OIL EXPLORATION AND DEVELOPMENT IN THE NORTH DAKOTA WILLISTON BASIN: 1992-1993 UPDATE

by

Thomas J. Heck

MISCELLANEOUS SERIES NO. 80

NORTH DAKOTA GEOLOGICAL SURVEY

John P. Bluemle, State Geologist

1995

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Thomas J. Heck
North Dakota Geological Survey
M.S. 80

1895 - North Dakota Geological Survey's Centennial Year - 1995

The North Dakota Geological Survey was created by an act of the North Dakota Legislature in 1895, six years after statehood. The Geological Survey was directed to make a

> *... complete account of the mineral kingdom ... including the number, order, dip and magnitude of the several geological strata, their richness in ores, coals, clays, peats, salines and mineral water, marls, cements, building stones and other useful materials, the value of said substances for economic purposes, and their accessibility.*

Such studies continue, but over the years the Geological Survey's mission has grown and is now three-fold: to investigate the geology of North Dakota; to administer regulatory programs and act in an advisory capacity to other state agencies; and to provide public service and information to the people of North Dakota.

The Geological Survey serves as the primary source of geological information in the State. A large amount of geological information can be obtained from NDGS publications; comprehensive collections of cores, samples, and fossils; oil and gas records; coal and subsurface mineral records; and through our affiliate office of the nationwide Earth Science Information Center.

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ACKNOWLEDGEMENTS

This update benefitted from the review and suggestions from Bob Biek, Bill McClellan, and John Bluemle. Their help was greatly appreciated.

INTRODUCTION

This update summarizes oil exploration and development of the 1980s and 1990s but focuses on the events of 1992 and 1993. The 1980s saw many changes in North Dakota's oil industry. The decade began with activity at record highs, a direct response of the domestic oil industry to the Arab oil embargo and subsequent rapid price increases of the 1970s. Oil prices began to decline in 1982 and activity decreased in response to lower prices. Many thought that prices had hit bottom in 1985, but over-production by OPEC caused oil prices to fall to record lows in 1986. The oil industry has not yet recovered from the price drop as industry activity in North Dakota continues at levels far below those of 1980-1981.

Data presented here are largely from the files of the North Dakota Industrial Commission as collected by the Oil and Gas Division. Additional data were provided by the State Tax Department, the State Land Department, and Amoco Oil Company, Bismarck, North Dakota. Help from these sources is gratefully acknowledged. Interpretations of the data, however, are my own. Following the precedent set in the 1988-1989 update (Heck, 1990), the historical overview of exploration in North Dakota before 1980, included in all prior updates, has been dropped. The reader is referred to Fischer and Bluemle (1988) for this information.

1980-1989

During 1980, oil-industry activity reached record levels, both nationally and in North Dakota. Oil prices were high, averaging $28/barrel in North Dakota (Fischer and Bluemle, 1988) and operators aggressively pursued new plays and prospects. State lease sales brought record revenues (Fig. 1), and tax revenues were climbing (Fig. 2). Of the nearly 600 wells drilled in North Dakota during 1980 (Fig. 3), 182 (31%) were wildcats (Fig. 4). There were 84 new-pool discoveries (Fig. 5) and production rose to 40,354,030 barrels, a second consecutive annual record (Fig. 6).

The records set during 1980 fell in 1981 as the "oil boom" peaked in North Dakota. New records of 834 total wells, 267 wildcats, and 102 new-pool discoveries were set. The 1980 annual production record was surpassed when 45,706,999 barrels of oil were produced during 1981, setting a third straight annual production record. State revenues increased as the new extraction tax began generating its first revenue (Fig. 2). Together, the extraction and production taxes supplied more than 20 percent of the state's budget in 1981, the first year the extraction tax was in place (Fig. 7).

The oil industry could not maintain a high level of activity after oil prices began to slip during 1982. However, oil production and tax revenues continued to climb despite a decrease in drilling because the emphasis shifted toward developing existing fields and away from exploring. Another reason for the continued increase in tax revenue is that a time-lag of one to three years exists between a field's discovery and its peak of production. Fields discovered in 1980 and 1981 did not peak until 1982 to 1984.

Oil prices continued to decline during 1983, exerting downward pressure on drilling. Wildcat drilling (Fig. 4) was one-third of 1981 levels, reflecting the lower oil prices, but development drilling remained high. However, oil production continued to rise as did tax revenues (Figs. 2 & 6). The drilling of both wildcat and development wells recovered slightly during 1984 (Figs. 3 & 4) and oil production reached its all-time high of 52,654,336 barrels (Fig. 6) Tax revenues declined for the first time since 1973 (Fig. 2) because of falling oil prices. Drilling activity resumed its decline during 1985 as oil prices slid further and began to fluctuate. Over-production by OPEC caused a rapid price drop in early 1986 (Fig. 8), with prices falling to less than $10 a barrel for certain types of crude oil. Drilling fell dramatically and oil companies began to downsize and reduce spending in response to lower crude oil prices and uncertainties about future prices. A continuing side effect of reduced drilling has been a decrease in the number and size of oil-field service companies in North Dakota. Many companies either went bankrupt and closed their doors or moved out of state to cut costs.

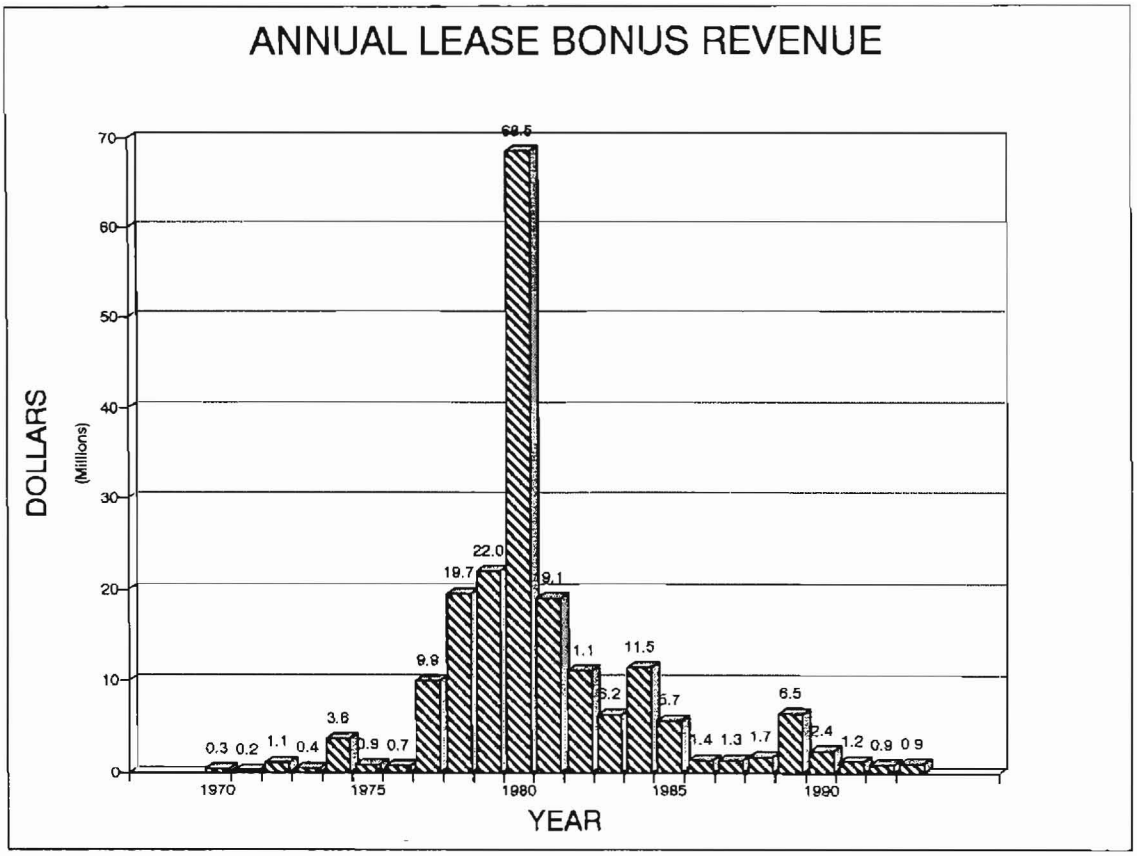

Figure 1. Bar diagram of annual revenue from quarterly state oil-lease sales held for the period 1970-1993. (Source: N.D. State Land Department).

From mid-1986 through early 1987 crude oil prices rose gradually and a modest increase in drilling followed from mid-1987 into early 1988. Although the number of wells spudded increased during the second half of 1987, activity during the first half was so low (Fig. 8) that only 190 wells were drilled during the year (Fig. 3). In 1988, drilling jumped sharply to 255 wells. Some of the increase was the result of development drilling in Wabek Field, an important field along the Mississippian Sherwood subinterval shoreline. Wabek Field was discovered in 1985, but development did not truly begin until 1988. During 1989, another important field, Plaza Field, was discovered near Wabek Field and development was begun. Plaza Field produces from the Bluell subinterval, which immediately overlies the Sherwood subinterval. Sperr, et al. (1993) estimate ultimate recoveries of 6 to 8 million barrels from Wabek Field and 3.5 million barrels from Plaza Field. These two fields are the largest Madison fields that have been discovered in several years.

Since 1986, between two and three hundred wells and 35 to 67 wildcat wells have been drilled each year. During 1987 and 1989, drilling fell below 200 wells annually, the lowest levels recorded since 1974. Wildcats accounted for 67 of the 190 total wells drilled in 1987 and 35 of the 188 wells drilled in 1989.

