NORTH DAKOTA GEOLOGICAL SURVEY

Wilson M. Laird, State Geologist

NORTH DAKOTA CRUDE OIL INVENTORY AS OF JANUARY 1, 1968

by

Clarence B. Folsom, Jr. P. E.

Miscellaneous Series #36

Grand Forks, North Dakota, 1968

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ABSTRACT

North Dakota's reserves of crude oil, recoverable with present technical knowledge, available equipment, and current operating practices, were 713,717,844 barrels on 1 January 1968. This figure is an increase over the 667,601,462 barrels reported for 1 January 1967.

The increase in inventory represented increased drilling activity in the state during 1967 as well as the initiation of six new energy supplementation projects.

319,190,966 barrels, or 44.7% of the total reserves, will be recovered by energy supplementation.

Reports of 140 well completions were received by the Geological Survey in 1967. Of these, 53 were completed as producing wells. About 56% of the production in the month of December, 1967 came from unit operation and 17.4% of the producing wells are considered to be marginal, or stripper wells.

Six new pools were opened during the year but only three were credited to wildcat exploration. With permits issued for 40 wildcat prospects the success ratio was 1 in 13.

The methods used, the data sources, and the assumptions made in previous reports in this series have been followed so that the results may be compared and valid conclusions drawn therefrom.

1/ Chief Petroleum Engineer, North Dakota Geological Survey

Results of the Study

Technically recoverable reserves of crude oil in North Dakota were 713,717,844 stock tank barrels on 1 January 1968. Of this, 319,190,966 barrels, or 44.7%, were credited to energy supplementation projects. Twenty-one of the 132 producing pools in the state were undergoing unitized operation compared with 15 on 1 January 1967. These operations accounted for 55.7% of the production in the state during December 1967.

Oil production for the year of 1967 was 25,850,668 stock tank barrels, down 7.8% from 1966. Cumulative oil recovery to 1 January 1968 was 282,595,706 stock tank barrels. During 1967 two pools began to produce from second order reserves. 2/

The initiation of injection in the six energy supplementation projects, approved by the Industrial Commission during 1967, added 39,700,000 barrels to the inventory to more than offset the year's withdrawals. During the year three new fields were discovered and three new pools were developed in previously existing fields. These new producing pools added 6,550,000 barrels and 25,717,000 barrels were added by extension of existing fields and revisions of prior estimates due to additional development which caused a revision in the estimated pay thickness in several pools.

There were 2,070 wells in the state capable of producing on the first of January, 1968. Of these, 360 were classified as stripper wells unable to produce more than ten barrels per day, compared with 370 on 1 January 1967. Twenty-one of the stripper wells, were abandoned during 1968 and 11 wells reached stripper stage during the year. Some of the abandoned wells were converted to service wells.

2/ The terms "primary" and "secondary" have been dropped in favor of the terms "first order" and "second order" because it is felt that these programs should constitute a continuing phase of production and should not be defined by rigid time boundaries.

During 1967 the Geological Survey issued 163 drilling permits and received 140 reports of completion. There were 86 wells abandoned as dry holes and one well was temporarily abandoned. Forty wells, classified as wildcats when the permit was issued, were completed and resulted in three new field discoveries. Total footage drilled during 1967 was 993,039 feet giving an average of 6,710 feet per well. Comparing this with the average for 1966 (6400 feet) reflects the deeper drilling in the southwestern part of the state and on the Nesson Anticline in District I.

The results of the study have been tabulated in several categories and the tables appear at the end of the report.

The Problem of Definitions

In previous reports in this series the statistics on drilling were broken down by well classifications. Reference to these classifications has been omitted in this report except for the wildcat success ratio.

There are a number of groups assembling drilling statistics for the United States and they have complicated systems of classification which make it difficult to correlate the results. Since the sole value of such statistics lies in the ability to compare them to prior and subsequent data the need for the more detailed classification is questionable.

