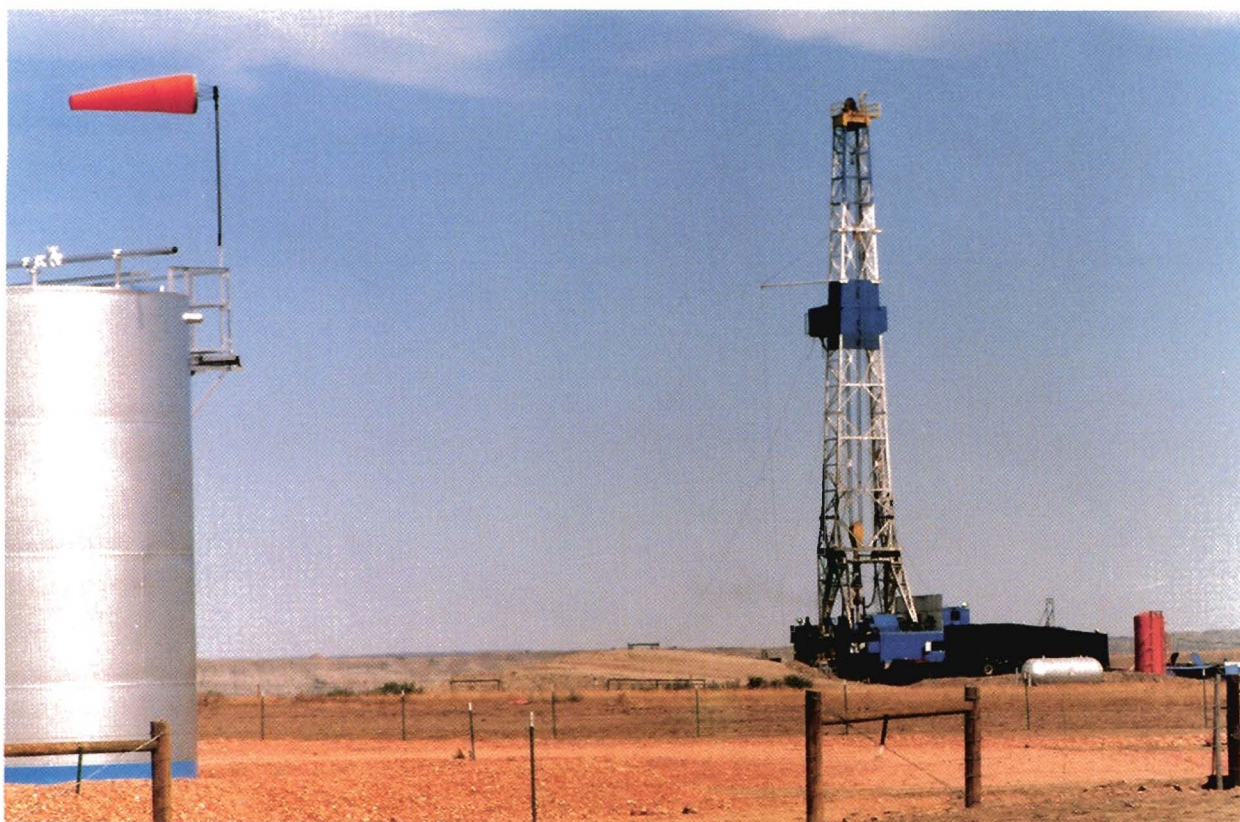


# Oil Exploration and Development in the North Dakota Williston Basin: 1994-1995 Update

By Thomas J. Heck



OIL EXPLORATION AND DEVELOPMENT IN THE NORTH DAKOTA WILLISTON BASIN: 1994-1995 Update  
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North Dakota Geological Survey  
Thomas J. Heck

MISCELLANEOUS SERIES NO. 84  
North Dakota Geological Survey  
John P. Bluemle, State Geologist  
1996

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***Cover Photograph:*** Photograph is a view to the northeast from the production facilities of the Continental Resources Inc. Duffield #1-14; located in the NE NE Section 14-T132N-R107W, Bowman County, towards the location of the then drilling Continental Resources Inc. Bidy #1-12 in the SW SW section 12-T132N-R107W. Both are development wells in Cedar Hills Field drilled horizontally into the "B" Zone of the Red River Formation. The surface locations of the two wells are located approximately 1,300 feet apart. The wellbores were drilled in opposite directions with the Bidy well being drilled to the northeast and the Duffield well to the southwest. The length of horizontal wellbore drilled in Cedar Hills Field commonly exceeds 5,000 feet.

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## ACKNOWLEDGMENTS

This update benefitted from the review and suggestions from John Bluemle and Rod Bassler. Their help was greatly appreciated.

## INTRODUCTION

This update summarizes oil exploration and development of the 1980s and 1990s, but focuses on the events of 1994 and 1995. 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 during the late 1970s. Record high crude oil prices were reached during the early 1980s but crude oil prices began to decline in 1982. Exploration increased during the 1970s, but began to decrease in response to the lower prices of the 1980s. Many had thought that prices had hit bottom in 1985, but over-production by OPEC caused oil prices to fall even further in 1986 and the oil industry may only now be recovering from that price drop. Oil industry activity in North Dakota is currently at a relatively high level of activity, but is still far below the levels seen during 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, Amoco Oil Company, Mandan, North Dakota, and Saskatchewan Energy and Mines. 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 many earlier 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 (Figure 1), and tax revenues doubled from 1979 (Figure 2). Of the nearly 600 wells drilled in North Dakota during 1980 (Figure 3), 182 (31%) were wildcats (Figure 4). There were 84 new-pool discoveries (Figure 5) and production rose to 40,354,030 barrels, a second consecutive annual record (Figure 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 (Figure 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 (Figure 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 there is a one to three year time-lag between discovery and the peak of production of an oil field. In general, the larger the field the longer the time-lag as the number of wells required to develop the field increases. Many fields discovered during 1980 and 1981 did not reach peak production until 1982 to 1984.

Oil prices continued to decline during 1983, exerting downward pressure on drilling. Wildcat drilling (Figure 4) was one-third of 1981 levels, reflecting the lower oil prices, but development



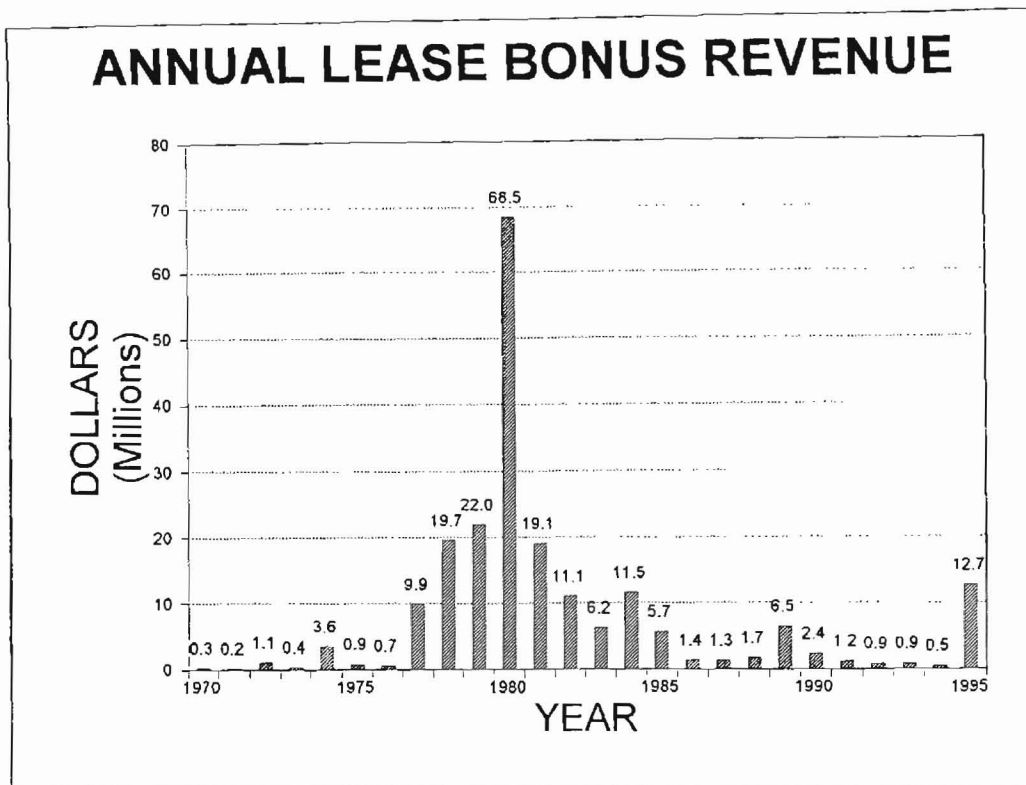


Figure 1. Bar diagram of annual revenue from quarterly state oil lease sales held for the period 1970-1995. (Source: N.D. State Land Department).

drilling remained high. However, oil production continued to rise as did tax revenues (Figures 2 & 6). The drilling of both wildcat and development wells recovered slightly during 1984 (Figures 3 & 4) and oil production reached its all-time high of 52,654,336 barrels (Figure 6) Despite record production volumes, tax revenues declined for the first time since 1973 (Figure 2) because of lower oil prices. Drilling again declined during 1985 as oil prices slid further and began to fluctuate. Over-production by OPEC caused a rapid price drop in early 1986 (Figure 8), with prices falling to less than \$10 a barrel for certain types of crude oil. Drilling dwindled and oil companies began to downsize and reduce spending in response to lower crude oil prices and uncertainties about future prices. The impact on North Dakota's oil industry was a drop in drilling and a decrease in the number and size of oil-field service companies. Many companies either went bankrupt and closed their doors or moved out of state to cut costs.

From mid-1986 through early 1987 crude oil prices rose gradually and a modest increase in drilling occurred between mid-1987 and early 1988. Although the number of wells spudded increased during the second half of 1987, activity during the first half was so low (Figure 8) that only 190 wells were drilled during the year (Figure 3). In 1988, drilling jumped sharply to 255 wells. Some of the increase was the result of development drilling in Wabek Field, an important new oil field discovered along the Mississippian Sherwood subinterval shoreline. During 1989, another important field, Plaza Field, was discovered near Wabek Field and development began. 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 discovered during the late 1980's.

From 1986 through 1991, between two and three hundred wells were usually drilled each year but during 1987 and 1989, drilling fell below 200 wells recording the lowest numbers of wells drilled since 1974 (Figure 3). Between 35 and 67 of the wells drilled annually were wildcat wells during this period. For example, 67 of the 190 total wells drilled in 1987 and 35 of the 188 wells drilled in 1989 were wildcats. The number of wells drilled annually decreased steadily from 1990 until 1995 when a slight increase occurred. Wildcat drilling correspondingly decreased, declining to 20 and 17 wildcats during 1994 and 1995, respectively.