Lease bonus revenue (Fig. 1) jumped in 1989 as the horizontally drilled Bakken Shale play, which began in 1987, prompted a great deal of industry interest. Many state oil leases brought favorable per-acre bonuses at auction during 1989 and 1990. Horizontal drilling into the Bakken Shale increased from 1987 through 1990 as the

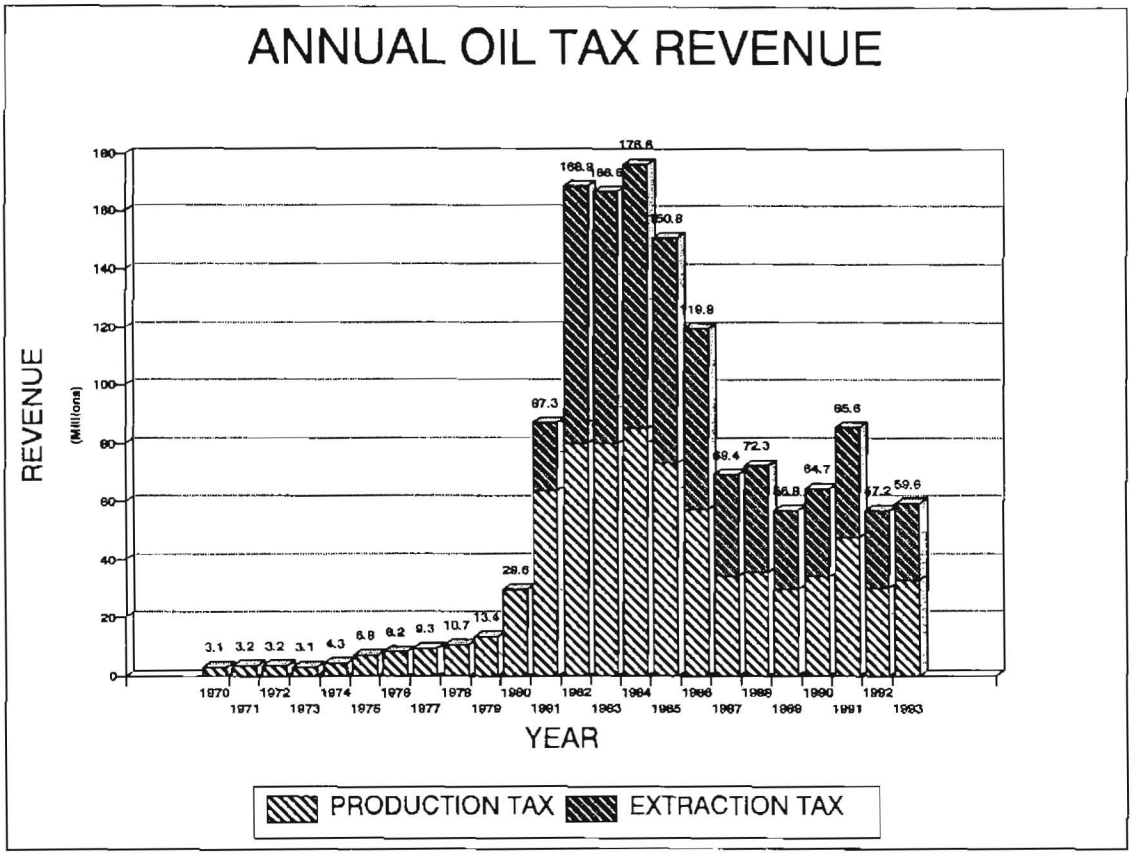

Figure 2. Bar diagram of annual tax revenue generated by the production and extraction taxes on crude oil for the period 1970-1993. The extraction tax took effect on January 1, 1981. (Source: N.D. State Tax Commission).

Bakken play continued to develop. Since then, the number of Bakken Shale tests drilled has decreased and lease bonuses have fallen.

1990-1993

The 1990s began with many recently acquired leases in the Bakken Shale play being drilled as the play peaked in 1990. The total number of wells drilled increased significantly from 1989 to 1990, rising by 86 to a total 274 wells. Of this number, 77 were Bakken tests. Bakken drilling decreased during the early 1990s. During 1991, 48 Bakken tests were completed. During 1992 and 1993, 30 and 24 Bakken tests were completed, respectively. Success rates for Bakken tests, as judged solely by a well being completed as a producing oil well, remained high. The success rate during 1991 was 97% and both 1992 and 1993 had 100% success rates. Despite the appearance of success by this one measure, some of these wells will be economic failures because they will not recover sufficient hydrocarbons to pay for the cost of drilling and completion.

Another important factor in the 1990 increase in drilling was the invasion of Kuwait by Iraq in August, 1990. World oil prices surged because of uncertainties about the security of the Middle East's oil supply. Oil prices in North Dakota also increased in 1990 (Fig. 8). The rapid deployment of allied military forces during the fourth quarter of 1990 generated a downward pressure on oil prices and uncertainties lessened, but the price of oil remained $1-$3/barrel above the July, 1990 price well into 1991. By late 1991,

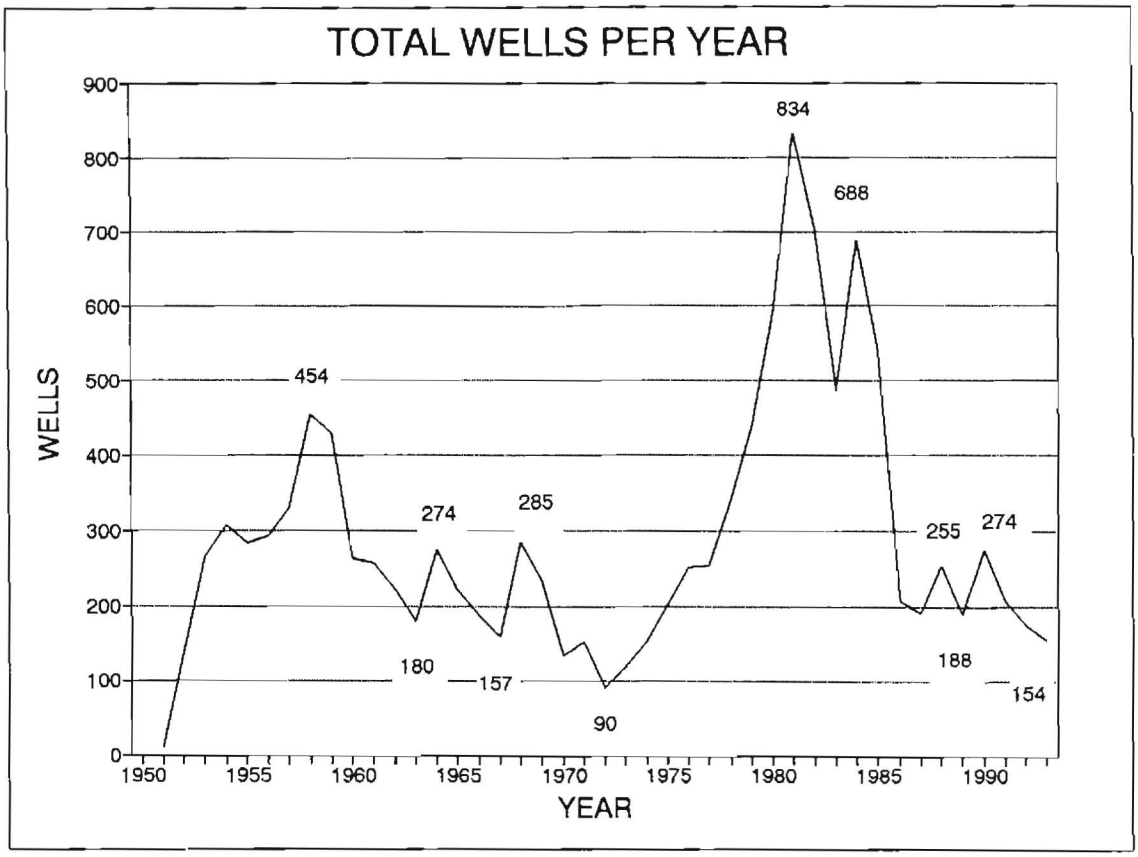

Figure 3. Line graph of the number of oil wells drilled annually in North Dakota since 1951. (Source: N.D. Geological Survey and N.D. Oil and Gas Division).

prices had returned to pre-Gulf War levels.

Oil companies, responding quickly to the price surge in 1990 following the invasion of Kuwait, nearly doubled the number of wells spudded each month in North Dakota (Fig. 8). As the price of oil began to fall in late 1990 and continued to decline into 1991, the number of wells spudded also dropped.

Annual oil production had been declining between 5 and 10% per year since 1985 but, in 1990, it declined by only 21,057 barrels or 5/100 of 1% (.05%) from 1989 (Fig. 6). The fact that annual production did not decline from 1989 and 1990 can be attributed to two factors. Approximately 2.2 million barrels of oil were produced from Wabek and Plaza Fields in the Sherwood shoreline play in Ward and Mountrail Counties and another 2.7 million barrels were produced from horizontal Bakken wells in western North Dakota. Production from these two plays virtually matched the production decline from all the other wells in the state.

Since 1990, the areal limits of the horizontal Bakken play have been better defined, but most wells have declined faster than expected. As a result, drilling activity decreased as companies reevaluated the play. Of the 207 total wells drilled in 1991, 48 were horizontal Bakken tests. In 1992 and 1993, the total number of wells drilled decreased to near record-low levels. The number of Bakken wells decreased to 30 and 24 during this same period. Wildcat drilling has fluctuated since 1990, but has recorded an overall downward trend.

