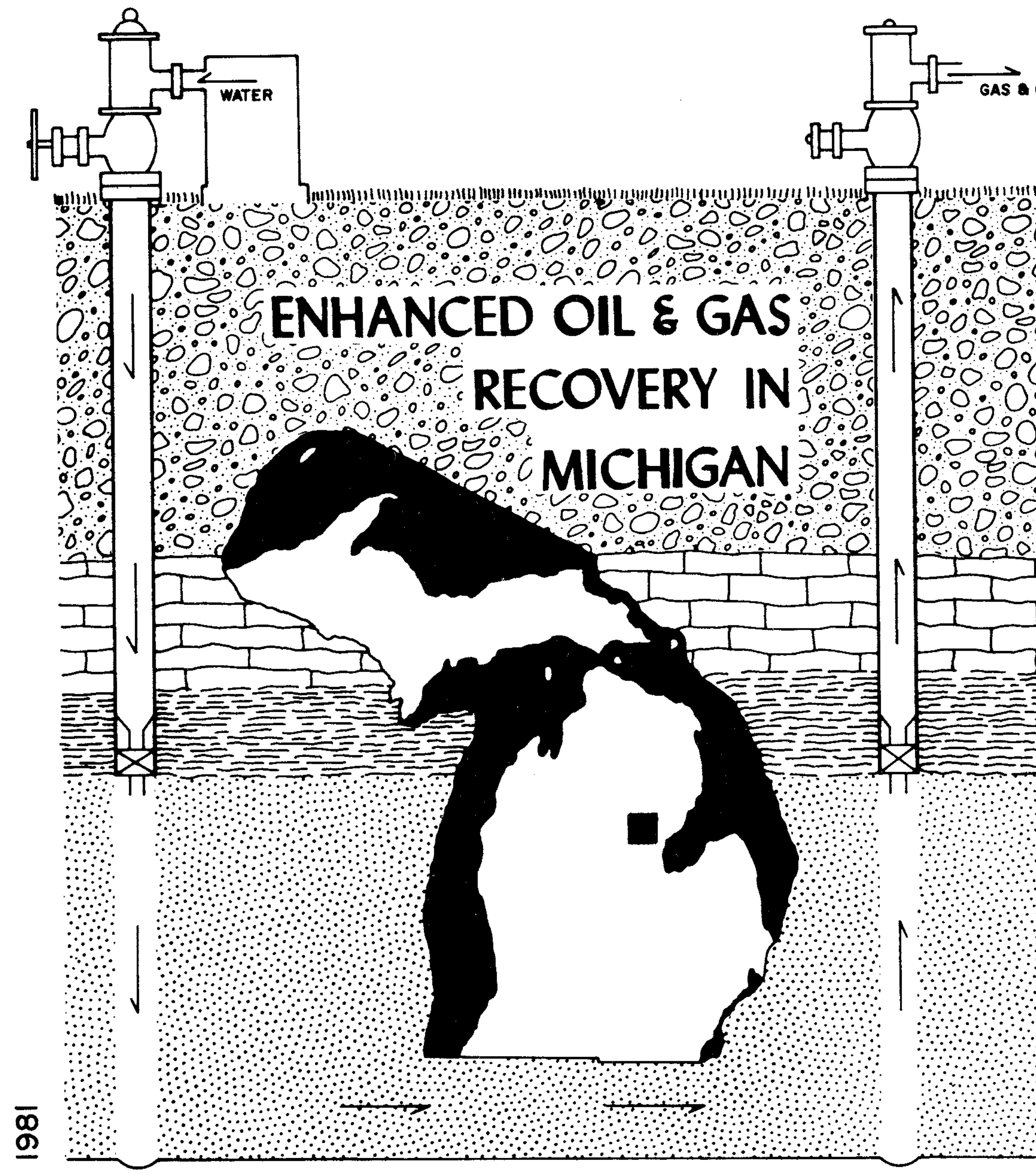
West Branch Field
Dundee Oil Pool



1981

DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY DIVISION

PRODUCTION AND PRORATION UNIT
SECONDARY RECOVERY REPORT NO. 8

GEOLOGICAL SURVEY
DIVISION

SECONDARY RECOVERY REPORT NO. 8

West Branch Field Dundee Oil Pool

ENHANCED OIL & GAS RECOVERY IN MICHIGAN

BY
RAYMOND G. VUGRINOVICH
AND
ARTHUR D. MATZKANIN

LANSING, MICHIGAN 1981

STATE OF MICHIGAN
Governor
William G. Milliken

DEPARTMENT OF NATURAL RESOURCES
Director
Howard A. Tanner

GEOLOGICAL SURVEY DIVISION
Acting Chief and State Geologist
R. Thomas Segall

Published by authority of State of Michigan
Compiled Laws of 1970 section 321.6

Copies of this and all other Department of Natural Resources publications
are available from:
Information Services Center
Michigan Department of Natural Resources
Box 30028
Lansing, Michigan 48909