Horizontal drilling has become a major drilling method for the oil industry in North Dakota. Horizontal drilling in the Williston Basin began during 1987 when the first horizontal Bakken Shale wells were drilled in North Dakota and the first horizontal Madison wells were drilled in Saskatchewan. Horizontal drilling in these plays became common-place during 1989. One result of the horizontal Bakken play was that state lease bonus revenue (Figure 1) jumped in 1989 as industry interest in the play continued to rise. Many state oil leases brought favorable per-acre bonuses at auctions during 1989 and 1990. In contrast, the U. S. Forest Service, which was unable to lease the Little Missouri National Grasslands at this time because of a court-imposed environmental impact statement requirement, lost lease and production revenue that would have exceeded those of the State Land Department.

In many respects, the 1980's ended with the oil industry in North Dakota in the best shape it had been in for several years. Oil production and drilling were up as the result of new plays and horizontal

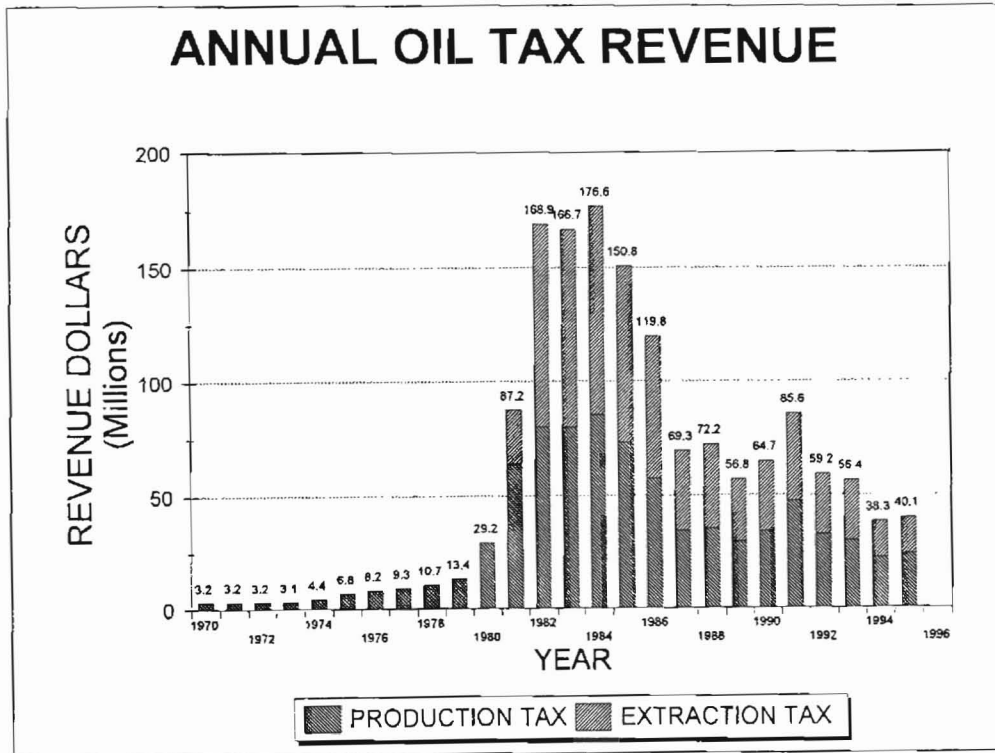
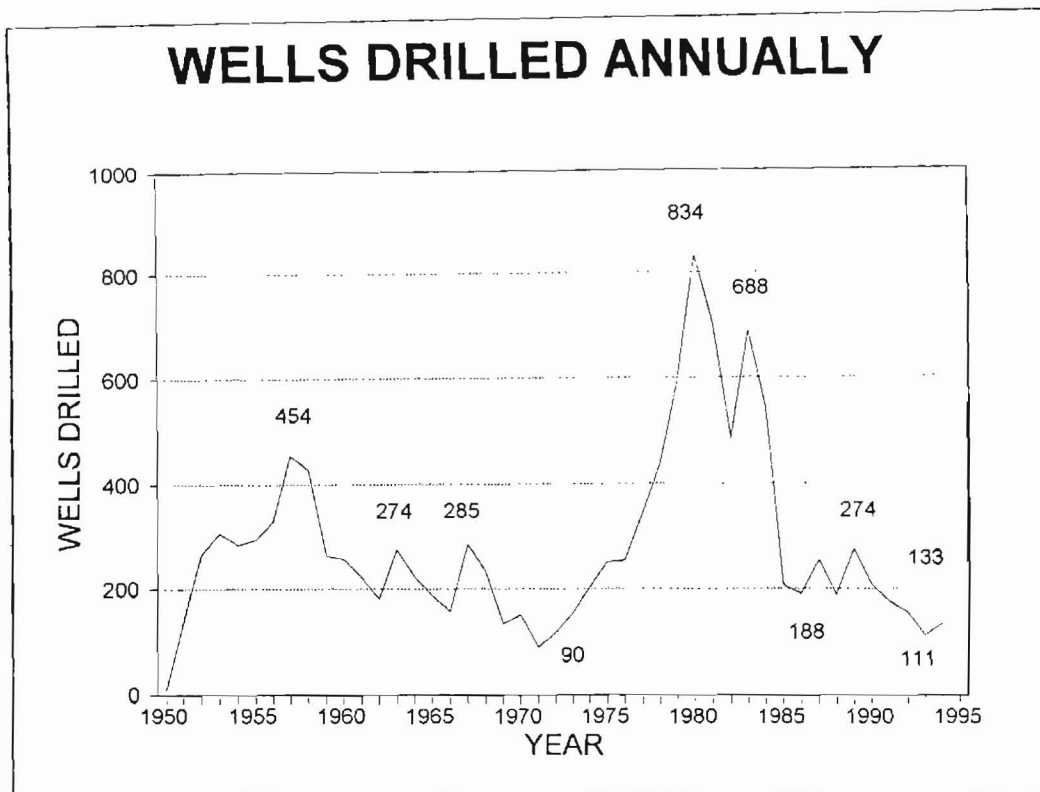


Figure 2. Bar diagram of annual tax revenue generated by the production and extraction taxes on crude oil for the period 1970-1995. The extraction tax took effect on January 1, 1981. (Source: N.D. State Tax Commission).



**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).

drilling technology was becoming important to the local industry. In addition, oil prices were up slightly (Figure 7) , increasing the positive effects at the end of the decade.

### 1990-1995

The 1990s began with many of the recently acquired leases in the horizontal Bakken Shale play being drilled as activity in the play peaked during 1990. The total number of wells drilled in the state rose significantly from 1989 to 1990, climbing 86 to a total 274 wells, the most wells drilled since 1985 (Figure 3). Seventy-seven of those wells drilled were Bakken tests. During 1991, 48 Bakken tests were completed while 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 the success rates during both 1992 and 1993 were 100%. Despite the appearance of success by this one measure, some of these wells will be economic failures because the volume of hydrocarbons recovered will not be sufficient to pay for the costs of drilling and completion.

Since 1990, the areal limits of the horizontal Bakken play have been defined. In addition, many Bakken wells declined faster than expected. As a result, drilling activity decreased as companies re-evaluated the play. By 1994, the horizontal Bakken play was nearly over with only nine horizontal Bakken wells being completed. In 1995 three wells were completed marking the end of the play.

Another important factor in the 1990 drilling increase was the invasion of Kuwait by Iraq in August, 1990. World oil prices surged as uncertainties about the security of the Middle East oil supply rose and oil prices in North Dakota also increased (Figure 8). Oil companies, responding quickly to the price surge in 1990, increased drilling and nearly doubled the number of wells spudded each month in North Dakota (Figure 8). The rapid deployment of allied military forces during the fourth quarter of 1990 generated a downward pressure on oil prices and the number of wells spudded decreased as uncertainties lessened. The price of oil began to fall in late 1990 and continued to decline into 1991, but the price of oil remained \$1-\$3/barrel above the July, 1990 price well into 1991. By late 1991, after Kuwait was liberated, prices had returned to pre-Gulf War levels.

Drilling during the 1990s has been on a downward trend. From 1990 through 1994 the number of wells drilled annually in the state steadily decreased from 274 to 111. A small increase occurred during 1995 (Figure 3) as a result of intense interest in the Lodgepole and horizontal Red River plays in western North Dakota. Wildcat drilling decreased from 58 to 17 (Figure 4) between 1990 and 1995 without any increase in response to the Lodgepole and Red River plays.

Two new plays began in North Dakota during the 1990's. The first was initiated by Conoco, Inc. when they discovered what has been described as Waulsortian bioherms or Waulsortian-like mounds in the basal Lodgepole Formation while drilling a deep test in Dickinson Field. This well was completed during 1993 and is the first economic Lodgepole oil production in North Dakota. The flow-rates of this and subsequent wells drew national attention. The hunt for similar features is underway in many parts of the Williston Basin.

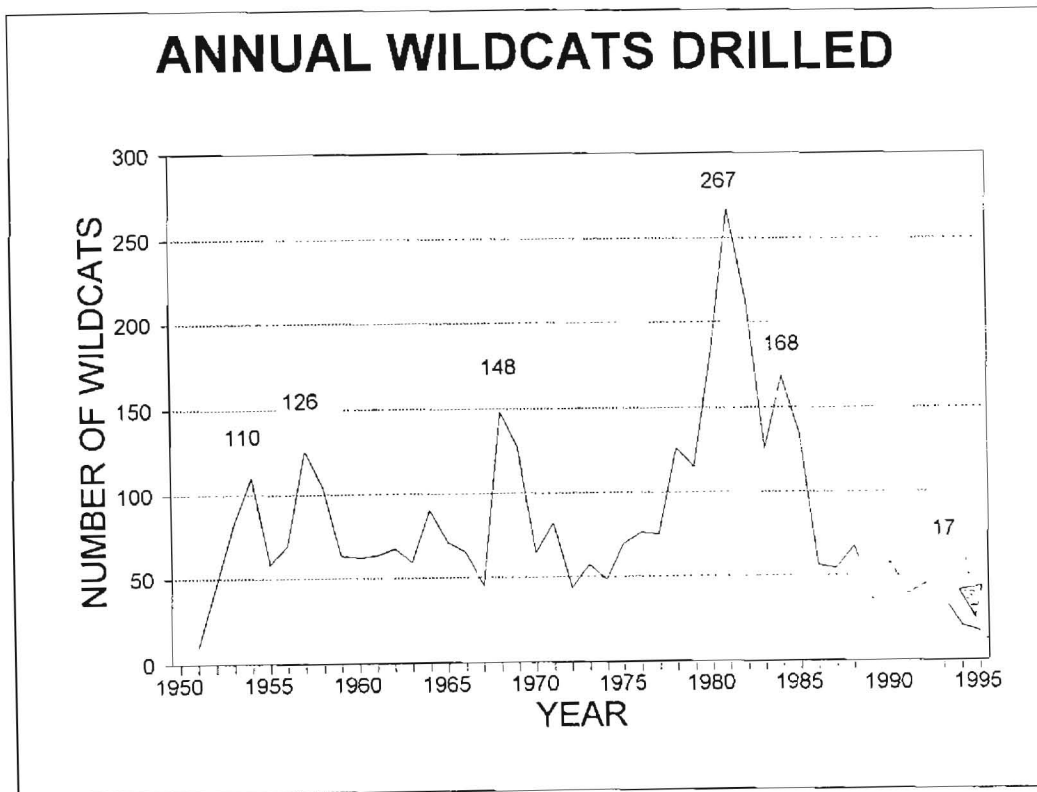


Figure 4. Line graph of the number of wildcat wells drilled annually in North Dakota since 1951. (Source: N.D. Geological Survey and N.D. Oil and Gas Division).

