producing oil wells and two water injection wells. In the completion of five oil wells in the field, 5½-inch diameter casing and 2½-inch tubing were used.

Through June, 1977 a total of 1,280,829 barrels of oil have been produced with 676,511 Mcf of gas. Estimated primary production of 804,000 barrels was exceeded in the first quarter of 1976. The initial reservoir pressure was measured at 1869 psia. When the pressure maintenance project is completed and abandoned the subsurface pressure is expected to be about 2300 psia. Because the field is a solution-gas reservoir with no apparent water influx, a pressure maintenance project recovery of 32.2 percent is expected as compared to a projected primary recovery of 10.4 percent.

A summary of field data is presented in Data Sheet No. 1. Historical oil and gas production data are listed in Table 1, with water injection data listed in Table 2.

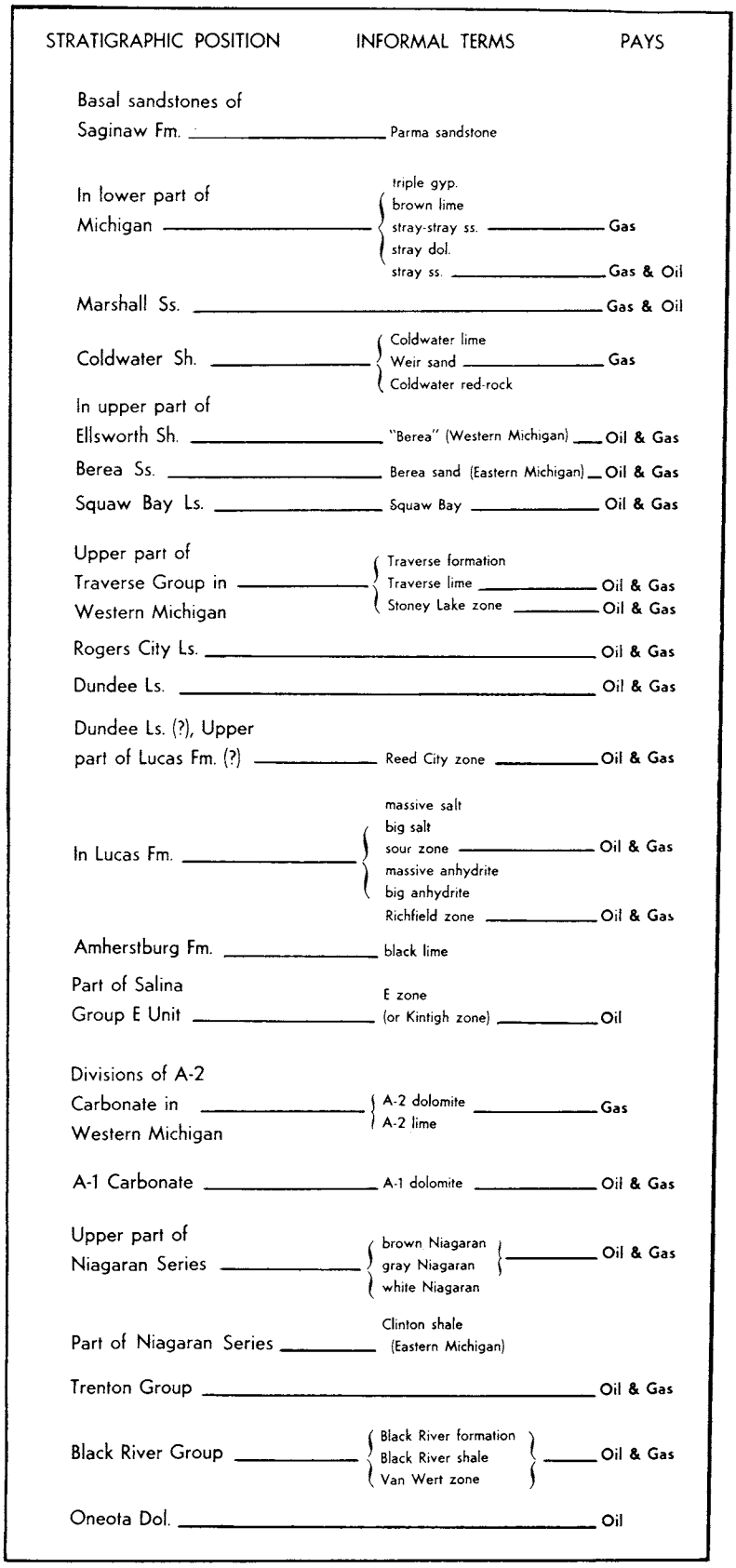


Figure 1. Principal oil and gas pays and informal terms used in petroleum exploration applied to parts of formations or groups of formations in the subsurface of the Michigan Basin.

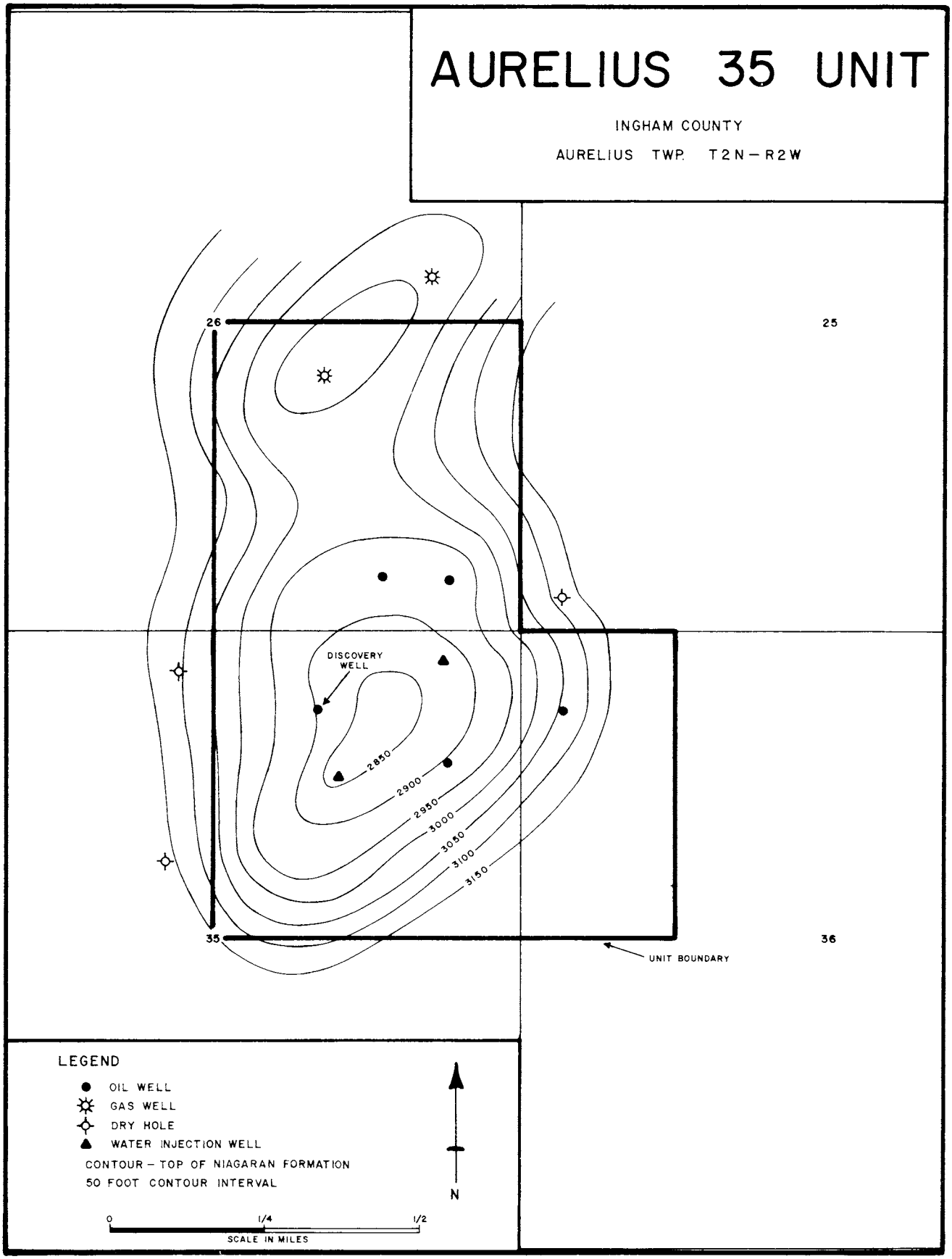


Figure 2: Structure of the Aurelius 35 Unit contoured on top of the Niagaran Formation.

