

# Oil Exploration and Development in the North Dakota Williston Basin: 2000-2001 Update

By Thomas J. Heck



MISCELLANEOUS SERIES NO. 90  
North Dakota Geological Survey  
John P. Bluemle, State Geologist  
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OIL EXPLORATION AND DEVELOPMENT IN THE NORTH DAKOTA WILLISTON BASIN: 2000-2001 Update  
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**Front and Back Cover Photos:**

The Mandan, North Dakota Refinery was purchased by Tesoro Petroleum Corporation on September 6, 2001. Tesoro owns and operates six refineries and markets motor fuels through branded retail outlets in Tesoro's core Western United States market, including Alaska and Hawaii, and via wholesale channels. It sells jet and marine fuels to the aviation and shipping industries. Tesoro has a refining capacity of nearly 560,000 barrels per day and more than 750 retail locations. Tesoro's other refineries are located in Anacortes, Washington; Kapolei, Hawaii; Kenai, Alaska; Martinez, California; and Salt Lake City, Utah.

The Mandan Refinery was dedicated on October 2, 1954 and can process up to 60,000 barrels per day. It has 210 employees and manufactures 15 different products with approximately 55% of it gasoline. The products are shipped by pipeline, truck and rail to customers in North Dakota, South Dakota, Minnesota, and Wisconsin.

Tesoro is committed to operating the Mandan Refinery in harmony with the natural environment. Nowhere is that goal more in evidence than in Mandan's award winning North 40 waste water treatment system. One-third of the refinery's 960 acre property is used by its process units as storage tanks. The remaining 640 acres are dedicated to waste water treatment and wildlife conservation. Nearly 200 bird species as well as many types of mammals find food, cover and breeding sites in this wildlife habitat.

The benefits of the North 40 are felt far beyond its borders. The North Dakota Game and Fish Service has transplanted to other sites more than 500 of over 1,000 Canada geese hatched at the North 40. Records show that geese banded at the refinery have been sighted as far away as Texas and Louisiana.

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## INTRODUCTION

This update summarizes oil exploration and development in North Dakota during the 1980s and 1990s, but focuses on the events of 2000 and 2001. The 1980s and 1990s saw many changes in North Dakota's oil industry. The 1980s began with domestic oil industry activity at record highs in response to the Arab oil embargo in 1974 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 the mid-1980s. Exploration, which had increased during the 1970s, began to decrease in response to lower prices during the early 1980s. Many had thought that prices had hit bottom in 1985, but overproduction by OPEC caused oil prices to fall even further in 1986. Between 1986 and 1998, oil prices fluctuated between \$12 and \$22 per barrel. North Dakota's oil industry had adjusted to the level of price uncertainty that that price range brought when, in early 1998, oil prices began to drop. When crude oil prices fell below \$10/barrel early in 1999, many wells were shut-in, and new drilling nearly stopped. Despite rising oil prices for the rest of 1999, reaching the highest price since 1991, the number of wells drilled during the year was the lowest since 1951, the year oil was discovered in North Dakota. Thus the 1990s ended with high oil prices but little drilling.

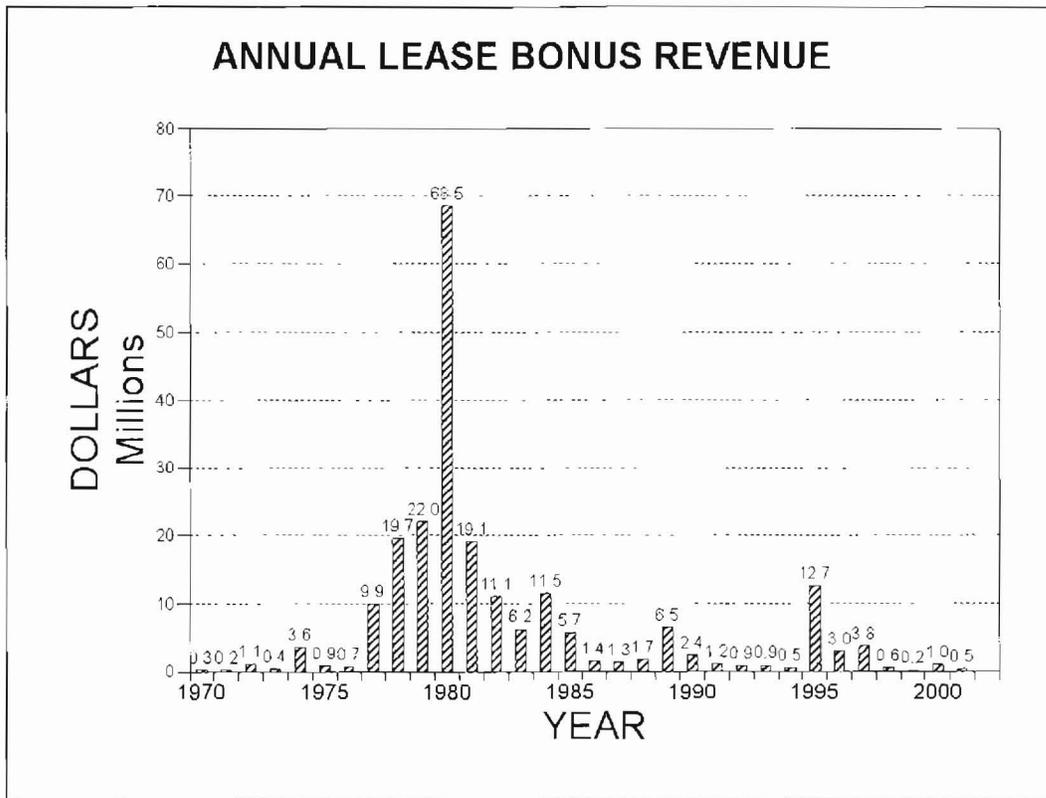
Data included in this report are primarily from the files of the North Dakota Industrial Commission-Oil and Gas Division. Additional data were provided by the State Tax Department, the State Land Department, Amoco Oil, and Tesoro Refining & Marketing. Help from these sources is gratefully acknowledged. 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. For those readers unfamiliar with the oil-field abbreviations used in this report, Table 1 lists the most common ones.

**Table 1**  
**Land Terminology**

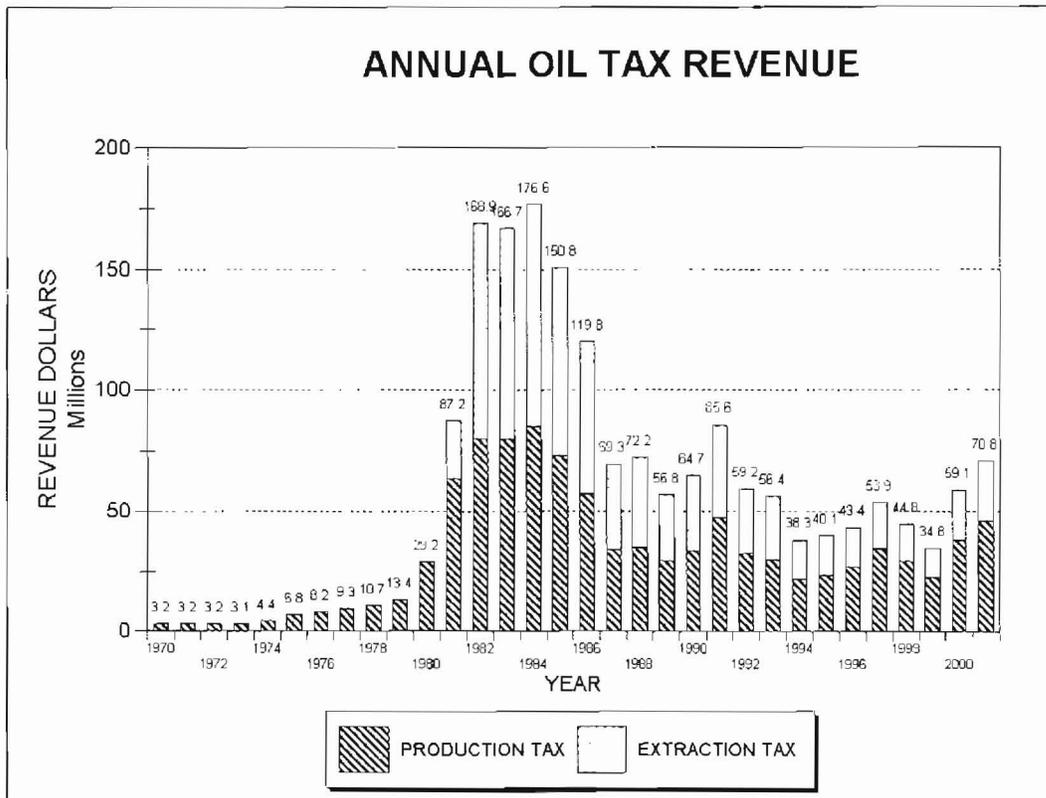
BO	Barrel(s) of oil. One barrel equals 42 U.S. gallons
BOPD	Barrels of oil per day. Daily production rate of an oil well
BW	Barrel(s) of water
BWPD	Barrels of water per day
EUR	Estimated ultimate recovery
GOR	Gas-Oil Ratio. Number of standard cubic feet of gas per BO
MCF	One thousand cubic feet of natural gas
MCFPD	Thousand(s) of cubic feet of gas per day
MMCFG	Million cubic feet of gas
Oil Pool	One or more oil wells producing from a single zone
Oil Field	One or more wells producing oil from one or more pools
Wildcat	A well drilled more than one mile from existing oil production
IP	Initial potential or daily rate a well is completed at
Incremental oil	New reserves added by secondary-recovery or infill drilling

## 1980-1989

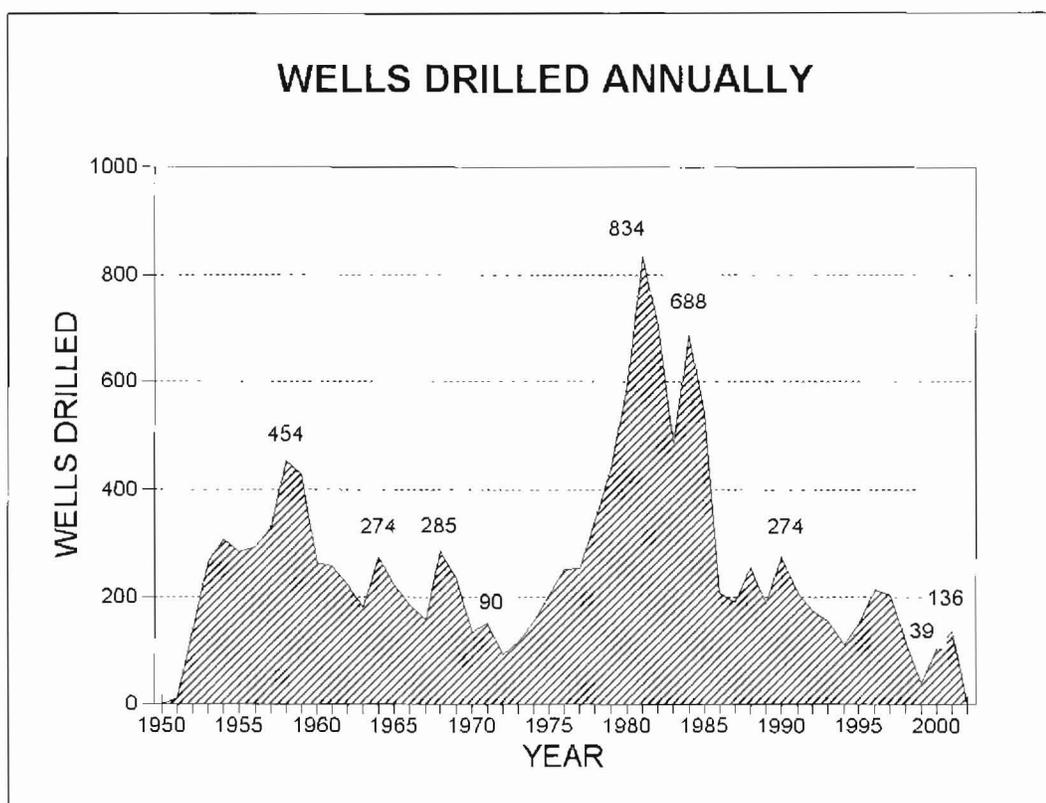
The oil-industry entered the 1980s with activity at record levels, both nationally and in North Dakota. Oil prices were high, averaging \$28 per barrel in North Dakota (Fischer and Bluemle, 1988), and operators aggressively pursued new plays and prospects. State lease sales brought record revenues (Figure 1) and tax revenues from the production tax in 1980 more than doubled from 1979 (Figure 2).