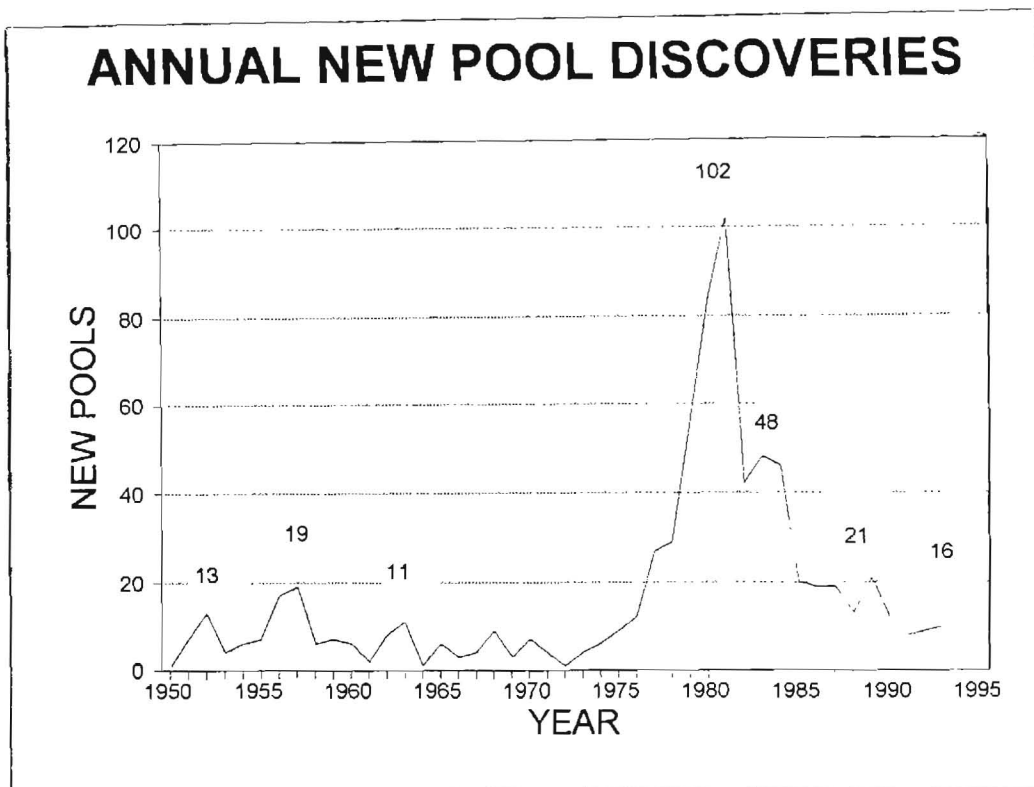


Figure 5. Line graph of the number of new pools discovered annually in North Dakota since 1951. (Source: N.D. Geological Survey and N.D. Oil and Gas Division).

The second play is the horizontal Red River B zone play in Bowman and Slope counties. The first horizontally drilled Red River well in North Dakota was completed by Meridian Oil, Inc. (MOI) during 1994. MOI began the horizontal Bakken play during 1987 and also drilled the first horizontal Red River B zone wells in Montana near East Lookout Butte Field on the Cedar Creek Anticline during 1988. Between the two plays, MOI has drilled more horizontal wells in the state than any other operator to date. The horizontal Red River play discovery sparked a large land play and widespread drilling. While the horizontal Red River play did not grab the attention of oil companies as the Lodgepole play did, it has proven to be economically attractive and has surpassed the Lodgepole play in terms of continuous drilling and number of wells drilled. In addition, in December, 1995, the horizontal Red River play produced nearly two-thirds as much oil as did the Lodgepole fields. As more horizontal Red River wells come on-stream, monthly production from this play will probably surpass the monthly production from the presently known Lodgepole fields.

Annual oil production in North Dakota declined between 5 and 10% per year from 1985 through 1989. In 1990, annual production declined by only 21,057 barrels (.0005%) from 1989 (Figure 6). The fact that annual production did not decline between 1989 and 1990 is attributed to production from two new fields and wells completed in the horizontal Bakken play. Approximately 2.2 million barrels of oil were produced from Wabek and Plaza fields along the Sherwood and Bluell shorelines in Ward and Mountrail counties and another 2.7 million barrels were produced from horizontal Bakken wells in western North Dakota. Together, the 4.9 million barrels of oil that were produced offset the production decline from the other 3,500 wells in the state. Production declined by a modest 2% to

35,895,278 BO in 1991 as new production was no longer able to offset the decline. During 1992, 1993, and 1994 production fell 8, 6, and 11%, respectively. Falling production was reversed during 1995 as production from two new plays, the horizontal Red River and the Lodgepole mound plays, came on-line. Production rose 1,758,147 BO, slightly more than 6% of 1994's total. Annual production during 1996 will certainly increase again as many more new Red River wells have been completed and other Lodgepole plays are unitized. For at least the next year or two, annual production will increase.

State lease bonus revenue (Figure 1) soared in response to the Lodgepole and horizontal Red River plays. Diehl and Burke (1995) published their interpretation of areas favorable for Lodgepole buildups in western North Dakota. Reaction to this map by the oil industry can be seen in Figure 9 where, along the trend interpreted by Diehl and Burke, many state leases were taken during three state lease sales. In a similar manner, McClellan (1994) had concluded that the Red River Formation in southwestern North Dakota was an attractive horizontal target several months before Cedar Hills Field was discovered. While McClellan's study may not have been the main reason companies decided to enter the play, oil company executives have said it did influence their decision.

At the end of 1995, thanks to some new important discoveries, North Dakota's oil industry was again very active. The activity focused on development drilling in the horizontal Red River play and on extending the Lodgepole play outside the Dickinson area. Declining oil production was more than offset by new production from these two plays. The short-term prospects for North Dakota appear to be very good.

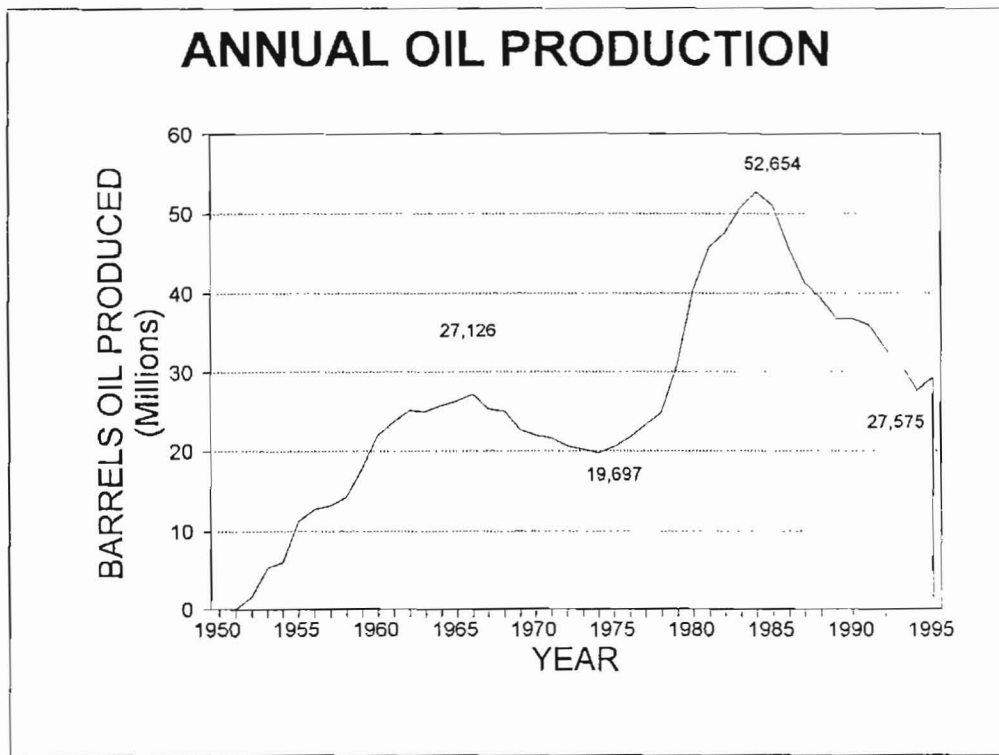


Figure 6. Line graph of the annual oil production in North Dakota since 1951. (Source: N.D. Geological Survey and N.D. Oil and Gas Division).

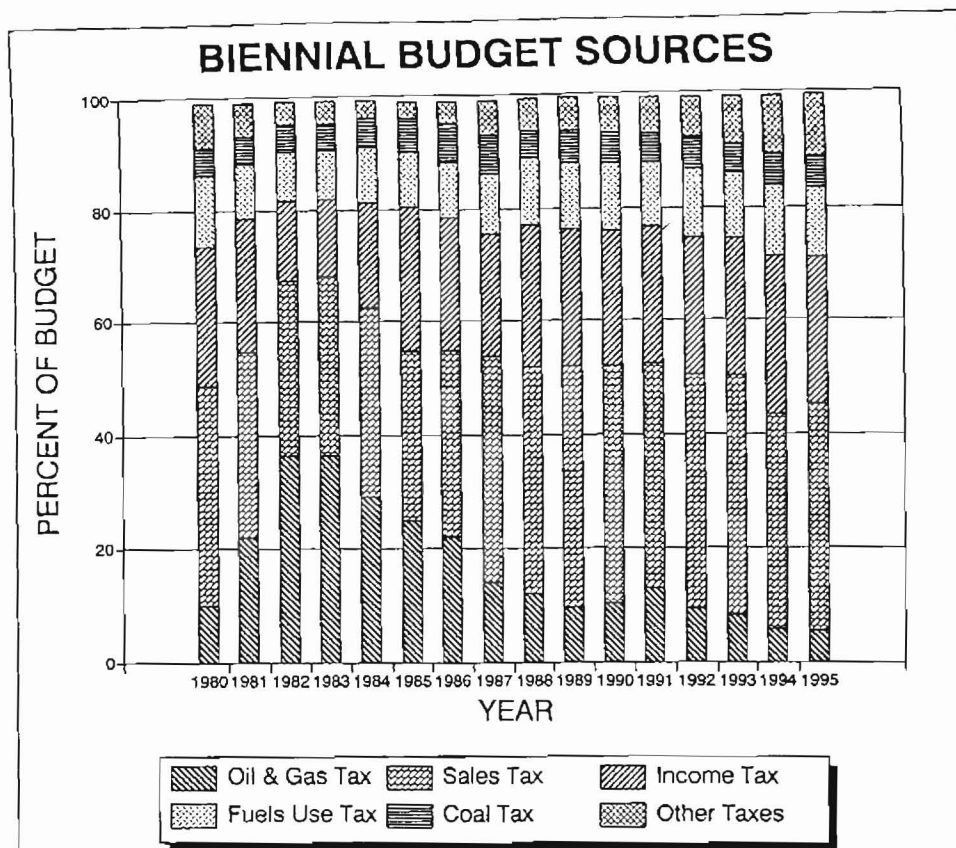


Figure 7. Bar graph of the sources and percentage contribution to North Dakota's biennial budget since 1981. (Source: N.D. State Tax Commission).