Data Sheet No. 1

Aurelius 35 Unit

Salina-Niagaran Pressure
Maintenance Waterflood Project

## GENERAL POOL DATA

| | |
|---|---|
| Location | Ingham County, Aurelius Twp. (T2N, R2W), Sections 26, 35, 36 |
| Date of pool discovery | December 14, 1971 |
| Discovery Well | Mobil Oil Corporation, Hawkins #1 Permit Number 28689 |
| Producing formation | Salina-Niagaran |
| Pay lithology | Dolomitized carbonates |
| Type of trap | Reef |
| Drilled acres | 400 |
| Unit acres | 400 |
| Reservoir area, estimated acres | 207 |

## ENGINEERING DATA

| | |
|---|---|
| Type of reservoir energy | Solution gas |
| Original reservoir pressure | 1869 Psia |
| Reservoir temperature | 92°F |
| Viscosity of original reservoir oil | .90 cp |
| Bubble point pressure | 1590 Psia |
| Formation volume factor | 1.2856 |
| API oil gravity | 37° |
| Original solution gas-oil ratio | 590 cfpb |
| Average porosity | 6.67% |
| Average permeability | 8.0 md |
| Connate water, estimated | 16% |
| Net oil pay thickness | 110 ft. |
| Acre feet of oil pay | 22,899 |

## RECOVERABLE HYDROCARBON DATA

| | |
|---|---|
| Estimated original stock tank oil in place | 7,735,100 bbls. |
| Estimated original recoverable stock tank oil | 805,000 bbls. |
| Calculated recoverable stock tank oil per acre foot | 35.1 bbls. primary; 109 bbls. primary and secondary |
| Original gas in solution | 4,564 Mcf |
| Estimated original recoverable gas | 2,573.9 Mcf |
| Estimated additional recoverable oil due to secondary recovery methods | 1,686,200 bbls. |