**Figure 1.** Bar diagram of annual state Land Department lease sale revenue for the period 1970 to 2001. (Source: N. D. State Land Dept.).



**Figure 2.** Bar diagram of annual production and extraction tax revenue from crude oil production for the period 1970 to 2001. The extraction tax took effect January 1, 1981. (Source: N. D. State Tax commission).



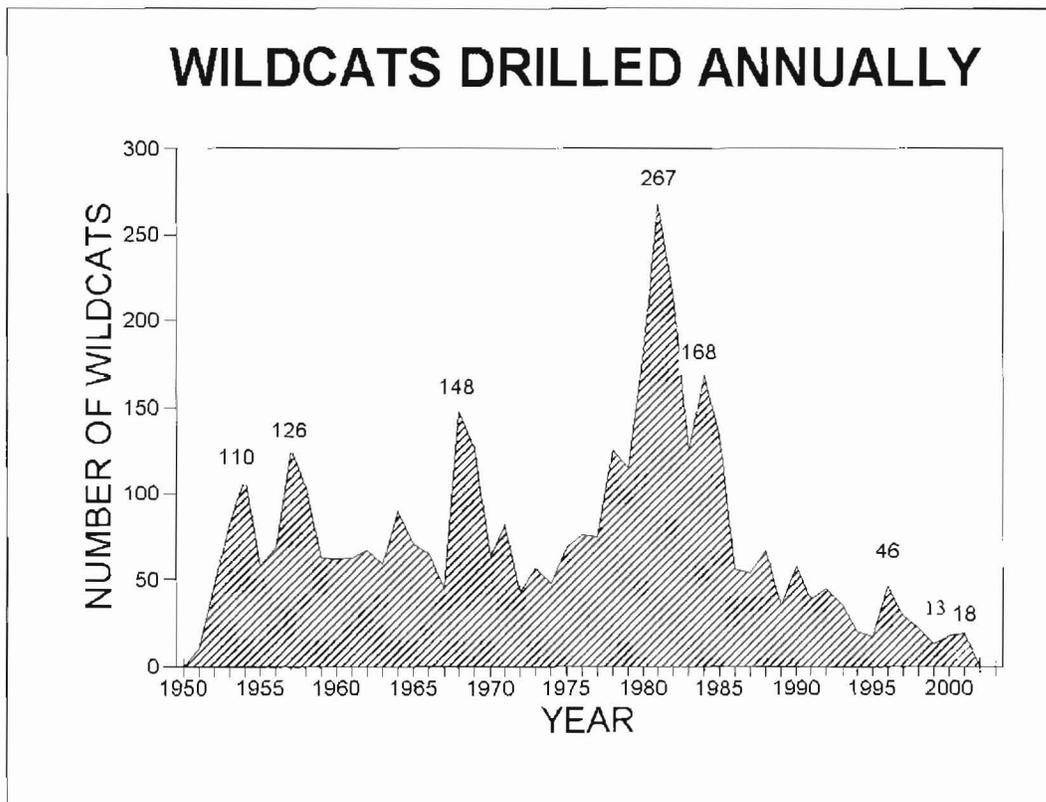
**Figure 3.** Line graph of the number of oil and gas wells drilled annually in North Dakota since 1951. (Source: N. D. Geological Survey and N. D. Oil & Gas Division).

Of the nearly 600 wells drilled in North Dakota during 1980 (Figure 3), 182 (31%) were wildcats (Figure 4). Eighty four new pools were discovered (Figure 5) and annual production rose to 40,354,030 BO, a second consecutive record (Figure 6).

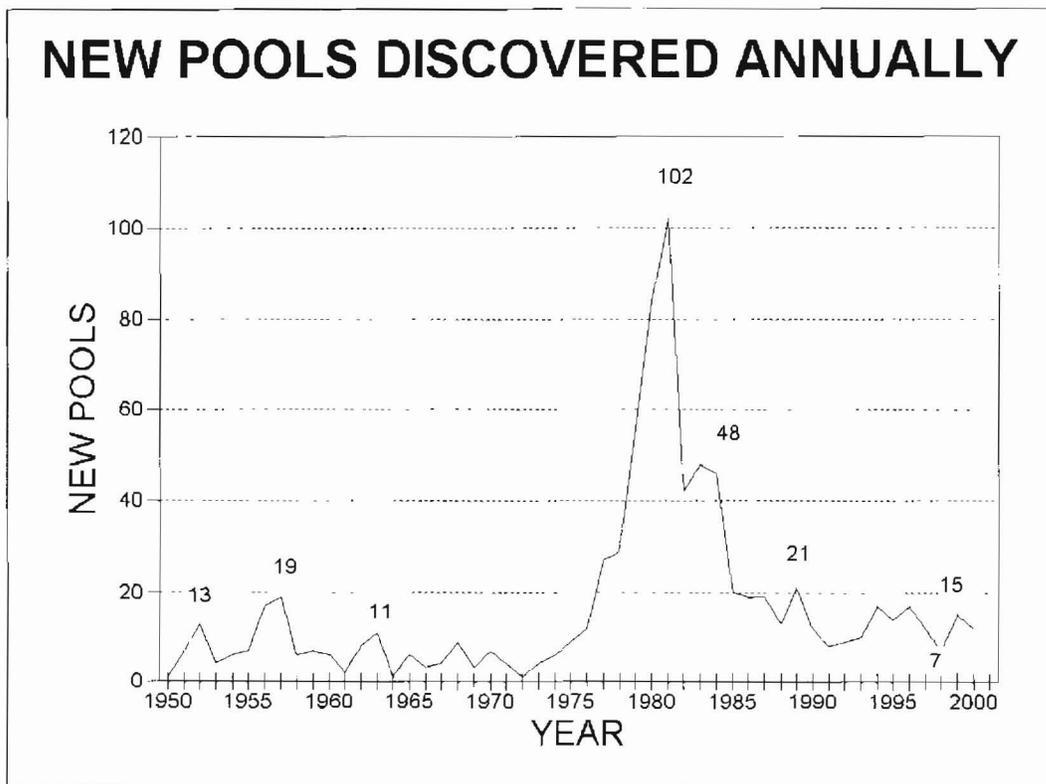
The records set during 1980 fell in 1981 as the “oil boom” peaked in North Dakota. New records included 834 total wells drilled, 267 wildcats drilled, and 102 new pools discovered. The 1980 annual production record was also surpassed by the 45,706,999 BO produced during 1981, setting a third straight annual production record. State petroleum tax 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 collections in 1981, the first year the extraction tax was in place (Figure 7).

The oil industry could not maintain as high a level of activity after oil prices began to slip during 1982 and drilling decreased. However, oil production and tax revenues continued to climb despite reduced drilling because the drilling emphasis shifted toward developing existing fields and away from exploration. Another reason for the continued increase in oil production is that there typically is a one-to three-year lag between the discovery and peak production from an oil field. In general, the larger the field the longer the lag because more wells are required to develop the field. Many fields discovered during 1980 and 1981 did not reach peak production until 1982 to 1984.

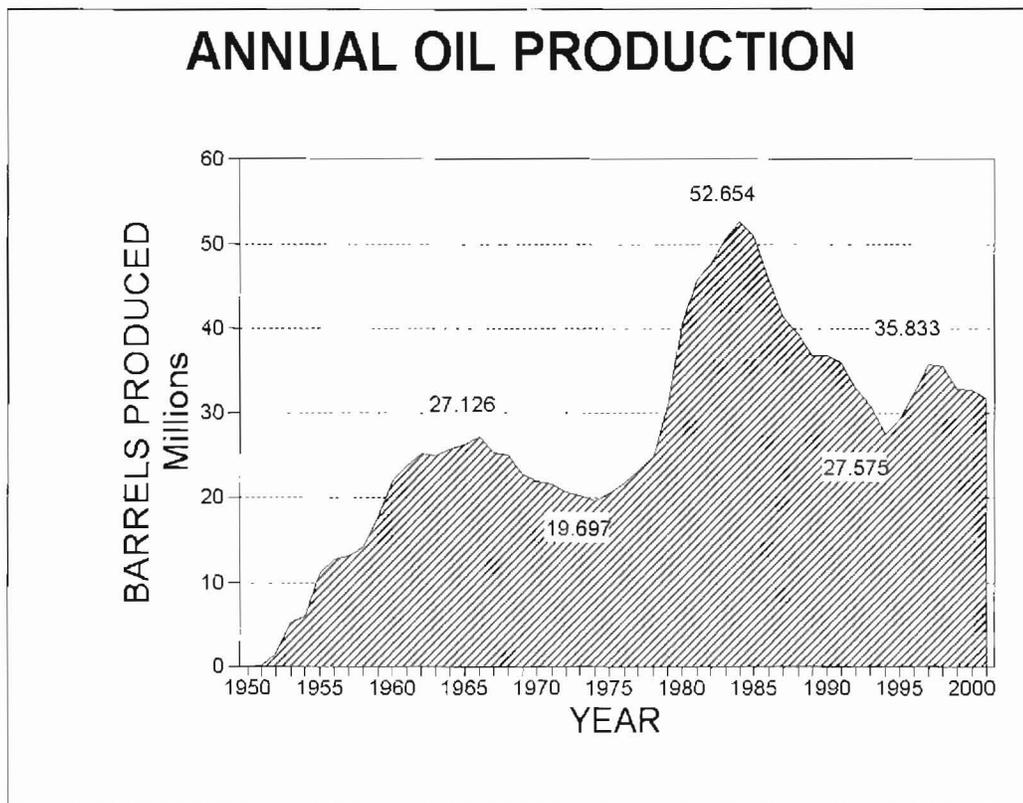
Oil prices declined further during 1983 and drilling decreased in response. Wildcat drilling (Figure 4) was one-third of 1981 levels, reflecting the lower oil prices, but development drilling remained high as fields continued to be developed. Oil production continued to rise, as did tax revenues (Figures 2 & 6). Both wildcat and development drilling rose slightly during 1984 (Figures 3 & 4) and oil production in North Dakota reached its all-time high of 52,654,336 barrels (Figure 6). Despite record oil production,



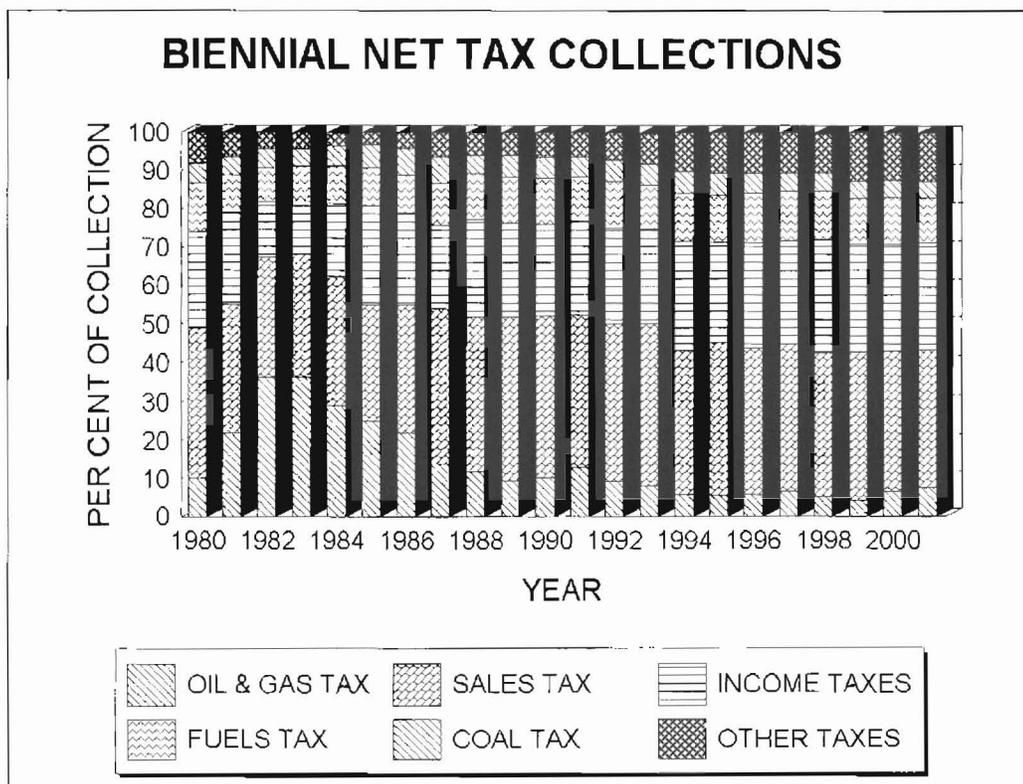
**Figure 4.** Line graph of the number of wildcat wells drilled annually in North Dakota since 1951. (Source: N. D. Geological Survey and N. D. Oil & Gas Division).