When a permit is issued by the Geological Survey the well is classified as follows: A wildcat well shall be any well drilled more than a mile and a half from a producing well or an established field boundary. An outpost well shall be any well drilled less than a mile and a half but more than one location from a producing well or an established field boundary. An extension well shall be any well drilled as an offset to a producing well or an

established field boundary, since it is assumed that the operator's decision to drill was based on the situation at that time.[3/]

When a well is drilled within an existing field, but with the objective of seeking a deeper pool, it is classified as a development well since the operator is reasonably assured of production in the existing pool should the deeper horizons prove unproductive. Without the attendant risk it would not seem logical to place the well in a category with exploratory wells drilled in an unproven area.

This inventory has been prepared for use of the North Dakota Industrial Commission which is responsible for Oil and Gas Conservation. The Commission is charged with the duty of obtaining maximum ultimate recovery from the oil and gas pools in the state. Therefore an estimate which includes all reserves technically recoverable provides a means by which the success of their programs can be measured. By technically recoverable reserves is meant that amount of oil which could be recovered using present technical knowledge, available equipment, and current operating methods. It does not take into account the economics of production since one of the objectives of the Conservation program is to improve the economics of production and thereby preclude the premature abandonment of wells which could still contribute to ultimate recovery.

Some reserve estimates include speculative reserves variously designated as "potential", "possible", or "probable" additional discoveries. Such speculation, while vital to some sectors of the industry, is not considered pertinent to the purpose of this report and no effort has been made to "gaze into the crystal ball". In accordance with this policy second order reserves are not included in the inventory until an energy supplementation program is actually initiated and fluid injection begun.

3/ Results of drilling, using these definitions, can be found in the semi-annual publication 'Oil in North Dakota' published by the Survey.

Table I indicates the progress made in developing energy supplementation projects in North Dakota. Most of the larger pools were either under injection or under consideration for injection on 1 January 1968. This reflects the policy of the North Dakota State Industrial Commission.

TABLE I

Year	2nd Order Reserves Added	Production
1962	29,074,000 STO Barrels	24,854,396 STO Barrels
1963	64,427,000	26,280,379
1964	17,478,000	24,594,791
1965	-0-	26,358,388
1966	21,324,000	28,024,204
1967	39,700,000	25,850,668

Explanation of Methods used in this Study

Throughout this inventory the standard volumetric method of estimating reserves has been used, according to the following formula:

$$R = 7758\ A\ h\ p\ (1-s)\ r\ /\ B$$ where

- R Recoverable reserves by presently known techniques
- A Proven acreage
- h Net average productive thickness in feet
- p Percent porosity
- s Percent water saturation
- r Recovery factor-percent
- B Reservoir volume factor - Barrels per barrel

The recovery factor, used here, does not take into account the economics of production. Since the study is intended to serve the same purpose as the annual inventories conducted by private business concerns, the economic situation was considered to be beyond the scope of the work.

For the purpose of this inventory a 40-acre tract was considered proven acreage if it contained a producing well, or if it offset a producing well. Credit given to offsetting 40-acre tracts was reduced if they contained dry holes or were offset in turn by dry holes.

The net average productive thickness was determined by Sidney B. Anderson, Chief Subsurface Geologist for the North Dakota Geological Survey, from

mechanical logs on file in his office. Drill stem tests, core analyses and other information were considered. Additional development, particularly in relatively new pools, tended to reduce the average thicknesses used in earlier estimates.

Porosities and saturations were taken from core analyses, where available, or from log calculations. When such data was not available, values were assigned by analogy to other nearby pools producing from the same geologic intervals under similar conditions.

The formation volume factors were obtained from reservoir fluid analyses, when available, or by analogy.

The final result of the calculation was rounded off to the nearest thousand barrels, if the total was over 1 million, or to the nearest 500 barrels. The cumulative production to 1 January 1966 was then deducted to arrive at the final figure. Since the production is known to the exact barrel, this results in the final figure being shown to the single barrel.

Discussion of the Tables

Marketing District I showed the only substantial increase in percent of the state total. This was due to increased development of deeper producing formations. The increase was mostly at the expense of District IIc which saw little drilling activity during the year. Changes in the other districts were minor.

