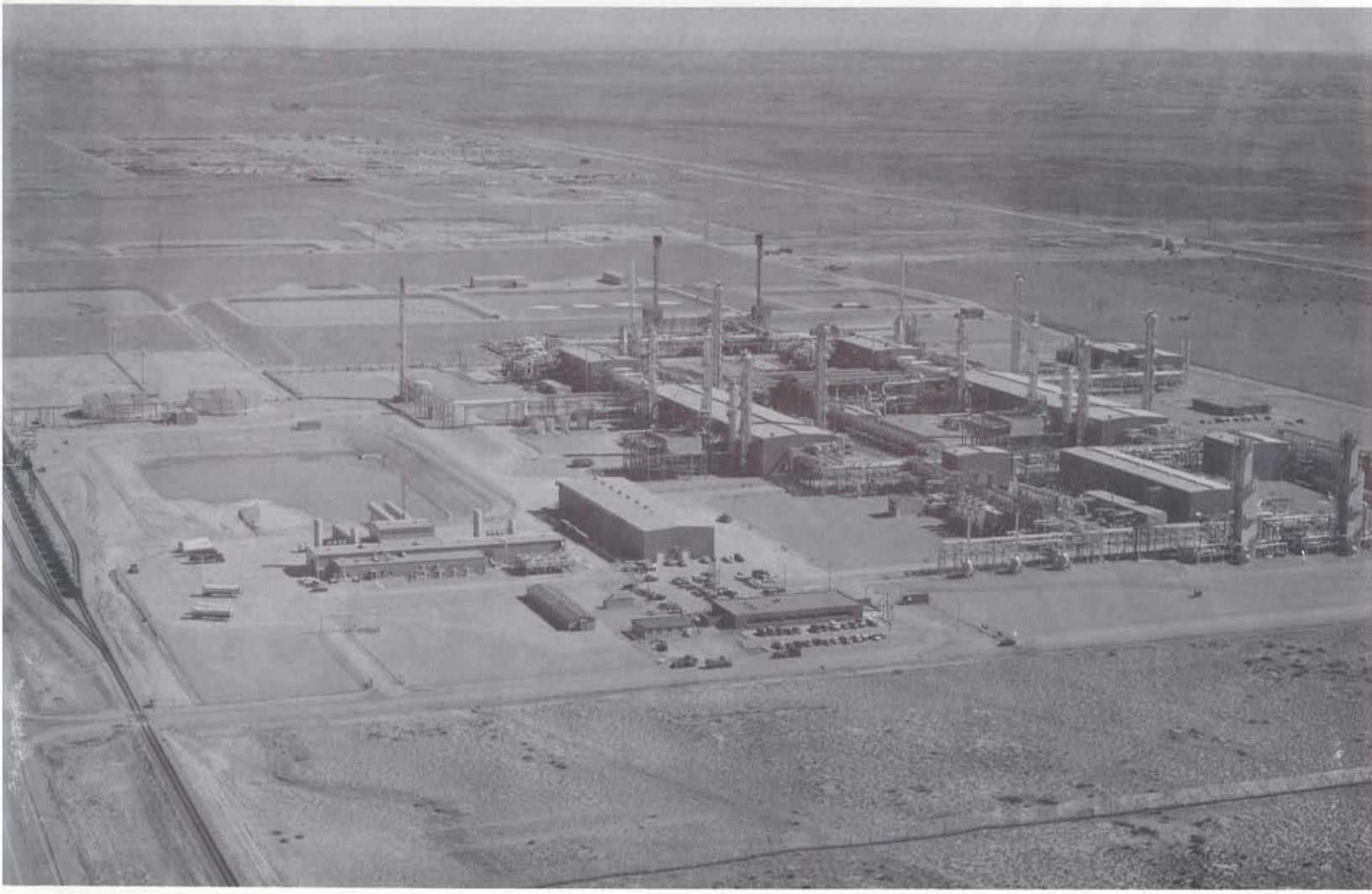
THE GEOLOGICAL SURVEY OF WYOMING
Gary B. Glass, State Geologist

WYOMING'S OIL AND GAS INDUSTRY IN THE 1980s: A TIME OF CHANGE

by
Rodney H. DeBruin



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Front cover: Exxon Company, U.S.A., Shute Creek gas processing facility, La Barge operations. Exxon's Shute Creek plant is the largest gas processing plant in Wyoming. The plant produces methane as well as carbon dioxide for enhanced oil recovery projects. Helium and sulfur are important by-products from the plant. (Photograph courtesy of Exxon Company, U.S.A.)

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RODNEY H. DEBRUIN

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STATE OF WYOMING
1933
GEOLOGICAL SURVEY

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Introduction: fluctuating prices

The price that oil and gas producers receive for their products ultimately affects every aspect of the oil and gas industry, from exploration and production to processing. Many circumstances have influenced oil and gas prices in Wyoming since oil was first discovered in the State by Mike Murphy at Dallas Dome in 1884.

In the early years, Wyoming oil could not compete with crude oil produced closer to population centers on the East and West Coasts, and in the Midwest. Prices dropped as low as 10 cents per barrel during the 1930s because of the Great Depression and the large surplus of crude that followed the discovery of several giant oil fields in Texas. The price of oil increased in the 1940s with the United State's involvement in World War II. Beginning in 1948 and continuing through 1972, the average price of crude oil in Wyoming fluctuated between $2.15 and $2.10 per barrel (American Petroleum Institute, 1985).

Natural gas prices in Wyoming averaged only 5 cents per thousand cubic feet (MCF) in 1947 (American Petroleum Institute, 1985), the first year for which prices for this commodity were accurately determined. The average price of Wyoming natural gas went up gradually and averaged 16.2 cents per MCF in 1972.

The Organization of Petroleum Exporting Countries (OPEC) orchestrated oil embargoes in 1973 and 1979. These embargoes, along with price decontrol in the United States, increased average oil prices in Wyoming from $3.09 to $8.50 per barrel and average gas prices from 16.2 cents to $1.13 per MCF between 1972 and 1979. Even larger increases followed in the early 1980s. Average oil prices peaked at over $32 a barrel in 1981 but declined to near $23 a barrel by 1985. The price reduction was mainly caused by increased worldwide production from OPEC, the North Sea, and Mexico. Demand also slowed somewhat because of conservation measures adopted in developed countries.

OPEC once again manipulated prices in 1986. This time they flooded the market with crude oil to regain their market share. This maneuver lowered the average price of Wyoming crude oil in 1986 to $12.96 per barrel, its lowest price in the 1980s. Oil prices rebounded in 1987 but once again nosedived in the second half of 1988 due to a lack of production restraint by OPEC. Oil prices in Wyoming will probably not exceed an average of $16 per barrel for the remainder of the 1980s unless OPEC is able to maintain production quotas among its members. New oil production in the North Sea will also contribute to excess world production and related lower prices for the next several years.

Natural gas prices also climbed rapidly in the early 1980s; prices stayed above $3 per MCF from 1982 through 1985. A high level of drilling for natural gas produced major new gas discoveries that caused an oversupply. The price for Wyoming natural gas responded to the surplus and declined to an average of $1.76 per MCF in 1987, the lowest average during the 1980s. Natural gas prices have not yet recovered and may not begin increasing until 1990, when supply and demand should begin to balance.

The large price fluctuations for oil and gas in the 1980s has had a far-reaching influence on the way the Wyoming oil and gas industry operates in the State. Every person living in Wyoming is affected to some degree by these price fluctuations since the oil and gas industry is the largest taxpayer and employer in the State.

Production in the 1980s

According to 1987 statistics (U.S. Department of Energy, 1988b), Wyoming ranked sixth in crude oil production behind Texas, Alaska, Louisiana, California, and Oklahoma. The State ranked fifth in natural gas production behind Texas, Louisiana, Oklahoma, and New Mexico.

Wyoming's highest yearly oil production was 155.7 million barrels in 1970. Since that time, the general trend, with the exception of a few years, has been a production decline. **Figure 1** shows oil production from 1980 through 1987 with estimates of production for 1988 through 1990. During 1983 through 1985, the production decline was reversed by the drilling boom of 1980 through 1985. However, the inevitable drop in production from most of the large old oil fields and a tremendous drop in well completions, which started in 1986 and continued through 1987, has returned the State's oil production to a yearly decline. The projected stabilization in production for 1988 and 1989 (**Figure 1**) reflects expected increased production from tertiary projects at Wertz, Lost Soldier, and Buck Draw Fields and from full development of Luckey Ditch Field. After 1989, production is expected to decrease once again.

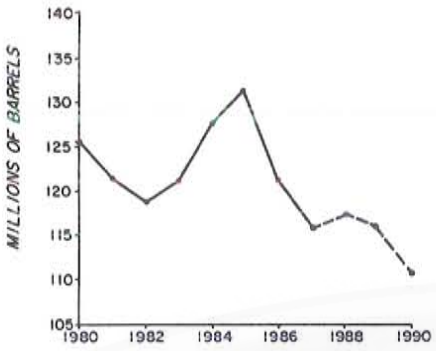

Figure 1. Production of crude oil in Wyoming, 1980-1990 (Wyoming Oil and Gas Conservation Commission, 1981, 1988). Production for 1988-1990 is estimated by the author.

Natural gas production showed a steady yearly rise from 450.6 billion cubic feet in 1980 to 600.1 billion cubic feet in 1984 (**Figure 2**). After small declines in natural gas production in 1985 and 1986, production in 1987 increased to 733.2 billion cubic feet. However, nearly 120 billion cubic feet of the total was carbon dioxide processed by Exxon's Shute Creek gas processing plant (**cover photo**). Increases in natural gas production are predicted for 1988 and 1989 because of increased demand. Production could increase even more sharply after 1989 if a proposed pipeline from Wyoming to southern California is built.