**Figure 5.** Line graph of the number of new oil and/or natural gas pools discovered annually since 1951. (Source: N. D. Geological Survey and N. D. Oil & Gas Division).



**Figure 6.** Line graph of annual oil production in North Dakota since 1951. Production is in millions of U. S. barrels. (Source: N. D. Geological Survey and N. D. Oil & Gas Division).



**Figure 7.** Bar diagram of the net tax collections in North Dakota since 1980. Source of tax collections are shown as a percentage of total collection. (Source: N. D. State Tax Commission).

tax revenues declined for the first time since 1973 because of lower oil prices (Figure 2). Drilling resumed its decline during 1985 as oil prices slid further and began to fluctuate. Overproduction by OPEC caused a rapid price drop in early 1986, with prices falling below \$10 a barrel for some crude oils. Drilling plummeted and the oil industry 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 oilfield service companies. Many 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 of the year was so low that only 190 wells were drilled during the year (Figure 3). In 1988, drilling jumped sharply to 255 wells. Part of the increase was the result of development drilling in Wabek Field, an important new oil field discovered along the Mississippian Sherwood subinterval shoreline. Another important field, Plaza Field, was discovered near Wabek Field in 1989 and development of the field began. Plaza Field produces from the Bluell subinterval, which immediately overlies the Sherwood subinterval. Sperr, et al. (1993) estimate ultimate recoveries of six to eight million barrels from Wabek Field and 3.5 million barrels from Plaza Field. These two fields were the largest Madison fields discovered during the late 1980s.

From 1986 through 1991, between 188 and 274 wells were drilled annually. The 188 wells drilled in 1989 was the fewest wells drilled in a year since 1974 (Figure 3). Between 35 and 67 of the wells drilled annually were wildcat wells during this period with 35 of the 188 wells drilled in 1989 and 67 of the 190 wells drilled in 1987 being wildcats.

Horizontal drilling has become the drilling method of choice 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 commonplace 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 rose. Many state oil leases brought favorable per-acre bonuses at auctions during 1989 and 1990. In contrast, the U. S. Forest Service was unable to lease the Little Missouri National Grasslands (LMNG) at this time because of a court-imposed requirement for an environmental impact statement for the LMNG. As a result they lost both lease and production revenues that would have exceeded those of the State Land Department because the U. S. Forest Service had much more acreage in the Bakken play.

The 1980s ended with the North Dakota oil industry in the best shape it had been in for several years. Oil production and drilling were up, new plays were raising industry interest, and horizontal drilling technology was becoming important in North Dakota. In addition, oil prices were up slightly, increasing the positive effects at the end of the decade.

## **1990-1999**

### **Drilling**

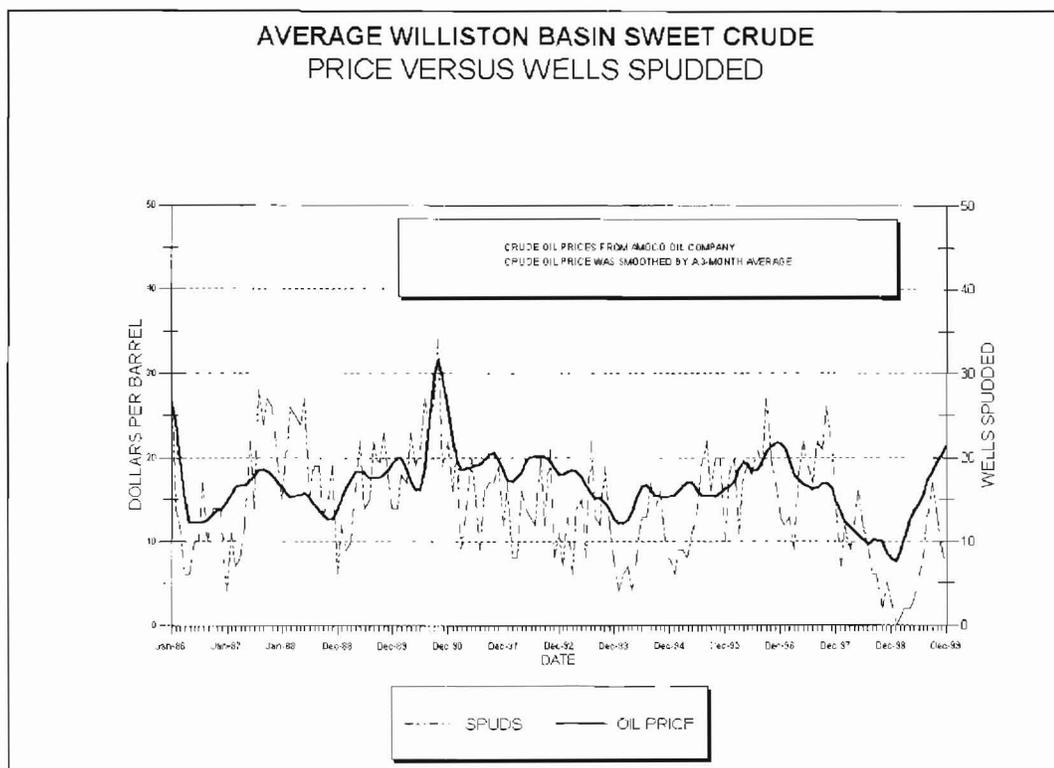
The 1990s began with many of the recently acquired leases in the horizontal Bakken Shale play being drilled as activity in the play peaked during 1990. The total number of wells drilled in the state rose significantly from 1989 to 1990, climbing 86 to a total 274 wells, the most wells drilled in any year 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, based solely on 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, many of these wells were economic failures because the volume of hydrocarbons recovered was not sufficient to pay for the drilling and completion costs.

The viable extent of the horizontal Bakken play was defined between 1990 and 1993 and two drawbacks to the play became apparent in this same period. First, many Bakken wells declined faster than expected, which meant that (second), reserves were lower than expected. As a result, drilling decreased as companies re-evaluated the play. By 1994, the horizontal Bakken play was nearly over with only nine horizontal Bakken wells completed. In 1995, only three horizontal Bakken wells were completed, marking the end of the play.

A major factor in the 1990 drilling increase was Iraq's invasion of Kuwait in August, 1990. World oil prices surged as uncertainties about the security of the Middle East oil supply rose. Oil prices in North Dakota also increased (Figure 8) and, responding quickly to the price increase, oil companies nearly doubled the number of wells spudded each month in North Dakota. The rapid deployment of allied military forces during the fourth quarter of 1990 caused oil prices to fall and the number of wells spudded in North Dakota fell with the oil prices. Oil price continued to fall into 1991, but remained \$1 to \$3 per 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 activity during the 1990s generally decreased. From 1990 through 1994, the number of wells drilled annually in the state decreased from 274 to 111. A small increase occurred during 1995 and then rose to 212 and 202 during 1996 and 1997, respectively (Figure 3). The number of wells drilled then fell to 121 in 1998 and 39 in 1999 with the big oil-price drop during this period (See Figure 8



**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 1, 1986. (Source: Oil prices are from Amoco Oil Company and Tesoro Refining & Marketing. The number of wells spudded is from the N. D. Oil & Gas Division).

for oil prices). The 39 wells drilled in 1999 were the fewest wells drilled during a year since 1951, the year oil was discovered in North Dakota, when 10 were drilled. The 200-plus wells drilled per year during 1996-1998 were the result of activity in two new plays and one new application.

The first new play began when Conoco, Inc. discovered Waulsortian bioherms or Waulsortian-like mounds in the basal Lodgepole Formation while drilling a deep test in Dickinson Field during 1993 (Burke and Diehl, 1993). This well was the first economic Lodgepole production in North Dakota and the flow-rates of the discovery well, and subsequent wells, drew national attention. The last Lodgepole development wells were drilled during 1998 and the Lodgepole has become a zone to examine more carefully when drilling through it. Unfortunately, the hunt for mounds outside the Dickinson area has been unsuccessful so far and the play appears to be fully developed.

The second new play is the horizontal Red River B play in Bowman and Slope counties and in adjacent parts of Montana. The first horizontally drilled Red River well in North Dakota was completed in 1994 by Meridian Oil, Inc. (now Burlington Resources Oil & Gas Co.). Meridian Oil, Inc. (MOI) began the horizontal Bakken play during 1987 and also began the Red River B play by drilling the first horizontal wells in the play in Montana near East Lookout Butte Field in 1988. The early horizontal Red River B wells in Montana were disappointing, but the discovery of Bog Creek Field during 1994, later renamed Cedar Hills Field, sparked a large land play and widespread drilling.

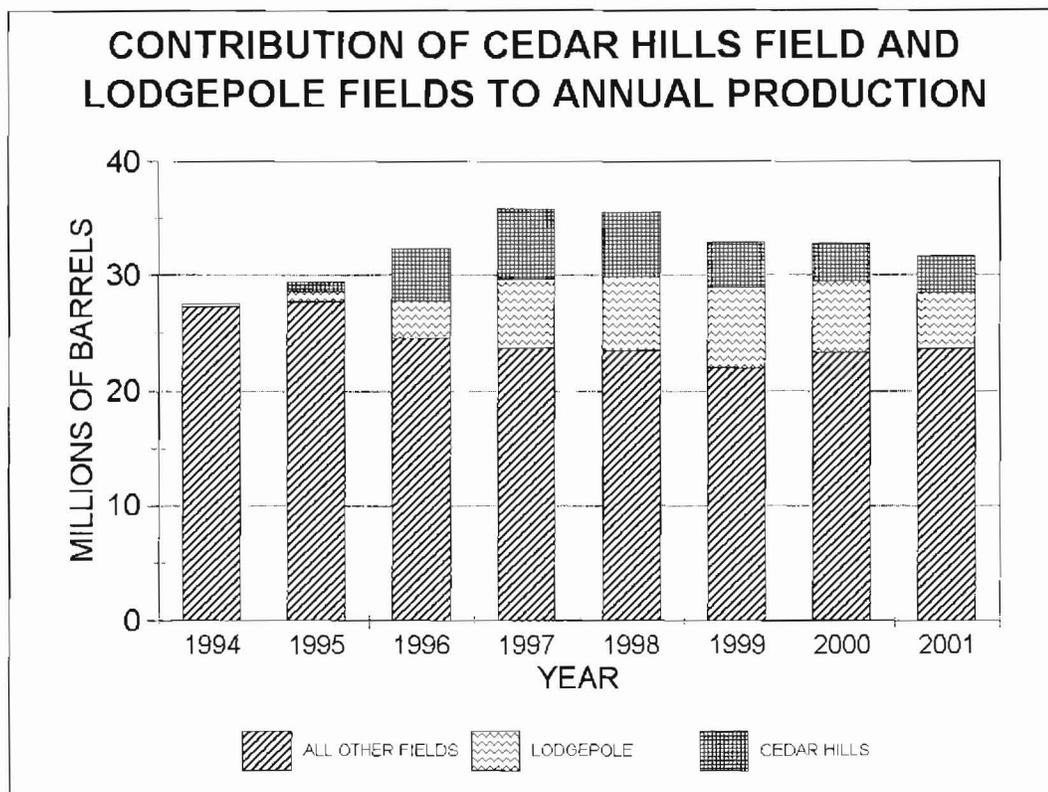
Although the horizontal Red River B play did not immediately capture national oil company attention as the discovery of the first Lodgepole mound did, it has proven to be economically attractive. By the end of 2001, 247 wells had been completed in Cedar Hills, Medicine Pole Hills, Cold Turkey Creek, and Horse Creek Red River B fields and the fields had produced 27,347,265 BO. Together, the two plays have produced more than 62,000,000 BO and averaged more than 30% of all the oil produced in the state during 1996-2001 (Figure 9). Ultimately, primary production from the Cedar Hills Field will probably exceed the total of primary and secondary production from all the presently known Lodgepole fields in Stark County. The "low-key" discovery will probably out-produce the exciting discovery but, whether it does or not, both plays have become very large oil producers in North Dakota.

The new application, horizontal drilling, occurs in two ways. Either a new, grass-roots, well is drilled or an existing well is re-entered, and one or more horizontal legs are drilled. Operators are drilling horizontally anywhere they think their geologic criteria for a successful Madison well are met. Horizontal drilling has been extremely successful in Saskatchewan and is becoming more important in North Dakota every year. Horizontal drilling has become the drilling method of choice in North Dakota.

In addition to total drilling, wildcat drilling also decreased during the 1990s. The number of wildcat wells drilled decreased from 58 wells during 1990 to 17 wells during 1995 (Figure 4), the fewest wildcat wells drilled in North Dakota since 1951 when oil was discovered in the state. Wildcat drilling jumped to 46 in 1996 as the hunt for Lodgepole mounds peaked, but then dropped to 28 in 1997, when the play was not extended outside of the Dickinson area, and then decreased to 13 in both 1998 and 1999. Most of the reason behind the 1998-1999 low was that few operators were willing to explore during a period when oil prices were extremely low (Figure 8).