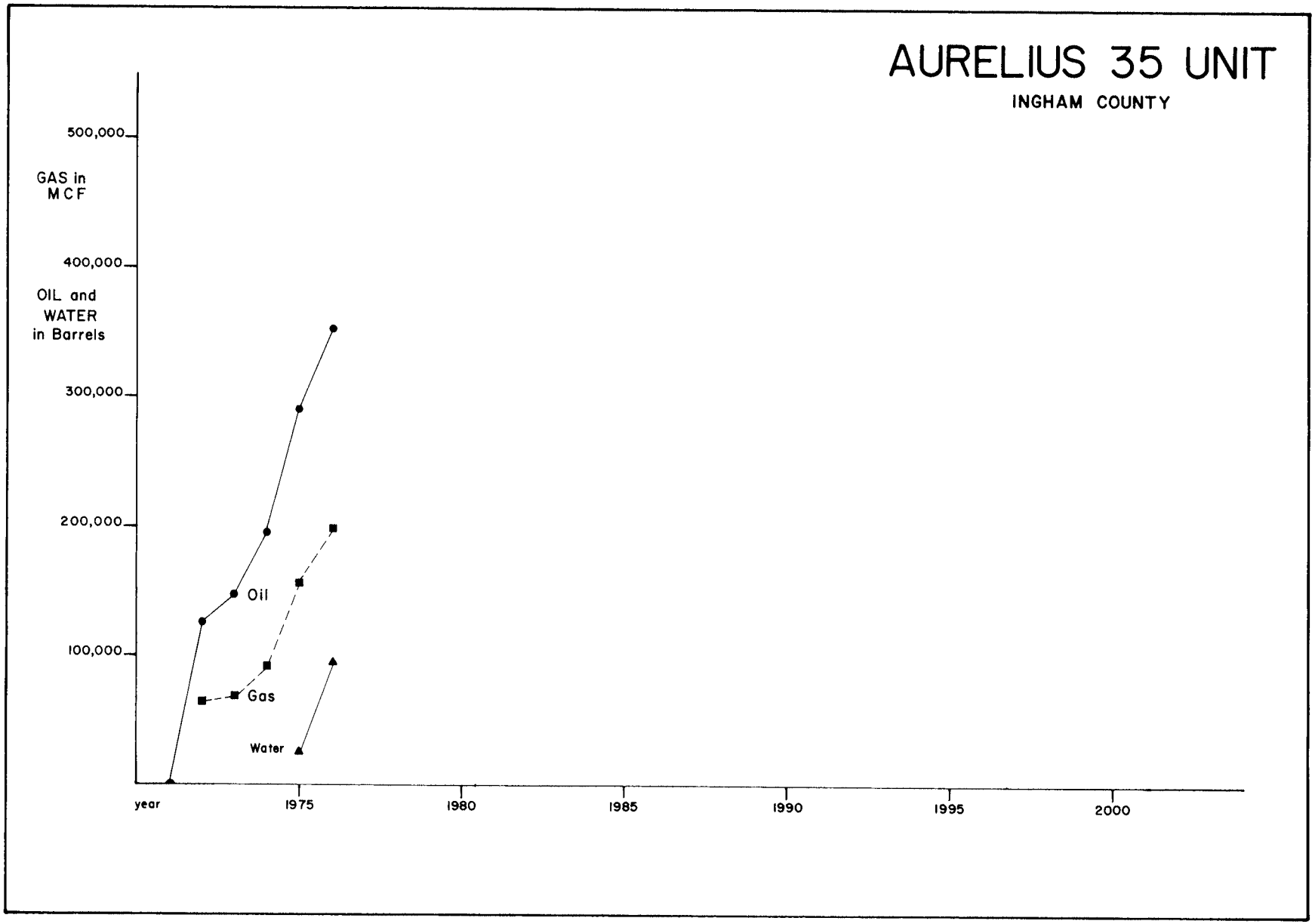


Figure 3: Oil, gas, and water production from the Aurelius 35 Unit. Oil and water production is shown in barrels. Gas production is shown in thousand cubic feet (MCF).

| Aurelius 35 Unit, Ingham County | | | | | | | |
|---|---|---|---|---|---|---|---|
| Year | Production Data | | | | | | Remarks |
| | Gas | | Oil | | Water (estimated) | | |
| | Annual | Cumulative | Annual | Cumulative | Annual | Cumulative | |
| 1971 | 0 | 0 | 1,628 | 1,628 | | | |
| 1972 | 63,133 | 63,133 | 125,756 | 127,384 | | | |
| 1973 | 63,109 | 131,777 | 147,320 | 274,704 | | | |
| 1974 | 91,233 | 222,506 | 195,025 | 469,729 | | | Waterflood begins |
| 1975 | 156,989 | 379,495 | 291,462 | 761,191 | 26,250 | 26,250 | Oil production surpasses |
| 1976 | 199,732 | 579,227 | 353,832 | 1,115,023 | 95,000 | 121,250 | original primary estimates. |

Table 1. Oil, gas, and water production from the Aurelius 35 Unit. Oil and water production figures are shown in barrels. Gas production figures are shown in thousand cubic feet (Mcf).