On deposit in many libraries in Michigan and other selected locations

PREFACE

The eighth in a series of reports dealing with enhanced oil recovery projects in the State of Michigan is the first to deal with the Dundee Limestone. These reports, by the Production and Proration Unit of the Geological Survey Division, represent an effort to better serve the State of Michigan, the petroleum industry, and the general public, by making the information within more readily available to all interested parties. Future reports are planned and will be published as they are completed.

CONTENTS

Figures

Data Sheets

Tables

WEST BRANCH FIELD

Enhanced Oil and Gas Recovery in Michigan

ABSTRACT

The West Branch oil field produces from an anticlinal structure in the Dundee Limestone. Since waterflooding was initiated in 1966, oil production has exceeded original primary production estimates by almost 930,000 barrels.

INTRODUCTION

The West Branch Field is located in parts of Ogemaw, Horton, Churchill, West Branch, and Mills townships, Ogemaw County. The field was discovered in 1934 and was found to contain reservoirs in four rock units.

Primary production is from the Dundee Limestone of Middle Devonian age. In the West Branch Field, the Dundee is found at a depth of approximately 2,500 feet and averages 300 feet in thickness. Pay zones are found 10, 100, and 140-150 feet below the top of the Dundee. The average total thickness of the pay zones is 20-30 feet.

In 1938 production was established in rocks of the "sour zone" in the Detroit River Group of Lower Middle Devonian age. The discovery well was the T. F. Caldwell No. 9 State-Mills (P.N. 5421), located in Section 6, T.21N., R.3E. The reservoir rocks are a sequence of evaporites, dolomites, and limestones immediately underlying the Dundee Limestone. The pay zone is found at a depth of about 3,650 feet and averages less than 10 feet in thickness. At present, 32 wells in the West Branch Field produce from this zone. These wells are confined to the northwest and southeast portions of the field.

Sweet crude production from the Richfield Member of the Detroit River Group (approximately 500 feet deeper than the "sour zone") was established in 1952 with the completion of the Ogma Development Company No. 1 Weiler (P.N. 17596). This well is located in Section 14, T.22N., R.1E. Twenty-eight wells in the West Branch Field are presently producing from this zone.

Shows of oil and gas have also been reported from Traverse Group limestones, found at a depth of approximately 1,700 feet. The productive zone is found some 100 feet below the top of the Traverse Group. Two wells in the West Branch Field are now producing from Traverse Group rocks.

ROGERS CITY - DUNDEE LIMESTONE RESERVOIR ROCKS

The Dundee Limestone was originally defined to include the limestones and dolomites between the base of the Traverse Group and the top of the underlying Detroit River Group. On the basis of brachiopod, gastropod, and pelecypod fossils, Ehlers and Radabaugh (1939) divided the Dundee into two formations. The name Rogers City Limestone was proposed for the upper division and the name Dundee Limestone was retained for the lower section. Many geologists have since adopted these formation names (e.g., Cohee and Underwood 1945, and Tinkelpaugh 1957).

Tinkelpaugh (1957) describes the Dundee Limestone as buff to light brown, becoming more dolomitic and anhydritic in western Michigan. She further characterizes the Dundee Limestone in the eastern and northeastern part of the Michigan basin as a marine limestone with oolites and stylolites and "a more varied fauna in the peripheral areas." The Rogers City Limestone is described as a dark brown to buff dolomitic limestone or dolomite and "A predominantly fossiliferous, marine limestone altered locally to dolomite." Cohee and Underwood (1945) and Tinkelpaugh (1957) agree that the Rogers City Limestone overlays the Dundee Limestone in the northern two-thirds of the southern peninsula of Michigan, but that both formations are absent in the southwestern corner of the state.

Most of the Rogers City - Dundee structures contain dolomite along with associated porosity. Tinkelpaugh (1957) stated that "it would appear, from statistical evidence, that there is a direct relationship between the magnitude of structure and the degree of dolomitization."