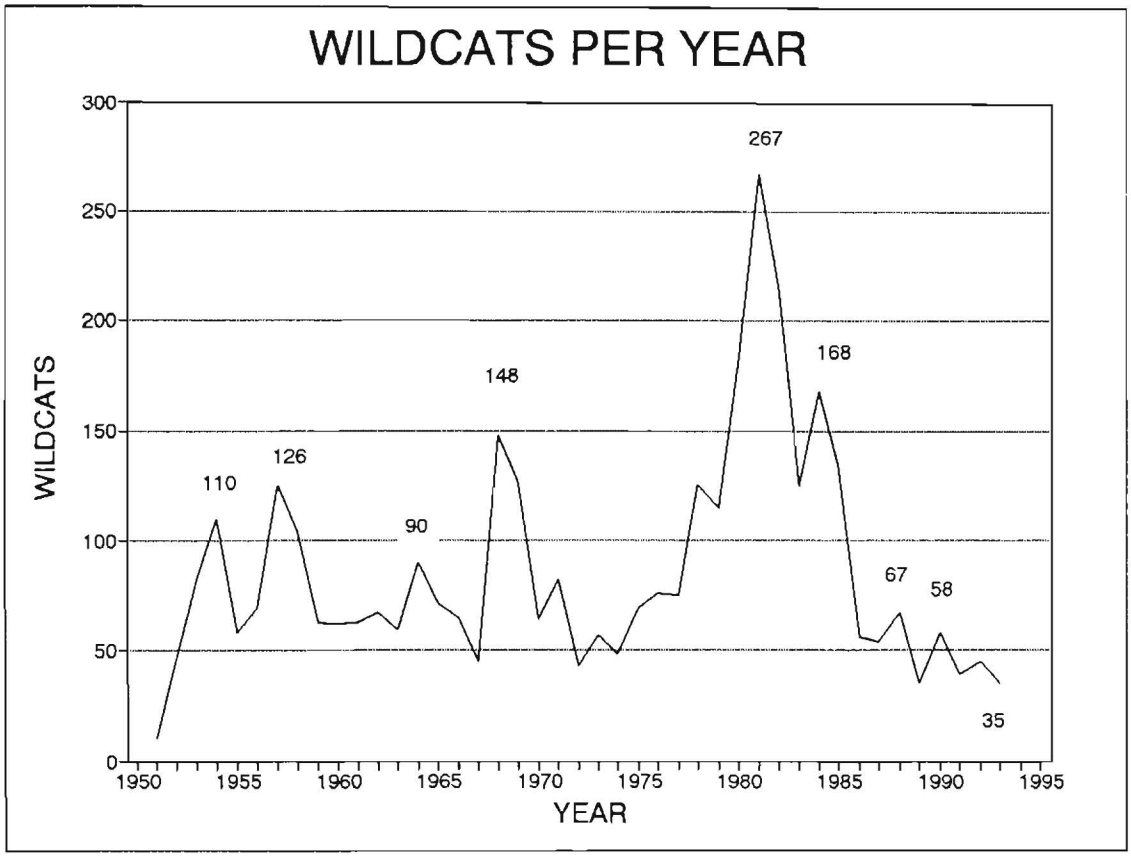

Figure 4. Line graph of the number of wildcat wells drilled annually in North Dakota since 1951. (Source: N.D. Geological Survey and N.D. Oil and Gas Division).

HISTORICAL ANALYSIS

From 1980-1985, record oil prices, revenues, and numbers of wells drilled were recorded by the oil industry in North Dakota. In 1986, a major price drop caused drilling to plummet. Since then, drilling has remained fairly constant at a level of drilling not seen since the 1960s (Fig. 3). If a large newly discovered field were to be developed and/or a new play was actively being evaluated in North Dakota, the total number of wells drilled annually would probably be between 250 and 300 wells as was the case during 1990, when Wabek Field was being developed and the Bakken play was active. Otherwise, fewer than 200 wells are likely to be drilled (Fig. 3).

Annual production began to decline during 1983 as fields aged and uneconomic wells were plugged. Annual production will continue to decline because the number of oil wells completed at present drilling levels is not sufficient to offset the production decline. In 1990, production from two important plays, the Sherwood shoreline and the horizontal Bakken Shale plays, temporarily stopped the decline. The effect, however, was short-lived and the annual production decline resumed in 1991. An annual decline rate of 5-10%/year should be anticipated unless additional significant discoveries are made.

The discovery of the Wabek and Plaza Fields and the flurry of activity during the horizontal Bakken play clearly illustrate one way to offset the state's decline in oil production: find and develop a new large oil field or a new oil play. Wells completed in both the Sherwood shoreline and horizontal Bakken plays had initial potential's

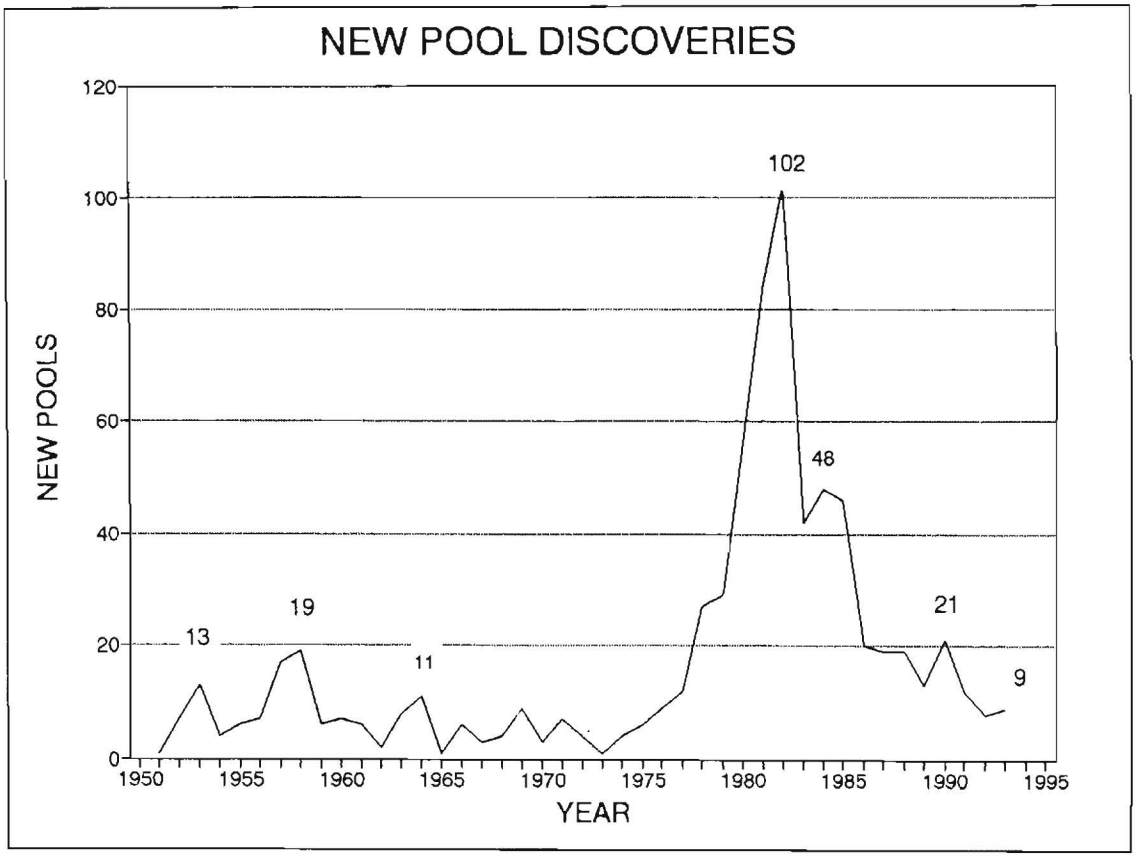

Figure 5. Line graph of the number of new pools discovered annually in North Dakota since 1951. (Source: N.D. Geological Survey and N.D. Oil and Gas Division).

that were higher than typical. Therefore, either additional new significant discoveries must be developed, more average new wells must be completed, or many more poorer wells must be completed to offset the annual production decline. In each case, a large investment of capital for drilling wells is required.

The North Dakota portion of the Williston Basin remains under-explored and many opportunities remain for finding large oil fields. A study of the petroleum potential of the Little Missouri National Grasslands by Fischer, et al. (1991), estimated that at least 100 million barrels of oil equivalents remain undiscovered in McKenzie, Dunn, Billings, and Golden Valley Counties. Some of this oil was discovered during the horizontal Bakken play, but much of this potential remains undiscovered. The discovery of a 5-million-barrel or larger field would result in additional drilling as operators would explore for similar fields, just as they did during the horizontal Bakken and Sherwood shoreline plays.

Another way to increase production is to unitize a field and initiate enhanced recovery operations. Enhanced recovery programs can be a relatively inexpensive way to recover additional, otherwise-unrecoverable hydrocarbons. A successful unit often recovers these hydrocarbons at a much higher rate than an equivalent non-unitized field. Five new units were formed during 1993, equaling the peak year of 1968 (Fig. 9). North Dakota may have seen the beginning of a surge in unitization during 1993 as many oil fields approach the end of their primary productive life-span. The 1991 North Dakota legislature encouraged unitization by enacting legislation that lowered the per