Among the counties, McKenzie had the largest percentage increase, followed by Burke County. These counties gained in second order reserves with two units in McKenzie and three in Burke for a total of five out of the six units approved by the Commission.

There were only minor changes in the distribution of reserves between the several geological intervals. The Mississippian pools still provide the majority of North Dakota's reserves, both first and second order.

The reserves found in the Heath formation are credited to Permo-Pennsylvanian, reflecting the present thinking of the sub-surface section of the Survey.

Developments in 1967

Renewed drilling activity in the area of the Nesson Anticline was the feature of 1967. Operators initiated development of the deeper pays which were known to exist below the Madison. The Devonian and Ordovician were developed in the Tioga Field with completion in the Silurian following shortly after the first of 1968. The Sanish trend was extended across the Missouri River into Williams County with the discovery of the Bakken Pool in the Hofflund Field.

When proration was suspended in November 1965, it was anticipated that that action would spur development and exploratory drilling in the district. The activity, however, came in 1967 rather than 1966, as expected. This indicates the time required to get drilling operations from the planning stage to production. This time-lag factor is important when considering any expansion of deliverability in an emergency. Groups studying the problem of productive capacity should sound a clear warning to those concerned, that the national security will depend on the deliverability of the fields in production at the time of the emergency and that we cannot expect material increases for a period of 1½ to 2 years later.

The North Dakota Geological Survey added the API unique well numbers to its files. These numbers begin at 00001 in each county. However, the filing of well information will continue to be by NDGS well number and requests for information should cite the NDGS number in order to avoid the delay necessary in running down the file from the API number.

The Survey also converted its files to micro-film during the year. The field offices will continue to work from duplicates of the original well files. Duplicate files of mechanical logs were assembled for the field offices and will be available for use in the spring of 1968. These log libraries will be open to the public during regular business hours but the logs cannot be taken out of the office.

Most of the production from Marketing District IIa was diverted to Mandan during the year as demand there continued to exceed the supply of crude. This imbalance may be overcome by the development of the deeper pools in District I.

The Industrial Commission approved plans of unitization for the Hofflund-Madison Pool, the Charlson-Madison (South) Pool, the Blue Buttes-Madison Pool, the Flaxton-Madison (East) Pool, the Lignite-Madison Pool, and the Black Slough-Madison (South) Pool. Possibilities for unitized operation were being studied for the Fryburg, Medora, and Dickinson areas at year's end.

New field (or pool) discoveries are shown below.

TABLE II

New Field and Pool Discoveries during 1967

Mackobee Coulee-Madison	Renville County	1-27-67*
Medicine Pole Hills-Red River	Bowman County	5-29-67*
Tioga-Red River	Williams County	8- 1-67
Lone Tree-Madison	Ward County	8-16-67*
Hofflund-Bakken	Williams County	9-20-67
Tioga-Devonian	Williams County	10-31-67

*New Field

Stripper Well Survey

Table VIa is included for comparison.[4/] Production from marginal wells amounted to 3.1% of the total production in 1967, unchanged from 1966.

4/ From Miscellaneous Series #29

ACKNOWLEDGMENTS

All of the information and data used in making this inventory was obtained from the files and records of the North Dakota State Industrial Commission, at the office of the North Dakota Geological Survey in Grand Forks.

In addition to Mr. Anderson, recognition is herewith given to the help and assistance of Mr. Wesley D. Norton and Miss Juanita Williams, Assistant Petroleum Engineers for the Survey, and Mr. F. E. Wilborn, Jr., the Survey's Statistician.