Many theories have been advanced to explain the amount of intercrystalline porosity and permeability associated wth secondary dolomitization. One of the first theories of dolomitization was put forth by Beaumont in 1836. Beaumont stated that the replacement of calcite ($CaCO_3$) by dolomite ($Ca,Mg(CO_3)_2$) would cause a "volume shrinkage" of about twelve percent. Considerable laboratory data, both chemical and physical, support this theory, but Landes (1946) and others maintain that there is a lack of field evidence. Landes (1946) stated:

> that local diastophism has produced master fissures in the limestone-containing section; than an artesian circulation has been developed which has carried waters through deeper dolomites and up into the limestone; and that these waters have replaced some of the limestone by dolomites that is locally porous where there was an excess of solution over precipitation during the replacement process."

The two main theories of secondary dolomitization (and its accompanying porosity) can be stated as follows:

1. Chemical replacement of Ca^{++} by Mg^{++} in the carbonate molecule itself:

   $$2(CaCO_3) + Mg^{++} \rightleftharpoons Ca,Mg(CO_3)_2 + Ca^{++}.$$

2. Physical solution of the more soluble calcite and replacement by dolomite.

Dundee Formation dolomite in the far western part of the southern peninsula is believed to be primary and related to near-shore environmental and/or seepage reflux conditions (Gardner, 1974).

Most of the oil produced from the Rogers City - Dundee Formations is found in anticlinal domes in the central part of the southern peninsula. These anticlines, along with most of the central basin fold structures, appeared in Late Mississippian times (Dorr and Eschman, 1971) during one of the most important periods of folding and uplift in the Michigan basin (Cohee, 1965). The types of porosity found in these structures range from "solution cavities or fossiliferous zones" (Newman, 1936) to porosity associated with secondary dolomitization. Producing zones within the Rogers City - Dundee formations vary in depth from field to field, occurring anywhere from immediately below the Bell Shale (as in the Cat Creek Field, Osceola County) down to the inferred contact between the Rogers City and Dundee Limestones in the West Branch Field, Ogemaw County. Within a given productive interval, there may be several more porous zones, often called "pays". Wells are completed in these zones. Although the porous zones may be separate within a given well, the pays seem to be connected wthin a given field.

Most of the Rogers City - Dundee fields have an efficient natural water-drive system to maintain reservoir pressure (Michigan Basin Geological Society, 1968). Hydrogen sulfide is not usually present, althouth an H_2S concentration of 25 grains/100 standard cubic feet is reported from the Falmouth Field in Missaukee County. The average A.P.I. gravity of the crude is 43°. To date the Rogers City - Dundee reservoirs have been the most prolific sources of hydrocarbons in the state of Michigan. Through 1979 a total of 346,513,811 barrels of oil and 49,514,891,000 cubic feet of gas has been produced from these rocks. These figures include production from the Reed City zone, which is believed by some geologists to be part of the Detroit River Group.

GENERAL WEST BRANCH FIELD HISTORY

The West Branch Field was discovered in the mid-1930's by the Ohio Oil Company. The No. 1 Mary Fisk (P.N. 1848) was completed on March 8, 1934, in Section 27 of West Branch Township, Ogemaw County. The well was drilled to a depth of 2,807 feet and was plugged back to 2,700 feet. Natural initial production was 21 barrels of oil per day.

Development of the field proceeded on ten-acre spacing, with the wells located in the centers of governmental-surveyed quarter-quarter-quarter sections. Drilling by the Ohio Oil Company and several independent producers extended the field to the southeast into Section 6, T.21N., R.3E., Mills Township, and to the northwest into Sections 23 and 24, T.22N., R.1E., Ogemaw Township.

By 1963, declining oil production rates lead the now Marathon Oil Company to conduct air and water injectivity tests to determine whether the Dundee Formation could be successfully waterflooded. The positive results of these tests lead to the establishment of a successful pilot waterflood project.

In 1965, Marathon Oil Company and Henry Sappington petitioned the Supervisor of Wells to order the unitization of Sections 34 and 35, portions of Sections 21, 26, 28, 33, and 36 of T.22N., R.2E., and Section 2, T.21N., R.2E. The order granting unitization was signed in January, 1966 and the full-scale waterflood began. Waterflooding was conducted on ten-acre spacing utilizing a five-spot pattern.

Initial recoverable oil in the unitized area of the West Branch Field was estimated at 4,000,000 barrels. This production figure was attained in 1977. Since that time, approximately 930,000 barrels of oil attributable to secondary recovery have been produced.