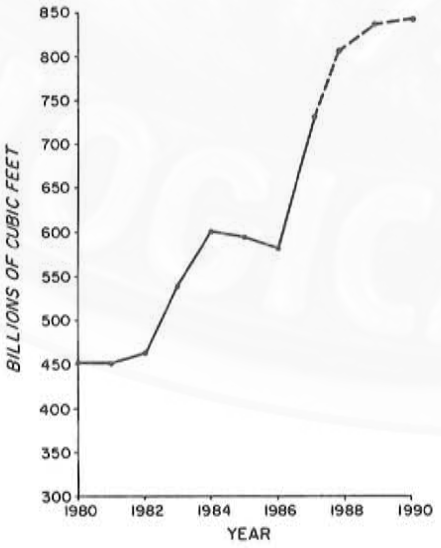

Figure 2. Production of natural gas in Wyoming, 1980-1990 (Wyoming Oil and Gas Conservation Commission, 1981-1988). Production for 1988-1990 is estimated by the author and production for 1986-1990 includes carbon dioxide.

Producing formations

Oil and (or) natural gas were produced from 161 different formations, combinations of formations, or zones within formations during 1987. These producing reservoir rocks are Tertiary to Cambrian in age. Table 1 shows the 10 most prolific oil-producing stratigraphic units in the State in 1980 and 1987. In 1987, 77.38 percent of all the oil in Wyoming was produced from these 10 stratigraphic units. When compared to the top 10 oil-producing stratigraphic units in 1980, the most striking change is that the gap between production from the Tensleep Sandstone and from the Minnelusa Formation has narrowed considerably. In 1980, there was a difference in production of 16.5 million barrels between the two; in 1987 the difference was less than 3 million barrels. While production from the Tensleep, mainly

Table 1. The 10 most prolific oil-producing stratigraphic units in Wyoming in (A) 1987 and (B) 1980 (Wyoming Oil and Gas Conservation Commission, 1981a, 1988b).

1987 A. Formation or member	Production (barrels)	Percent of total production
Pennsylvanian Tensleep Sandstone	22,442,634	19.36
Permian/Pennsylvanian Minnelusa Formation	19,673,165	16.97
Jurassic/Triassic Nugget Sandstone	9,212,879	7.95
Upper Cretaceous Shannon Sandstone Member of Cody Shale	8,726,590	7.53
Mississippian Madison Limestone	6,932,077	5.98
Upper Cretaceous Wall Creek Sandstone Member of Frontier Formation	4,856,570	4.19
Upper Cretaceous Frontier Formation	4,771,295	4.12
Permian Embar[2] formation	4,534,873	3.91
Permian Phosphoria Formation	4,416,455	3.81
Lower Cretaceous Dakota Sandstone[1]	4,131,218	3.56
TOTAL	89,697,756	77.38

1980 B. Formation or member	Production (barrels)	Percent of total production
Pennsylvanian Tensleep Sandstone	31,279,800	24.8
Permian/Pennsylvanian Minnelusa Formation	14,774,006	11.7
Jurassic/Triassic Nugget Sandstone	9,276,966	7.3
Mississippian Madison Limestone	7,316,361	5.8
Upper Cretaceous Shannon Sandstone Member of Cody Shale	7,183,322	5.7
Lower Cretaceous Muddy Sandstone Member of Thermopolis Shale	5,864,132	4.6
Permian Phosphoria Formation	5,463,087	4.3
Permian Phosphoria Formation/ Pennsylvanian Tensleep Formation		
Pennsylvanian Tensleep Sandstone	5,375,561	4.3
Permian Embar[2] formation	4,514,021	3.6
Upper Cretaceous Wall Creek Sandstone Member of Frontier Formation	4,209,621	3.3
TOTAL	95,256,877	75.4

[1] Term variously used for Cloverly Formation and Muddy Sandstone Member of the Thermopolis Shale.

[2] The Embar formation was introduced to designate beds between Pennsylvanian Tensleep Sandstone and Triassic Chugwater Formation (Darton, 1906). Although the name is now considered obsolete, it is still used by some companies when reporting production.

from old declining fields, decreased over 8.8 million barrels between 1980 and 1987, the production from the Minnelusa increased by more than 4.8 million barrels in the same period. This gap in production between the two formations should continue to narrow in 1988 as Minnelusa production increases and Tensleep production decreases. The production gain for the Minnelusa Formation between 1980 and 1987 was the result of production from new Minnelusa field discoveries, which outweighed production declines in old Minnelusa fields.

From 1980 to 1987, there were 113 new field discoveries in the Minnelusa, more than in any other formation in the State. There were 60 new field discoveries in the Muddy Sandstone, 39 in the Frontier Formation, and 38 in the Dakota Formation (Wyoming Oil and Gas Conservation Commission, 1981b, 1982, 1983, 1984, 1985, 1986, 1987, 1988a; Stephenson and others, 1984).

Natural gas production from the top 10 natural gas-producing stratigraphic units for 1987 was 344.7 billion cubic feet more than from the top 10 for 1980 (**Table 2**). Most of the increase in 1987 production came from the top three gas-producing formations, which accounted for 452.1 billion cubic feet, about 135 billion cubic feet more than was produced by the entire top 10 gas-producing stratigraphic units for 1980 and 1.5 billion cubic feet more than the total gas production in Wyoming in 1980. The doubling of production from the Nugget Sandstone is explained by increased production from that formation in the Overthrust Belt. The 231-billion-cubic-foot increase in production from the Madison Limestone was mainly from Overthrust Belt fields and from the fields that supply Exxon's gas plant at Shute Creek. Gas production from the Madison Limestone took over the lead in 1987, with production over 248 billion cubic feet. About one-half of the production from the Madison in 1987 was carbon dioxide. Increased production from the Frontier Formation was mostly due to production increases from fields in the Greater Green River Basin.

Table 2. The ten most prolific natural gas-producing stratigraphic units in Wyoming in (A) 1987 and (B) 1980. (Wyoming Oil and Gas Conservation Commission, 1981a, 1988b).

1987 A. Formation or member	Production (MCF)[1]	Percent of total production
Mississippian Madison Limestone	248,295,603	33.86
Jurassic/Triassic Nugget Sandstone	104,718,915	14.23
Upper Cretaceous Frontier Formation	99,115,313	13.52
Upper Cretaceous Mesaverde Formation	48,779,491	6.65
Lower Cretaceous Dakota sandstone[2]	37,418,310	5.10
Lower Cretaceous Muddy Sandstone Member of Thermopolis Shale	34,211,067	4.67
Mississippian Mission Canyon Limestone	29,940,317	4.08
Pennsylvanian Weber Sandstone	23,999,799	3.27
Upper Cretaceous Cody Shale	20,031,136	2.73
Upper Cretaceous Almond Formation	15,599,771	2.13
TOTAL	662,109,722	90.29

1980 B. Formation or member	Production (MCF)	Percent of total production
Upper Cretaceous Frontier Formation	66,438,811	14.7
Triassic/Jurassic Nugget Sandstone	52,176,125	11.6
Upper Cretaceous Mesaverde Formation	49,298,306	10.9
Upper Cretaceous Lewis Shale	28,841,572	6.4
Lower Cretaceous Muddy Sandstone Member of Thermopolis Shale	28,434,511	6.3
Upper Cretaceous Almond Formation	23,787,249	5.3
Lower Cretaceous Dakota Sandstone[2]	20,402,903	4.5
Mississippian Madison Limestone	17,235,918	3.8
Pennsylvanian Weber Sandstone	16,637,366	3.7
Paleocene Fort Union Formation	14,181,397	3.1
TOTAL	317,434,158	70.3

[1] Thousand cubic feet

[2] Term variously used for Cloverly Formation and Muddy Sandstone Member of the Thermopolis Shale.

Production by county

Table 3 shows oil and gas production by county. It also shows the State produced less oil but much more natural gas from more wells and fields in 1987 than in 1980. The five leading oil-producing counties are Campbell, Park, Uinta, Sweetwater, and Natrona. Comparisons with the 1980 leaders show that Campbell has replaced Park as the top oil- producing county while Uinta has replaced Hot Springs in the top five. Campbell County's top spot is mainly due to large production increases since 1980 from Hartzog Draw Field (**Figure 3**) and to increased production from a large number of recently discovered fields producing from the Minnelusa Formation. The decline in Park and Hot Springs Counties can be traced to declining production in several large old fields such as Oregon Basin, Elk Basin, Little Buffalo Basin, Grass Creek, and Hamilton Dome (**Figure 3**). Sweetwater County's decline is linked in part to declines at Lost Soldier Field (**Figure 3**). Uinta County's increase was influenced by production increases at Painter Reservoir and Whitney Canyon-Carter Creek Fields in the Overthrust Belt and by production from several new discoveries, especially Luckey Ditch Field, on the southern end of the Moxa arch in the Greater Green River Basin (**Figure 3**). In 1987, Natrona County's production decreased over 1 million barrels from 1980 production, mainly because of decreased production from Salt Creek Field (**Figure 3**). Converse County's oil production stayed fairly constant because the increase in production at Powell Field offset the production decline at Well Draw Field (**Figure 3**). Wells at Well Draw Field are mostly stripper wells and quite a few of them were shut in during the price drop in 1986. In most

Table 3. Production of oil and gas by county for 1987 and 1980 (Wyoming Oil and Gas Conservation Commission, 1981a and 1988b).