## **Oil Production**

Annual oil production in North Dakota declined between five and 10 percent per year from 1985 through 1989. From 1989 to 1990, annual production remained virtually flat, declining only 21,057 barrels (.0005%) over the year (Figure 6). The fact that annual production did not decline between 1989 and 1990 was due to production from two new Madison fields and many wells completed in the horizontal Bakken play. Approximately 2.2 million BO were produced from Wabek and Plaza fields along the Sherwood and Bluell shorelines in Ward and Mountrail counties and another 2.7 million BO were produced from horizontal Bakken wells in western North Dakota. The 4.9 million BO that they

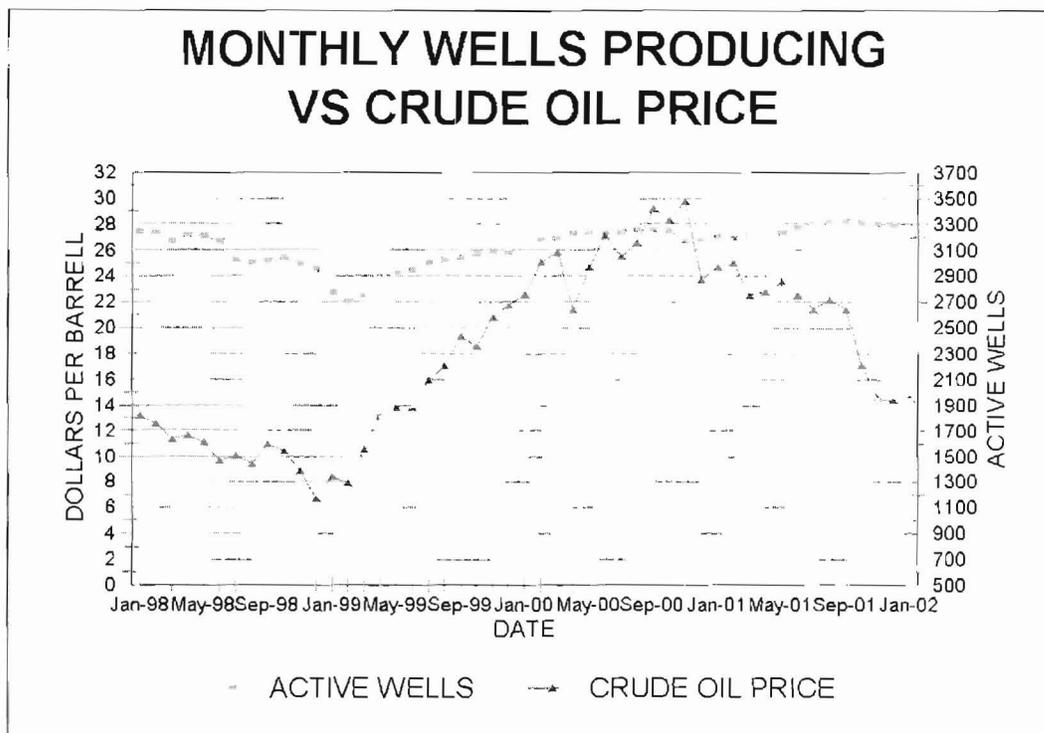


**Figure 9.** Bar diagram of the annual oil production since 1994 from Cedar Hills Field, all known Lodgepole mound fields, and all other producing oil wells in North Dakota. (Source: N. D. Oil & Gas Division).

produced offset the production decline of the other 3,500 wells in the state.

Production declined a modest 2% to 35,895,278 BO in 1991 as new production was no longer able to stave off decline. During 1992, 1993, and 1994 production fell eight, six, and 11%, respectively (Figure 6). During 1995, oil from two new plays, the horizontal Red River and the Lodgepole mound plays, came on-line and annual production rose 1,758,147 BO, more than 6% above 1994 annual production. Annual production rose again during 1996 and 1997 to 35,832,705 BO. Part of the increase can be attributed to the number of wells completed in Cedar Hills Field, but as much oil came from the discovery and subsequent unitization of the Lodgepole mound fields around Dickinson (Figure 9). During 1998, annual production was 35,562,201 BO, less than a 1% decrease from 1997. A much greater decrease occurred during 1999 when a 7.5% decrease was recorded and annual production fell to 32,882,297 BO. Production declined only 167,775 barrels during 2000, less than one-half of one percent. The annual decline rate increased to more than 3%, the average annual decline rate since 1998, during 2001 with the year's total falling to 31,691,652 barrels. A 3% annual decline rate is probably a good estimate of the most annual production would decline over the next 2-3 years because I expect production to increase from the Cedar Hills North and South units as injection continues in the units. How big the production increase will be is uncertain.

Part of the 1999 decrease was due to low oil prices. Some wells were shut-in when operating costs exceeded earnings at the low prices (Figure 10). Once prices began to rise again, shut-in wells were put back on production. Amoco's average 1998 posted price for 40-gravity sweet crude was \$10.47/barrel, but during the first three months of 1999, it fell below \$9/barrel. Some of North Dakota's crude oils received less than the average price because they are lower gravity crudes and/or are sour (contain sulfur). The net effect is that, for an operator to break even on a lower gravity or sour crude



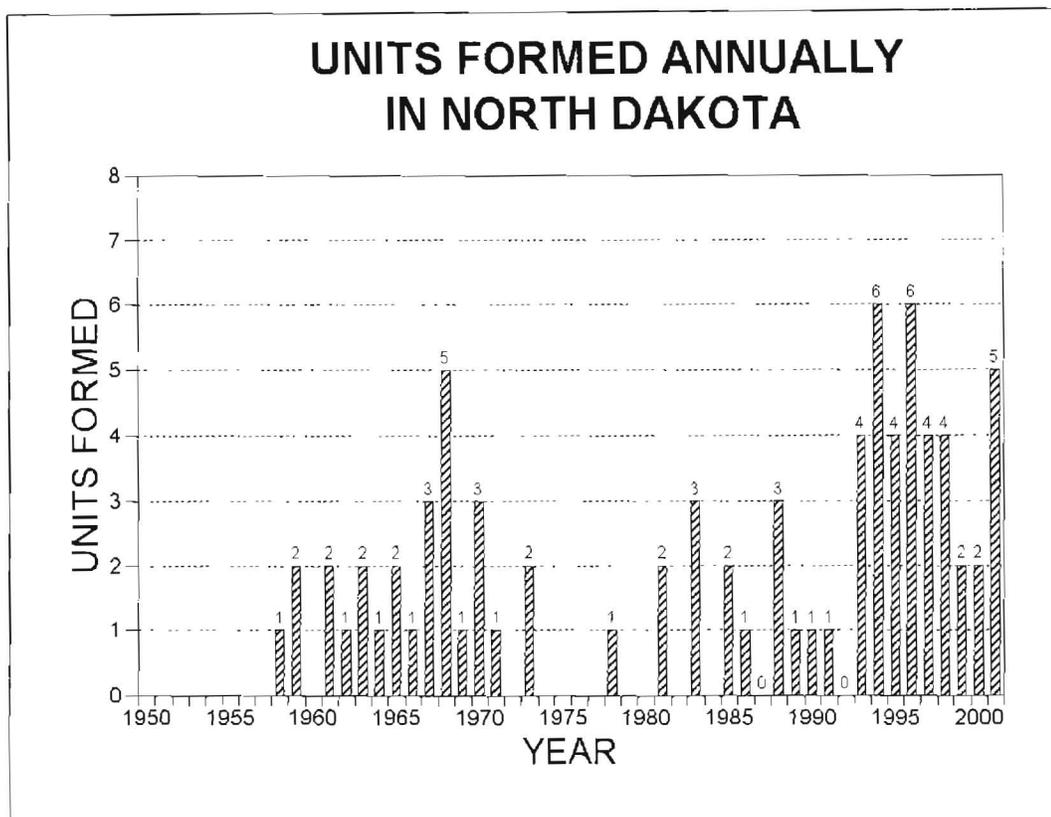
**Figure 10.** Line graph of monthly average price for Williston Basin 40-gravity "sweet" crude oil and the number of producing oil wells monthly since 1998. (Source: Oil prices are from Amoco Oil Company and Tesoro Refining & Marketing. The number of producing oil wells is from the N. D. Oil & Gas Division).

well, the well must produce more oil. As operators could not increase the volume of oil a well produced, wells were shut-in once they no longer produced enough oil to pay operating costs.

Declining annual oil production could be halted or reversed in several ways. One way would be to discover and development of a large oil field. Another way would be to discover one or more new oil plays containing new fields while a third method is to unitize sufficient existing oil fields that, with the successful implementation of secondary-recovery operations, could increase production from the unitized field(s). A last possibility is that some combination of the three methods occurs. Whatever the combination, there must be either a number of new, high IP and high EUR completions; many average new completions; or a large number of marginal completions to increase annual production. However, the capital requirements to drill and complete the required number of wells increases with each option making each more dependant upon higher oil prices.

The 1991 North Dakota legislature encouraged the unitization of oil fields by enacting legislation that lowered the percentage of mineral and working-interest owners required to form a unit. An increase in unitizations began in North Dakota during 1992 just when many oil fields were approaching the end of their primary productive life-spans. Legislation like this encourages companies to invest the capital necessary to unitize an oil field.

Unitizing more oil fields is an important tool in minimizing declining oil production in North Dakota. A successful secondary-recovery project will produce the remaining primary reserves in an oil field at a higher rate than an equivalent non-unitized field, and then go on to produce additional barrels of secondary reserves that otherwise could not be produced. Units can be a cost-effective way of increasing production in existing oil fields. Two units were formed during 2000 and five during 2001 (Figure 11). The most important of these units are the Cedar Hills North and South units and the Medicine Pole Hills

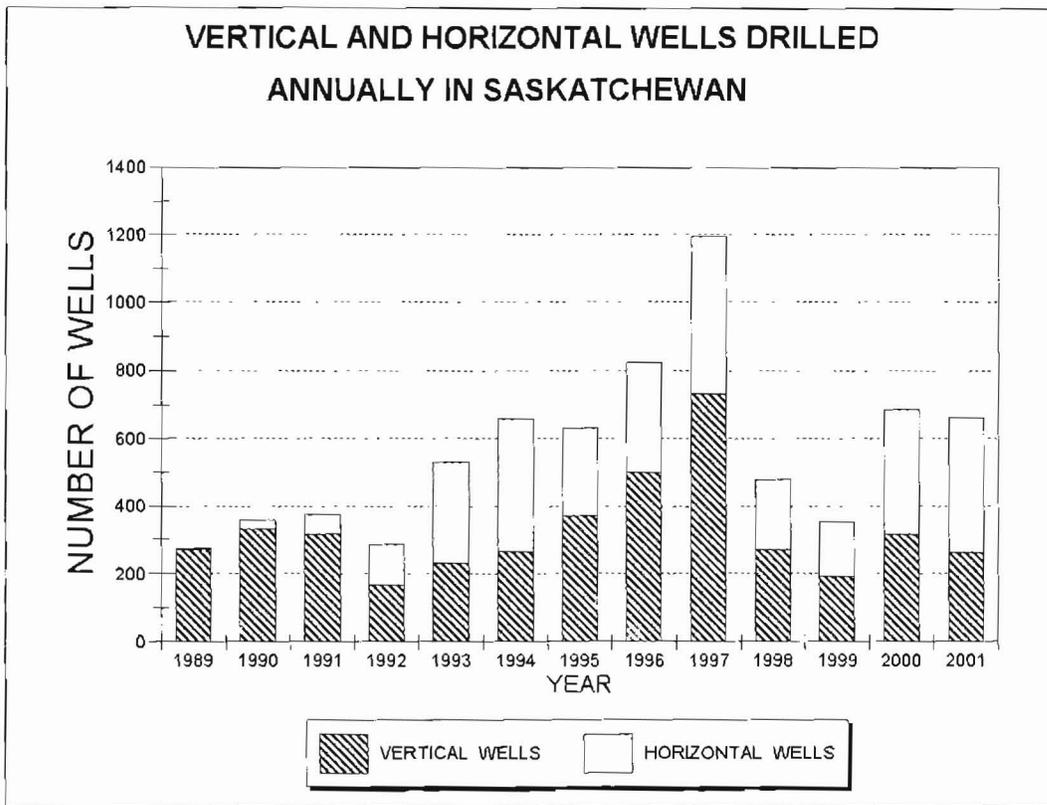


**Figure 11.** Bar diagram of the annual number of unitized oil fields since 1950. Units were included in the year in which operations began. (Source: N. D. Oil & Gas Division).