In 1978, unitization was ordered for portions of Sections 28 and 29, T.22N., R.2E., to allow Muskegon Development Company to waterflood that portion of the reservoir. At the time of this writing, no secondary recovery operations were underway in the so-called West Branch 28 Unit.

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	Gas
	A-2 lime	
A-1 Carbonate	A-1 dolomite	Oil & Gas
Upper part of Niagaran Series	brown Niagaran, gray Niagaran	Oil & Gas
	white Niagaran	
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.

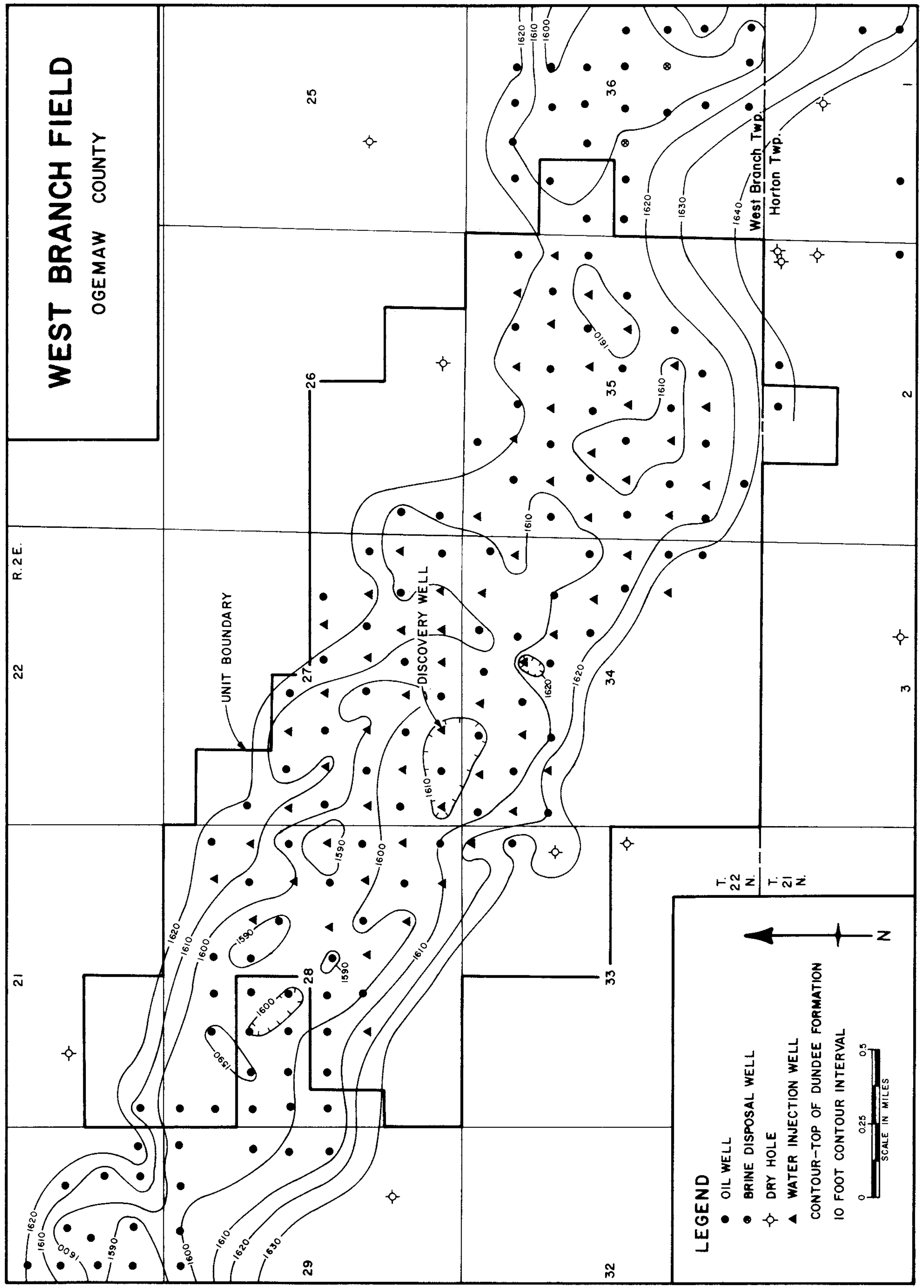


Figure 2. Structure of the West Branch Field contoured on the top of the Dundee Formation