	1987				1980			
	Number of fields	Number of wells	Oil production (barrels)	Gas production (MCF)[1]	Number of fields	Number of wells	Oil production (barrels)	Gas production (MCF)[1]
Albany	6	38	117,671	30,698	6	35	164,571	18
Big Horn	23	437	4,039,692	1,975,310	23	452	6,038,738	4,355,871
Campbell	270	2,021	27,178,671	32,172,099	169	1,508	23,591,348	25,188,075
Carbon	48	415	3,034,956	46,549,871	43	348	1,719,005	39,428,733
Converse	64	1,188	6,983,017	33,126,289	43	995	7,642,650	19,156,171
Crook	69	651	4,651,756	227,065	47	372	2,983,478	307,704
Fremont	47	897	4,934,298	41,259,845	50	767	7,210,475	68,379,301
Goshen	4	8	12,333	6,320	2	5	2,180	
Hot Springs	26	981	7,604,598	518,775	25	844	10,207,475	149,992
Johnson	35	580	3,143,546	1,868,516	25	506	3,513,285	2,149,313
Laramie	14	93	426,121	138,389	10	51	236,326	36,237
Lincoln	22	268	706,885	37,496,264	19	220	264,787	18,824,416
Natrona	51	2,626	7,783,610	13,151,958	45	2,078	9,389,214	11,607,813
Niobrara	29	275	971,816	828,072	25	262	1,451,427	1,202,702
Park	41	1,418	20,402,365	12,214,054	43	1,188	27,099,350	14,816,525
Platte		3						
Sheridan	4	49	155,123	32,575	5	37	150,890	12,273
Sublette	28	770	1,202,880	220,184,503	23	656	1,990,670	50,034,086
Sweetwater	104	1,020	7,820,547	85,502,611	95	767	11,220,335	144,264,423
Teton		1						
Uinta	29	196	10,689,327	199,692,397	14	93	6,757,155	43,690,951
Washakie	18	296	2,079,231	3,936,059	20	245	2,448,300	5,241,251
Weston	36	1,575	1,983,560	2,298,568	33	1,219	2,280,303	1,707,190
TOTAL	968	15,806	115,922,003	733,210,238	765	12,648	126,361,962	450,553,045

[1]Thousand cubic feet

cases, the production changes are tied to changes in production from one or more large, often old, fields within a county. In 1987, the largest 25 oil fields in Wyoming (Table 4) produced 55.1 percent of the State's total oil for that year.

For 1987, Sublette, Uinta, Sweetwater, Carbon, and Fremont Counties were the top five gas producers (Table 3). Sublette and Uinta Counties produced over 57 percent of the total gas from the State. Most of the gas production from Uinta County came from Whitney Canyon-Carter Creek, Painter Reservoir, and Ryckman Creek Fields (Figure 4) in the Overthrust Belt. Most of the natural gas from Sublette County and a good share of the natural gas from Sweetwater County was produced from fields on the Moxa arch. Fogarty Creek Field in Sublette County produced over 56 percent of that county's gas. Most of the decline in gas production in Sweetwater County between 1980 and 1987 was the result of decreased production from Table Rock, Wild Rose, and Desert Springs Fields. These three fields and Brady Field produced 57 percent of the gas from Sweetwater County (Figure 4). Nearly two-thirds of the gas produced in Carbon County came from Echo Springs and Standard Draw Fields (Figure 4). Madden and Beaver Creek Fields (Figure 4) produced nearly three-fourths of the natural gas from Fremont County. Except for Fremont County, the top five gas-producing counties are all in the Overthrust Belt and Greater Green River Basin; together the top five counties accounted for 80.9 percent of the State's total gas production. As with oil production, most of the gas produced in the State comes from large fields. In 1987, the 25 largest gas fields (Table 5) accounted for 76.3 percent of the total natural gas produced in Wyoming.

Production by company

Of the nearly 600 oil-and-gas-producing companies operating in Wyoming, the 10 largest gas producers account for 80 percent of the natural gas production (Table 6) and the 10 largest oil producers account for 65 percent of the oil production (Table 7). Although these top 10 oil and gas producers are mainly major oil and gas companies, the smaller independent companies

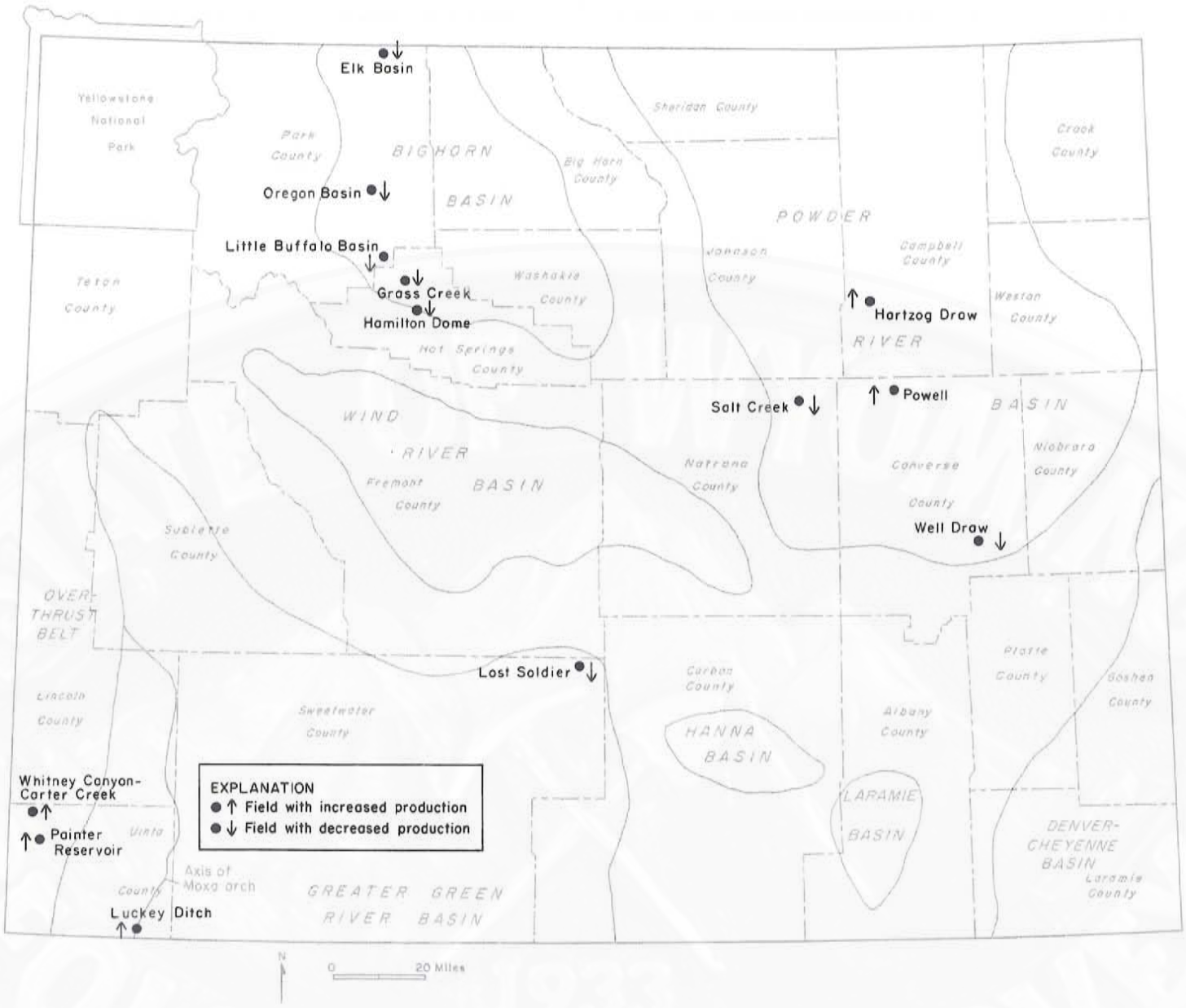

Figure 3. Fields responsible for most of the increases or decreases in total Wyoming oil production since 1980.

produce a large part of the natural gas and oil. Union Pacific Resources, Woods Petroleum, Terra Resources, HPC, and Maxus were the five largest independent oil producers in Wyoming in 1987; they produced over 12 million barrels. Union Pacific Resources, Enron Oil and Gas, Woods Petroleum, Mountain Fuel Supply, and Natural Gas Corporation of California were the five largest independent natural gas producers in Wyoming in 1987; and they produced nearly 97 billion cubic feet.

When the 10 largest oil and gas producers of 1987 are compared to the 10 largest in 1980, several major changes are evident. Chevron moved from fifth to third largest among oil producers and from fifth to third largest among gas producers, mainly because of the company's success in the Overthrust Belt. Chevron has a large share of production from the giant Whitney Canyon-Carter Creek Field. Exxon moved from forty-second place to first place in natural gas production with the completion of the Shute Creek gas processing plant, which processes gas from the Lake Ridge, Fogarty Creek, and Graphite units. Exxon produced over 190 billion cubic feet of gas; however, almost 66 percent of that total was carbon dioxide, while only about 22 percent was methane. Amoco, Marathon, and Conoco operate several large, old, declining oil fields in Wyoming

Table 4. The top 25 oil fields in Wyoming based on 1987 production (Wyoming Oil and Gas Conservation Commission, 1988a).

Name	Year discovered	1987 Production (barrels)	Cumulative production through 1987 (barrels)
Oregon Basin	1912	9,086,649	379,197,148
Hartzog Draw	1976	6,829,163	59,819,299
Salt Creek	1889	4,982,911	621,480,774
Painter Reservoir East[1]	1977	3,491,415	3,491,415
Wertz	1921	3,172,664	95,843,702
Hamilton Dome	1918	2,944,580	227,329,824
Elk Basin	1915	2,872,268	429,009,700
Little Buffalo Basin	1914	2,862,738	115,774,534
Brady	1973	2,725,373	52,982,741
Garland	1906	2,601,900	160,116,498
Powell	1954	2,443,335	16,904,165
Grass Creek	1914	2,426,463	182,487,226
Lost Soldier	1916	2,311,582	207,707,459
Pitchfork	1930	1,961,699	33,077,551
Painter Reservoir[1]	1977	1,910,939	43,053,775
Whitney Canyon - Carter Creek	1978	1,732,484	7,380,469
Frannie	1928	1,287,598	111,172,264
Luckey Ditch	1985	1,253,525	2,119,764
Byron	1918	1,243,343	119,391,917
Winkleman	1917	1,156,005	85,369,629
Teapot Dome Naval Reserve	1922	1,095,793	19,161,016
Ryckman Creek	1976	987,191	16,111,729
Scott	1979	923,473	10,776,760
Cottonwood Creek	1953	828,244	52,035,954
Steamboat Butte	1943	720,001	84,934,238
TOTAL		63,851,336	3,136,729,551

[1] Before 1987, production for Painter Reservoir and Painter Reservoir East Fields was combined under Painter Reservoir.

and the percentages of total oil production in the State from those companies all dropped between 1980 and 1987. Cities Service moved from eighth largest oil producer in 1980 to fourth largest oil producer in 1987. The increase was almost entirely the result of production from Hartzog Draw Field, which is operated by Cities Service. Amoco has retained its first place in oil production through all eight years.