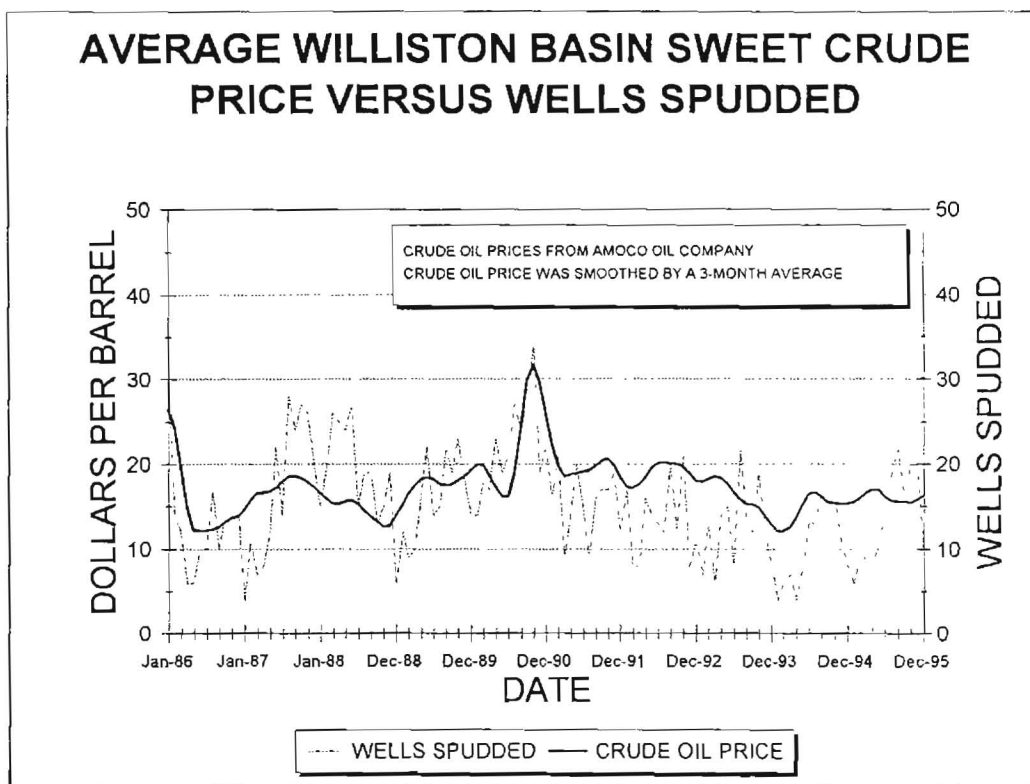
### HISTORICAL ANALYSIS

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. Drilling remained fairly constant during the late 1980s. Drilling steadily decreased since 1990 to a level not seen since the 1960s (Figure 3). That decline may be temporarily reversed by the drilling in the Lodgepole and Red River plays, which saw many wells drilled during 1994 and 1995. From the recent historical record, it appears that if more than 175 wells are drilled during a year it is because a large field or fields are being developed and/or a new play or plays are active. This is what happened during the late 1980s when Wabek Field was being developed and the Bakken play was active. If fewer than 175 wells are drilled then no plays or fields are being developed (Figure 3).

Annual oil production began to decline during 1983 as fields aged and uneconomic wells were plugged. 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 production declined again during 1991. Decline rates of 6-10%/year were recorded between 1992 and 1994. Annual production during 1995 rose more than 6% over 1994 production as new wells in the Red River and Lodgepole plays were brought on-line. Once these plays are fully developed, annual production will again begin to decline unless new fields, plays, or units are developed.

The development of Wabek and Plaza fields along the Sherwood shoreline play coupled with the activity in the horizontal Bakken play clearly illustrate one way to offset the state's decline in oil production: find and develop a single large oil field or discover a new oil play with many new fields. Wells completed in both plays had higher initial potential's (IP's) than the average well. To offset declining production, either new high IP discoveries must be developed, many more average new wells must be completed, or very many marginal wells must be completed. In these three cases, increasing amounts of capital are needed to drill the wells required to raise annual production. At current oil prices only the first two options appear feasible.

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 remained undiscovered in McKenzie, Dunn, Billings, Golden Valley, Stark, and Slope counties. Some of this oil was discovered during the horizontal Bakken and the Lodgepole plays, but much of the potential resource in this area remains undiscovered. Oil is produced in many more North Dakota counties than the few listed and some of them undoubtedly contain substantial volumes of undiscovered hydrocarbons. The discovery of a single five-million-barrel or larger oil field would result in many new wells as operators would explore for similar fields, just as they are currently doing in the Lodgepole and horizontal Red River plays. Such an event could reverse or offset declining production.



**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).



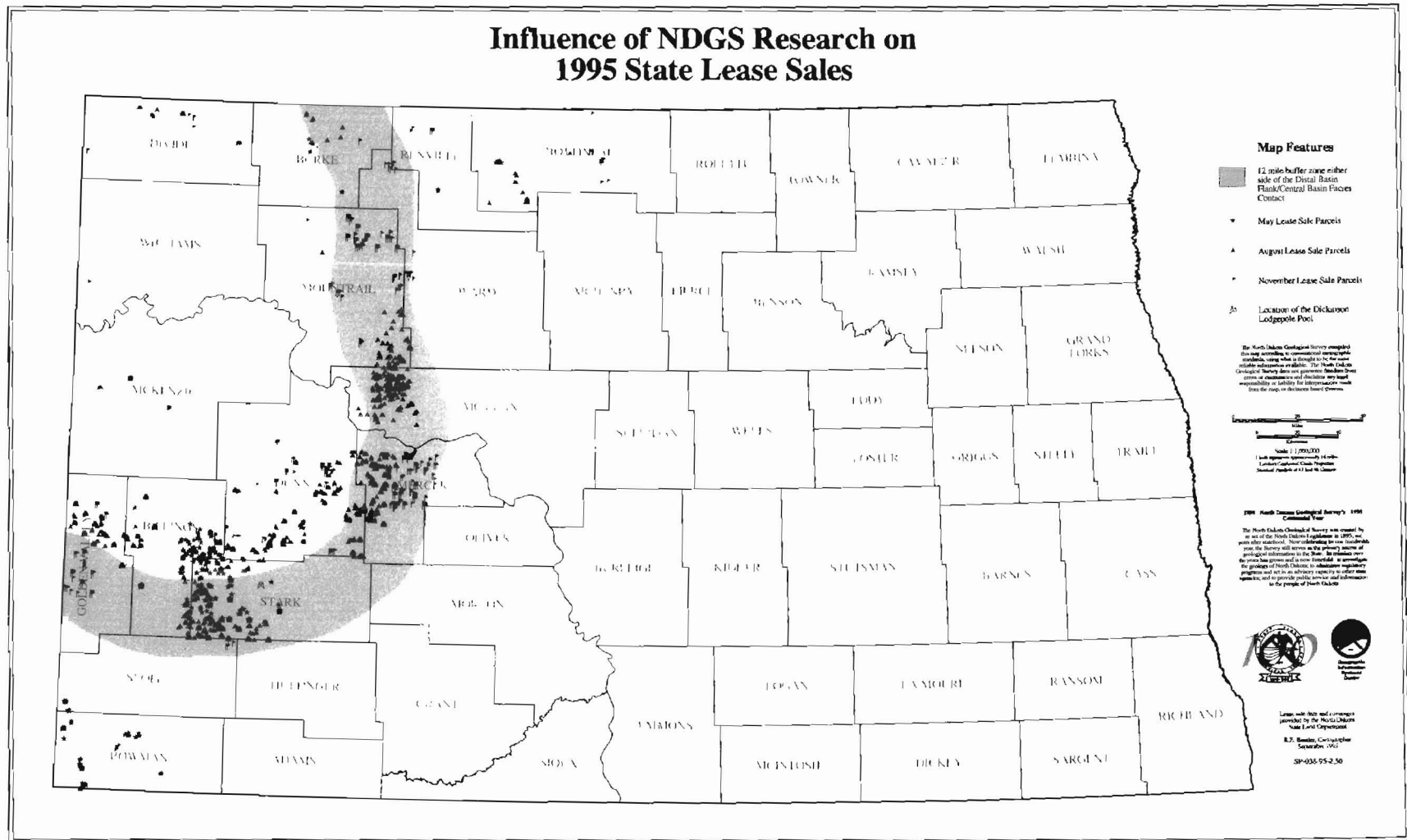


Figure 9. 1995 State lease sale parcels with approximate location of lease parcels sold during the May, August, and November, 1995 State lease sales and their relationship to the favorable Lodgepole buildup trend of Diehl & Burke (1995). Modified from Bassler (1995).

Another way to increase oil production is to unitize known oil fields and initiate enhanced-recovery operations. A successful secondary recovery project will recover the remaining primary reserves in an oil field at a much higher rate than will an equivalent non-unitized field. The unitized field will then produce many additional barrels of secondary reserves. Five new units were formed during 1993 and 1994, equaling the peak year of 1968 (Figure 10). Another four fields were unitized during 1995. The apparent surge in unitizations in North Dakota comes as many oil fields approach the end of their primary productive life-spans. The 1991 North Dakota legislature encouraged unitizing fields by enacting legislation that lowered the percentage of mineral and working interest owners required to form a unit. Methods like this encourage capital investments in unitizing oil-fields and are instrumental in minimizing declining oil production in North Dakota.

A final way to slow or possibly reverse declining annual production is by drilling horizontal wells in existing Madison Group fields. The effect that a successful horizontal well program might have in North Dakota is surmised by 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 in Saskatchewan during 1993 alone (Figure 11). From 1987 through the first 3-1/2 months of 1994, a total of 585 horizontal wells had been drilled in the Saskatchewan portion of the Williston Basin. Horizontal wells represented 8% of their Williston Basin well count during December, 1993, but accounted for 40% (Figures 11 & 12) of the oil produced that month (Stalwick, 1994). Horizontal wells have contributed so much oil that production in the province has increased instead of declining as it had been (Figure 12). The same strata that produce in Saskatchewan are present and productive in North Dakota. A similar 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.