Data Sheet No. 1

West Branch Field
Dundee Waterflood Project

GENERAL POOL DATA

Location	Ogemaw County
Date of pool discovery	March 23, 1934
Discovery Well	Ohio Oil Company, Fisk #1, PN 1848
Producing formation	Dundee
Pay lithology	Dolomitized limestone
Type of trap	Anticline
Drilled acres	2,750
Unit acres	2,730
Reservoir acre, estimated acres	1,870

ENGINEERING DATA

Type of reservoir energy	Solution gas drive
Original reservoir pressure	650-750 psi
Reservoir temperature	85°F
Viscosity of original reservoir oil	9 cp
Bubble point pressure	NA
Formation volume factor	1.05
API oil gravity	34°
Original solution gas-oil ratio	NA
Average porosity	10.5%
Average permeability	4 md
Connate water, estimated	30%
Net oil pay thickness	28 ft
Acre-feet of oil pay	47,600

RECOVERABLE HYDROCARBON DATA

Estimated original stock-tank oil in place	26,370,400 bbl
Estimated original recoverable stock-tank oil	4,000,000 bbl
Calculated recoverable stock-tank oil per acre-foot	84 bbl
Original gas in solution	
Estimated original recoverable gas	
Estimated additional recoverable oil due to secondary recovery methods	2,250,000 bbl