TABLE III

CRUDE OIL INVENTORY IN NORTH DAKOTA

	Primary Reserves Bbls. STO	Secondary Reserves Bbls. STO	Total Recoverable Bbls. STO	Production to 1-1-68 Bbls. STO	Remaining Recoverable Bbls. STO	% of Total	Fields Disc. to 1-1-68	Pools Disc. to 1-1-68	Fields Abandoned to 1-1-68	Fields Producing 1-1-68	Pools Producing 1-1-68	Producing Acres
District I	365675550	296921000	662596550	197601366	464995184	65.11	35	56	1	5	51	161266
District IIa	70052000	5300000	75352000	23819408	51532592	7.22	21	21	4	4	17	10940
b	81540500		81540500	26489102	55051398	7.71	30	31	5	6	25	53980
c	45476500	10938000	56414500	15638575	40775925	5.71	17	18	1	1	17	34125
District IIIa	6364000		6364000	1992406	4371594	0.60	1	1			1	3788
b	107868000	6178000	114046000	16642854	97403146	13.65	9	13	2	3	10	37109
				282183711	714129839		113	140	13	19	121	301208
Less Gasoline Plant Recovery				411995	411995							
				282595706	713717844							

TABLE IV

CRUDE OIL INVENTORY IN NORTH DAKOTA

	Primary Reserves Bbls. STO	Secondary Reserves Bbls. STO	Total Recoverable Bbls. STO	Production to 1-1-68 Bbls. STO	Remaining Recoverable Bbls. STO	% of Total	Fields Producing 1-1-68	Pools Producing 1-1-68	Producing Acres
Billings	57795500		57795500	10451652	47343848	6.63	4	7	27420
Pottineau	91058500	10938000	101996500	25744350	76252150	10.68	27	28	57125
Bowman	44909500	6178000	51087500	5337996	45749504	6.41	3	3	7969
Burke	81318000	23109750	104427750	32434595	71993155	10.09	19	19	13285
Divide	14050000	9052500	23102500	3332285	19770215	2.77	6	6	9035
Dunn	390000		390000	286570	103430	0.01	1	1	360
McHenry	3230000		3230000	271933	2958067	0.41	1	1	1000
McKenzie	155902000	85497000	241399000	69462632	171936368	24.08	14	22	65777
Mountrail	28329000	43994000	72323000	22648131	49674869	6.96	3	3	15060
Renville	25913500		25913500	14568649	11344851	1.59	9	9	21480
Slope	1713000		1713000	177170	1535830	0.20	1	1	720
Stark	6572000		6572000	1454202	5117798	0.72	3	3	7840
Ward	243000		243000	88543	154457	0.02	2	2	660
Williams	165552550	140567750	306120300	95925003	210195297	29.44	10	18	74037
				282183711	714129839				
Less Gasoline Plant Recovery				411995	41195				
				282595706	713717844				

TABLE V

CRUDE OIL INVENTORY IN NORTH DAKOTA

	Primary Reserves Bbls. STO	Secondary Reserves Bbls. STO	Total Recoverable Bbls. STO	Production to 1-1-68 Bbls. STO	Remaining Recoverable Bbls. STO	% of Total	Fields Disc. to 1-1-68	Pools Disc. to 1-1-68	Fields Producing 1-1-68	Pools Producing 1-1-68	Producing Acres
Devonian	62323000	36670000	98993000	25785135	73207865	10.26	14	17	13	13	32051
Mississippian	513224055	275889000	789113055	237899196	551213859	77.25	102	102	93	91	222137
Ordovician	50519500	6178000	56697500	6257173	50440327	7.13	9	9	8	8	17109
Permo-Penn	33479000		33479000	7318786	26160214	3.69	6	6	5	5	20780
Silurian	14685000	600000	15285000	4872965	11612035	1.65	3	3	3	2	8771
Triassic	1134000		1134000	50456	1083544	0.02	1	1	1	1	360
				282183711	713717844						
Less Gasoline Plant Recovery				411995							
				282595706							

TABLE VIa

NORTH DAKOTA STRIPPER WELLS

	No. of Wells	1966 Prod. Bbls.	Acres	Abandoned 1966	Primary Reserves 1-1-67	Secondary Reserves 1-1-67	Average daily Production December 1966	Average daily Production per Well 1966
Billings	8	23266	2160	0	3603683		41	7.0
Bottineau	80	192078	3840	1	4056639	154500	457	6.6
Bowman	3	5188	400	0	1877074	248500	11	5.4
Burke	101	240371	13278	1	10654922	266080	476	11.5
Divide	1	1238	160	0	299881	549600	0	0.0
McKenzie	68	147870	6478	8	6496917	2570000	262	7.1
Mountrail	24	51560	1915	2	52365	3093120	93	6.7
Renville	14	30026	1120	2	1222369		72	7.1
Williams	71	187773	6438	0	7851454	7635000	324	6.5
	370	879369	35789	14	36071304	14516800	1736	6.93