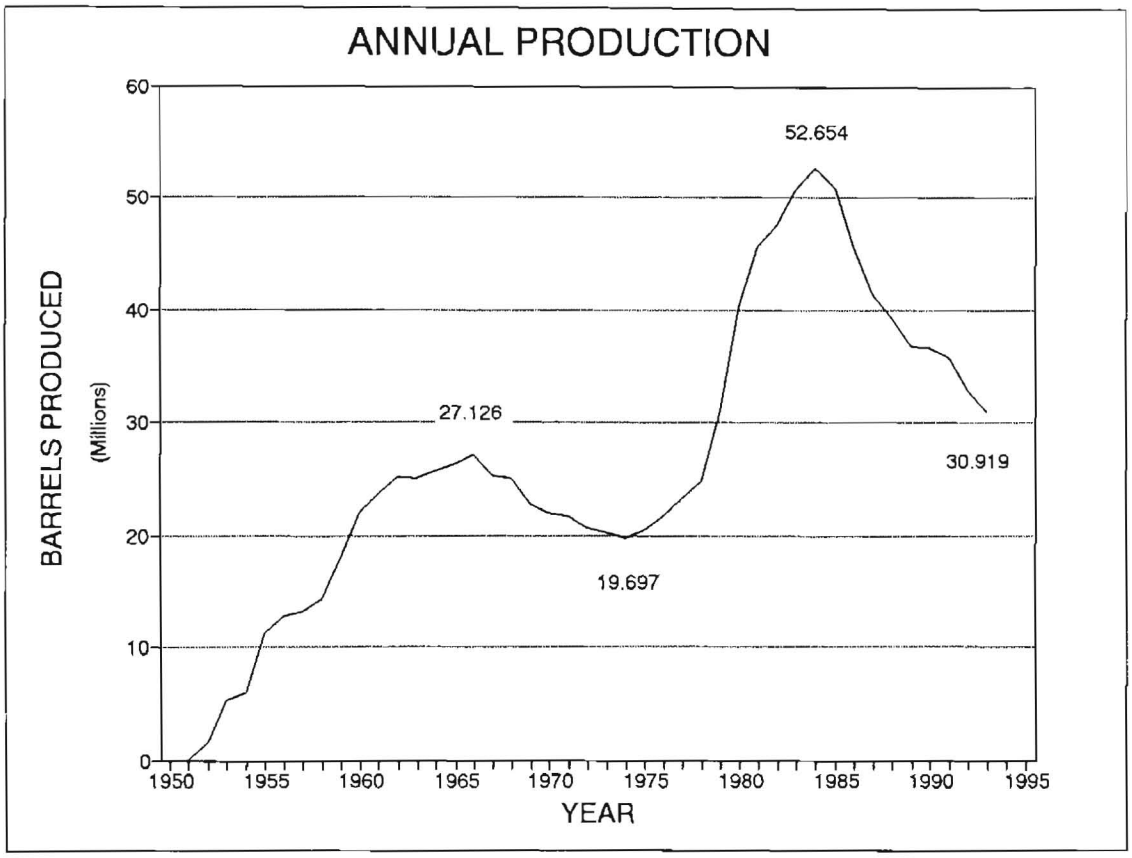

Figure 6. Line graph of the annual oil production in North Dakota since 1951. (Source: N.D. Geological Survey and N.D. Oil and Gas Division).

centage of mineral and working interest owners required to form a unit. Unitization was also encouraged during the 1987 and 1991 by legislation granting tax incentives to projects meeting specified increased performance criteria. Methods that encourage the necessary capital investment, either within units or for new drilling, are needed to reverse the annual decline in production in North Dakota.

A final way to slow or possibly reverse the decline in annual production is by drilling horizontal wells in existing Madison Group fields. The effect that a successful program could have in North Dakota can be seen in the recent events in Saskatchewan. Stalwick (1994) reported that, between 1987 when the first horizontal Madison wells were drilled and the end of 1992, a total of 452 horizontal wells had been drilled throughout the province. Another 510 horizontal wells were drilled during 1993 alone. From 1987 through the first 3 1/2 months of 1994, a total of 585 horizontal wells had been drilled in Area IV, that part of Saskatchewan within the Williston Basin. During December, 1993, horizontal wells represented 8% of Area IV's well count, but accounted for 40% (Fig. 10) of the oil produced that month (Stalwick, 1994). Horizontal wells have contributed so much oil that Area IV production has increased instead of declining as it had been (Fig. 11). The same strata that produce in Saskatchewan are present and productive in North Dakota. A Madison Group horizontal drilling program in North Dakota has the potential to dramatically increase the state's oil production just as the horizontal drilling program did in Saskatchewan.

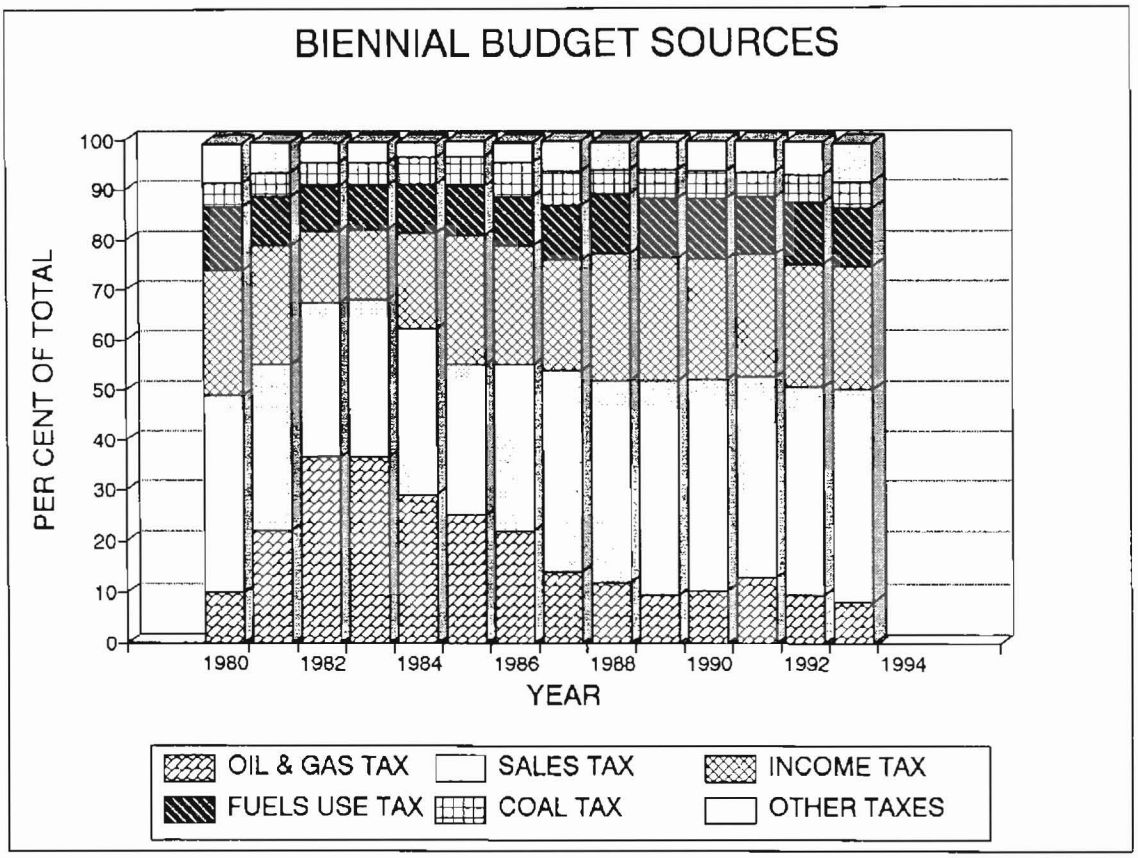

Figure 7. Bar graph of the sources and percentage contribution to North Dakota's biennial budget since 1981. (Source: N.D. State Tax Commission).

1992

STATISTICS

A total of 175 wells were drilled in 1992, a decrease of 32 or 15% from 1991 (Fig. 3). The number of wildcats drilled increased by six to 45 in 1992, a 15% increase (Fig. 4) and seven new pools or fields were discovered by those 45 wildcats (these discoveries are summarized in Appendix I). Ward County saw two discoveries with one each in Billings, Bottineau, Burke, McKenzie, and Renville Counties (Table 1). The wildcat success rate was 24% while 74% of the development and extension wells were completed as hydrocarbon producers. The combined success rate for all wells was 61%, a slight improvement over 1991. In total, 1,502,094 feet of hole were drilled during 1991, a decrease of 226,456 feet or 13%. Wildcat footage was 300,430 feet, an increase of 20,061 feet from 1991. Total production during 1992 was 32,900,171 BO, an annual decline of 8% or 2,995,107 BO. Of the 33 horizontal wells were drilled during 1992, 30 of them were Bakken tests while three tested other zones.

DRILLING ACTIVITY

The Bakken Formation remained the best target in the state during 1992 despite a decrease in interest in the zone. Meridian Oil, Inc. and Conoco, Inc. operated most of the thirty horizontal Bakken wells drilled during 1992. All 30 were completed as producing oil wells but no new fields were discovered. Although 30 Bakken wells represents a significant percentage of the year's total well count, it is a decrease of 18 wells from 1991. The average IP of these 30 wells was 312 BO + 312 MCFGPD, the highest average of any

Table 1 - 1992 and 1993 New Pool and Field Discoveries
Listed by County and Formation

	1992	1993
Billings County		
Total	1	1
Silurian	0	1
Tyler	1	0
Bottineau County		
Total	1	0
Madison	1	0
Burke County		
Total	1	0
Madison	1	0
Divide County		
Total	0	2
Bakken	0	1
Red River	0	1
Golden Valley County		
Total	0	1
Stonewall	0	1
McKenzie County		
Total	2	1
Duperow	0	1
Red River	1	0
Winnipeg/Deadwood	1	0
McLean County		
Total	0	1
Madison	0	1
Renville County		
Total	1	1
Madison	1	1
Stark County		
Total	0	1
Lodgepole	0	1
Ward County		
Total	2	0
Madison	2	0

formation during 1992. The best single well IP of the year was 1,281 BO + 1,281 MCFGPD from the Bakken Formation from the Slawson Exploration Company, Inc. Pegasus #1-36 located in Section 36-T142N-R102W in Demores Field. Two other completions in Demores Field during 1992 had IP's of 258 and 838 BOPD. The field average IP was 792 BOPD, the highest of any field or zone during the year. In Flat Top Butte Field, seven horizontal Bakken completions averaged 311 BOPD while the six completions in Rough Rider Field averaged 277 BOPD. Four Bakken wells were completed in Morgan Draw and Pierre Creek Fields. The wells averaged 235 and 322 BOPD, respectively. The remaining 6 Bakken completions were located in 5 different fields and had an average IP of 155 BOPD. Although many Bakken Formation completions during 1992 had high IP's, wells continued to decline rapidly making the economic viability of the play questionable.

The year's second most active play, and arguably the most important one, was the Pennsylvanian Tyler Sandstone play near Fryburg Field. A total of 20 Tyler wells were drilled, 19 of which were completed as producing oil wells for a 95% success rate. The average IP of the 19 wells was 245 BO + 52 MCFGPD. One new field, Tracy Mountain Field, was discovered by Duncan Energy Co. by their #1 O'Connell, located in Section 9-T138N-R101W. Another eight producing oil wells were subsequently completed in the field by Duncan Energy Co. and the 9 producing wells had an average IP of 227 BO + 29 MCFGPD.