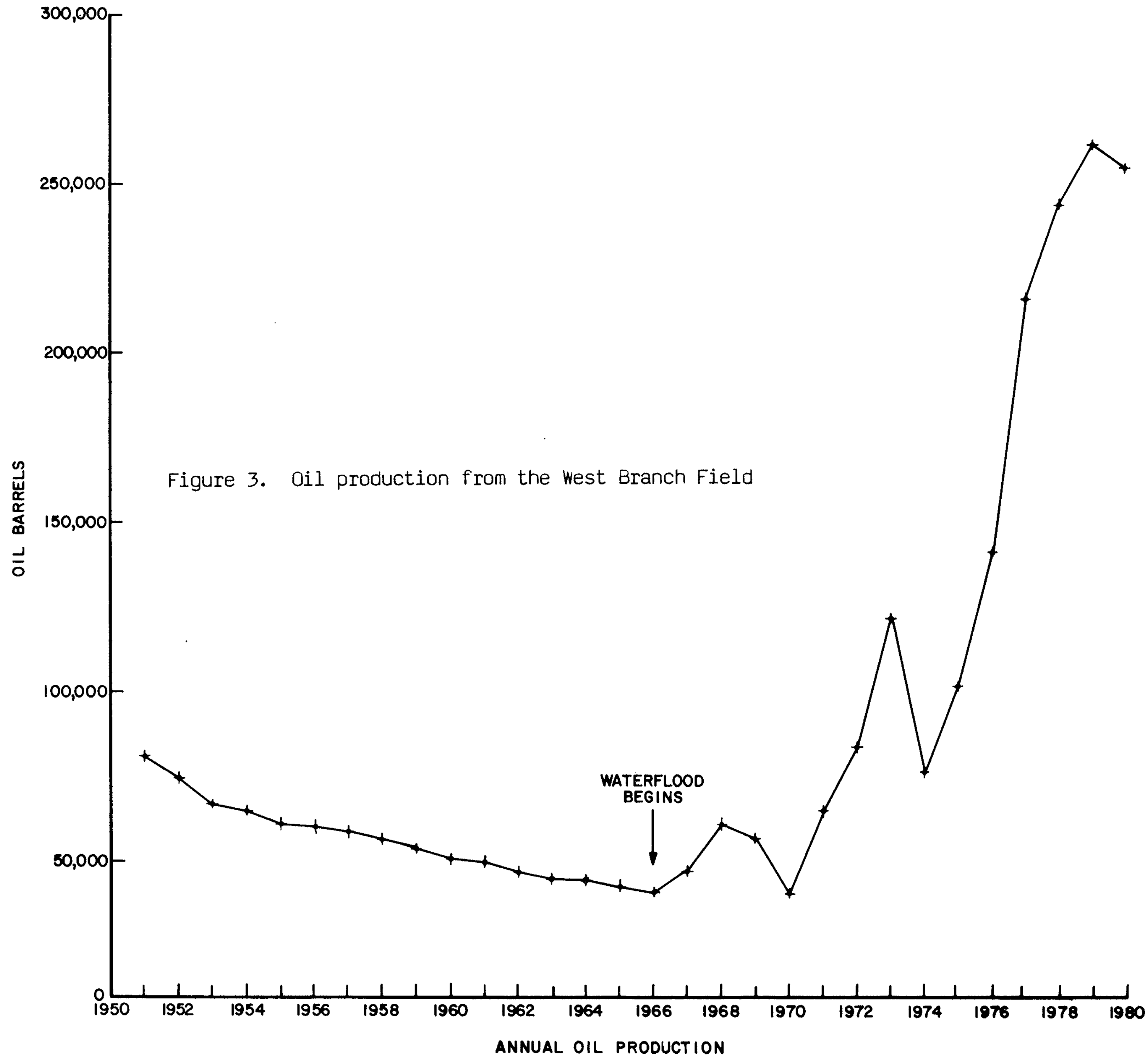


Figure 3. Oil production from the West Branch Field

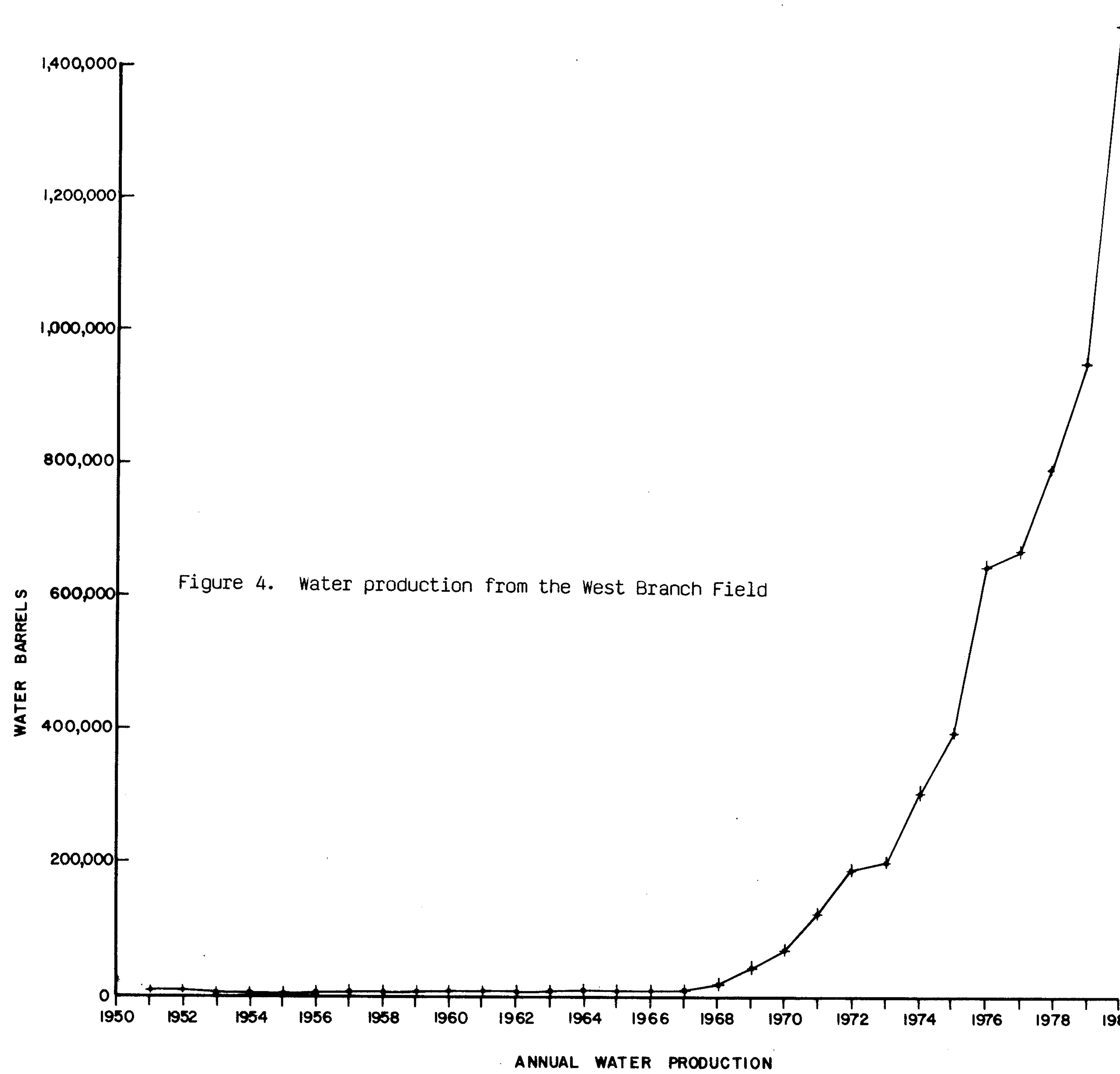


Figure 4. Water production from the West Branch Field

WEST BRANCH FIELD, OGEMAW COUNTY

Production Data

Year	Oil Annual	Oil Cumulative	Water (Estimated) Annual	Water (Estimated) Cumulative	Remarks
1950		2,252,546		108,040	
1951	81,230	2,333,776	7,665	115,705	
1952	74,489	2,408,265	8,760	124,465	
1953	66,756	2,475,021	6,935	131,360	
1954	65,473	2,540,499	4,745	136,105	
1955	61,902	2,602,396	5,840	141,945	
1956	60,699	2,663,095	6,570	148,515	
1957	58,632	2,721,727	8,395	156,910	
1958	56,843	2,778,570	8,395	165,305	
1959	54,118	2,832,688	8,395	173,700	
1960	51,462	2,884,150	8,030	181,730	
1961	50,202	2,934,352	8,030	189,760	
1962	46,771	2,981,123	7,665	197,425	
1963	45,725	3,026,848	9,125	206,550	
1964	45,538	3,072,386	9,855	216,405	
1965	42,852	3,115,238	9,490	225,895	
1966	40,179	3,155,417	8,030	233,925	Waterflood begins
1967	47,085	3,202,502	10,950	244,875	
1968	61,469	3,263,971	20,805	265,680	
1969	58,400	3,322,371	44,530	310,210	
1970	40,555	3,362,926	70,080	380,290	
1971	64,971	3,427,897	125,925	506,215	
1972	84,004	3,511,901	191,260	697,475	
1973	121,286	3,633,187	200,750	898,225	
1974	76,025	3,709,212	304,702	1,202,927	
1975	101,054	3,810,266	397,667	1,600,594	
1976	141,220	3,951,486	645,867	2,246,461	
1977	216,232	4,167,718	667,968	2,914,429	Original recovery figure reached
1978	244,637	4,412,355	789,395	3,803,824	
1979	262,162	4,674,517	950,801	4,754,625	
1980	254,508	4,929,025	1,441,081	6,195,706	

Table 1. Oil and Water Production for the West Branch Field. Oil and Water Figures are shown in Barrels.