Exploration

From 1980 through 1985, high prices fostered an oil and gas drilling boom in the State (**Table 8**). During this period, average Wyoming oil prices were above $20 per barrel and averaged as high as $32.53 per barrel in 1981 (**Figure 5**). This very high average oil price and an $.85 per MCF increase in average gas prices to $2.77 per MCF in 1981 were responsible for a record 2,062 well completions in 1982 in Wyoming (664 of these wells were exploratory wells, see **Table 8**).

Even though gas prices stayed relatively high through 1985 (**Figure 6**), emphasis shifted away from gas exploration as early as 1983 because of a growing oversupply of natural gas in the United States ("gas-bubble"). Exploratory gas discoveries declined dramatically in 1986 and 1987 from the levels of 1981 and 1982 (**Table 8**). Whitney Canyon-Carter Creek Field came on stream in 1983 when two gas processing plants with a combined capacity of 400 million cubic feet of gas per day were completed to serve the field. Natural gas production from fields in the Overthrust Belt reached 168.7 billion cubic feet in 1983, nearly one-third of the State's total production that year. This tremendous volume of production from the Overthrust Belt satisfied most of the demand for Wyoming's natural gas that existed before 1983. Although there was a natural gas production increase in Wyoming in 1984, most of the increase once again came from Overthrust Belt fields, with total production of 195 billion cubic feet. Statewide production leveled off between 1984 and 1986 (**Figure 2**), and the number of exploratory wells also decreased from pre-1983 levels, especially in the gas-producing Green River Basin.

Of the 4,028 exploratory wells drilled in Wyoming from 1980 through 1987, 2,690 (66.8 percent) were drilled in the Powder River Basin. During 1984 through 1987, when exploration for gas became less profitable, 1,481 (76.5 percent) of the 1,937 exploratory wells drilled in the State were completed in the Powder River Basin where production is predominately oil.

Important new field discoveries

In 1980, the most important new field discovery in terms of production was Henry Field on the southern end of the Moxa arch in the Greater Green River Basin (**Figure 7**). Between 1980 and the end of 1987, production from this field was 2,125,521 barrels of oil and 23,790,696 MCF of gas from the Dakota Formation. This is 23.7 percent of the total oil and 76.9 percent of the total natural gas produced thus far from new fields discovered in 1980.

Edsel, a Minnelusa Formation discovery in the Powder River Basin, was the most important oil field discovered in 1981. Production was 3,170,635 barrels of

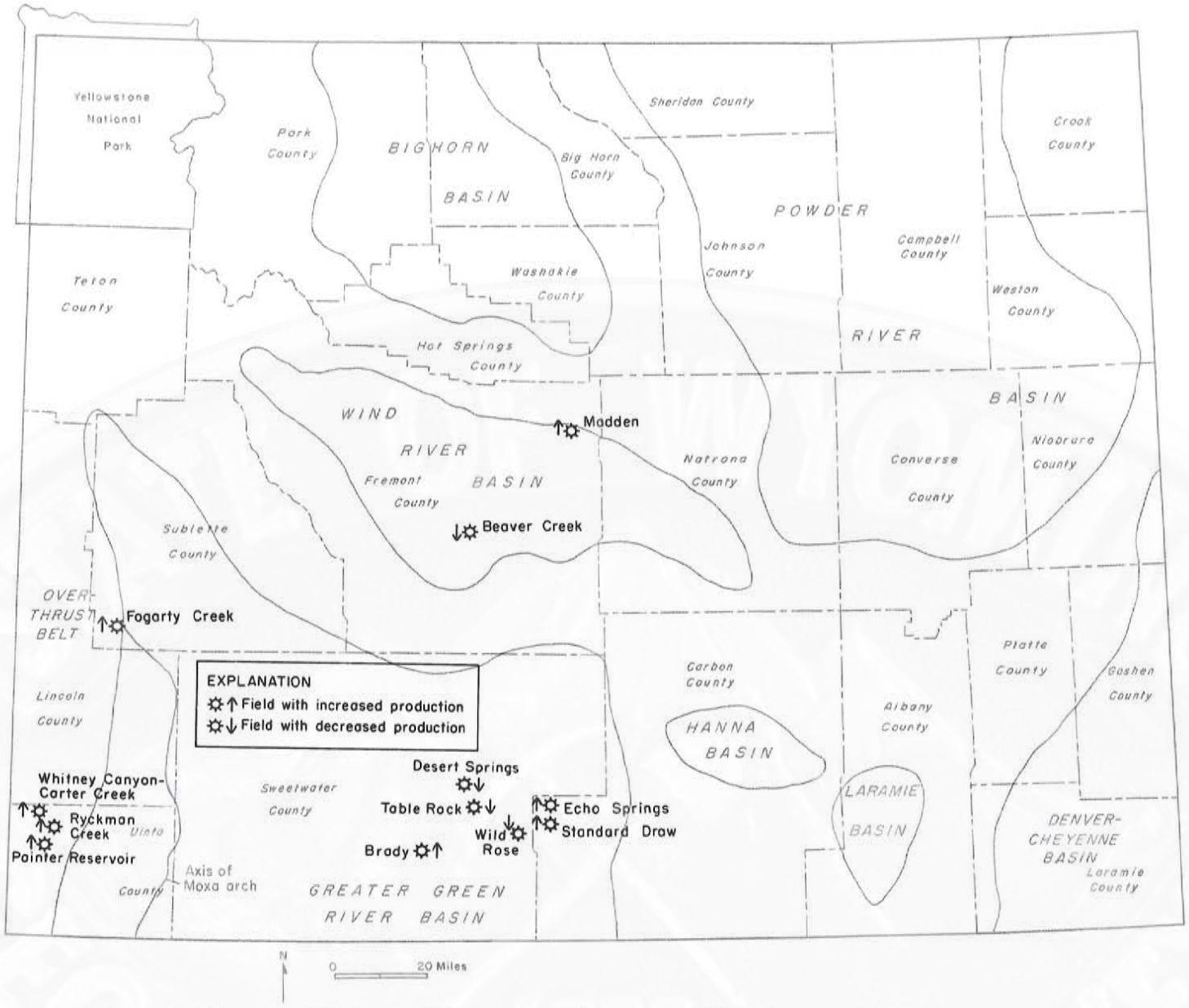

Figure 4. Fields responsible for most of the increases or decreases in total Wyoming natural gas production since 1980.

oil through 1987, which was 29.6 percent of the total oil produced from new field discoveries made in 1981. Other important discoveries included Road Hollow, a Bighorn Dolomite discovery in the Overthrust Belt; Sand Dunes, a Dakota Formation, Muddy Sandstone, and Frontier Formation discovery in the Powder River Basin; and School Creek, a Muddy Sandstone and Turner Sandstone discovery in the Powder River Basin. Production from these three discoveries (**Figure 7**) has been 3,356,134 barrels of oil/condensate and 31,483,820 MCF of natural gas, which was 31.3 percent of the oil/condensate and 32.0 percent of the gas produced from 1981 through 1987 from new field discoveries made in 1981. In addition, Lake Ridge Field in the Overthrust Belt (**Figure 7**) was discovered in 1981. This is one of three fields that supply Exxon's Shute Creek plant with carbon dioxide rich gas. Lake Ridge Field has produced 57,266,187 MCF of natural gas through 1987, which is 58.1 percent of the gas produced by new fields discovered in 1981; however, about 38 million MCF are carbon dioxide.

Several significant new field discoveries were made in 1982, thanks to the completion of a high number of exploration wells (**Table 8**). Amos Draw and Felix Fields were both Muddy Sandstone discoveries in the Powder River Basin; Anschutz Ranch East Field was completed as a Bighorn Dolomite and Nugget Sandstone discovery in the Overthrust Belt; Finley Draw Field was a Powder River Basin discovery completed in the Frontier Forma-

Table 5. The top 25 natural gas fields in Wyoming based on 1987 production (Wyoming Oil and Gas Conservation Commission, 1988a).

Name	Year discovered	1987 Production (MCF)[1]	Cumulative production through 1987 (MCF)[1]
Fogarty Creek[2]	1976	111,625,772	160,152,608
Whitney Canyon - Carter Creek	1978	99,987,425	491,514,275
Lake Ridge[2]	1981	53,461,941	57,266,187
Painter Reservoir[3]	1977	34,556,317	318,962,138
LaBarge	1925	25,648,090	243,329,565
Painter Reservoir East[3]	1977	24,134,974	24,134,974
Brady	1973	22,455,215	263,042,308
Madden	1969	21,448,856	253,193,179
Powell	1954	17,397,582	77,907,493
Ryckman Creek	1976	17,241,015	102,615,735
Clear Creek	1979	16,148,254	88,329,721
Echo Springs	1976	15,437,832	129,060,179
Standard Draw	1979	14,920,427	88,370,958
Table Rock	1946	14,235,648	414,509,389
Bruff	1974	9,541,900	102,273,383
Beaver Creek	1938	8,768,756	553,371,142
Wild Rose	1975	7,633,542	68,502,984
Amos Draw	1982	7,038,038	33,978,734
Green River Bend	1958	6,506,014	180,008,890
Church Buttes	1956	6,462,245	346,130,838
Tip Top	1928	5,603,179	327,332,099
Luckey Ditch	1985	5,434,437	9,871,072
Bird Canyon	1971	5,300,826	36,639,425
Fontenelle	1974	4,543,967	43,698,949
Grieve	1954	4,186,355	93,305,742
TOTAL		559,718,607[4]	4,507,499,967[5]

[1] Thousand cubic feet
[2] Approximately two-thirds of production from this field is carbon dioxide
[3] Before 1987, production from Painter Reservoir and Painter Reservoir East Fields was combined under Painter Reservoir.
[4] Approximately 110,000,000 MCF are carbon dioxide.
[5] Approximately 145,000,000 MCF are carbon dioxide.