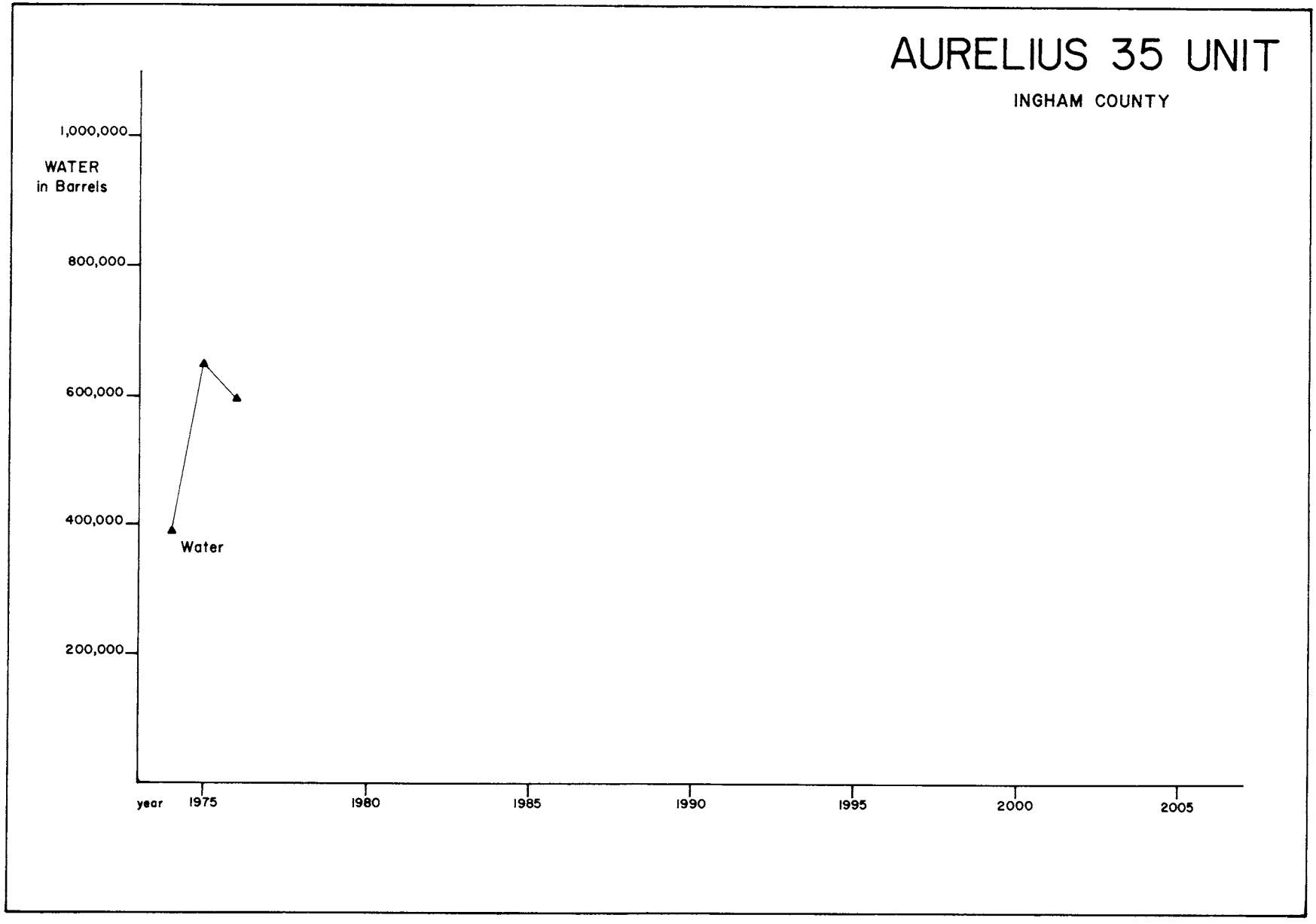


Figure 4: Water injected into the Aurelius 35 Unit. Injected water is shown in barrels.

| Aurelius 35 Unit, Ingham County | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Injection Data | | | | | | | |
| | Gas | | | Water | | | Pressure | |
| | No. Wells | Annual | Cumulative | No. Wells | Annual | Cumulative | Gas | Water |
| 1971 | | | | | | | | |
| 1972 | | | | | | | | |
| 1973 | | | | | | | | |
| 1974 | | | | 2 | 390,327 | 390,327 | | 500 |
| 1975 | | | | 2 | 646,436 | 1,036,763 | | 1,000 |
| 1976 | | | | 2 | 579,360 | 1,616,123 | | 940 |

Table 2. Water injection data for the Aurelius 35 Unit. Water figures are in barrels.