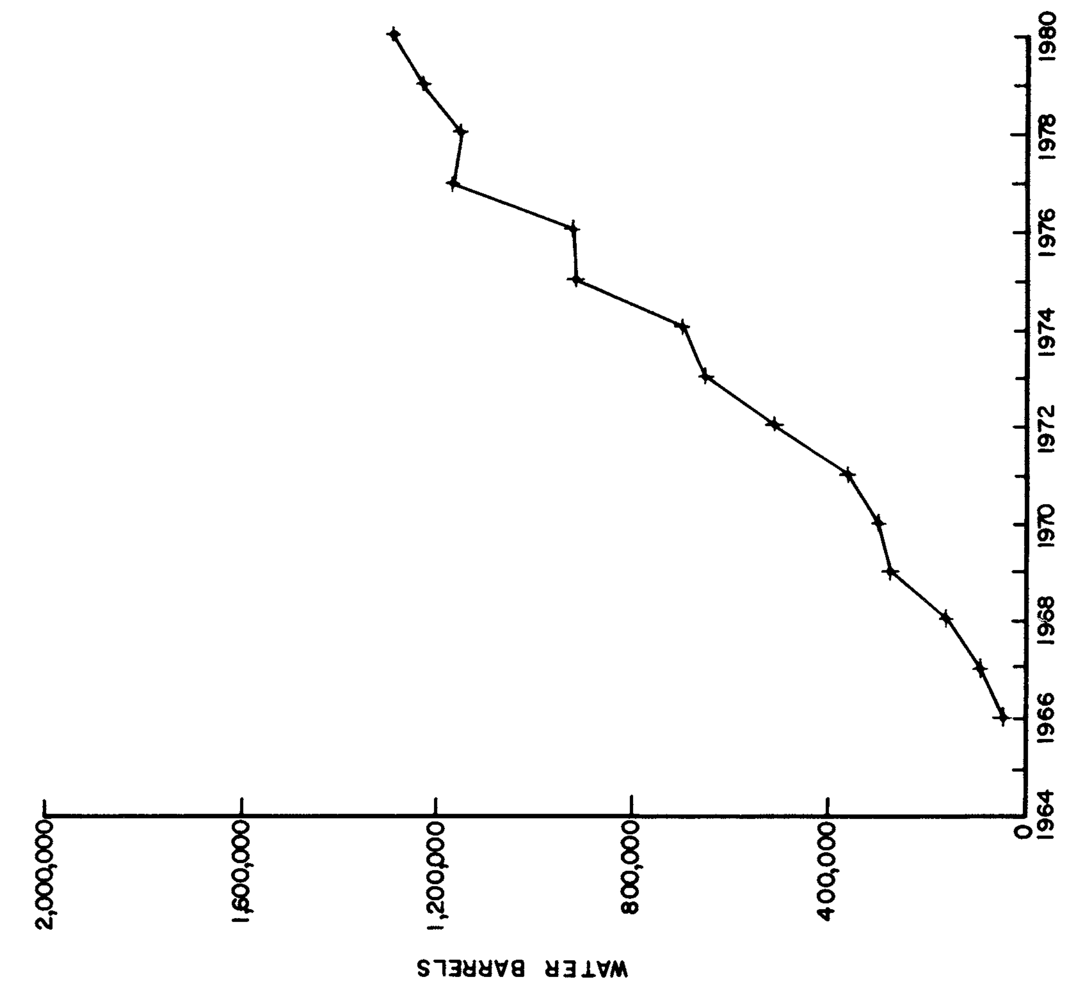


Figure 5. Water injected into the West Branch Field to enhance oil and gas recovery

WEST BRANCH FIELD, OGEMAW COUNTY

Injection Data

Year	Water Annual	Water Cumulative	Pressure
1966	40,871	40,871	
1967	90,213	131,084	1,380
1968	159,023	290,107	NA
1969	272,394	562,501	1,038
1970	291,420	853,921	1,472
1971	360,311	1,214,232	1,564
1972	509,404	1,723,636	1,585
1973	654,058	2,377,694	1,595
1974	695,144	3,072,838	1,630
1975	924,917	3,997,755	1,605
1976	924,994	4,922,749	1,509
1977	1,167,913	6,090,662	1,446
1978	1,151,894	7,242,556	1,396
1979	1,233,794	8,476,350	1,363
1980	1,292,177	9,768,527	1,500

Table 2. Water Injection Data for the West Branch Field. Water Injected is shown in Barrels.

REFERENCES

Beaumont, Société Géologique de France, p. 174, cited by Francis M. Van Tuyl, The Origin of Dolomite, Iowa Geological Survey, v. 25, 1914, p. 251.

Champion, B. L., 1968, Oil and Gas Producing Zones in Michigan, in Oil and Gas Field Symposium: Michigan Basin Geological Society, 199 p.

Cohee, G. V., 1965, Geological History of the Michigan Basin: Washington Academy of Sciences Journal, v. 55, p. 211-223.

_____ and L. B. Underwood, 1945, Lithology and Thickness of the Dundee Formation and the Rogers City Limestone in the Michigan Basin: U. S. Geological Survey, Oil and Gas Inventory, Preliminary Map 38.

Dorr, J. A. and D. F. Eschman, 1971, Geology of Michigan: University of Michigan Press, 2nd edition, 476 p.

Ehlers, G. M. and R. E. Radabaugh, 1937, The Rogers City Limestone, A New Middle Devonian Formation in Michigan: Michigan Academy of Science Papers, v. 23, p. 441-446.

Gardner, W. C., 1974, Middle Devonian Stratigraphy and Depositional Environments in the Michigan Basin: Michigan Basin Geological Society, Special Paper #1.

Landes, K. K., 1946, Porosity Through Dolomitization: American Association of Petroleum Geologists Journal, v. 30, #3, p. 305.

Michigan's Oil and Gas Fields, 1979: Michigan Department of Natural Resources, Geological Survey Division, Annual Statistical Summary 32, 64 p.

Newman, E. A., 1936, Geology of Ogemaw County and West Branch Oil Field: Michigan Geological Survey Progress Report #2, 17 p.

Tinklepaugh, B. M., 1957, A Chemical, Statistical, and Structural Analysis of Secondary Dolomitization in the Rogers City-Dundee Formation of the Central Michigan Basin: Ph.D. Thesis, East Lansing, Michigan State University, 125 p.