Another active area for the Tyler Sandstone play was in a southward extension of the Fryburg Field Heath Pool in T139N-R100 & 101W. Axem Resources, Inc. completed nine additional wells during 1992 with an average IP of

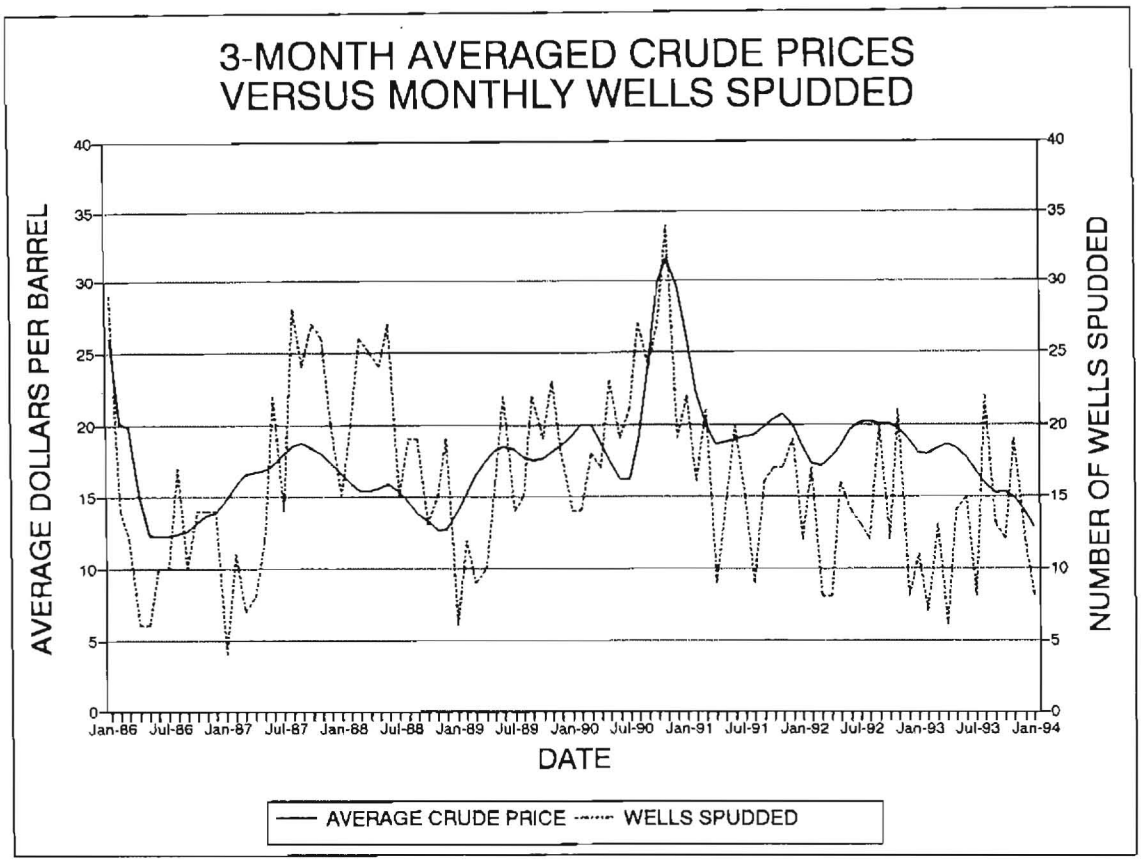

Figure 8. Line graph of the monthly average posted price for Williston Basin 40-gravity "sweet" crude oil and the number of wells spudded monthly since January, 1986. (Source: oil prices from Amoco Oil Co. and wells spudded from the N.D. Oil and Gas Division).

252 BO + 68 MCFGPD. Elsewhere, a poor Tyler well was completed in Zenith Field and a dry hole was plugged in Rocky Ridge Field. The renewed interest in the Tyler Sandstone play is due to favorable economics, the probability that, from past experience, a waterflood in the Tyler Sandstone will be successful, and the recent discoveries of Tracy Mountain Field and the south Fryburg Field extension, both of which contain important reserves.

Another reason the area around Fryburg and Tracy Mountain Fields is of interest is because of proven multiple-pay potential. Fryburg Field produces oil from both the Mississippian Madison Group and the Tyler Sandstone. At the end of 1992, the Fryburg Madison pool had produced nearly 12,000,000 BO and the Heath pool more than 17,500,000 BO since their discoveries. Four of the nine Tyler completions during 1992 in the Fryburg Field extension were dually completed in the Madison Group and two other wells were completed in the Madison Group only and these 6 Madison completions had an average IP of 87 BO + 41 MCFGPD.

The Madison play was the most frequently drilled play in the state with 68 development or extension wells testing one or more of the Madison pay zones. Of these 68 wells, 38 were completed as producing wells for a 56% success rate. In addition, 36 of the 45 wildcats tested only the Madison and resulted in 5 new field discoveries (Appendix I) for a 14% Madison wildcat success rate. At least one offset well was drilled in each of the newly discovered Madison fields but the rest of

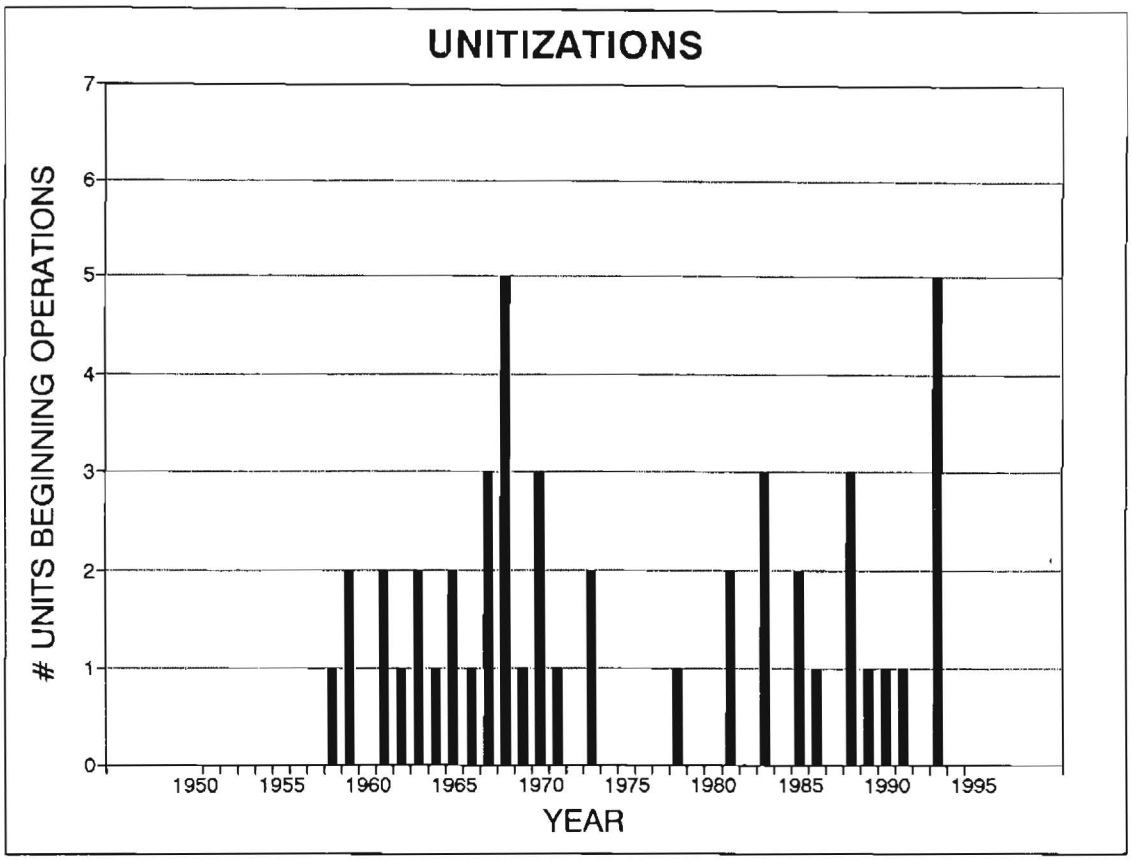

Figure 9. Bar graph of the annual number of unitized fields beginning operations (Source: N. D. Oil and Gas Division).

the 68 development wells were scattered among 42 different fields. Fryburg Field saw the most activity in the Madison followed by Stoneview, Shealey, and Mandaree Fields with three tests in each. All three tests in both Stoneview and Mandaree Fields were completed as oil wells, but only one was completed in Shealey Field. The average IP of all the producing Madison wildcat and development wells was 85 BOPD.

Drilling below the Bakken Formation was not common during 1992. Development of the Stoneview Stonewall Pool continued as Conoco, Inc. completed another four wells during 1992 bringing the total number of wells to 9. Based upon the successive IP's, the limits of the pool have been defined. The first well, the #16 Berger in Section 23-T160N-R95W, flowed 552 BO + 637 MCFPD while the last completion, the #20 Johnson State in Section 26-T160N-R95W along the southern edge of the field, flowed only 52 BO + 80 MCFPD.