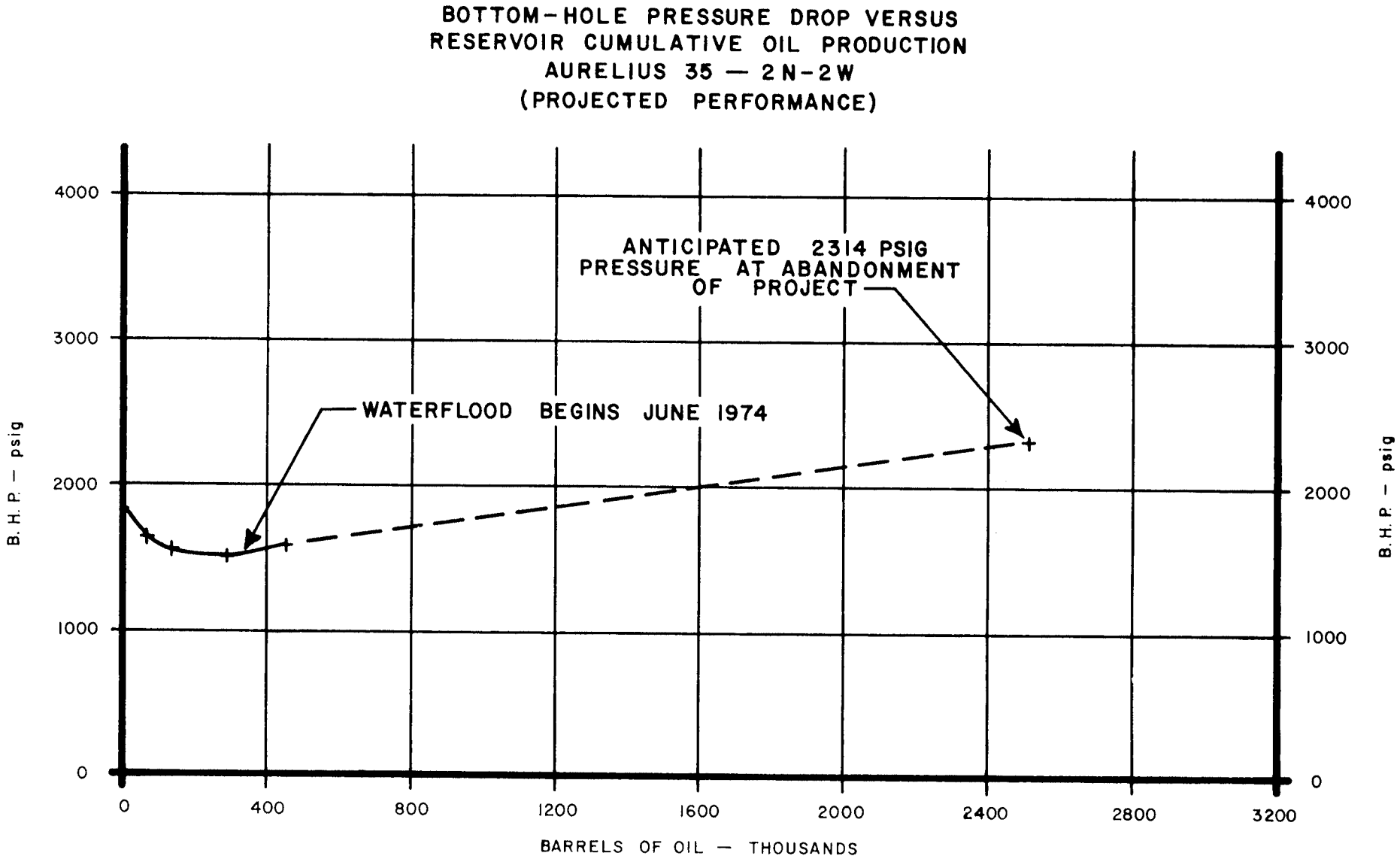


Figure 5. Bottom-hole pressure drop versus reservoir cumulative oil production for the Aurelius 35 Unit. Pressure in pounds per square inch (psig) and production in barrels.

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