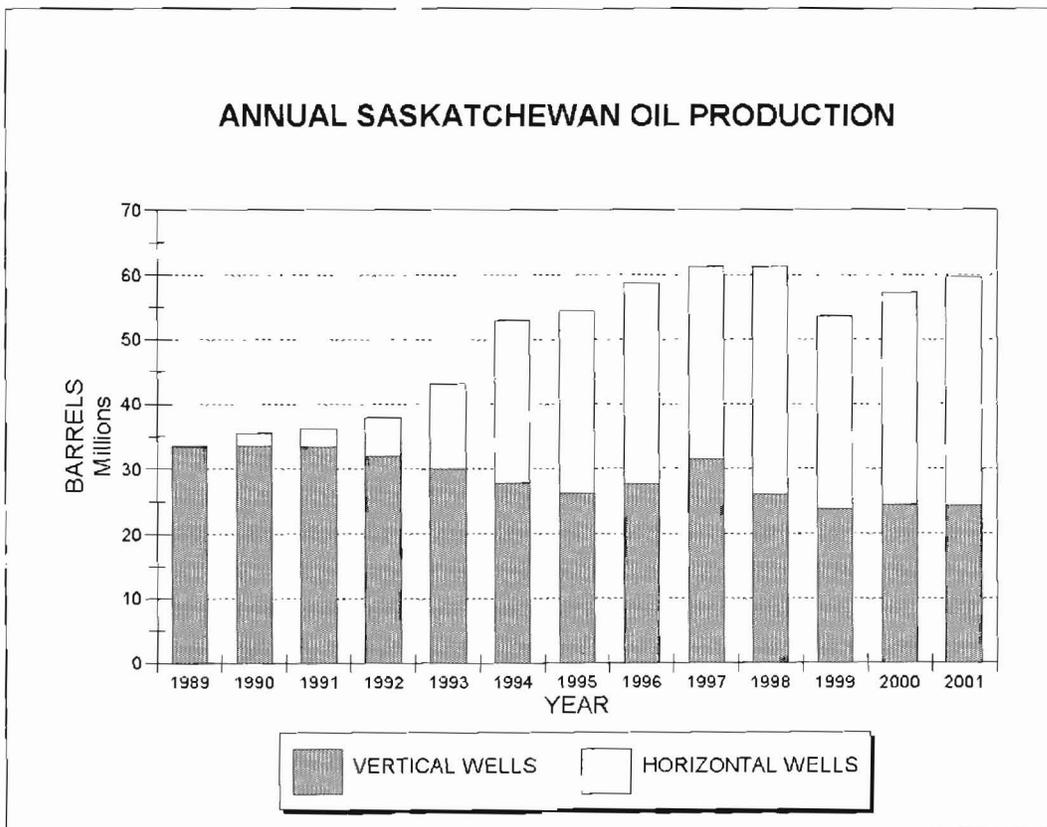
West unit. These units encompass most of area in Bowman County where the Red River B is productive. The creation of these units is important because of the increased oil production that will ultimately result to the benefit of all the various interest owners.

Another way to slow or possibly reverse declining annual production in North Dakota might be to drill horizontal wells in existing Madison Group fields. Horizontal drilling in Saskatchewan has significantly increased oil production in the province. From 1987 through 2001, 2,811 horizontal wells were drilled in the Saskatchewan Williston Basin (Figure 12). These wells contributed 63% of the year's oil production in Saskatchewan during 2001 (Figure 13). Horizontal wells produced so much oil that the province's oil production increased for several years before beginning to decline again. It has been thought by many that a similar horizontal drilling program in North Dakota has the potential to dramatically increase the state's oil production, just as it did in Saskatchewan. It now appears that this may be beginning to take place.

A number of horizontal Madison wells have been re-entered and drilled-out horizontally, both on the Nesson Anticline and elsewhere. In a recent study, decline curves from eight new or re-entered horizontal wells in Tioga Field were compared to decline curves from vertical wells close to the horizontal well bores. The study concluded that minimal interference occurs between the horizontal and vertical wells and that most of the produced oil was incremental reserves (Helms & Hicks, 1999); the reserves of the eight horizontal wells were estimated to be 1,006,000 BO. The study also reported that other horizontal wells in TR Madison, Wayne Madison, Cedar Creek Ordovician, and Haas Madison pools had also added incremental oil reserves. The report concluded that the 72 horizontal wells studied had added a total of 10,385,000 barrels of incremental oil in North Dakota. More horizontal wells are being drilled in older oil fields adding new reserves and increasing oil and natural gas production in the state.



**Figure 12.** Bar diagram of the number of horizontal and vertical wells drilled annually in the Saskatchewan Williston Basin since 1989. (Source: Saskatchewan Energy and Mines).



**Figure 13.** Bar diagram of annual oil production from vertical and horizontal wells in the Saskatchewan Williston Basin. Production has been converted from cubic meters to U. S. barrels (Source: Saskatchewan Energy and Mines).

At the end of 1999, thanks to some earlier important discoveries, North Dakota's oil industry was producing more oil than it had since the early 1990s. Drilling was limited, but focused on exploration drilling and, to a lesser extent, on horizontal drilling in older fields. The North Dakota oil-industry was not in good financial shape after the low oil prices of 1998 and early 1999, but the higher oil prices of late 1999 were helping companies to recover.

## **2000-2001**

### **Drilling**

The first decade of the new millennium began with an increase in drilling with 103 wells drilled in 2000 and 138 wells in 2001. The main reason the number of wells drilled rose was due to rising oil prices. Following the lowest point in December, 1998 when the posted price for North Dakota sweet crude oil was less than \$7.00 per barrel at the Amoco refinery, posted prices rose until, in late 2000, they were just under \$30.00 per barrel. Crude oil prices that high had not been seen since the Gulf War in 1991. Drilling also increased, in response to the higher prices, although not as quickly as prices rose. Late in 2001, crude oil prices fell from over \$20 per barrel to around \$15 per barrel so that, at the very end of 2001, there was a drop in the number of wells spudded. Over all, the first two years of the decade began with better economic conditions and higher activity levels than the last two years of the 1990s.

### **Exploration Potential**

The North Dakota Williston Basin is under-explored and many opportunities remain for finding large new oil fields and new plays. 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 these counties remains to be discovered. LeFever and Heck (1995) estimated that more than 800 million barrels of oil equivalents remained undiscovered in the productive portion of North Dakota. They suggested that Ordovician strata, like the Red River Formation, would contain the bulk of these resources. Cedar Hills Field will produce around 40 million barrels during the primary phase of its productive life. This field was a very significant discovery in North Dakota, and it is one of the ten largest oil fields ever found in North Dakota. In addition, it is one of the largest onshore oil fields discovered in the U.S. during the past five years. Bowman County, where the field was discovered, is an area where oil has been produced for more than 30 years. This discovery is proof that new concepts and technologies can lead to surprising results in mature areas. Similar opportunities likely exist elsewhere in North Dakota.

Throughout much of the Rocky Mountain region there is great interest in shallow gas from conventional reservoirs or from coal bed methane. The region is thought to contain large volumes of natural gas that will need to be produced as the nation's energy consumption continues to rise. Consequently, many companies are pursuing shallow gas ideas. The Williston Basin has, up to now, traditionally been thought of as an oil basin with only minor gas deposits. A number of proponents have said that significant volumes of gas remains to be discovered in the basin, particularly shallow gas, but it is only recently that any attempts have been made to prove the concept by drilling outside of the Cedar Creek Anticline area.

## **HISTORICAL SUMMARY**

From 1980-1985, records were set for oil prices, revenues, and numbers of wells drilled in North Dakota. In 1986, a major price drop caused drilling to plummet. Annual drilling remained in the 200-

plus wells range during the late 1980s but, with the exception of 1995 and 1996, drilling steadily decreased after 1990 (Figure 3). 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 1995 and 1996 when the Lodgepole play was active and Cedar Hills Field was being developed. If fewer than 175 wells are drilled, then no significant plays or fields are currently being developed.

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% to 10% per year were recorded between 1992 and 1994. Annual production during 1995 rose more than 6% above 1994 production as new wells in the Red River and Lodgepole plays were brought on-line. Annual production rose another 10% during 1996 and 11% more during 1997 as Cedar Hills Field was further developed and most of the Lodgepole fields were unitized and producing at optimal rates (Figure 6). 1998 production was virtually the same as in 1997, declining less than 1%, but annual production declined by 7.6% in 1999 as the earlier increases of the Lodgepole and Cedar Hills discoveries were overcome by normal decline. However, voluntary production restrictions in the Cedar Hills Field and the number of wells shut-in exaggerated the 1999 decline as did the low oil prices during early 1999. From 1999 to the end of 2001, annual production has declined only 3.6%.

## 2000

### Statistics

One hundred and three new wells were completed in North Dakota during 2000, a 264% increase from the thirty-nine completed during 1999 (Figure 3). Of the total, 18 wells (17.5%) were wildcat wells. Fifteen new pools were discovered, more than double the seven discovered during 1999. The new-pools discovered during 2000 are summarized in Appendix I. Those discoveries that were both new-field and new-pool discoveries are located on Figure 14. McKenzie County had the most new pools discovered with six new pools. Williams County was second with four new pools (Table 2). Two new pools were found in Billings and Dunn counties and Divide County had one new pool.

Thirty (29%) of the 103 wells completed during 2000 were grass-roots horizontal wells whereas during 1999, 36% of all wells were drilled horizontally. The decrease continues a trend away from horizontal drilling that started in 1999 when the percentage of wells drilled horizontally fell below 50%. A major reason for the decrease was the lull in drilling in Cedar Hills Field during the period between full development of the field and before drilling for secondary-recovery operations began. However, simply considering the number of new wells drilled understates the amount of drilling that occurred during 2000 because new horizontal legs were drilled in 26 existing wells. If these are added to the totals, then approximately 43% of the wells drilled during 2000 were horizontal wells.

The Madison pool remained the target of choice with 57 of the 103 wells (55%) completed in that pool. The number of grass-roots horizontal Madison wells drilled in North Dakota increased from 14 during 1999 to 30 during 2000 and to 41 during 2001. In addition to the grass-roots wells, 19 vertical wells were re-entered and drilled horizontally in 2000 and 41 more in 2001.

Eighteen wildcat wells were drilled during 2000, an increase of five (38%) over the thirteen wildcat wells drilled during 1999, 17.5% of all the grass-roots wells drilled during 2000. Two new-field discoveries were made by these wildcat wells for an 11% success rate, significantly lower than the 31% success rate of 1999. However, several wildcat wells either tested unusual zones or were drilled in relatively sparsely explored areas.

**Table 2**  
**2000 and 2001 New Pool and Field Discoveries**  
**(Listed by County and Formation)**

	2000	2001		2000	2001
Billings County			Golden Valley		
Total	3	1	Total	0	1
Birdbear	1	1	Stonewall	0	1
Madison	1	0			
Stonewall	1*	0	McKenzie County		
			Total	6	4
Bowman County			Bakken	0	1
Total	0	3	Birdbear	2	0
Ordovician	0	1*	Madison	1	1
Red River	0	1*	Duperow	1	1
Red River B	0	1	Silurian	0	1
			Stonewall	2	0
Burke County					
Total	0	1	Stark County		
Red River	0	1	Total	0	1
			Madison	0	1
Divide County					
Total	1	0	Williams County		
Madison	1	0	Total	5	1
			Bakken	1	0
Dunn County			Birdbear	2	0
Total	2	2	Ratcliffe	1*	1
Duperow	1	0	Winnipegosis	1	0
Madison	1	2			

\* Discoveries that the result of administrative changes in spacing, changed field boundaries, or are an earlier discovery. These are not included in Figure 5, annual new pool discoveries.