Table 6. The 10 largest natural gas producers in Wyoming for 1987 (Wyoming Oil and Gas Conservation Commission, 1988b).

Producer	Production (MCF)[1]	Percent of Wyoming production
Exxon Corporation	190,005,937	25.91
Amoco Production Company	134,940,998	18.40
Chevron, USA, Incorporated	124,074,165	16.92
Union Pacific Resources[2]	30,946,212	4.22
Enron Oil and Gas[3]	23,296,950	3.18
BHP Petroleum Company Incorporated	20,836,445	2.84
Woods Petroleum Corporation	19,631,902	2.68
Texaco, Incorporated	17,917,045	2.44
Mountain Fuel Supply Company	16,154,642	2.20
Sun Exploration and Production	9,900,510	1.35
TOTAL	587,704,806	80.14

[1] Thousand cubic feet
[2] Formerly Champlin Petroleum Corporation.
[3] Formerly Belnorth Petroleum Corporation.

Table 7. The 10 largest oil producers in Wyoming for 1987 (Wyoming Oil and Gas Conservation Commission, 1988b).

Producer	Production in barrels	Percent of Wyoming production
Amoco Production Company	23,533,652	20.30
Marathon Oil Company	18,647,218	16.09
Chevron, USA, Incorporated	7,979,335	6.88
Cities Service Oil & Gas Corporation	7,333,425	6.33
Conoco, Incorporated	4,686,788	4.04
Union Pacific Resources[1]	3,402,551	2.94
Woods Petroleum Corporation	3,310,543	2.86
Atlantic Richfield Company	2,510,535	2.17
Texaco, Incorporated	2,341,749	2.02
Terra Resources, Incorporated	2,102,301	1.81
TOTAL	75,848,097	65.44

[1] Formerly Champlin Petroleum Corporation.

tion and Shannon Sandstone Member of the Cody Shale; and Long Butte Field was completed in the Cody Shale, Mesaverde Formation, and the Shannon Sandstone in the Wind River Basin (**Figure 7**). These five new fields accounted for 5,230,987 barrels of oil/condensate and 107,563,811 MCF of natural gas. This is 43.5 percent of the oil/condensate and 87.9 percent of the natural gas produced in the 1982 through 1987 period from new fields discovered in 1982.

Andy, a Muddy Sandstone discovery in the Powder River Basin (**Figure 7**), was the only discovery of any significance in 1983; this was a very poor year for wildcat discoveries. Andy has accounted for 748,588 barrels of oil/condensate and 10,992,846 MCF of gas from 1983 through 1987, which was 29.5 percent of the oil/condensate and 56.4 percent of the natural gas produced from new fields discovered in 1983.

1984 was one of the best years in terms of quality oil/condensate discoveries. Even though no single discovery stands out, 10 fields discovered that year have all produced over 200,000 barrels. The most prolific has been Thorson Field (**Figure 7**), a Minnelusa Formation discovery in the Powder River Basin that has accounted for 1,615,184 barrels of oil. This is 17.7 percent of all oil produced from 1984 through 1987 from new fields discovered in 1984. Production from two gas discoveries in the Greater Green River Basin, Dripping Rock Field, a Mesaverde Formation discovery, and Hogsback South Field (**Figure 7**), a Frontier Formation and Muddy Sandstone discovery, totaled 8,492,084 MCF of natural gas, which is 55.9 percent of all gas produced in 1984 through 1987 from 1984 discoveries.

By far the most significant discovery of 1985 was Luckey Ditch (**Figure 7**), a Dakota Formation field on

Table 8. Wyoming completion summary for exploration wells, 1980 through 1987 (Teselle and others, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988).

		Powder River Basin	Green River Basin	Bighorn Basin	Overthrust Belt	Wind River Basin	Denver Basin	Laramie and Hanna Basins	Total
1980	Oil	35	3	3	7	1	0	1	50
	Gas	4	38	2	3	3	0	2	52
	Dry	188	44	23	7	15	13	11	311
	Total	227	85	28	27	19	13	14	413
	Success (%)	17.2	48.2	17.9	37.0	21.1	0.0	21.4	24.7
1981	Oil	59	5	6	1	2	4	3	80
	Gas	1	33	2	4	1	0	0	41
	Dry	289	46	27	29	20	19	24	454
	Total	349	84	35	34	23	23	27	575
	Success (%)	17.2	45.2	22.9	14.7	13.0	17.4	11.1	21.0
1982	Oil	78	4	6	5	3	7	4	107
	Gas	1	38	4	9	4	0	4	60
	Dry	284	37	31	60	30	34	21	497
	Total	363	79	41	74	37	41	29	664
	Success (%)	21.8	53.2	24.4	18.9	18.9	17.1	27.6	25.2
1983	Oil	45	0	4	0	0	3	0	52
	Gas	2	14	2	4	1	0	2	25
	Dry	224	25	28	36	19	17	13	362
	Total	271	39	34	40	20	20	5	439
	Success (%)	17.3	35.9	21.4	10.0	5.0	15.0	13.3	17.5
1984	Oil	52	2	1	0	4	10	0	69
	Gas	3	5	0	1	3	0	0	12
	Dry	310	9	57	9	26	12	7	430
	Total	365	16	58	10	33	22	7	511
	Success (%)	15.1	48.2	1.7	10.0	21.2	45.5	0.0	15.9
1985	Oil	84	2	1	4	0	7	0	98
	Gas	0	6	2	6	2	0	0	16
	Dry	431	21	33	27	23	23	0	558
	Total	515	29	36	37	25	30	0	672
	Success (%)	16.3	27.6	8.3	27.0	8.0	23.3	0.0	17.0
1986	Oil	46	1	4	4	0	1	0	56
	Gas	1	7	1	5	5	0	0	19
	Dry	277	17	11	12	14	12	4	347
	Total	324	25	16	21	19	13	4	422
	Success (%)	14.5	32.0	31.3	42.9	26.3	7.7	0.0	17.8
1987	Oil	50	1	3	0	1	0	0	55
	Gas	0	5	0	0	2	0	0	7
	Dry	227	10	6	5	10	9	3	270
	Total	277	16	9	5	13	9	3	332
	Success (%)	18.1	37.5	33.3	0.0	23.1	0.0	0.0	18.7

the southern end of the Moxa arch in the Greater Green River Basin. From 1985 through 1987, production from this field totaled 2,119,764 barrels of oil/condensate and 9,871,072 MCF of natural gas. This was 25.3 percent of the oil/condensate and 73.5 percent of the gas produced from 1985 through 1987 from new fields discovered in 1985. Luckey Ditch Field will account for around 2 million barrels of oil/condensate and over 8 million MCF of natural gas in 1988. Sun Exploration and Production, the operator of Luckey Ditch, has estimated recoverable reserves of at least 30 million barrels of oil equivalent for the field. This makes Luckey Ditch the most impor-

tant recent discovery in the United States. Other oil fields discovered in 1985, which will more than likely all account for over 1 million barrels of production over their lifetimes, are Pierce, Shippy, and Terrace Fields (**Figure 7**). All these are Minnelusa discoveries in the Powder River Basin.

Figure 5. Average price for Wyoming crude oil, 1980-1988 (U.S. Department of Energy, 1989).

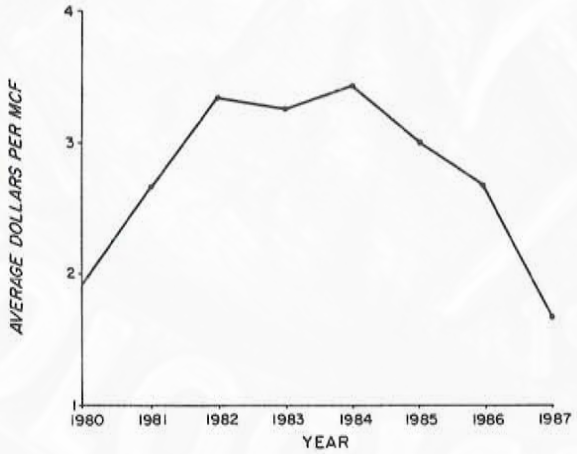

Figure 6. Average price for Wyoming natural gas, 1980-1987 (U.S. Department of Energy, 1988a).

Hawk Point Field (**Figure 7**), a Minnelusa Formation discovery in the Powder River Basin, may be the best discovery of 1986 (see DeBruin, 1989). Production in 1986 and 1987 from this field was 800,979 barrels of oil, which was 38.4 percent of all oil produced by new fields discovered in 1986. Raptor Field (**Figure 7**), a significant carbon dioxide discovery by Amoco in the Greater Green River Basin, flowed over 13,000 MCF of 95 percent carbon dioxide per day. This field could be developed later to supply carbon dioxide for enhanced oil recovery at several projects planned by Amoco.

Alpha Field (**Figure 7**), a Minnelusa discovery in the Powder River Basin, is one of the best discoveries of 1987. Production in 1987 was 324,152 barrels of oil even though production did not begin until May, 1987. Eight wells are currently producing a total of over 1,100 barrels of oil per day. Sun Ranch Field in the Wind River Basin (**Figure 7**), also shows promise of being an excellent producer. Eight wells have now been completed in the Muddy Sandstone. However, in November, 1988, the Wyoming Oil and Gas Conservation Commission ordered production from the field shut in until a pressure maintenance unit is formed. Production should resume in the summer of 1989. As many as 12 wells may be required to fully develop the field and reserves will be several million barrels.

Whiskey Springs Field (**Figure 7**) near Luckey Ditch Field produced 148,166 barrels of oil and 1,476,929 MCF of natural gas from the Dakota Formation in 1987. Alpha, Sun Ranch, and Whiskey Springs Fields produced 558,441 barrels of oil in 1987 and accounted for 54 percent of the oil produced by new fields discovered in 1987. Whiskey Springs produced 90.5 percent of the natural gas by new fields discovered in 1987.

In all, new fields discovered from 1980 to 1987 have produced almost 55 million barrels of oil and over 315 billion cubic feet of gas (**Table 9**).