## 1994

### *Statistics*

During 1994, one-hundred and eleven wells were drilled and completed, a decrease of 43 wells from 1993 (Figure 3). Only twice in North Dakota's history since the discovery of oil were fewer wells drilled than during 1994. Ninety wells were drilled during 1972 and ten wells during 1951, the year during which the first oil-well was completed in the state. The total of one-hundred and eleven wells drilled during 1994 includes six water disposal or unit wells, which are not included in the other statistics. The number of wildcat tests drilled during 1994 dropped significantly, falling from 35 in 1993 to 20 in 1994 (Figure 4). However, the number of new fields or pools discovered during 1994 increased to ten from nine during 1993, despite the drop in wildcat drilling. These new discoveries are summarized in Appendix 1 and are shown in Figure 13. McKenzie County saw the most new discoveries with five while Adams County joined the ranks of oil-producing counties with its first oil field, Cow Butte Field. Bowman, Stark, Ward and Billings counties each had one new field or pool discovered during 1994.

The wildcat success rate was 15% as 3 of 20 wildcats were completed. For development wells, 74% of the 85 wells were completed and 63% of all the wells completed during 1994 produced oil or gas. These percentages represent slight increases over 1993 percentages for wildcat, development, and all wells completed. A total of 996,985 feet of hole were drilled during 1994, a decrease of 315,140

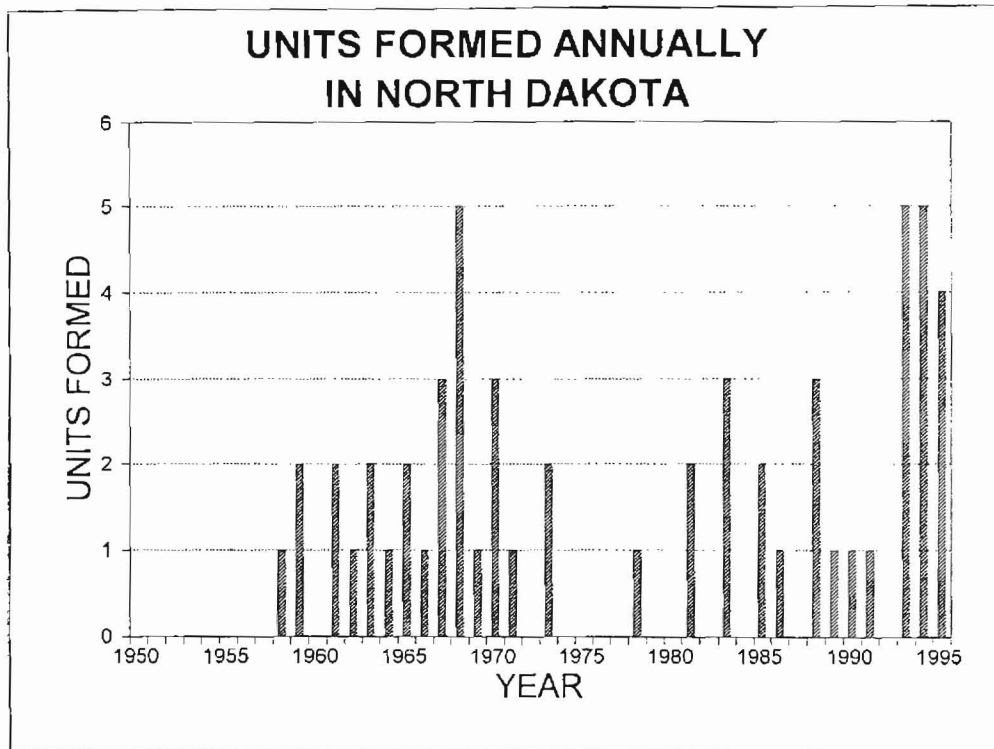


Figure 10. Bar graph of the annual number of unitized fields beginning operations (Source: N. D. Oil and Gas Division).

feet from 1993. Oil production fell nearly 11% (3,343,302 BO) during 1994 to an annual total of 27,575,371 BO.

A total of 25 wells were drilled horizontally during 1994, two less than during 1993. Nine of the horizontal wells were drilled into the Bakken Formation, 14 into Madison Group strata, and two into the Red River Formation. The earlier of the two Red River horizontal wells was the discovery well for Cedar Hills Field and the horizontal Red River B zone play now active in Bowman and Slope counties.

**Drilling Activity**

1994 was a year of contrasts. Relatively few wells were drilled, but several that were drilled were important new discoveries. Duncan Oil, Inc. completed the #1-11 Knopik (Appendix 1) discovering Eland Field and confirming the Lodgepole mound play. The Knopik well caught the attention of the domestic oil industry with its exceptional initial potential (IP) flowing 2,707 BOPD + 1,551 MCFGPD with no water. The discovery not only confirmed the Lodgepole Waulsortian mound play in the immediate Dickinson area, but the discovery of a second mound also has implications for other parts of North Dakota. It is unlikely that the mound complex in the Dickinson area is a unique geologic feature. Rather it is more likely that additional mound complexes will be found elsewhere in the Williston Basin. At least eight wells were drilled in the Dickinson area in search of more Lodgepole mounds but Eland was the only field discovered in the play during 1994. The eight wells were drilled

by Armstrong Operating, Inc., Duncan Oil, Inc., True Oil Co., Amerada Hess Corp., West Bay Exploration Co., or Conoco, Inc.

A second, and presently extremely active, play in North Dakota was kicked-off by the discovery of Cedar Hills Field in Bowman County during 1994. Meridian Oil, Inc. completed their Larkin #14-18H, located in section 18, T131N, R105W, in the Red River B zone with an IP of 250 BO + 80 MCFG + 24 BWPD. The horizontal Red River B zone play was first tested in Montana near East Lookout Butte Field by Meridian Oil, Inc. during 1988. Only a few wells were drilled in this original program. Either this first attempt was not an economic venture or drilling horizontal Red River wells was abandoned in favor of drilling horizontal wells in the Bakken Formation play, which had begun during 1987. Before the discovery of Cedar Hills Field, vertically drilled Red River B zone wells in Bowman County were not completed unless they were on or near the crests of structures because a combination of low oil and high water-cuts made them uneconomic. The Larkin completion was proof that a horizontally drilled Red River B zone well could be productive because the greater borehole contact with the producing zone increased the oil-cut and decreased the water-cut. One of the theoretical benefits to drilling a horizontal well is that the coning of water into the productive wellbore is reduced and this has been shown to be true in this play. While the oil production rates from this first and subsequent wells are not equal to those from Lodgepole mound wells, initial potentials are usually in the 200-500 BOPD range. In addition, water production is not excessive for the oil volumes and the success rate is high with only a couple of wells completed as dry holes. From the first few horizontal

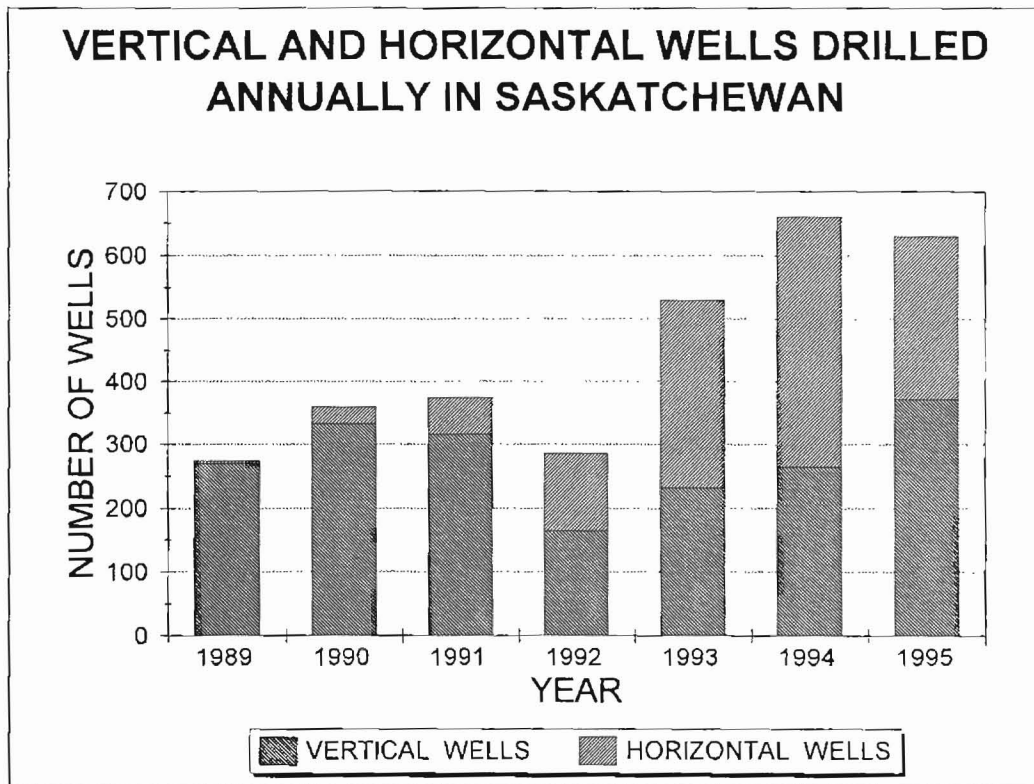


Figure 11. Bar graph with the annual number of horizontally and vertically drilled wells in Saskatchewan since 1989.

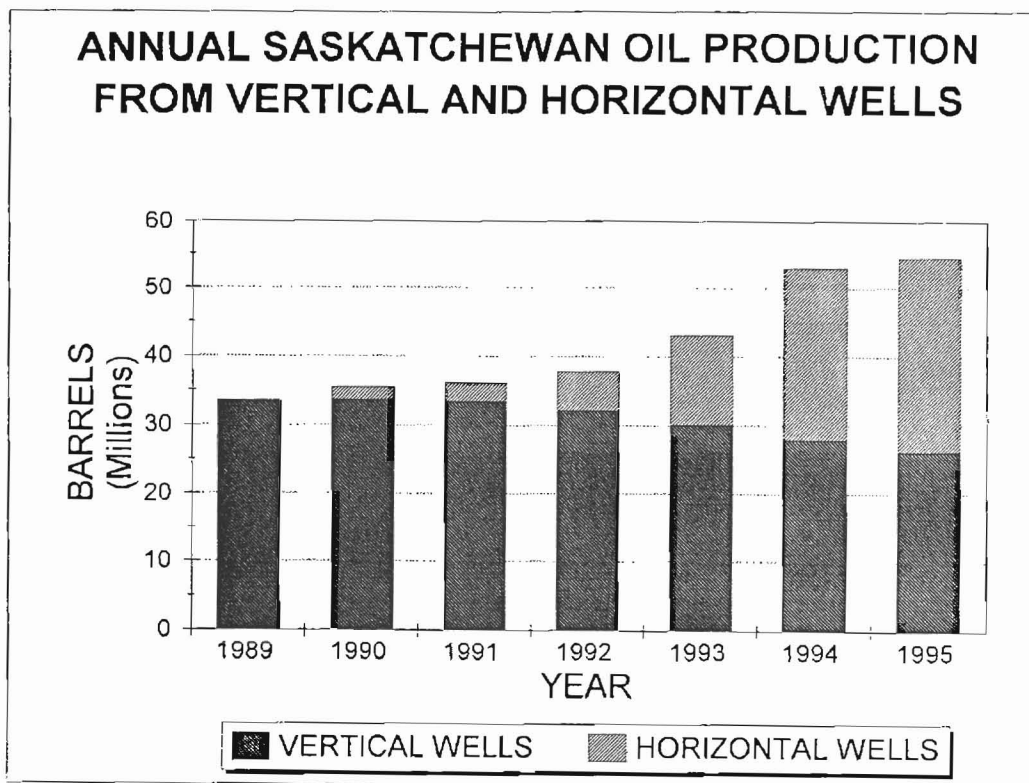


Figure 12. Bar graph of the annual oil production in Saskatchewan Area IV converted from cubic meters to barrels since 1989. Production from vertical and horizontal wells is shown.