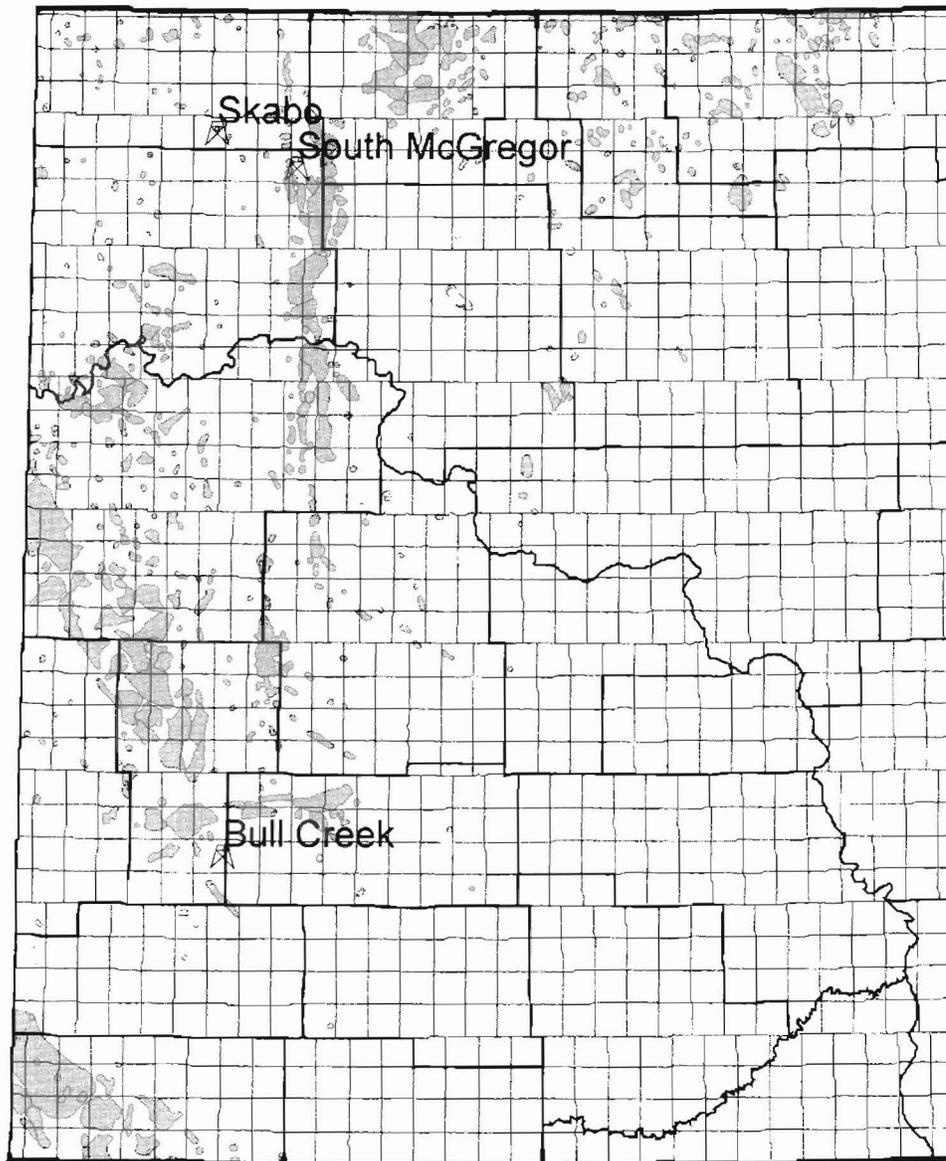
## Drilling

With one exception, wildcat wells drilled during 2000 were concentrated either in a tier along the Canadian border or in the Dunn-Stark-Billings-Golden Valley counties area. The single exception, a remote dry hole, was drilled in southeastern Ward County twenty miles from the nearest production in Torning Field.

Another wildcat of interest is the Eagle Operating, Inc. #27-10 Strong, which was drilled in section 27-T163N-R73W, 25 miles east of the closest production in North Dakota. The well was drilled to the Devonian Birdbear Formation, but no shows were encountered beneath the Mississippian unconformity. At this location, the only part of the Madison Group that remains is the Lodgepole Formation. The overlying Charles and Mission Canyon formations have been eroded off.

Wildcat drilling led to the discovery of three new fields during 2000. Skabo Field was discovered when Armstrong Operating, Inc. drilled their #14-1 Schilke in section 14-T160N-R98W. The well had an IP of 344 BO + 16 BW + 128 MCFPD on pump. The well is still producing, but at less than 50 BOPD. The well has produced slightly more than 41,000 BO, but no offset well has yet been permitted.

The second new-field discovery was Bull Creek Field discovered in Billings County by Belco Energy Corp. Their #2-24H Richard was a horizontally-drilled wildcat that tested the Sherwood beds of the Mississippian Fryburg. The well was IP'd for 43 BO + 2,055 BW + 16 MCFPD, but produced only 58,919 BO before being plugged and abandoned. Despite the relatively low cumulative production of



**Figure 14.** Map of western North Dakota with the location of all known producing wells and all 2000 new field discoveries.

the discovery well, a number of development wells have been drilled.

McGregor Field is the third new-field discovered during 2000. The discovery well was drilled by Prospect Oil & Gas, Inc. in section 20-T158N-R95W. The #1-20H tested the Mississippian Ratcliffe with disappointing results. The well was completed pumping 28 BO + 55 BWPD but, to date, has produced less than 5,000 BO. The well has not been offset.

For non-wildcat drilling in North Dakota, the focus shifted out of Bowman County during 1999 as the development phase of Cedar Hills Field ended, and into two general areas, the Nesson Anticline and west-central North Dakota (Billings-Golden Valley-McKenzie-Dunn counties). These two areas also saw the bulk of the new drilling during 2000.

The first area, the Nesson Anticline, saw fifteen new wells, ten of which were drilled horizontally. All fifteen wells were completed as oil wells. Drilling occurred in Beaver Lodge (7 wells), Charlson (2),

McGregor (3), Stoneview (2), and Tioga (1) fields. The target horizons were in five different zones. The Madison was the target of six wells, the Devonian-three, Winnipegosis-three, Silurian-one, and the Stonewall-two. In addition to the new wells, six other wells were re-entered and new horizontal legs were drilled, one in Beaver Lodge, three in Hawkeye, and two in Tioga fields. Five of the six were completed producing oil. The average IP of the fifteen new wells was 366 BO + 638 BW + 521 MCFPD while the six re-entered wells, including the one dry hole, had an average IP of 60 BO + 467 BW + 69 MCFPD.

The highest IP reported during 2000 was from one of the seven new wells drilled in Beaver Lodge Field by the Amerada Hess Corporation. Their #H-12AH BLMU, located in N/2 NW/4 section 1-T155N-R96W, tested at a rate of 2,380 BO + 2,243 BW + 2,196 MCFPD on Gas Lift. The oil rate recorded from this well is more than twice the next highest IP reported during 2000. Another Amerada Hess Corp. well drilled in Beaver Lodge Field also had a high IP. The #Q-22H BLMU was completed producing 632 BO + 1,760 BW + 1,382 MCFPD on Gas Lift and the well has produced more than 80,000 BO to date. The entire seven-well program has, to date, produced around 600,000 BO, a very successful program.

A successful three-well program on the Nesson Anticline was drilled by Berco Resources, LLC in McGregor Field. Two of the three had IPs above 400 BOPD. The average IP for all three was 380 BO + 101 BW + 106 MCFPD. Through mid-2002, the wells have produced more than 208,000 BO.

Two horizontal wells were drilled in Stoneview Field during 2000 by Berco Resources, LLC. The average IP was 314 BO + 207 BW + 874 MCFPD. The wells have produced nearly 170,000 BO and 500,000 MCF while producing under 22,000 BW. Together, the twelve wells mentioned here have produced close to 1,000,000 BO. Most of these wells were completed in the second-half of 2000, and it is expected that these wells will continue to produce oil for many more years.

In the second area where non-wildcat drilling was concentrated, west-central North Dakota, a number of high-IP and high cumulative production wells were completed. The second highest IP reported during 2000 was by Edward Mike Davis in his #34-36 Davis State test in Killdeer Field. The well was a northwest step-out to Killdeer Field that tested the Red River Formation. Although not productive in the Red River, it was completed up-hole in the Duperow Formation with an IP of 1,080 BO + 54 BWPD. The well produced almost 35,000 BO, but is now shut-in — a disappointing status for such a promising completion.

Three other tests were drilled in Killdeer Field, but only one was completed. The Ritchie Exploration, Inc. #1 Brown flowed 623 BO + 1,150 MCFPD from the Red River Formation. The well's production has since declined and it is now on pump. It has produced close to 80,000 BO and 200,000 MCF.

The third through fifth highest IP wells completed during 2000 were all drilled by BTA Oil Producers and were all completed in the Birdbear Formation. Two of the wells were in Beaver Creek Field while the third was in Bicentennial Field. The average cumulative production of these three wells, through mid-2002, was 369,967 BO + 194,153 BW + 198,635 MCF. The average IP of the three wells was 750 BO + 40 BW + 378 MCFPD. This level of productivity places these wells among the best in the state.

Beaver Creek and Bicentennial fields each had another Birdbear completion, but they were not as productive as the other three. The average IP of the two wells was 118 BO + 475 BW + 334 MCFPD. Combining the production data of these two wells with that from the first three, the average cumulative production of all five wells through mid-2002, was 258,915 BO + 221,550 BW + 132,984 MCF. This includes one well that was plugged after producing only 26,695 BO. In total, the five wells have produced more oil than any other five wells completed during 2000, nearly 1,300,000 BO.

It was also a good year for Birdbear completions in Boxcar Butte and Ash Coulee fields. Each had one Birdbear well completed in it during 2000. Devon Energy Corporation (Nevada) completed their #6-16 ND State test in Boxcar Butte Field with an IP of 337 BO + 3 BW + 281 MCFPD. The well has produced nearly 130,000 BO, but is currently shut-in. The other well, the BTA Oil Producers #1 Olsen 9210 JV-P, was IP'd for 187 BO + 103 MCFPD. It has produced more than 50,000 BO to date. While neither of these two wells is as good as the wells in Beaver Creek and Bicentennial, they were definitely worth drilling.

Elsewhere, in Mondak Field, Nance Petroleum Corp. drilled two wells in the southeast quarter-section of section 28-T148N-R104W. The first test, the #16-28 Federal, was completed in the Red River Formation flowing 655 BO + 5 BW + 590 MCFPD. The second test was the #16-28X Federal, which was completed pumping 640 BO + 458 MCFPD. Together, the two wells have produced nearly 240,000 BO and 250 MMCFG while producing only 5,364 BW. These are two exceptional wells.

Two Pennsylvanian Tyler wells were completed during 2000, less than four miles apart in two separate fields. The Upton Resources USA, Inc. #10-1H Tracy Mountain Federal was located in section 10-T138N-R101N in Tracy Mountain Field. It was completed pumping 135 BO + 22 MCFPD and has produced more than 60,000 BO since November, 2000. The other well is the Westport Oil & Gas Co., Inc. #13-23 SFTU, located in section 23-T139N-R101W. This is the better of the two wells as it had an IP of 407 BO + 20 MCFPD. The well has produced more than 150,000 BO since June, 2000 and is still producing about 100 BOPD over two years later. Both of these wells are among the better completions made during 2000.

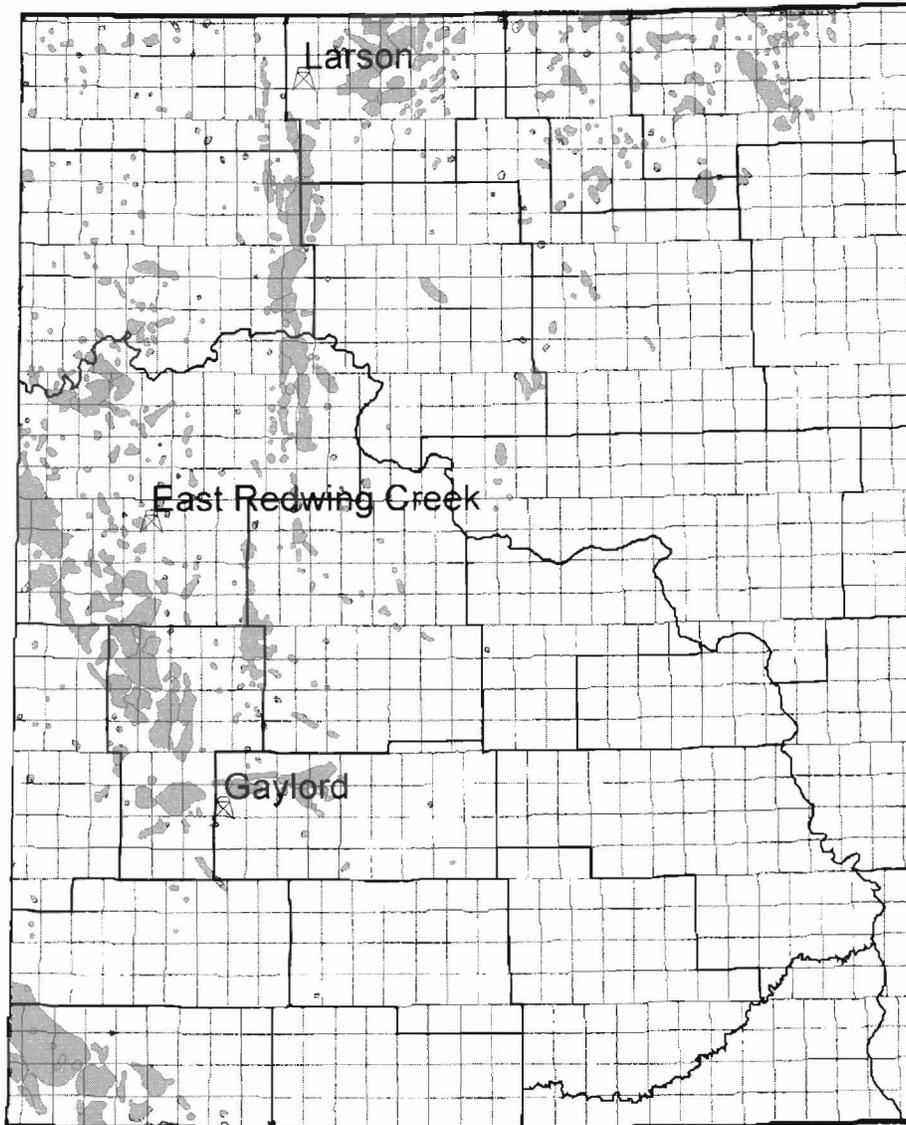
Other drilling in North Dakota during 2000 included that in the north-central part of the state. In Renville County, Ensign Operating Co. drilled five wells in the Truro Madison Unit. Four wells were completed as oil wells while the fifth was converted to a water-injection well. The four wells have produced more than 65,000 BO despite relatively low initial potentials.