Methane resources and reserves

Resources

The Potential Gas Committee (1987) estimated most likely undiscovered recoverable resources and discovered unconfirmed resources of natural gas in Wyoming basins (which extend somewhat into surrounding states) at 79.1 trillion cubic feet (**Table 10**). Of the 79.1 trillion cubic feet (tcf), 42.4 tcf (53.6 percent) are assigned to the Greater Green River Basin. Estimates by the U.S. Geological Survey (*in* Dolton and others, 1981) and by Barlow and Doelger (1983) are also for undiscovered recoverable resources (**Table 10**). The Barlow and Doelger estimate is for Wyoming only, while the U.S. Geological Survey estimate covers the same area as the Potential Gas Committee estimate.

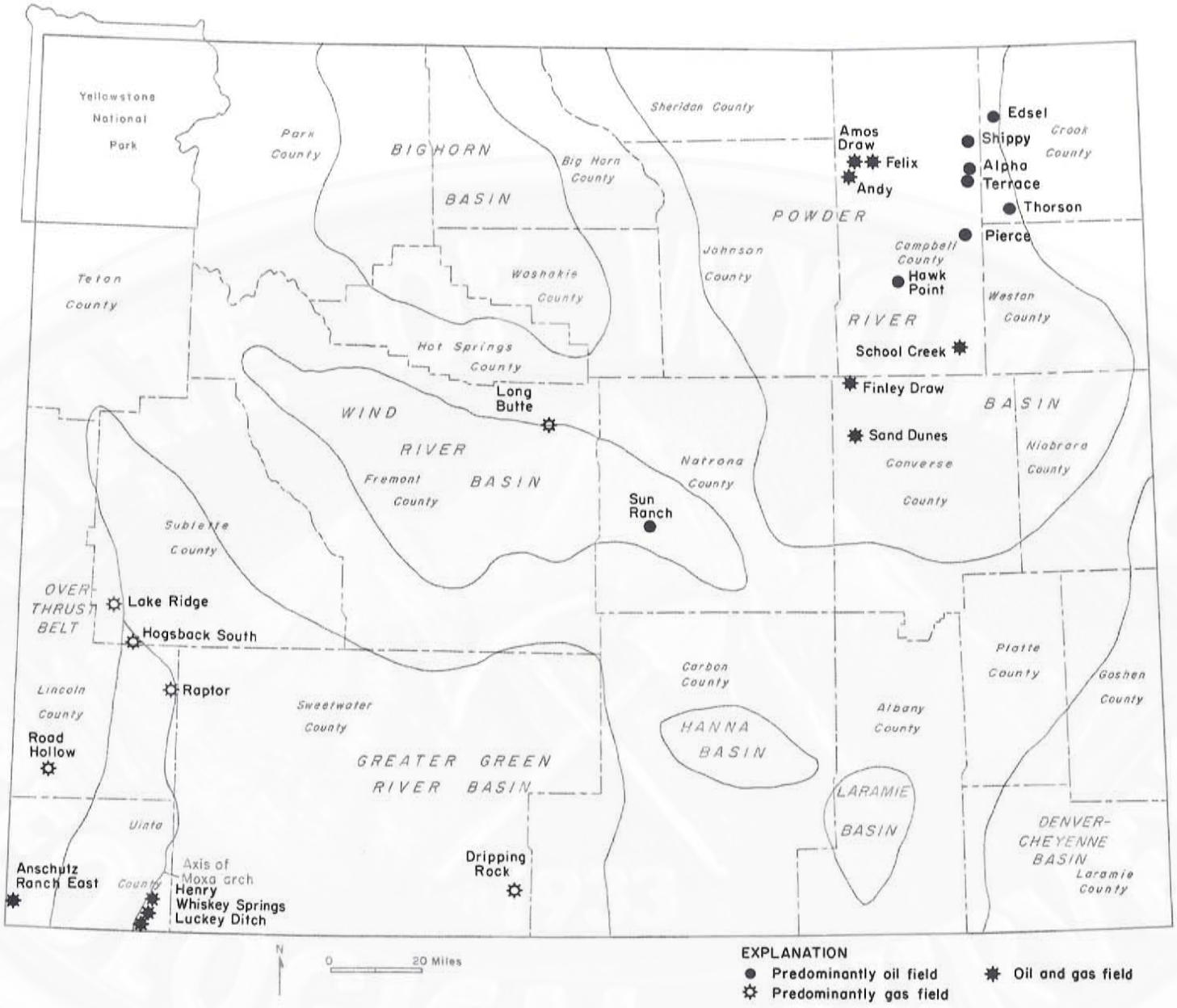

Figure 7. Important new field discoveries, 1980-1987.

Allowing for overlap of Wyoming's basins into surrounding states and for the inclusion of discovered unconfirmed resources in the Potential Gas Committee estimate, the Barlow and Doelger estimate of 58 trillion cubic feet of undiscovered recoverable resources of natural gas for Wyoming compares favorably with the Potential Gas Committee estimate and is probably the best estimate for the State. The U.S. Geological Survey estimate is probably too high because it was made during the time when natural gas exploration and prices were very high. Since that time, exploration results in the Overthrust Belt have been disappointing. The U.S. Geological Survey is in the process of making new estimates of undiscovered recoverable crude oil and natural gas (Mast and others, 1988). The preliminary estimates for the United States showed very large declines from

Table 9. Incremental contribution to production by new field discoveries, 1980-1987 (Wyoming Oil and Gas Conservation Commission, 1981b, 1982, 1983, 1984, 1985, 1986, 1987, 1988a).

Discovery Year		Production year 1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
1980	Oil[1]	218,734	962,079	1,250,300	1,556,789	1,553,543	1,196,954	1,056,102	1,186,221	8,980,722
	Gas[2]	564,014	1,033,141	3,816,967	6,188,093	5,537,162	5,290,194	4,271,872	4,222,021	30,923,464
1981	Oil		492,978	1,384,855	1,264,867	1,521,619	2,432,132	1,963,266	1,669,653	10,729,370
	Gas		1,057,323	2,770,217	4,011,653	8,875,248	10,813,619	11,587,767[3]	59,331,798[4]	98,447,625
1982	Oil			469,925	1,531,824	2,636,155	3,270,390	2,414,458	1,710,730	12,033,482
	Gas			10,261,071	14,551,550	20,624,501	30,362,765	27,391,728	28,633,119	131,824,734
1983	Oil				437,212	633,340	592,394	461,273	409,768	2,533,987
	Gas				1,940,361	4,486,649	3,988,632	4,927,743	4,134,519	19,477,904
1984	Oil					1,600,882	3,585,707	2,144,278	1,808,360	9,139,227
	Gas					2,027,030	4,109,084	4,430,522	4,475,647	15,042,283
1985	Oil						1,505,414	3,081,233	3,801,203	8,387,850
	Gas						1,025,652	4,909,470	7,479,969	13,415,091
1986	Oil							771,188	1,317,237	2,088,425
	Gas							1,744,013[5]	3,148,052[6]	4,892,065
1987	Oil								1,092,115	1,092,115
	Gas								1,636,648	1,636,648
								TOTAL	OIL	54,985,178
									GAS	315,659,814[7]

[1] Oil production is in barrels.
[2] Gas production is in MCF (thousand cubic feet).
[3] Approximately 2,500,000 MCF are carbon dioxide produced at Lake Ridge Field.
[4] Approximately 36,000,000 MCF are carbon dioxide produced at Lake Ridge Field.
[5] Approximately 700,000 MCF are carbon dioxide produced at Graphite Field.
[6] Approximately 1,600,000 MCF are carbon dioxide produced at Graphite Field.
[7] Approximately 40,800,000 MCF are carbon dioxide.

the 1980 estimates, which means the estimates for Wyoming will also show large declines.

Methane related to coal deposits is a somewhat unconventional natural gas resource in Wyoming. Estimates of in-place coalbed methane in the Powder River, Wind River, and Greater Green River Basins range from 6.6 to 72.5 trillion cubic feet (Potential Gas Committee, 1987). The variation in these estimates reflects the uncertainties of the assumptions used in making any estimate of Wyoming's coalbed methane resources. If 50 percent of the estimated 6.6 to 72.5 trillion cubic feet of coalbed methane in place in the three Wyoming basins could be recovered by future drilling (50 percent is the figure used by the Potential Gas Committee 1987), between 3.3 and 36.2 trillion cubic feet of these resources could be recovered. Even the lower estimate represents a significant contribution to the future gas supply of Wyoming.

Reserves

According to estimates by the U.S. Department of Energy (1980), at the end of 1979 Wyoming had proved reserves of 841 million barrels of crude oil, 285 million barrels of natural gas liquids, and 7.834 trillion cubic feet of natural gas (Table 11). The State also had indicated additional reserves of 40 million barrels of crude oil. Proved reserves are those volumes of hydrocarbons that geological and engineering data demonstrate with reasonable certainty are recoverable in the future under existing economic and operating conditions (U.S. Department of Energy, 1980). Indicated additional crude

Table 10. Estimated undiscovered recoverable resources of crude oil and natural gas in Wyoming basins.

Estimated by	Year estimated	Crude oil[1]	Combustible natural gas[2]
Potential Gas Committee[3] (1987)	1986	no estimate	79.1
Barlow and Doelger (1983)	1982	7.6	58
U.S. Geological Survey[4] (*in* Dolton and others, 1981)	1980	12.3	84.5

[1] Billions of barrels.
[2] Trillions of cubic feet.
[3] Estimate includes discovered unconfirmed resource and is a total of most likely values.
[4] Estimates are totals of mean values.

oil reserves are quantities of crude oil (other than proved reserves) that may become economically recoverable from known reservoirs through the application of improved recovery techniques using current technology (U.S. Department of Energy, 1980). Improved recovery techniques could include waterfloods, polymer-augmented waterfloods, gas injection, or pressure maintenance projects.