TABLE VIb

NORTH DAKOTA STRIPPER WELLS

County	Number of Wells	1967 Prod. Bbls.	Acres	Abandoned 1967	Primary Reserves 1-1-68	Secondary Reserves 1-1-68	Average BOPD Dec. 1967	Average BOPD/Well 1967
Billings	7	14046	1760	0	2117158		4.7	5.5
Bottineau	78	161072	5841	2	8112729	10104421	6.0	1.6
Bowman	2	2870	240	3	788806	80314	0.0	7.8
Burke	97	213743	12393.11	3	8144727	2012725	6.6	0.4
Divide	0			0				
McKenzie	57	157881	5686.87	1	4953673	5318900	4.7	0.7
Mountrail	18	34742	1438.64	0	126033	2023724	5.6	5.3
Renville	15	40612	1200	3	1185600		6.1	7.4
Williams	85	192445	7409.92	9	8680721	12515379	6.9	6.2
Ward	1	1262	80	0	12000		0	3.5
	360	818673	36049.54	21	34117447	32055463	4.6	3.9

APPENDIX A

MARKETING DISTRICT I

Geographical description: Township 148 North to 161 North, Ranges 94 West to 97 West, inclusive

Fields: Gros Ventre, Viking, North Tioga, Tioga, McGregor, West Tioga, East Tioga, White Earth, Beaver Lodge, Capa, Hofflund, Delta, Charlson, Blue Buttes, Antelope, Croff, Bear Den, Lost Bridge, Pershing, Camel Butte, Fancy Buttes, Dimmick Lake, Clear Creek, Keene, Sand Creek, Northwest McGregor, Stoneview, Wildrose, and Hawkeye.

MARKETING DISTRICT II

Subdistrict A

Geographical description: Township 164 North, Ranges 88 West to 103 West, inclusive, Township 163 North, Ranges 88 West to 103 West, inclusive, Township 162 North, Ranges 88 West to 103 West, inclusive, Township 161 North, Ranges 88 West to 93 West, and 98 West to 103 West, inclusive, and Township 160 North, Ranges 88 West to 93 West, and 98 West to 103 West, inclusive.

Fields: Baukol-Noonan, Noonan, Short Creek, Columbus, Portal, Rival, Black Slough, Foothills, Northeast Foothills, Rennie Lake, Lignite, Flaxton, Stony Run, Woburn, Bowbells, and Perella.

Subdistrict B

Geographical description: All of the state not included in other districts or subdistricts.

Fields: Dickinson, Haas, North Haas, Kuroki, Wayne, Wiley, Elmore, Sherwood Eden Valley, Pratt, Glenburn, Lansford, Lone Tree, Mackobee Coulee, Mohall, North Maxbass, South Antler Creek, Southwest Haas, Tolley, Chola, Southwest Aurelia, and Mouse River Park.

Subdistrict C

Geographical description: Townships 160 North to 164 North, Ranges 77 West to 80 West, inclusive.

Fields: North Souris, Scandia, Northeast Landa, Roth, Starbuck, South Starbuck, North Westhope, Westhope, South Westhope, Newburg, East Newburg, West Roth, Boundary Creek, and Russell.

MARKETING DISTRICT III

Subdistrict A

Geographical description: Townships 158 North to 160 North, Ranges 98 West to 107 West, inclusive.

Fields: Grenora

Subdistrict B

Geographical description: Townships 129 North to 158 North, Ranges 98 West to 107 West, inclusive.

Fields: Little Missouri, Cedar Creek, Medicine Pole Hills, Rocky Ridge, Fryburg, Medora, and Rough Rider.