Red River B zone wells, most of Bowman County appears to be prospective. There will be many more wells drilled in the play for years to come.

Drilling in the horizontal Bakken play declined during 1994. Only nine wells were drilled and completed during the year for a 100% success rate. The average IP was 150 BOPD, but only two of the nine flowed oil with the other seven wells being completed on pump. These IP's and the change from flowing to pumping wells indicate a significant change in reservoir performance has occurred. This apparent decrease in reservoir performance is also evidence that the ultimate recoveries of these wells will be low compared to earlier Bakken completions. Together, these changes were an indication that the horizontal Bakken play was dying because the play was no longer economically viable.

Besides Eland and Cedar Hills fields, eight other new fields or pools were discovered during 1994 (Table 1). Four of the discoveries were in the Madison Group, the main producing horizon in the state, while the remaining four discoveries were in the Devonian Birdbear, Silurian Interlake, and Ordovician Red River formations. The Williston Basin is known for producing oil from multiple pay zones. In recent years, the deeper, pre-Madison potential had been sparsely drilled. Seven of the ten 1994 new-field or pool discoveries were either a re-entry or recompletion in an older wellbore that initially tested pre-Madison strata (Appendix I). The last discovery was 1994's third new field discovery, Great Northern Field, completed in the Madison by Texas Crude Energy, Inc. in Ward County.

Twenty-three wells, or 21% of all the wells drilled during the year, were drilled below the Bakken Formation during 1994. This is an increase of three more deep wells than were drilled during 1993, but 23 of 111 wells represents a 10% increase in the number of deep tests drilled. Fifteen of the 23 tested either the Red River Formation or deeper strata.

Amerada Hess Corporation drilled three Winnipeg/Deadwood tests along the Nesson Anticline during 1994. A single development well was drilled in each of Beaver Lodge and Antelope fields and both were completed as gas wells. Amerada's third test, a wildcat in 18-T154N-R95W, was a dry hole.

In a state where fewer than 4,000 wells have ever penetrated pre-Mississippian strata, the potential to discover many new fields and pools remains high. Amerada Hess Corporations continuing success in establishing Winnipeg and Deadwood Formation production on the Nesson Anticline over the last few years and the discovery of Red River production in Cedar Hills Field are two good examples of this potential. The ultimate primary recovery of Cedar Hills Field is still unknown but the field will probably rank among the five largest oil fields in North Dakota. It is interesting to note that both the Nesson Anticline and Bowman County have seen extensive drilling since the 1950's. If the deep

**Table 1**  
**1994 and 1995 New Pool and Field Discoveries**  
(Listed by County and Formation)

	1994	1995		1994	1995
<i>Adams County</i>			<i>McKenzie County</i>		
Total	1	0	Total	5	5
Red River	1	0	Madison	2	0
<i>Billings County</i>			Duperow	0	2
Total	1	1	Birdbear	2	2
Madison	1	0	Silurian	1	1
Birdbear	0	1	<i>Stark County</i>		
<i>Bowman County</i>			Total	1	3
Total	1	1	Lodgepole	1	3
Red River	1	1	<i>Ward County</i>		
<i>Divide County</i>			Total	1	0
Total	0	2	Madison	1	0
Bakken	0	1	<i>Williams County</i>		
Birdbear	0	1	Total	0	2
<i>Dunn County</i>			Madison	0	1
Total	0	2	Bakken	0	1
Stonewall	0	1			
Red River	0	1			

potential in these more heavily tested areas is still high then what might be the potential in the less well unexplored parts of North Dakota ?

Horizontal drilling was common during 1994. In north-central North Dakota, Tidal Resources (USA) Inc., Camwest Limited Partnership, Amerada Hess Corp., and Ballantyne Oil each drilled one or more horizontal Madison wells in existing fields testing the validity of drilling horizontal wells in mature Madison oil fields in North Dakota. Drilling horizontal wells in similar oil fields in Saskatchewan has greatly increased oil production in that province.

Tidal drilled seven wells in Haas Field for an average IP of 184 BO + 205 BWPD. After six months of production, these seven wells were producing an average of 61 BO + 107 BWPD. These rates might not appear to be very promising, but using averages to evaluate a program can be misleading. At the end of 1995, four of the wells have a historical oil-water ratio of 1:1 or greater while the other three wells were in the 1:2 to 1:10 range. Given enough time and continuing good oil-water ratios, the entire seven-well program might be an economic venture.

Camwest drilled two horizontal wells in Rival Field but the program was unsuccessful. At the end of 1995 the two wells had produced 34,269 BO + 327,708 BW with 77% of the oil coming from one well. Neither well is likely to produce enough oil to pay for the drilling and completion costs.

Another apparently unsuccessful venture was a well drilled in Newburg Field by Amerada Hess Corporation. The well produced 37 BO + 1909 BW in six days before being shut-in. At the end of 1995 the well was still listed as temporarily abandoned, but it is unlikely it will ever be produced.

Ballantyne Oil drilled the only clearly successful horizontal well in north-central North Dakota during 1994. Their Hedges #7H well in section 30-T162N-R81W was completed in Wayne Field pumping 280 BOPD with no water. The well produced 50,396 BO + 18,786 BW in the first year of production and still produces around 64 BOPD. Ballantyne's well provided the missing element, the first good well, to initiate an active horizontal Madison play in North Dakota. Ballantyne's success has provided a strong impetus for drilling horizontal Madison wells in existing fields, but the risk of a new program will be balanced against other marginal and unsuccessful programs.

Meridian Oil, Inc. (MOI) drilled two horizontal Madison development wells in western North Dakota in Grassy Butte and Harding fields. The Grassy Butte Field well pumped 374 BO + 363 MCF + 139 BWPD. The Harding Field well pumped only 40 BO + 40 MCF + 188 BWPD.

Overall, the results from the 1994 horizontal drilling programs were poor. MOI's horizontal Bakken completions were not equal to those of previous years while only one of their two horizontal Madison wells appears to be economic. Other companies fared even worse. The one unqualified success was completed in Madison Group Strata in Wayne Field by Ballantyne Oil. The Ballantyne completion has led to several additional wells. Most of the other horizontal wells completed in the state were marginal at best. The discovery of Cedar Hills Field, however, was another unqualified success.

Development drilling for Tyler or Madison pools occurred in Fryburg, Dickinson, and Medora fields. Five wells were drilled in the three fields and all produced oil from either the Fryburg zone of the Madison or from the Tyler Formation. Elsewhere, an extension to Rocky Ridge Field was drilled, but was dry.

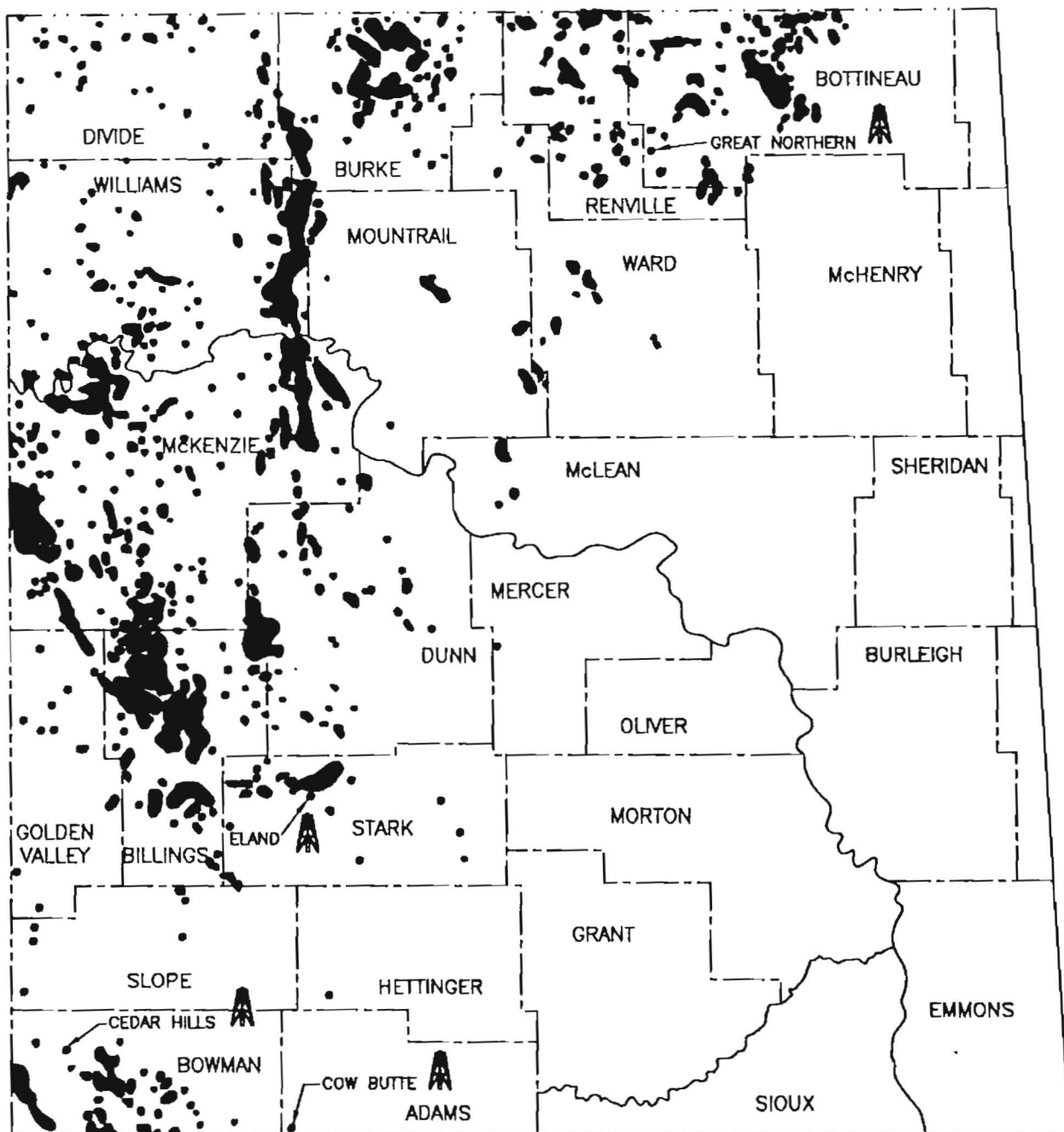


Figure 13. Map of western North Dakota with the locations of 1994 new field discoveries shown.