Estimates for the end of 1987 (U.S. Department of Energy, 1988b) show increases in both proved reserves of crude oil (854 million barrels) and natural gas (10.572 trillion cubic feet) (**Table 11**). For confidentiality purposes, the U.S. Department of Energy combined Wyoming's and Utah's proved reserves of 924 million barrels of natural gas liquids. The author assigned proved reserves of 702 million barrels of natural gas liquids to Wyoming and the remainder to Utah (based on the 1986 percentage breakdown by the Interstate Oil Compact Commission, 1987). At the end of 1987, Wyoming ranked fourth in the Nation in proved crude oil reserves, fourth in proved natural gas liquids reserves, and seventh in proved natural gas reserves (**Table 12**). The State also tied for ninth place in indicated additional reserves of crude oil, with 27 million barrels (**Table 13**).

Table 11. Estimated proved reserves of oil, natural gas, and natural gas liquids and indicated additional reserves of crude oil for Wyoming from the end of 1979 to the end of 1987 (modified from U.S. Department of Energy, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988a).

Date	Proved reserves			Indicated additional crude oil reserves[1]	Proved reserves natural gas[2]
	Crude oil[1]	Natural gas liquids[1]	Total liquids[1]		
1979	.841	.285	1.126	.040	7.834
1980	.928	.341	1.269	.028	9.413
1981	.840	.394	1.224	.053	9.659
1982	.856	.476	1.332	.058	10.155
1983	.957	.568	1.525	.061	10.728
1984	.954	.602	1.556	.071	11.014
1985	.951	.664	1.615	.018	11.229
1986	.849	.722	1.571	.126	10.393
1987	.854	.702[3]	1.556	.027	10.572

[1] Billions of barrels
[2] Trillions of cubic feet
[3] Value estimated by author

There was a drop in proved crude oil reserves from 1985 to 1986 of 102 million barrels (**Table 11**) because the price of crude oil was too low to produce higher cost reserves. Most of the decrease in proved reserves in 1986 is accounted for by the relatively small number of development wells drilled in 1986 (**Table 14**); the abandonment of over 1,200 stripper wells (Petroleum Association of Wyoming, 1988) and their sizable reserves; and the low oil prices in 1986, which caused many companies to reevaluate the quantity of reserves that could be economically recovered. The large drop in proved reserves of crude oil and natural gas in 1986 was significant (**Figures 8** and **9**).

Table 12. Wyoming's relative ranking at the end of 1987 among the 10 states with the largest proved reserves of crude oil, natural gas liquids, and natural gas (U.S. Department of Energy, 1988b).

State	Crude Oil[1]	State	Natural gas liquids[1]	State	Natural gas[2]
Alaska	7.378	Texas[3]	2.822	Texas[3]	42.192
Texas[3]	7.112	Oklahoma	.781	Alaska	33.715
California[3]	4.709	New Mexico	.771	Oklahoma	17.703
Wyoming	.854	Wyoming[4]	.702	Louisiana[3]	12.852
Louisiana[3]	.807	Louisiana[3]	.525	New Mexico	12.621
Oklahoma	.788	Kansas	.462	Kansas	11.089
New Mexico	.654	Alaska	.418	Wyoming	10.572
Kansas	.357	Utah[4]	.222	California[3]	3.893
Utah	.284	Alabama	.166	Colorado	3.131
Montana	.246	Colorado	.166	West Virginia	2.360

[1] Billions of barrels
[2] Trillions of cubic feet
[3] Does not include Federal offshore
[4] Wyoming's and Utah's reserves of natural gas liquids are combined by U.S. Department of Energy (1988b). Separate figures shown here are estimated by the author.

Table 13. Wyoming's relative ranking at the end of 1987 among the 10 states with the largest reported indicated additional crude oil reserves (U.S. Department of Energy, 1988b).

State	Indicated additional reserves[1]
California	1.491
Texas	1.028
Alaska	.565
New Mexico	.235
Colorado	.067
Oklahoma	.056
Louisiana	.037
North Dakota	.033
Wyoming	.027
Michigan	.027

[1] Billions of barrels

Table 14. Wyoming drilling summary, 1980-1987 (Petroleum Information, 1987; and Teselle and others, 1988).

Year	Exploration wells	Percent successful	Development wells	Percent successful	Total wells	Total footage drilled[1]	Average depth[2]	Average active rotary rigs
1980	413	24.7	995	75.5	1,408	10.8	7,667	155
1981	575	21.0	1,098	75.1	1,673	12.3	7,104	190
1982	664	25.2	1,398	77.9	2,062	15.1	7,183	142
1983	439	17.5	979	79.7	1,418	9.3	6,591	97
1984	511	15.9	997	78.1	1,508	10.7	7,121	117
1985	672	17.0	1,096	74.1	1,768	12.8	7,222	100
1986	422	17.7	626	75.4	1,048	7.3	6,960	38
1987	332	18.7	448	76.1	780	5.1	6,471	40

[1] Millions [2] Feet

The main reason that crude oil reserves gained slightly between 1986 and 1987 was the movement of indicated additional reserves into the proved reserves category. Part of these indicated additional reserves were moved into the proved reserves category when enhanced recovery projects in Wyoming were started. The carbon dioxide project at Wertz Field alone probably added over 15 million barrels to the proved reserves category since initial results were much better than had been anticipated.

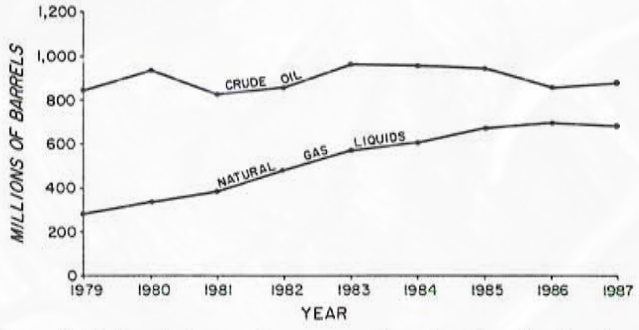

Figure 8. Estimated proved reserves of crude oil and natural gas liquids in Wyoming from the end of 1979 to the end of 1987 (crude oil from U.S. Department of Energy, 1980-1988; natural gas liquids from Interstate Oil Compast Commission, 1987).

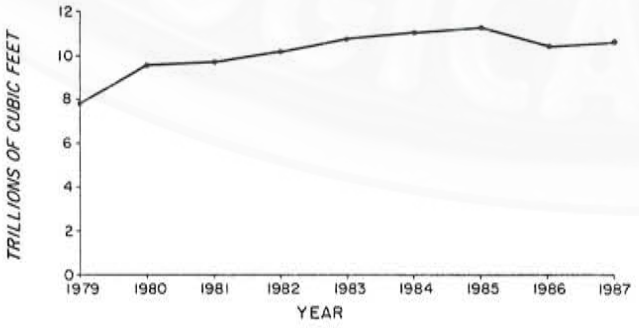

Figure 9. Estimated proved reserves of combustible natural gas in Wyoming for the end of 1979 to the end of 1987 (U.S. Department of Energy, 1980-1988).

From 1986 to 1987, new field discoveries added 6 million barrels to proved reserve totals. This was the highest of any state in the country except Alaska and nearly one-fourth of all onshore new-field oil discovered in the lower 48 states. Wyoming's 1987 total of new field discoveries plus new reservoir discoveries in old fields was 9 million barrels. Wyoming ranked second behind Texas for onshore new field and new reservoir discoveries among producing states in the lower 48 states (U.S. Department of Energy, 1988b).

The small increase in 1987 proved reserves over 1986 proved reserves is an encouraging sign. When 1987 year-end reserves are compared to 1979 year-end reserves (**Table 11**), 1987 reserves are higher for crude oil, natural gas, and natural gas liquids. Wyoming is the only major producing state in the Nation that has increased its proved reserves in all three of these categories over this period (U.S. Department of Energy, 1980 and 1988b; and Interstate Oil Compact Commission, 1987). The largest increases in proved reserves in Wyoming during the 1980s have come in natural gas and natural gas liquids (**Table 11**).

The discovery of giant gas volumes in the Madison Limestone at Madden anticline in the northern Wind River Basin should add at least a trillion cubic feet of natural gas to the State's proved reserves over the next several years (Dunleavy and Gilbertson, 1986). Unfortunately, the Madison Limestone is below 23,000 feet and development wells will each take over a year to drill. The confirmation well for the Madison gas discovery was completed in May, 1988. After treatment with acid, the Madison flowed 38 million cubic feet of gas daily on a one-inch choke.

Refining

At the end of 1980, there were 13 oil refineries operating in the State (**Table 15**). By the end of 1987, only six of these refineries were still operating (**Table 15** and **Figure 10**). The net effect of losing seven refineries has been the loss of 43,990 barrels per day of crude oil refining capacity. Wyoming refineries now have only 79 percent of the refining capacity that they had in 1980. This means that if all six refineries operate at full capacity, they can only refine slightly more than one-half of Wyoming's crude oil production. Since these refineries are not continually running at full capacity, over one-half of Wyoming's crude oil is being shipped to Colorado, Montana, Utah, and several states in the Midwest. For comparison, Wyoming refineries were capable of refining 60 percent of Wyoming's crude oil production in 1980. Incidentally, some Wyoming crude has been shipped out-of-state for refining since the early 1900's.

Table 15. Rated capacities of refineries operating in Wyoming, 1980 and 1987 (Cantrell, 1981; Corbett, 1988).

Location	Operating company	1980 Rated capacity (barrels per calendar day)	1987 Rated capacity (barrels per calendar day)
Casper	Amoco Oil Company	48,000	40,000
Casper	Texaco, Incorporated	21,000	Inactive
Casper	Little America Refining	24,500	24,500
Cheyenne	Husky Oil Company (Frontier Oil and Refining)[1]	28,800	35,000
Cody	Husky Oil Company	11,500	Inactive
Cowley	Sage Creek Refining Company	1,000	Inactive
LaBarge	Mountaineer Refining	500	300
LaBarge	Southwestern Refining	800	Inactive
LaBarge	Silver Eagle Oil, Incorporated	2,000	Inactive
Lusk	C & H Refinery, Incorporated	190	Inactive
Newcastle	Wyoming Refining Company	12,500	12,500
Osage	Glacier Park Company	9,500	Inactive
Sinclair	Sinclair Oil Corporation	49,000	53,000
TOTAL		209,290	165,300

[1] Frontier Oil and Refining purchased the Cheyenne refinery from Husky Oil Company.