Only nine wells tested the Ordovician Red River Formation or deeper during 1992 but, even with so few wells, several are of interest. The first well was the completion of another development well in Simon Butte Field, which was discovered in Dunn County in 1990. Subsequent development wells established Red River Formation production as well as production from the Silurian Interlake Formation. Pacific Enterprises Oil Company completed the #14-16 S. E. Russian Creek in early 1992 and production tests proved the well is capable of producing oil from both the Red River and Stonewall pools. The well was finally completed in the Silurian Interlake Formation flowing 515 BO + 158 MCF + 736 BWPD. The new

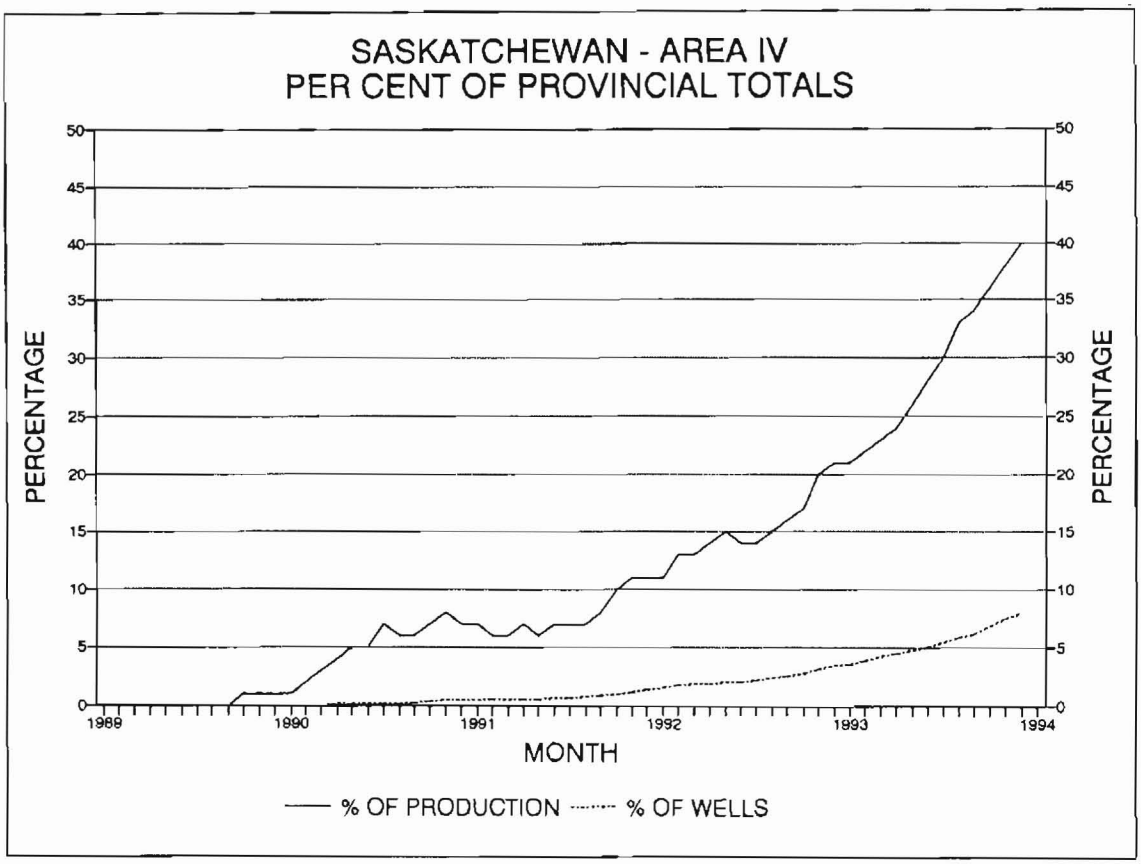

Figure 10. Line graph of the monthly percentage of wells in Saskatchewan that are horizontal wells and the percentage of the province's oil production contributed by the horizontal wells.

well shares the field characteristic of producing high volumes of both oil and water. The field is significant because it establishes production in a sparsely explored part of the basin.

The Ordovician Winnipeg and Cambrian Deadwood were the deepest formations tested during 1992. Amerada Hess Corporation completed the 1 Brenna-Lacey #32 in Section 1-T152N-R95W as the discovery well for the Antelope Field Winnipeg/Deadwood Pool. The well flowed at a combined rate of 14 BO + 7,663 MCFGPD from several zones in the Winnipeg and Deadwood Formations. This is the second, deeper-zone discovery in Antelope Field since Amerada Hess discovered the Antelope Red River Pool in 1989. These two discoveries hint at the deeper potential remaining on parts of the Nesson Anticline.

Three horizontal wells were drilled in formations other than the Bakken Formation during 1992 (LeFever, 1994). One of the three was the Amerada Hess #27-14H Sandy Creek. The well's surface location was in Section 36-T154N-R95W in Charlson Field, but the wellbore was highly deviated to the south to test Madison Group pay zones under Lake Sakakawea. The well was completed for an IP of 54 BO + 105 MCFG + 688 BWPD using nitrogen lift. Mechanical problems uphole in the Charles Formation caused the well to be abandoned (LeFever, 1994) after producing a total of 940 BO and 34,325 BW. A second non-Bakken horizontal well, drilled in North Haas Field by Ballantyne Oil, also tested Madison Group strata. The #1 Schwartz, located in Section 20-T163N-R82W, penetrated the Kisbey Sandstone and encountered a pressure-depleted

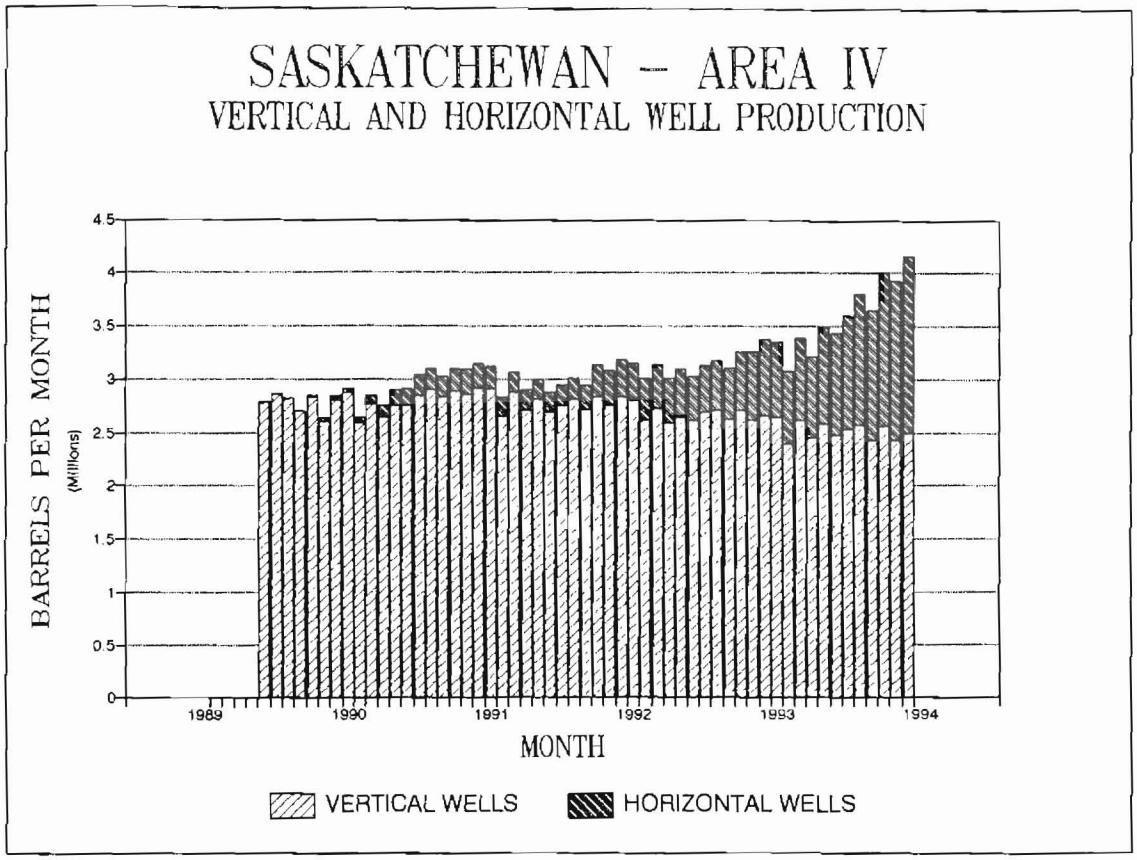

Figure 11. Monthly oil production in Saskatchewan from May, 1989 through December, 1993 from vertical wells and horizontal wells. Note the increase in the province's total production and in production from horizontal wells.

reservoir (LeFever, 1994). The well swabbed small volumes of fluids that were virtually 100% water and the well was shut in. The third, and best, non-Bakken horizontal well drilled during 1992 was the Axem Resources, Inc. #12-36H Tracy Mountain located in Section 36-T139N-R101W. The well was drilled into the Tyler Sandstone along the eastern edge of the south extension to Fryburg Field and had an IP of 32 BO + 37 BWPD on hydraulic pump. The well has produced 9,820 BO to the end of 1993. None of these three wells provided the necessary success to kick off a significant horizontal play in North Dakota.