Lastly, one new well was completed outside the two main areas of drilling. Amerada Hess Corp. drilled and completed a horizontal development well in the Newburg Spearfish-Charles Unit pumping 374 BO + 8 BW + 19 MCFPD. The #S-709AH NSCU is located in section 14-T161N-R79E in Bottineau County. This well has the distinction of being the highest IP ever reported from a Spearfish-Charles well and it has produced more than 83,000 BO to date. Along with other wells elsewhere in North Dakota, the well demonstrated that existing oil fields still have large volumes of oil in them. Much of that oil can be economically produced only with new, and especially horizontal, drilling.

## 2001

### Statistics

A total of 136 new wells were drilled in North Dakota during 2001, an increase of 33 over 2000 (132%). Nineteen of the wells, or almost 14%, were wildcat wells that discovered three new fields. Nine other new pools were discovered during 2001. Twelve new pools is a decrease of three from the fifteen found during 2000, a 20% drop. The 2001 new-pool discoveries are summarized in Appendix II. Those discoveries that were both new-field and new-pool discoveries are located on Figure 15. McKenzie County had the most new pools discovered in 2001 with four new pools and Dunn County was second with two new pools discovered (Table 2). One new pool was discovered each in Billings, Bowman, Burke, Golden Valley, Stark, and Williams counties. Four new pools were completed in the Madison with the remaining eight new-pool discoveries spread among eight pools, the Bakken, Birdbear, Duperow, Ratcliffe, Red River, Red River B, Silurian, and Stonewall.



**Figure 15.** Map of western North Dakota with the location of all known producing wells and all 2001 new field discoveries.

Seventy-eight of the 136 (57%) wells drilled during 2001 were horizontal wells. During 1999 and 2000, the percentage of wells drilled horizontally had dropped below 50%. As in 2000, the new-well completion count understates the amount of horizontal drilling done during 2001. Forty-one wells were re-entered and had horizontal legs drilled in them. If these were included in the drilling statistics, then 67% of the drilling during 2001 was horizontal.

**Drilling**

With one exception, wildcat drilling was again concentrated in two general areas. The first area, as in 2000, was in a tier along the Canadian border and the second area was in west-central North Dakota in McKenzie-Dunn Billings-Stark counties. The single exception was a wildcat well drilled in Hettinger County. This well, the Willow Creek Resources, Inc. #1-27 Kirschmann, located in section 27-T133N-R96W, tested the Lodgepole Formation. On a mud log from the well, fluorescence on some cuttings and flecks of brown oil in the mud were reported, but a drill-stem test over the show interval recovered only drilling mud. The presence of any show is quite interesting, but shows in a zone with relatively few, high productive wells is even more so. Perhaps a new Lodgepole play will be discovered

in southern North Dakota.

Another remote wildcat well was drilled by Lamae Oil & Gas Corp. in section 2-T161N-R72W near the Canadian border. The well was drilled into the Devonian Souris River Formation and a small show of oil was reported during a production test in the lower Duperow Formation. Though the well has been abandoned, even a small show is of interest because the nearest Duperow production lies more than 120 miles to the west. A discovery at this location would have indicated that a large, relatively unexplored part of North Dakota had potential Duperow production.

Three new fields were discovered in North Dakota during 2001. Larson Field was discovered in the northern tier by Jordan Exploration Co., LLC. Their #10-21 Lawrence was drilled in section 10-T162N-R94W and completed in the Red River B zone with an IP of 3 BO + 5 BW + 1,050 MCFPD. The discovery is interesting not only because it is the easternmost Red River producer in Burke County, but also because it is a gas well and not an oil well. Most Red River wells in North Dakota produce with a lower GOR than this well.

The second and third new fields were both discovered in west-central North Dakota and both were completed in the Madison pool. One discovery was in McKenzie County and the other was in Stark County. East Red Wing Creek Field was discovered by True Oil Co. with their Evanson #21-24 test located in section 24-T148N-R101W. The well was production-tested at a daily flowing rate of 500 BO + 565 MCF. The well had produced less than 3,000 barrels by the end of 2001 because it was shut-in awaiting production equipment.

The last new-field discovered is Gaylord Field, discovered by Westport Oil & Gas Co., Inc. Their #41-19 Hanson well, a horizontal test, was drilled in section 19-T139N-R99W, less than a mile from the Billings County line. The well, which was completed pumping 33 BO + 110 BWPD, has produced more than 20,000 BO. Westport has another location permitted about a mile to the west, but has not yet drilled this location.

Non-wildcat drilling was again focused outside of Bowman County, but not quite as strongly as during 2000. Thirty-one development wells were completed in Bowman County during 2001. Of these, twenty-two wells were completed in Cedar Hills Field, five in Cedar Creek Field, two in Cold Turkey Creek Field, and one in both Grand River and Horse Creek fields. These 31 wells represented approximately 23% of all the wells completed during 2001. The 104 wells completed outside Bowman County were scattered throughout west-central North Dakota, along the Nesson Anticline, and across north-central North Dakota.

West-central North Dakota, where the most development wells were completed, covers McKenzie, Dunn, Stark, Billings, and Golden Valley counties. Forty-three wells were completed in this area of which 36 (84%) produced oil. The second-most-active area was in north-central North Dakota in Burke, Ward, Mountrail, Towner, and Bottineau counties. Here, 23 wells were completed, all of which produced oil. The third area was the Nesson Anticline where 20 wells were completed, 19 (95%) of which produced oil. None of these were re-entered wells.

During 2001, five new wells with IPs greater than 400 BOPD were completed, eight less than the thirteen completed during 2000 even though 33 more wells were drilled during 2001 than in 2000. Although most of the wells were drilled in west-central North Dakota, many of the better wells completed during 2001 were on the Nesson Anticline.

The single best well completed in North Dakota during 2001 is the Berco Resources, LLC #41-17H Hoseth, drilled in section 17-T158N-R95W into the Winnipegosis pool of McGregor Field. This was a new-pool discovery during 2000 and the horizontal Hoseth well was drilled to develop it. The well

had the second highest IP reported during 2001, 598 BO + 283 MCFPD, and has produced more than 200,000 BO and 80,000 MCF to date, while producing less than 3,000 BW. This outstanding well compares very favorably with some of the excellent Birdbear pool completions made during 2000. A second test in the same pool, drilled by Basin Exploration, Inc., was dry.

Amerada Hess Corp. continued a grass-roots drilling program in Beaver Lodge Field in 2001 by drilling nine new wells to three different pools, two more new wells than they drilled during 2000. Three were in the Devonian pool, four the Madison, and two the Silurian. One of the Silurian wells, the BLSU #D-408B, was one of five wells completed during 2001 with an IP greater than 400 BOPD. This well was completed for 406 BO + 4 BW + 309 MCFPD. However, it is the four Madison wells that have produced the most oil, gas, and water. The totals to date are more than 175,000 BO, 1,000 MCF, and 1,200,000 BW. While disposing of produced water is an expense, the oil production has more than paid for it. The Devonian and Silurian programs, while not as productive, each had at least one well that had produced more than 50,000 BO. In total, the 2001 Beaver Lodge grass-roots drilling program has produced around 350,000 BO and 1,300,000 MCF.

In addition to the grass-roots drilling in Beaver Lodge Field, Amerada Hess Corp. also re-entered twelve older wells on the Nesson Anticline and drilled one or more horizontal legs in each well. Three wells were re-entered in Blue Buttes and Capa fields, two in Antelope and Tioga fields, and one in Charlson and Dimmick Lake fields. The two wells in Capa Field had new IPs of 600 and 379 BOPD. In general, the re-entered wells were either non-productive or were marginal producers so that nearly all the oil recovered by these wells should be considered new additions to reserves.

Another very good well was drilled in Stoneview Field by Berco Resources, LLC. Their #4410H Stoneview-Stonewall test was completed pumping 172 BO + 207 BW + 204 MCFPD but, to date, has produced more than 65,000 BO. A second well completed in Stonewall Field was in the Silurian pool.

The other three wells that had IPs greater than 400 BOPD were all drilled in west-central North Dakota. The highest reported IP reported during 2001 was from Bear Creek Field. The Berco Resources, LLC #11-2H Porcupine Ridge well, located in section 2-T147N-R96W, lies near the southern-most end of the Nesson Anticline but, for this report, is considered to be in the west-central North Dakota area. The well, which was completed in the Madison with an IP of 621 BO + 50 BW + 693 MCFPD, has produced around 65,000 BO. While an excellent well, the IP from this well was only slightly higher than that reported from the well with the second highest IP in McGregor Field, but the latter has produced nearly three-times as much oil. Other factors than IP, such as age, pressure, and lateral length, often determine the ultimate productivity of a well.

The third highest IP was reported from the Wascana Oil & Gas, Inc. #3H Wascana Schaefer. The well was drilled as a dual-leg horizontal well in the Madison pool and was completed for 453 BO + 80 BW + 32 MCFPD. The well has produced more than 60,000 BO to date and is still producing more than 50 BOPD.

The last of the five high-IP wells is the Aviara Energy Corp. #30-2 Aviara Energy Corp. State, located in section 30-T143N-R102W, in Roosevelt Field. The well was originally drilled vertically into the Duperow Formation, but a horizontal leg was later drilled in the Birdbear Formation, the producing horizon. The well was completed pumping 424 BO + 60 BW + 424 MCFPD and has produced more than 40,000 BO to date. While this well has not produced as much oil as some of the other high-IP wells, it nonetheless is an economic completion.

Elsewhere, Nance Petroleum completed a quite prolific well, the #1-2 Barnes located in section 2-T152N-R102W, in Indian Hill Field. The well, which had an IP of 364 BO + 10 BW + 320 MCFPD from the Red River Formation, has produced nearly 75,000 BO to date.

Significant completions were made in several other fields. Westport Oil & Gas Co., Inc. drilled five wells in Fryburg Field, four to the Madison and one to the Tyler. All five wells were completed, but only one, the Tyler completion, was drilled as a vertical well. The four Madison wells had an average IP of 170 BO + 280 BW + 70 MCFPD and together have thus far produced more than 150,000 BO. The Tyler completion has not held up as well. It had an IP of 102 BO + 62 BW + 30 MCFPD but has produced less than 17,000 BO.

A number of wells were drilled in Davis Creek Field, seven by Upton Resources USA, Inc. and an eighth by Whiting Petroleum Corporation. The eight wells had an average IP of 194 BO + 220 BW + 50 MCFPD and have produced more than 250,000 BO to date, or slightly more than 30,000 BO per well. However, several of the wells have begun to produce large volumes of water, more than 8,000 barrels per month in some cases, which may limit their EUR if disposal costs are high.

Westport Oil & Gas Co., Inc. drilled a grass-roots eight-well program in Wiley Madison Unit in the second-half of 2001. All eight wells were drilled horizontally and the average IP was 184 BO + 413 BWPD. Together, the eight wells have produced nearly 300,000 BO and more than 800,000 BW. In addition to the grass-root wells, Westport also re-entered nine other wells and drilled one or more horizontal legs in each. The field was unitized as a waterflood during 1997 and these seventeen horizontal wells are part of their continuing effort to efficiently drain the reservoir.