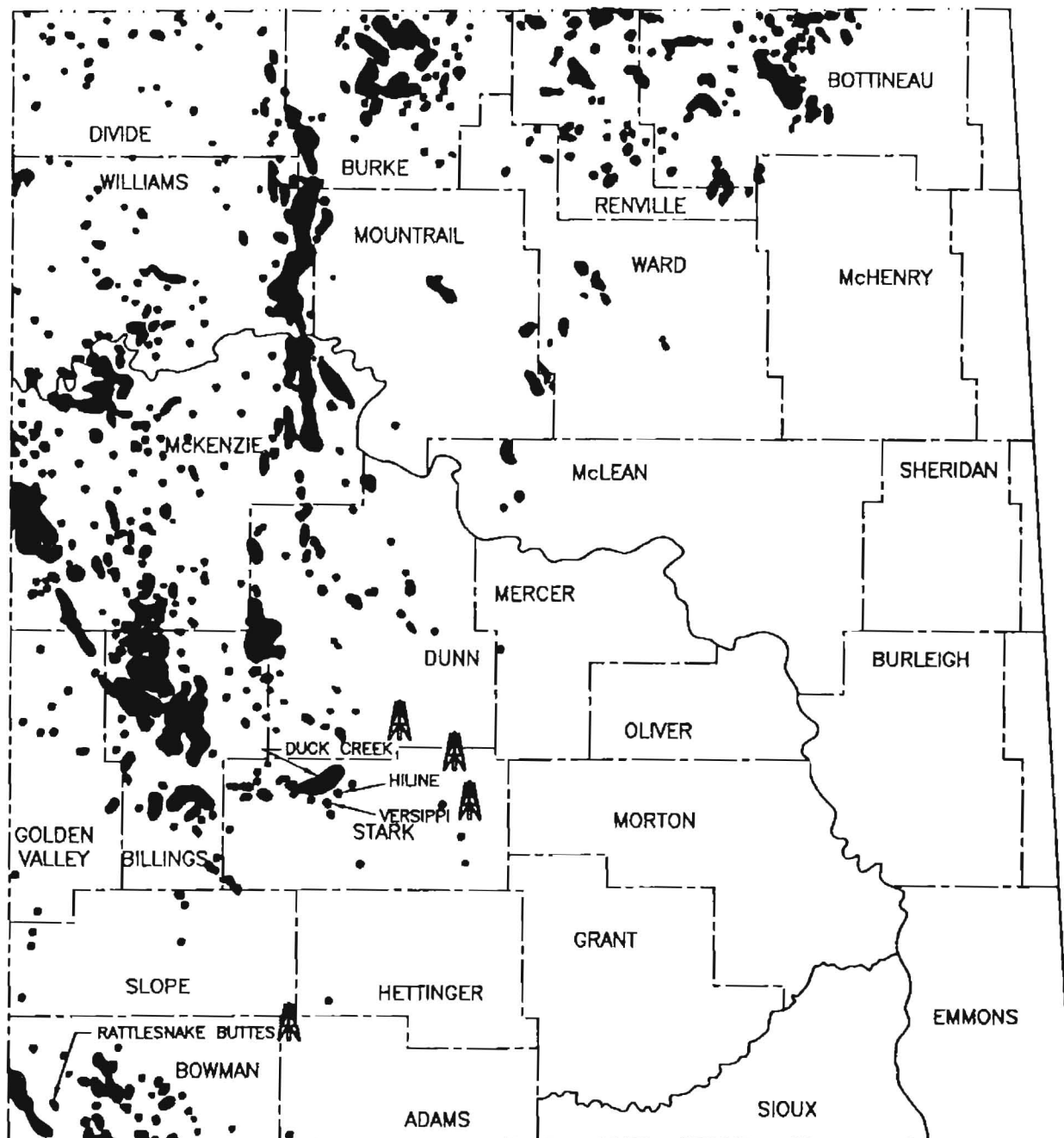


Figure 14. Map of western North Dakota with the location of 1995 new field discoveries shown.

Eagle Operating, Inc. completed three wells in West Greene Field. The first well pumped 210 BO + 95 MCF + 9 BWPD while a second well pumped 408 BO + 98 MCF + 7 BWPD. The third test was a dry hole. West Greene Field was discovered in 1981 and two field wells were completed during the mid-1980s. None of the three older wells has made more than 37,000 BO through 1995. Either of Eagle's new completions will produce more oil than the combined production from all three of the earlier wells. These new completions illustrate the fact that a fresh look at an older field can sometimes result in additional oil reserves.

Exxon Company, U. S. A. completed two infill wells in the Big Stick Madison Unit. The two wells had an average IP of 126 BO + 2 BW + 46 MCFPD and are part of a longer term program that has continued into 1996. Production from the Big Stick Madison Unit first responded to the waterflood in mid-1988 and the unit has been very successful, producing just under 3 million barrels more than would have been produced through primary production at the end of 1994. In December, 1993 Exxon completed their first well in an infill drilling program and the two completions in 1994 are part of this program.

Five units were formed during 1994. The most important of these was the Dickinson Lodgepole Unit which became effective on 7/1/94. The unit was formed to maximize the recovery of the reservoir by maintaining reservoir pressure above the bubble point with a waterflood. Other Madison units formed were the Baumann Drain, South Landa, and Little Knife North units. The fifth unit formed was the Rocky Ridge Southeast Heath unit. The formation of five units during 1994 matches 1966 and 1993, the only other years during which five units were formed. The high number of unitizations during 1994 is a good sign as more fields in North Dakota need to be unitized to maximize the recovery of oil in the state.

## 1995

### *Statistics*

A total of 133 wells were drilled during 1995 (Figure 3), an increase of 22 from 1994. Three fewer wildcat wells were drilled (Figure 4) with the remainder being development wells. Sixteen new fields or pools were discovered during 1995, an increase of six over 1994. As it had in 1994, McKenzie County led with five new-pool discoveries (Appendix 2 and Figure 14). Stark County saw three, and Divide, Dunn and Williams counties each had two discoveries. The remaining two pools were found in Billings and Bowman counties. Thirty-five percent of the wildcat wells drilled were completed producing oil, a significant jump over the 15% success rate of 1994. The success rate for development and extension wells was 77% and for all wells it was 71%, a 3% and a 10% increase over 1994 success rates, respectively. A total of 1,340,054 feet were drilled, an increase of 343,069 feet over 1994's total, but wildcat footage fell 9,860 feet despite the fact that three fewer wildcats were drilled. Oil production for 1995 rose 1,758,147 barrels over 1994 to an annual total of 29,333,518 barrels. This is the first year in which oil production increased since 1983. If production from the five Lodgepole fields in the Dickinson area was excluded, annual production would have fallen 870,260 barrels. Further, if the 1995 production from Cedar Hills Field was also excluded, annual oil production would have fallen another 750,859 barrels to a total of 1,621,119 barrels (6%). Instead 1995 recorded a 6% increase underscoring the importance of the Lodgepole and Red River plays.

## *Drilling Activity*

Much of the activity during 1995 was centered around the Lodgepole play near Dickinson and the horizontal Red River B zone play in Bowman County. The Lodgepole play continued to excite interest with high IP's from new completions. Thirty-three Lodgepole tests were drilled during 1995 and 22 were completed as oil producers. The average IP of the 22 wells was 1,013 BOPD + 498 MCFG + 27 BWPD. Using an average IP to describe the production capacity of Lodgepole wells is misleading because many of the wells were voluntarily completed at restricted rates. Production was restricted to maintain reservoir pressure until the field(s) could be unitized and secondary recovery operations begun. Some wells were completed at production rates far below their actual flow capacity. In Cedar Hills Field, 29 oil wells were completed with an average IP of 290 BO + 65 MCFG + 128 BWPD. The 29 wells were drilled in eleven different townships as operators tested different parts of Bowman County to determine what controls the play. The number of wells drilled in these two plays accounted for 47% of all the wells drilled in the state and they are the reason for the increase in the number of wells drilled. These 51 oil wells produced 3,379,266 BO during 1995 and this production is the reason annual oil production increased from 1994.

Leasing in the Lodgepole and horizontal Red River B zone plays generated significant revenue at state oil lease auctions during 1995. The annual total lease bonuses paid to the North Dakota Land Department since 1970 are shown in Figure 1. Lease sale revenues from 1994 were the lowest since 1973, but 1995 sale revenues increased 25-times over 1994 revenues recording the fifth highest annual lease bonus revenue since 1970. Only during the period between 1978 and 1981, the peak of the oil boom, was lease revenue greater than during 1995. Most of this lease revenue was generated because of the high level of interest in the Lodgepole play in the same fashion in which lease sale revenues had increased four-fold during 1989 at the height of the horizontal Bakken play. It is unknown how much money was paid to North Dakota land owners with private, or fee, mineral rights but certainly many of the fee minerals near the leased state lands were also leased and received higher-than-normal lease bonuses.

In one of the traditional North Dakota plays, Eagle Operating, Inc. completed two more wells in West Greene Field during 1995. One was dry, but the other was completed pumping 180 BO + 95 MCF + 35 BWPD. The latter well was the third new completion with an initial potential in excess of 150 BOPD that Eagle made during 1994 and 1995, significantly increasing the reserves of this field.

In Harding Field in western North Dakota, Intoil, Inc. recompleted the #2-32 Danielson in the Silurian pumping 387 BO + 7 BW + 234 MCFPD. The well was originally completed during 1994 in the Red River Formation pumping 500 BO + 37 BW + 500 MCFPD, but after 12 months of production, the well had declined to 47 BO + 130 BW + 59 MCFPD and the formation was temporarily abandoned. A second well was completed in Harding Field by Meridian Oil, Inc. This well, the Danielson #32-32, was perforated in the Madison and pumped 142 BO + 40 BW + 76 MCFPD.

The horizontal Bakken play that began during 1987 died during 1995. Only two new horizontal Bakken completions were made during 1995 with an average oil IP of 40 BOPD. Gradually decreasing initial potentials, probably caused by a drop in reservoir pressure (Price, 1996), record the depletion of the Bakken reservoir in the "Bakken Fairway". Without a change in current circumstances, such as a new way to stimulate Bakken Formation reservoirs or the discovery of a new area with rock and/or reservoir properties similar to the fairway, completions in the Bakken Formation will be made only for salvage.

Close to the Bakken Fairway, Amerada Hess Corp. drilled seven wells in Medora and Fryburg fields, including three horizontal wells, with disappointing results. The first test was a horizontal Madison completion in Medora Field which pumped 328 BO + 21 BW + 29 MCFPD. A later vertical Madison test in Medora Field was completed pumping 400 BO + 43 MCFPD in the Heath. Two other horizontal Madison tests in Medora Field were dry as were two vertical Heath and one horizontal Madison tests in Fryburg Field.

In other activity in the Tyler play, Duncan Oil, Inc. drilled a dry hole in Tracy Mountain Field, but tested Tyler oil from a Lodgepole wildcat. The #1-14 Julie, located in section 14, T139N-R96W, tested 68 BO + 28 MCFPD and is currently shut-in.