1993

STATISTICS

The number of wells drilled during 1993 decreased by 21, or 12% (Fig. 3). Only during two periods have fewer wells been drilled annually. The first period includes those years before the discovery of oil in North Dakota and the first two years of development, 1952 and 1953. The second period was from 1970 to 1974 (Fig. 3), the years immediately preceding the first Arab oil embargo. A total of 34 wildcat wells were drilled during 1993 (Fig. 4), a decrease of 10 (22%) from 1992. Nine new pools were discovered these wildcats and

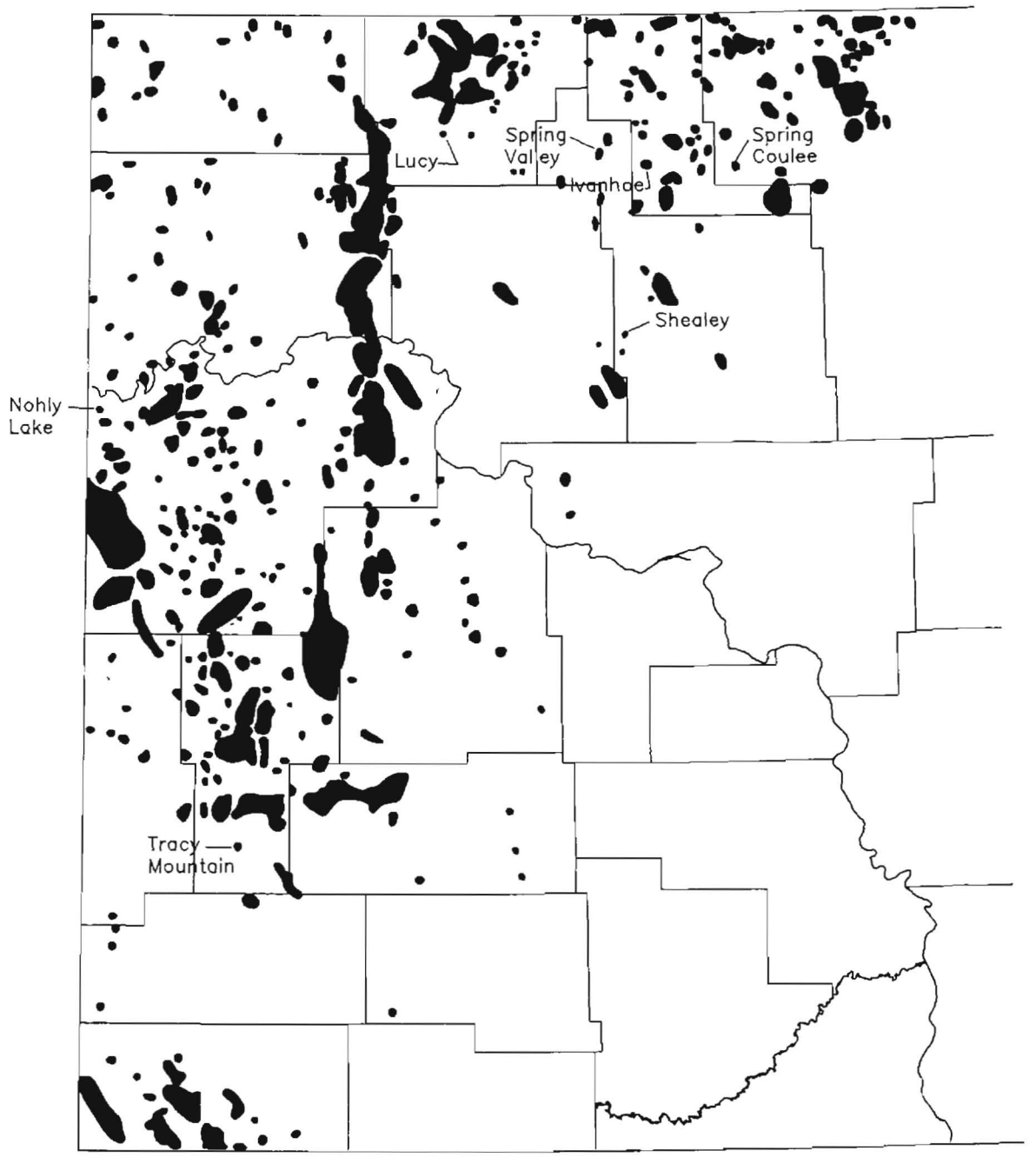

Figure 12. Western North Dakota oil fields with the 1992 new field discoveries.

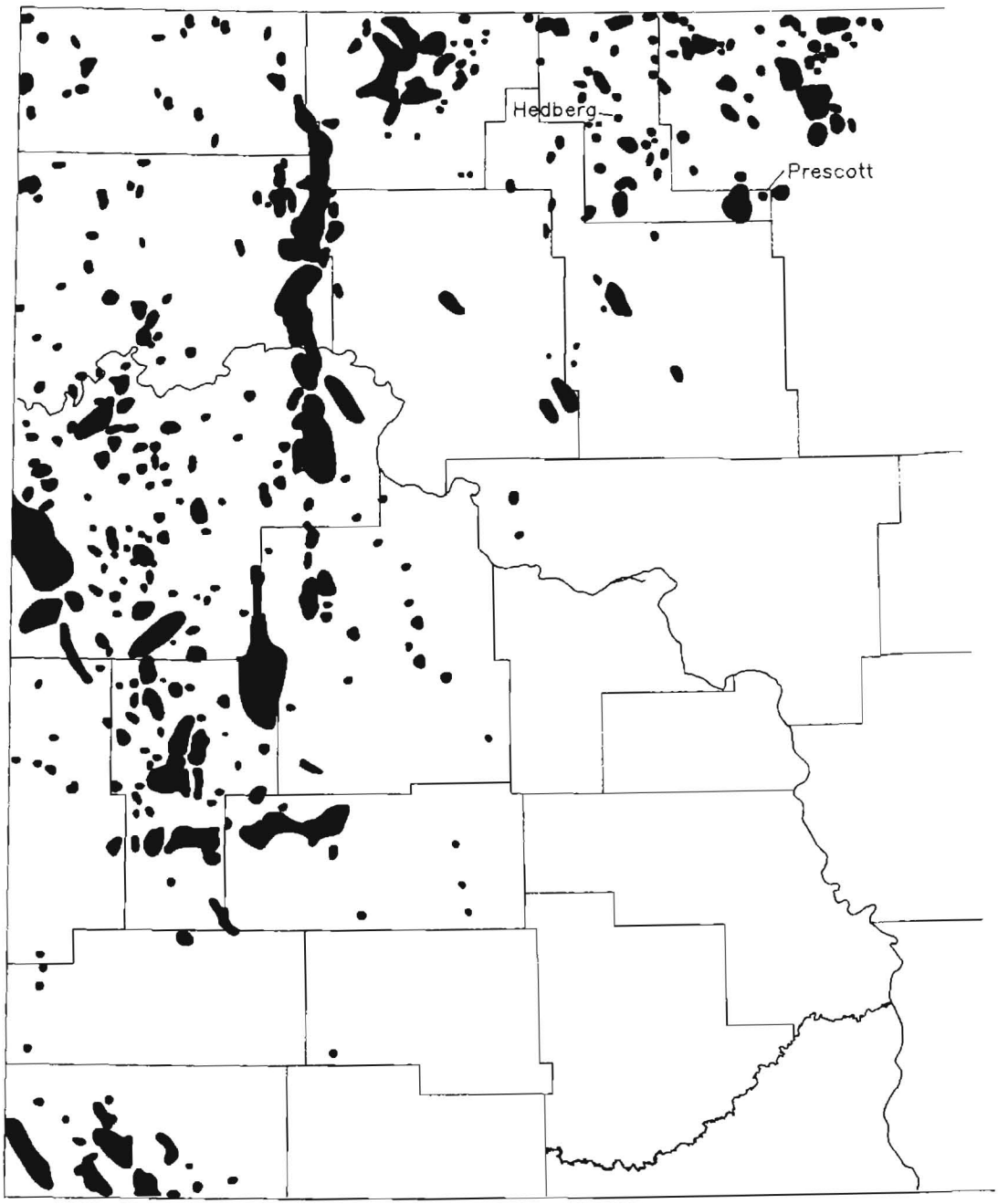

Figure 13. Western North Dakota oil fields with the 1993 new field discoveries.

three of them found were new fields (Fig. 11). These discoveries are summarized in Appendix II. Divide and Renville Counties each saw two new pool discoveries while Billings, Golden Valley, McKenzie, McLean, and Stark each had one (Table 1). Success rates during 1993 were 11% for wildcat wells, a 13% decrease, 73% for extension and development wells, and 58% for all wells. The success rate of development and extension wells decreased by 1% and the for all wells by 3%. A total of 1,312,125 feet of hole were drilled during 1993, a decrease of 189,969 feet or 13%. Oil production continued to decline falling 6% (1,981,498 BO) to 30,918,673 BO (Fig. 6). Twenty six horizontal wells were drilled during 1993 and, of them, 24 were Bakken tests. The other two tested Madison pay zones. In addition, JN Exploration & Production re-entered a producing well in Flaxton Field and drilled a horizontal leg in the field's Madison Group pay.

DRILLING ACTIVITY

Unquestionably, the most important event of 1993 was the completion of the Conoco, Incorporated #74 Dickinson State well. This well flowed 419 BO + 130 MCFGPD from the Mississippian Lodgepole Formation, a new and deeper pool discovery in Dickinson Field. The well was later production-tested at rates as high as 2,000 BOPD. By the end of 1993, four wells were producing from the pool. This discovery is significant for several reasons. First, before the Conoco discovery, the Lodgepole Formation had no more than a handful of wells producing from it. Second, the accumulation is interpreted to be a Waulsortian bioherm, a unique geologic feature that is probably identifiable with modern 3-D seismic data. Finally, flow rates as high as those possible from this accumulation are rare in North Dakota. Burke and Diehl (1993) have presented more data on this discovery, including data on Waulsortian bioherms. One result of this discovery is that many new leases were taken near Dickinson; however, unless another producing bioherm is discovered, each dry hole in this play will further diminish the status of the play.

Twenty-five horizontal Bakken tests were drilled during 1992, a decrease of five tests from 1991 and all 25 were completed as producing oil wells. However, several of these wells produce oil in such marginal volumes that they will never pay out. The near-perfect ability to complete a well in the Bakken Formation and produce at least some oil is a significant part of why the play originally became important. Cinnamon Creek Field saw the most activity with seven horizontal Bakken wells drilled. Two of these were first drilled vertically to the Red River Formation but, when the deeper zones proved nonproductive, the wells were plugged back and kicked out horizontally in the Bakken. The average IP of the seven was 176 BOPD, only slightly better than the average IP of all 25 wells, which was 173 BOPD. Pierre Creek and Flat Top Butte Fields each had four wells averaging 216 and 293 BOPD, respectively. The remaining 12 wells were divided among seven fields, the worst of which was Poker Jim Field where two wells were completed for an average of five BOPD. The drop in recorded IP's of horizontal Bakken wells may indicate that the best part of the play has been developed and, unless these lower IP wells decline at much lower rates than the higher IP wells did, the play may have run its course.