Finally, twenty-two wells were completed in Cedar Hills Field during 2001, sixteen more than during 2000. Six of the 22 were completed as water injectors as secondary-recovery operations began in both Cedar Hills North and Cedar Hills South units. Five of the six water injectors were originally completed as oil wells and produced some oil before later being converted to injectors. The sixth was completed as a water injector and never produced any oil. Ten of the 22 wells were completed by Burlington Resources Oil & Gas Co. in Cedar Hills South Unit, where the method of secondary-recovery is a waterflood. The remaining twelve were completed by Continental Resources, Inc. in the Cedar Hills North Unit, a High Pressure Air Injection project. The twenty-one wells that produced oil have produced more than 450,000 BO, 175,000 MCF, and 350,000 BW. Now that injection has begun in both Cedar Hills units, production should begin to rise over the next few years. After some period of time, perhaps 5-10 years, we should be able to evaluate how relatively effective each the two methods have been at recovering the oil trapped in the reservoir.

## **Other News**

An important event occurred during 2001 that, while not directly related to the drilling and production of oil, nevertheless impacts those activities. On September 6, 2001 Tesoro Refining & Marketing acquired the Mandan refinery from BP Corporation (see cover photos). The refinery processes up to 60,000 barrels per day of primarily sweet (low sulfur) crude oil per day and turns it into gasoline, jet fuel, distillates, propane and butane. Refined products are sold at Mandan or shipped via pipeline to eastern North Dakota and Minnesota to terminals at Jamestown, Moorhead, Sauk Centre, Spring Valley, and the Twin Cities where they are distributed. The change is important because nearly 95% of the oil refined in Mandan is domestic oil and 80% is from North Dakota. With the acquisition of the refinery, Tesoro has become the largest purchaser of crude oil in the state.

## **2000-2001 HIGHLIGHTS**

The North Dakota oil industry was in poor shape after the low oil prices of 1998-1999, but a recovery that began in late 1999 extended through 2001. Drilling rose each year from a modern-day low set during 1999. The recovery was, in large part, due to the high price of a barrel of crude oil during 2000 and 2001. Crude oil averaged over \$23/barrel for 2000 and 2001.

Seven units were formed in 2000 and 2001, the most important of which are the Cedar Hills North and South units and the Medicine Pole Hills West Red River Unit. Operations have begun in the units to maximize the oil recovery from the Red River B porosity, the productive zone in the Cedar Hills and Medicine Pole Hills units.

A few wildcat wells were drilled in attempts to extend production into new, unproductive areas, but none of them were successful. However, opportunities still exist and are still getting tested. Wildcat wells drilled in productive areas discovered three new fields in both 2000 and 2001. Twelve and nine new-pools were also discovered during 2000 and 2001, respectively. Eighteen of the twenty-seven new-field or new-pool discoveries were made in wells that were re-entered and a new zone tested.

New well development drilling during 2000 and 2001 was split nearly equally between horizontal and vertical wells. Fifty-three percent of the new development wells were horizontal. However, sixty older, vertical wells were re-entered and drilled out with one or more new horizontal legs. If these 60 wells are included, more than 64% of all development wells were drilled horizontally.

Many of the re-entered wells were drilled on the Nesson Anticline in wells that had either been abandoned or were close to abandonment when the new drilling put them back on production and booked new reserves. The continued development of these older fields promises to be an important part of North Dakota's drilling for years to come.

Similarly, seventeen new-wells or new horizontal legs were drilled in Wiley Field in North Central North Dakota. The field had been unitized in 1997 and began responding favorably to the waterflood within a few months. The new drilling will certainly produce the primary reserves sooner, but new reserves have probably been added too. The Wiley Field example may encourage other companies to look more closely at other old oil fields in the area.

Compared to the past, drilling activity has been relatively low in North Dakota for the past four years. However, some projects that are just coming on-stream and some trends in wildcat drilling and development drilling hold promise for the future.

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## APPENDIX I. 2000 NEW POOL DISCOVERIES

COUNTY FILE NO. ORDER #	COMP. DATE DISC. TYPE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (# OF PRODUCING WELLS IN POOL ON 12/31/01)	TOTAL MEASURED DEPTH -SPACING	PERFORATED INTERVAL	IP (CUR. -BOPD	GAS (MCF) GRAV.	GOR	WATER
*Williams 14907 8645	11/20/99 N	TPC Exploration Nelson #1-20H Sec. 20-T158N-R95W	South McGregor Ratcliffe 1	13,108 640	8,398-13,018	28 6	0 40	0	55
McKenzie 6904 NA	1/7/00 R	Black Hawk Resources, LLC Federal #3-221 Sec. 3-T147N-R104W	Mondak Stonewall 0	12,766 NA	12,336-12,374	762 0	0 43	0	133
Williams 14923 9072	1/18/00 N	Berco Resources, LLC NDCA #4 Sec. 21-T158N-R95W	McGregor Winnipegosis 4	11,420 160	11,170-11,244	463 68	0 42	0	64
McKenzie 9132 9066	2/2/00 R	Camwest II LP Skedsvold #23-6 Sec. 23-T151N-R101W	Alexander Duperow 1	13,800 320	11,459-11,464	248 75	309 39.8	1246	11
Divide 14926 9035	2/3/00 N	Armstrong Operating, Inc. Schilke #14-1 Sec. 14-T160N-R98W	Skabo 1	8,100 320	7,810-7,816	344 44	128 32.2	372	16
**Billings 14887 9071	2/4/00 N	Pacific Petroleum, LLC Rockies #23-43 Sec. 2 36-T142N-R98W	Saddle Butte Stonewall 1	13,250 320	12,644-12,728	172 119	195 49	1133	0
McKenzie 11108 9096	2/17/00 R	Wesco Operating Inc. Oland #35-44R Sec. 35-T149N-R102W	Boxcar Butte Birdbear 4	13,707 320	11,173-11,179	150 35	0 42	0	31
Dunn 11365 9099	4/4/00 R	Westport Oil & Gas Co. Brandvik #11-2 Sec. 11-T147N-R96W	Bear Creek Madison 2	11,654 160	9,554-9,576	92 36	4 38	342	248
Williams 9241 9081	4/23/00 R	Missouri Basin Well Service, Inc. Charles Bowen #21-1 Sec. 21-T153N-R102W	Trenton Birdbear 1	13,300 320	10,614-10,620	32 31	30 38.4	938	2
Billings 14966 9188	5/27/00 N	Belco Energy Corp. Richard #2-24H Sec. 24-T138N-R100W	Bull Creek Madison 2	14,792 640	9,255-14,792	43 0	16 45	372	2055

## APPENDIX I. 2000 NEW POOL DISCOVERIES CONTINUED

COUNTY FILE NO. ORDER #	COMP. DATE DISC. TYPE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (# OF PRODUCING WELLS IN POOL ON 12/31/01)	TOTAL MEASURED DEPTH -SPACING	PERFORATED INTERVAL	IP (CUR. -BOPD)	GAS (MCF) GRAV.	GOR	WATER
Dunn 7707 9160	5/28/00 R	Missouri River Royalty Corp. Borth #1-35 Sec 35-T145N-R93W	Saxon Duperow 1	13,280 320	10,854-10,858	57 30	10 39.2	175	19
Billings 14958 9177	6/26/00 R	BTA Oil Producers Inc. Olsen 9210 JV-P Sec 14-T142N-R102W	Ash Coulee Birdbear 1	12,780 320	10,679-10,683	187 50	103 45	550	0
Williams 7168 NA	7/19/00 R	Condor Petroleum, Inc. Sunhagen #1 Sec. 10-T158N-R96W	Big Meadow Birdbear 0	13,225 NA	9,970-9,985	2 0	0 35	0	24
McKenzie 13521 9124	8/4/01 R	Amerada Hess Corp. Antelope Unit "A" #2 Sec. 1-T152N-R905W	Antelope Stonewall 1	12,900 NA	12,730-12,771	97 0	284 48.8	2927	2
Williams 7168 NA	8/25/00 R	Condor Petroleum, Inc. Sunhagen #1 Sec. 10-T158N-R96W	Big Meadow Bakken 0	13,225 NA	9,654-9,748	1 0	0 40	0	0
McKenzie 9519 9310	10/12/00 R	Missouri Basin Well Service, Inc. Tank #1-3 Sec. 3-T150N-R96W	Johnson Corner Madison 1	14,163 160	9,350-9,490	15 7	0 43.5	0	40
McKenzie 8969 NA	11/11/00 R	Missouri Basin Well Service, Inc. A. Johnsrud "A" #1 Sec. 9-T150N-R99W	Tobacco Garden Birdbear 0	14,430 NA	11,460-11,464	NA 0	NA NA	NA	NA

\* A 1999 new field completion that was unnamed at the time of the last report and so is included in this report.

\*\* Saddle Butte Stonewall pool was actually discovered in 1979 but the well produced only a small amount of oil before being plugged and abandoned. The pool name was then dropped from the records

R=Recompletion  
N=New Well

## APPENDIX II. 2001 NEW POOL DISCOVERIES

COUNTY FILE NO. ORDER #	COMP. DATE DISC. TYPE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (# OF PRODUCING WELLS IN POOL ON 12/31/01)	TOTAL MEASURED DEPTH -SPACING	PERFORATED INTERVAL	IP (CUR. -BOPD)	GAS (MCF) GRAV.	GOR	WATER
Bowman 6639 9056	11/8/01 R	Luff Exploration Company Gross #1-8 Sec. 8-T130N-R103W	Amor Red River B 1	12,186 320	9,371-12,186	26 22	28 39.7	177	176
McKenzie 11913 9170	12/29/01 R	Flying J Oil & Gas, Inc. Bear Den Unit #4 Sec. 25-T149N-R96W	Bear Den Bakken 1	14,475 160/320	11,044-11,054	17 40	20 44.3	1176	0
Golden Valley 11029 NA	3/8/01 R	Wesco Operating Inc. Messersmith #1-1X Sec. 1-T144N-R104W	Bicentennial Stonewall 1	12,890 NA	12,266-12,272	22 1	24 44	1090	111
*Bowman 11656 NA	9/28/01 R	Continental Resources, Inc. USA #34-6 Sec. 6-T130N-R106W	Cedar Hills Ordovician 1	8,630 NA	8,420-8,517	50 0	21 27	420	38
McKenzie 15121 9089	7/2/01 N	True Oil LLC Evanson #21-24 Sec. 24-T148N-R101W	East Red Wing Creek Madison 1	9,719 160	9,497-9,558	500 4	565 42.4	1129	0
Stark 15134 9123	8/4/01 N	Westport Oil & Gas Co., LP Hanson #41-19 Sec. 19-T139N-R99W	Gaylord Madison 1	14,700 640	9,575-14,700	33 0	0 44.4	0	110
*Bowman 14991 NA	8/17/01 R	Luff Exploration Company Hansen #C-7 Sec. 7-T129N-R101W	Grand River Red River 3	9,550 Unit	9,425-9,462	260 0	357 38.1	1373	31
McKenzie 9430 9234	8/8/01	Westport Oil & Gas Co., LP M. J. Green #1 Sec. 7-T152N-R101W	Indian Hill Silurian 0	13,925 320	12,528-12,618	NA NA	NA NA	NA	NA
Dunn 14962 NA	5/5/01 N	PDC Corporation Davis State #34-36 Sec. 36-T146N-R95W	Killdeer Madison 0	13,755 NA	9,464-9,492	80 0	54 38.6	674	37
Burke 15095 9168	7/16/01 N	Jordan Exploration Company, LLC Lawrence #10-21 Sec. 21-T162N-R94W	Larson Red River 1	11,550 320	11,249-11,348	3 19	1050 49.9	350,000	5
Billings 14996 NA	7/31/01 R	BTA Oil Producers 20006 JV-P Morgan Sec. 32-T144N-R102W	Morgan Draw Birdbear 0	13,260 160	11,148-11,151	5 0	0 39.5	0	22

## APPENDIX II. 2001 NEW POOL DISCOVERIES CONTINUED

COUNTY FILE NO. ORDER #	COMP. DATE DISC. TYPE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (# OF PRODUCING WELLS IN POOL ON 12/31/01)	TOTAL MEASURED DEPTH -SPACING	PERFORATED INTERVAL	IP (CUR. -BOPD	GAS (MCF) GRAV.	GOR	WATER
Dunn 13224 9279	1/18/01 R	Armstrong Operating, Inc. S. E. Russian Creek #33-17 Sec. 17-T141N-R95W	Simon Butte Madison 1	12,700 160/320	9,170-9,190	128 31	67 34.3	523	267
Williams 15136 9255	9/5/01 N	Berco Resources, LLC McGinnity #2-6H Sec. 6-T158N-R95W	Temple Ratcliffe 1	11,469 320	8,408-11,469	243 47	235 36.9	967	0
McKenzie 5856 9169	10/20/01 R	Agate Petroleum, Inc. State #1-36 Sec. 36-T150N-R104W	Yellowstone Duperow 1	13,080 320	10,996-10,000	49 30	40 40	816	2

\* Pool was not discovered in 2001. It was administratively created by transferring wells from an existing pool into a new pool.

R=Recompletion  
N=New Well