Exxon Company, U. S. A. completed four wells in the Big Stick Madison Unit, two of which had high initial potentials. IP's ranged from a high of 511 BOPD to a low of 50 BOPD, but the average IP was 235 BO 141+ BW + 93 MCFPD. One of the wells was drilled to replace a well with collapsed casing, but the other three appear to be part of an infill drilling program in the unit. The Big Stick Madison Unit is a very successful project as production from the unit has remained well above the production levels attainable through primary production alone. There is a high probability that other Billing Nose Madison fields could be unitized and equally successfully waterflooded.

Finally, four new units were formed during 1995 but one of them, Little Missouri Red River Unit was terminated on October 1, 1995 without ever injecting any fluids. Versippi Field was unitized and was the second Lodgepole field to be unitized. It is important to unitize Lodgepole fields because the highly fractured and/or vugular nature of the reservoir and the high flow rates that can be attained from it can rapidly deplete these reservoirs unless a pressure maintenance program is initiated to maximize oil recovery. The other two units formed during 1995 are the Fryburg South and Stoneview Stonewall units. 1995 was the third straight year during which four or more units were formed (Figure 10).

## SUMMARY

The most active play during the late 1980's and early 1990's was the horizontal Bakken Shale play. By the end of 1995, drilling in the horizontal Bakken had ceased and the play was over. The play had 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 both mechanically possible and an economically desirable technology. Even though the play is over, there will always be a few completions in the Bakken Formation, but in those wells the Bakken will be completed as bailout zones.

During 1993 the Lodgepole Waulsortian mound play began in the Dickinson area. The play drew national attention and the excitement and interest generated by this play has exceeded that of the Bakken play.

During 1994 the horizontal Red River B zone play in Bowman and Slope counties began with the discovery of Cedar Hills Field. This play has some common origins with the horizontal Bakken play as what are probably the first wells in this play were drilled in Montana at about the same time as the first horizontal Bakken tests were drilled. The two plays are also similar in that very few of the wells are dry holes and initial production rates have been good. Drilling in the Red River play has already surpassed that of the Lodgepole play and the Red River wells are producing two-thirds as much oil as the five known Lodgepole mounds near Dickinson at the end of 1995. Admittedly this comparison is slanted because many of the Lodgepole wells are voluntarily restricted until the fields can be unitized.

Production from these two plays has resulted in an increase in annual oil production for the first time since 1982. Another bright spot in the state is that the number of units formed is up significantly in the last three years. In general, unitization results in increased production from the unitized formation over both the short and the long term and it is also an inexpensive way to add new reserves. Hopefully this trend will continue into 1996 and beyond.

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### APPENDIX I. 1994 New Pool Discoveries

County File No. Order No.	Comp. Date Disc. Type	Operator Well Name & Location	Field - Pool (No. of Producing Wells in Pool on 12/31/95)	Total Measured Depth of Spacing	Perforated Intervals	IP (Cur. BOPD)	Gor- Grav	Water
Ward 13642 6850	4/5/94 Wildcat	Texas Crude Energy, Inc. Smetana "31" #1 Sec. 31, T160N, R83W	Great Northern Madison	4,800 80	4,656-4,666	128	204 29.4 <sup>0</sup>	3
McKenzie 12550 6919	7/1/94 Recompletion	Pantera Petroleum North Branch #22X-35 Sec. 35, T148N, R102W	North Branch Madison	11,500 160	11,000-11,010 11,022-11,038	122	673 35 <sup>0</sup>	7
McKenzie 8933 6896	7/5/94 Recompletion	Flying J Oil & Gas, Inc. Flying J State #13-26 Sec. 26, T150N, R97W	North Fork Silurian	13,760 320	12,526-12,552 12,578-12,588 12,628-12,634	80	3,125 49.1 <sup>0</sup>	355
McKenzie 13635 6922	8/26/94 Recompletion	Meridian Oil, Inc. Nelson Flat Top Butte #11-24 Sec. 24, T146N, R102W	Flat Top Butte Birdbear	13,000 320	10,709-10,712 10,676-10,678	303	993 42.6 <sup>0</sup>	25
McKenzie 9707 6936	9/3/94 Re-entry	Geolinear Co. Young Bear #32-4RE Sec. 4, T148N, R92W	Heart Butte Madison	9,870 80	9,106-9,134	145	690 40.7 <sup>0</sup>	140
McKenzie 13452 7028	9/28/94 Recompletion	Meridian Oil, Inc. MOI Cinnamon Creek #31-7 Sec. 7, T145N, R102W	Cinnamon Creek Birdbear	13,200 160	10,913-10,921	548	800 41.9 <sup>0</sup>	89
Adams 6050 6965	10/12/94 Re-entry	Castle Resources Inc. Boonedog #1 Sec. 30, T129N, R98W	Cow Butte Red River	9,226 160	9,055-9,062	40	250 37 <sup>0</sup>	100
Billings 12331 7002	10/13/94 Recompletion	Meridian Oil, Inc. MOI Roosevelt #44-27H R/E Sec. 27, T146N, R102W	Roosevelt Madison	10,875 160	9,023-9,029	43	0 35.4 <sup>0</sup>	204
Bowman 13695 7045	10/31/94 Wildcat	Meridian Oil Inc. Larkin #14-18H Sec. 18, T131N, R105W	Cedar Hills Red River B	12,104 320	Open Hole 9,104-12,104	250	320 32.1 <sup>0</sup>	24
Stark 13715 7032	12/2/94 Wildcat	Duncan Oil, Inc. Knopik #1-11 Sec. 11, T139N, R97W	Eland Lodgepole	10,150 320	9,714-9,724 9,730-9,740 9,746-9,760	2,707	573 45 <sup>0</sup>	0

## APPENDIX II. 1995 New Pool Discoveries

County File No. Order No.	Comp. Date Disc. Type	Operator Well Name & Location	Field - Pool (No. of Producing Wells in Pool on 12/31/95)	Total Measured Depth of Spacing	Perforated Intervals	IP (Cur. BOPD)	Gor- Grav	Water
Divide 13698 7000	1/16/95 Recompletion	R/JL Oil & Gas, Inc. R/JL Dudley Kimberly #14-18 Sec. 18, T163N, R95W	Kimberly	7,950	7,806-7,814	14	857	212
			Birdbear	160	7,822-7,830	0	34 <sup>0</sup>	
McKenzie 13600 7003	1/22/95 Recompletion	Meridian Oil, Inc. MOI Bicentennial #31-33 Sec. 33, T144N, R103W	Bicentennial	10,867	10,676-10,684	285	365	366
			Birdbear	160	10,701-10,715	82	41 <sup>0</sup>	
Divide 12017 7065	2/13/95 Recompletion	Hugoton Energy Corp. Bakken #1 Sec. 32, T161N, R95W	Dolphin	10,650	8,755-8,766	150	0	0
			Bakken	160		14	48.2 <sup>0</sup>	
Stark 13754 7092	3/25/95 New well	Conoco, Inc. Leo V. Kuntz 2 #1 Sec. 2, T139N, R97W	Duck Creek	10,214	9,756-9,766	2,110	519	147
			Lodgepole	320	9,772-9,782	216	45 <sup>0</sup>	
McKenzie 9909 7071	3/29/95 Recompletion	Meridian Oil, Inc. Burlington Northern #21-7 Sec. 7, T147N, R101W	Bowline	13,410	11,340-11,344	116	500	228
			Duperow	160		5	44.8 <sup>0</sup>	
Williams 7903 7046	4/1/95 Recompletion	W. H. Hunt Trust Estate Cunningham #1 Sec. 23, T157N, R100W	Marmon	13,400	9,080-9,154	27	741	37
			Madison	160	9,200-9,208	24	40 <sup>0</sup>	
McKenzie 9909 7070	4/21/95 Recompletion	Meridian Oil, Inc. Burlington Northern #21-7 Sec. 7, T147N, R101W	Bowline	13,410	11,222-11,225	32	1,875	30
			Birdbear	160		22	44.8 <sup>0</sup>	
McKenzie 6959 7066	5/17/95 Recompletion	Tipperary Oil & Gas Corp. Duncan Federal #30-24 Sec. 30, T145N, R99W	Scairt Woman	13,565	11,351-11,354	67	2,156	109
			Duperow	320	11,382-11,396 11,505-11,546	46	39.8 <sup>0</sup>	
Dunn 13276 7047	6/14/96 Re-open perms	Hunt Oil Co. S.E. Russian Creek #14-16 Sec. 16, T141N, R95W	Simon Butte	12,621	12,490-12,514	357	2,669	4
			Red River	320		130	47.4 <sup>0</sup>	
Dunn 13276 7047	6/14/96 Re-open perms	Hunt Oil Co. S.E. Russian Creek #14-16 Sec. 16, T141N, R95W	Simon Butte	12,621	12,204-12,216	*See note	*	*
			Stonewall	320		0	*	



**APPENDIX II. 1995 New Pool Discoveries  
(Continued)**

County File No. Order No.	Comp. Date Disc. Type	Operator Well Name & Location	Field - Pool (No. of Producing Wells in Pool on 12/31/95)	Total Measured Depth of Spacing	Perforated Intervals	IP (Cur. BOPD)	Gor- Grav	Water
Stark 13784 7105	6/17/95 Wildcat	Armstrong Operating, Inc. Haller #29-1 Sec. 29, T139N, R96W	Versippi Lodgepole	10,050	9,622-9,634	157	500	55
				160	9,640-9,660	0	43.3 <sup>0</sup>	
Stark 13786 7121	7/12/95 Wildcat	Armstrong Operating, Inc. Hondl #15-1 Sec. 29, T139N, R96W	Hiline Lodgepole	9,622	9,544-9,566	1,615	511	0
				320		609	45.7 <sup>0</sup>	
Bowman 13777 7107	7/30/95 Wildcat	Meridian Oil, Inc. Buchholz #42-8 Sec. 8, T130N, R105W	Rattlesnake Buttes Red River	9,186	9,064-9,076	229	44	45
				320	9,090-9,097	84	41 <sup>0+</sup>	
Williams 8256 7143	8/29/95 Recompletion	Galaxy Oil Co. SOC Minerals #1 Sec. 13, T154N, R100W	Avoca Bakken	11,700	10,921-10,938	2	TSTM	0
				160	10,946-10,958 10,984-10,997	7	36.7 <sup>0</sup>	
Billings 12873 7274	10/1/95 Recompletion	Equitable Resources Energy Co. Rausch Shapiro Fee #32-9 Sec. 32, T142N, R102W	Roosevelt Birdbear	10,777	10,693-10,696	55	909est	0
				160		44	45.3 <sup>0</sup>	
McKenzie 13708 7204	11/13/95 Recompletion	Intoil, Inc. Danielson #2-32 Sec. 32, T151N, R104W	Harding Silurian	12,810	11,558-11,568	387	605	7
				160		101	49 <sup>0</sup>	

\* This well is listed as being completed in the Stonewall but a fingerprint of the crude produced by this well on July 3, 1996, allocates all the produced oil to the Red River Formation. This may change in later tests but, at the time of this report, no data was available.