Drilling activity in the Tyler play was again strong, but saw poorer results than in 1992. Of the thirteen wells that tested the Tyler, only eight produced oil. Fryburg Field had the most wells with seven. Six of the seven produced oil with an average IP of 120 BOPD. The remaining six wells were drilled near Tracy Mountain Field, but only two were completed for an average IP of 89 BOPD. Data from these 13 wells suggests that the limits of these two accumulations have been found. Any new, Tyler production will be found only with additional wildcatting. Limited wildcat drilling occurred in the Tyler play but, until the U. S. Bureau of Land Management (BLM) and U. S. Forest Service (USFS) resume leasing in the western part of North Dakota, exploration will be curtailed in the Tyler play. These agencies are in the process of writing an Environmental Impact Statement (EIS) for the southern Little Missouri National Grasslands and may soon be issuing leases in the Tyler play area. The availability of federal

lands for exploration is important to the future of the Tyler play.

Madison Group strata are normally the main target of drilling and 1993 was no exception. A total of 55 development or extension wells targeted Madison strata. Together with the 25 wildcat wells that tested the Madison, there were a total of 80 Madison tests or 52% of the year's total wells. Only three of the wildcats were successful and resulted in two new field discoveries, Raub and Hedberg Fields (Appendix II). Twenty-four development wells, excluding those in Dickinson Field, were completed as oil wells and averaged 97 BOPD. If the reported IP's of the Dickinson Field wells are included, the average was 183 BOPD. The success rate for all Madison wells drilled during 1993 was 37%, a decrease of 4% from 1992.

There are two encouraging signs for future activity in North Dakota. The first is an increase in the number of wells testing horizons below the Bakken Formation. Twenty pre-Bakken wells were drilled during 1992, amounting to 11% of the year's wells. During 1993, a year in which drilling decreased, the number of pre-Bakken wells increased to 25, or 16% of all the wells drilled. Even though the Madison Group will remain an important target, it is the deeper zones that will contain the bulk of the new hydrocarbons found in North Dakota. After all, if Conoco, Inc. had not drilled below the main pay in Dickinson Field they would not have discovered the most significant find of the year, the Dickinson Lodgepole pool. Because of the many pay zones present in the Williston Basin, chance will remain an important part of exploration in North Dakota.

The second encouraging sign is the drilling of two more non-Bakken horizontal wells and one re-entry. Slawson Exploration Company, Inc. drilled the #1-15 Night Train in Plaza Field in Section 15-T152N-R88W. The well has a total open-hole wellbore of 1,785 feet of which 1,338 feet were considered by the wellsite geologist to have effective porosity. The well swabbed 91 BO + 457 BWPD and was shut in. The other horizontal well was more successful. Snyder Oil Corp. drilled their #30-H Mosser in T. R. Field in Section 26-T141N-R101W. An open-hole completion was made between 9,485 and 11,620 feet, measured depth, for an IP of 150 BO + 150 MCFG + 350 BWPD and the well produced a total of 2,905 BO during the last two months of 1993. JN Exploration & Production re-entered their #2 Martin well in Flaxton Field. The well is located in Section 12-T163N-R91W and produced from the Bluell and Sherwood subintervals of the Madison Group. The well was no longer producing commercial volumes of oil when the well was re-entered and a 1,450-foot horizontal wellbore was drilled through the Bluell and Sherwood pay zones. The well probably is an economic failure because it was completed producing between 20 and 25 BOPD and between 250 and 300 BWPD. None of these three non-Bakken horizontal wells produced enough oil to give any impetus to the state's horizontal Madison play, but they do demonstrate that interest is still high.

SUMMARY

The most active play during the early 1990's was the horizontal Bakken Shale play. By the end of 1993, both the number of horizontal Bakken wells drilled and their average initial potential had decreased from previous years. These decreases may be evidence that the horizontal Bakken play is nearly over. The play has been important to North Dakota because it generated heightened interest in the state, caused new leases to be taken, caused many new wells to be drilled, produced enough oil to help stop the decline in annual oil production during 1990, and helped prove that horizontal drilling was mechanically possible and can be an economically desirable technology. Even if the play is over, there will always be some completions in the Bakken Formation, but we will not likely see the number of them as in previous years and any completions will probably occur sporadically.

Despite decreases in drilling during 1992 and 1993, some encouraging signs for the future exist. Drilling to pre-Bakken horizons increased from 1992 to 1993 and is important because signi-

ficant resources remain in the deeper horizons. The increase in the number of deeper tests drilled indicates a renewed interest in exploring in and developing deeper horizons. The number of Tyler Sandstone wells that have been drilled in recent years is also promising. This play was dormant for a number of years, but the number of producing wells drilled during 1992 and 1993 is an indication that this play is not yet exhausted. Finally, horizontal drilling continues in formations other than the Bakken Formation. Horizontal drilling of the Madison Group in Saskatchewan has been important to the province for both oil production and drilling activity. Continued horizontal drilling in North Dakota in older, nearly depleted fields may yet find new reserves and have the positive economic impact that it has had in Saskatchewan.

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APPENDICES

APPENDIX I. 1992 NEW FIELD DISCOVERIES

COUNTY FILE NO. ORDER #	COMP. DATE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (# OF PRODUCING WELLS IN POOL ON 12/31/93	TOTAL MEASURED DEPTH -SPACING	PERFORATED INTERVAL	IP (CUR. -BOPD	GOR- GRAV.	WATER
Ward	1/12/92	Equitable Resource Energy Co.	Shealey	7,157	7,004-7,014	130	300	7
13291		Dyke #32-22	Madison	160		36	36°	
6318		Sec. 22, T154N, R87W	1					
Burke	1/20/92	Patrick Petroleum Co.	Lucy	7,540	7,394-7,797	55	1,000	92
13210		Wilson #1-7	Madison	160	7,402-7,408	11	35°	
6386		Sec. 7, T160N, R92W	2		7,426-7,430			
Billings	6/4/92	Duncan Energy Co.	Tracy Mountain	8,250	8,096-8,112	307	100	2
13353		O'Connell #1	Tyler	160		29	33°	
6584		Sec. 9, T138N, R101W	11					
Renville	6/8/92	EOG (New Mexico) Inc.	Ivanhoe	5,704	5,503-5,508	40	125	160
13351		Triplett #1-2	Madison	80		13	26.7°	
6485		Sec. 9, T159N, R86W	1					
Bottineau	7/15/92	Texas Crude Energy, Inc.	Spring Coulee	4,900	4,714-4,719	67	150	10
13365		Sagsveen State "21" #1	Madison	80		44	27.1°	
6503		Sec. 21, T159N, R83W	2					
Ward	9/15/92	Axem Resources, Inc.	Spring Valley	7,240	7,102-7,114	86	581	6
13328		South Carpenter Lake #2-9	Madison	160		9	34°	
6519		Sec. 9, T153N, R87W	2					
McKenzie	11/10/92	Amerada Hess Corp.	Antelope	14,500	14,089-14,128	14	543,000	11
13405		Brenna Lacy 1 #32	Winnipeg/Deadwood	640	14,200-14,211	.6	44°-51.7°	
6570		Sec. 1, T152N, R95W	1		14,236-14,491			
McKenzie	12/12/92	Wyoming Resources Corp.	Nohly Lake	12,800	12,627-12,662	193	N/A	51
13442		Missouri #1	Red River	320		60	45.2°	
6586		Sec. 30, T151N, R104W	1					

APPENDIX II. 1993 NEW FIELD DISCOVERIES

COUNTY FILE NO. ORDER #	COMP. DATE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (# OF PRODUCING WELLS IN POOL ON 12/31/93	TOTAL MEASURED DEPTH -SPACING	PERFORATED INTERVAL	IP (CUR. -BOPD	GOR- GRAV.	WATER
McKenzie	1/10/93	Meridian Oil Inc.	Cinnamon Creek	13,200	11,233-11,240	312	N/A	tr
13452		MOI Cinnamon Creek #31-7	Duperow	160		144	41°	
6624		Sec. 7, T145N, R102W	1					
McLean	1/26/93	Balcron Oil	Raub	8,190	7,985-7,994	146	600	77
13451		State #22-16	Madison	160	8,004-8,006	37	37°	
6640		Sec. 16, T149N, R89W	2					
Stark	2/3/93	Conoco, Inc.	Dickinson	12,855	9,721-9,850	419	310	0
13447		Dickinson State No. 74	Lodgepole	320		656*	41.4°	
6607		Sec. 34, T140N, R96W	4					
Billings	3/18/93	William C. Kirkwood	Bullsnake	13,670	12,042-12,052	211	390	0
8603		Kordonowy State #34-31	Silurian	320		258	46°	
6854		Sec. 31, T142N, R98W	1					
Golden Valley	4/30/93	JVA Operating Company, Inc.	Beaver Creek	12,800	12,234-1,240	42	233	43
7768		Beaver Creek Federal #24-23	Stonewall	320		8	43°	
6812		Sec. 23, T143N, R103W	2					
Renville	9/30/93	Hallwood Petroleum, Inc.	Hedberg	5,291	5,085-5,100	118	N/A	25
13564		Bimini #1-8	Madison	80		39	29°	
6760		Sec. 8, T160N R85W	1					
Renville	10/19/93	EOG (New Mexico) Inc.	Prescott	4,528	4,482-4,485	25	280	17
13304		Swift #31-4	Madison	40	4,495-4,508	4	25°	
6651		Sec. 4, T158N, R81W	1					
Divide	10/23/93	General Atlantic Resources, Inc.	Ambrose	11,100	10,925-10,931	55	500	85
9903		#1 Ness 41-23	Red River	160		36	41°	
6793		Sec. 23, T163N, R99W	1					
Divide	12/16/93	Samedan Oil Corp.	Sadler	12,067	8,618-8,634	15	1200	3
13578		Camp Davis State #1-16	Bakken	160		5	41°	
6802		Sec. 16, T161N, R95W	1					

* The producing wells in the Dickinson Lodgepole pool are voluntarily restricted while Conoco, Inc. attempts to unitize the pool so the current production rates are not indicative of actual productive capacity.