Gas processing

Natural gas liquids have become much more valuable in the past few years and the extraction of propane, butane, natural gasoline, and other hydrocarbons from produced natural gas in Wyoming has increased tremendously since 1980. In 1980, there were 42 operating natural gas plants in the State. During 1980, these plants produced 10.5 million barrels of products by processing 299.5 billion cubic feet of natural gas (**Table 16**). In 1987, there were 53 plants operating during all or part of the year (**Figure 11**) and they produced 17.9 million barrels of products by processing 641.3 billion cubic feet of natural gas (**Table 16**).

Nearly 4 million barrels of the increased natural gas liquids production between 1980 and 1987 came from the Whitney Canyon and Carter Creek plants, which were finished late in 1982 and process gas from the giant Whitney Canyon-Carter Creek Field in southwestern Wyoming in the Overthrust Belt. The Opal and Douglas gas plants combined produced over 1.6 million barrels more of natural gas liquids in 1987 than in 1980.

Two of the newer gas processing plants are a 20 million cubic feet per day plant completed by Sun Production in 1987 to service the Luckey Ditch Field and a 45 million cubic feet per day plant completed in May, 1988, by Western Gas Processors to process gas from the Lincoln Road, Swan, and Blue Forest Fields.

By-product sulfur

Elemental sulfur is a valuable by-product from natural gas containing hydrogen sulfide. In 1980, gas processing plants reported sulfur production in Wyoming of over 46,000 tons from plants in Elk Basin and Table Rock (**Table 17**). Production of sulfur increased tremendously in 1983 (**Figure 12**), when the Whitney Canyon and Carter Creek plants began full-time operation. Chevron is transporting the sulfur produced at the Carter Creek plant to their newly completed $300 million fertilizer plant about 5 miles southeast of Rock Springs, where the sulfur is being used in the manufacture of phosphate fertilizers. Production of sulfur increased to almost 1.2 million short tons in 1987 (**Figure 12**) in response to Exxon's Shute Creek gas processing plant coming on-stream late in 1986. Over 97 percent of Wyoming's sulfur was produced at the Whitney Canyon, Carter Creek, and Shute Creek plants in 1987. The freight-on-board (F.O.B.) Gulf Coast price for sulfur in

Figure 10. Locations of refineries operating in Wyoming, showing present capacities of refineries.

late 1987 was $147.50 per ton (Engineering and Mining Journal, 1987), which makes the sale of Wyoming's sulfur production more than a $100 million a year enterprise.

By-product helium

Helium is a valuable light-weight inert gas that is mainly used for breathing mixtures, cryogenics, welding, pressurizing and purging systems, controlled atmospheres, and leak detection. Although helium occurs naturally in the Earth's atmosphere, the cost to extract it with existing technology is prohibitive. Presently, the only commercially produced helium is separated from natural gas, purified, and liquified or compressed for shipment.

The U.S. Bureau of Mines has analyzed 701 samples of natural gas from Wyoming for helium (Moore and Sigler, 1987). Although nearly every analyzed sample showed at least a trace of helium, only a few natural gas fields in the State have enough helium to favor the establishment of a helium extraction plant.

Currently, the only helium production in Wyoming is from Exxon's Shute Creek gas processing plant in

Table 16. Gas intake and hydrocarbon production from gas processing plants operating in Wyoming, 1980 and 1987 (Wyoming Oil and Gas Conservation Commission, 1981b and 1988a).

Plant or field area	County	Plant operator	Gas intake for 1980 (MCF)	Production of hydrocarbons propane-butane-gasoline in 1980 (barrels)	Gas intake for 1987 (MCF)	Production of hydrocarbons propane-butane-gasoline in 1987 (barrels)
Amos Draw	Campbell	Western Gas Processors			8,901,232	355,035
Anschutz Ranch East	Uinta	Amoco Production Company			3,422,484	181,192
Bass Belvoir	Laramie	Liquid Gas Corporation			13,495	1,663
Bairoil (Wertz)[1]	Sweetwater	Amoco Production Company	1,403,898	107,126	106,206	13,881
Beaver Creek	Fremont	Amoco Production Company	12,865,973	276,393	7,303,369	254,941
Beaver Creek-Phosphoria	Fremont	Amoco Production Company	383,283	34,666	2,258,714	57,515
Brady	Sweetwater	Champlin Petroleum Company (Union Pacific Resources)[2]	17,990,072	716,006	21,326,408	622,591
Carter Creek	Uinta	Chevron, U.S.A.			44,473,164	1,032,391
Casper	Natrona	Kansas-Nebraska Natural Gas Company	13,622,549	227,361	14,570,168	131,281
Chivington	Laramie	Elk Energy			10,203	222
Church Buttes	Sweetwater	Mountain Fuel Supply	7,646,023	44,986	7,297,240	13,424
Douglas	Converse	Phillips Petroleum Company	18,897,329	2,204,784	27,178,067	3,152,283
Elk Basin	Park	Amoco Production Company	4,585,968	419,362	3,778,053	437,828
Emigrant Trail	Uinta	Champlin Petroleum Company (Union Pacific Resources)[2]			13,984,439 7,442	311,074 1,193
Exxon Goertz	Laramie	Liquid Gas Corporation				
Flat Top	Converse	Kansas-Nebraska Natural Gas Company	1,270,659	73,190	484,522	30,632
Gillette	Campbell	Atlantic Richfield Company	3,001,257	320,131	2,668,875	372,044
Grieve	Natrona	Sun Oil Company	3,484,719	171,459	4,195,910	167,887
Hartzog Draw	Campbell	Ecology Engineering (Western Gas Processors)[2]	921,515	81,168	8,493,065 163,923	228,797 508
Heart Mountain	Park	Glacier Gas				
Hiland	Washakie	Spectrum Energy, Inc.			456,431	27,607
Hilight	Campbell	McCulloch Oil Corporation (Western Gas Processors)[2]	3,642,234	445,457	5,834,205	350,861
Inexco Plant #1	Converse	Inexco Oil Company	1,307,290	240,603	827,125	126,843
Jamison Prong	Campbell	McCulloch Oil Corporation	472,656	45,365		
LaBarge-Shute Creek	Lincoln	Exxon Corporation			179,125,684	
Lazy "B"	Campbell	CRA, Inc. (Farmland Industries)[2]	913,363	87,382	621,305	71,059
Luckey Ditch	Uinta	Sun Exploration Company			5,799,856	141,163
Manderson	Big Horn	Energy West, Ltd.(Five Mile Petroleum)[2]	208,384	3,266	314,914	4,870
Manning	Converse	Champlin Petroleum Company (Union Pacific Resources)[2]			138,371	6,193
Mikes Draw	Converse	Liquid Energy Corporation	192,602	30,473		
Morton	Converse	Pin Oak Petroleum			507,418	50,943
Moxa Arch	Lincoln	NGL Production Company			1,490,482	1,875
Mule Creek	Niobrara	Western Gas Processors			71,780	3,734
Newcastle	Weston	Western Gas Processors			1,086,251	170,735
N.P.R. #3	Natrona	Lawrence and Allison Associates West			3,767,219	118,293
Oedekoven	Campbell	McCulloch Oil Corporation (Western Gas Processors)[2]	1,300,646	92,213	943,840	34,143
Opal	Lincoln	Northwest Pipeline Corporation	56,802,115	1,318,202	58,286,974	2,058,285
Oregon Basin	Park	Ralston Processing Associates	1,556,102	94,502		
Oregon Basin	Park	Marathon Oil Company			2,278,580	142,304
Painter Complex	Uinta	Amoco Production Company			3,381,687	371,374
Painter Plant	Uinta	Northern Gas Products Company (Enron Oil and Gas Company)	10,071,000	395,696	34,698,436	1,174,279
Painter Reservoir	Uinta	Chevron, USA	13,162,496			
Patrick Draw	Sweetwater	Champlin Petroleum Company (Union Pacific Resources)[2]	7,378,085	517,533	6,565,037	356,360
Patrick Draw	Sweetwater	Coastal Oil and Gas Company	901,390	26,533		
Powell II	Converse	Sun Gas Company (Williston Basin Interstate)[2]	1,854,796	81,752	796,293	28,232
Powell PMU	Converse	Woods Petroleum Company			13,031,013	463,230
Ralston	Park	Husky Oil Company	855,289	11,945		
Rawlins	Carbon	Colorado Interstate Gas Company	59,414,696	884,353	61,637,475	1,089,473
Recluse	Campbell	Natomas North America, Inc.	1,013,351	146,807		
Red Desert	Sweetwater	Cities Service Company	10,498,472	329,698		
Riverton Dome	Fremont	Atlantic Richfield Company	2,785,302	28,158	1,941,845	19,813
Riverton, East	Fremont	Montana-Dakota Utilities Company	101,144			
Rock River	Carbon	Marathon Oil Company	259,322	3,169	46,292	3,096
Rocky Point	Campbell	McCulloch Oil Company	162,993	3,617		
Rozet-Springen (Rozet)[1]	Campbell	Ecology Engineering (Big Horn Fractionation Company)[2]	55,706	86,821		
Ryckman Creek	Uinta	Amoco Production Company	8,756,528	235,477	16,572,310	164,415
Spearhead Ranch	Converse	Quasar Energy, Inc. (Western Gas Processors)[2]	5,584,068	282,114	2,370,520	108,108
Sussex	Johnson	Continental Oil Company	405,160	26,830	146,899	9,357
Table Rock	Sweetwater	Colorado Interstate Gas Company	15,854,529	35,443	4,552,438	2,042
Thunder Basin	Campbell	Big Horn Fractionation Company			91,095	
Thunder Creek	Campbell	Cities Service Company	1,516,529	107,219	152,580	
Wamsutter	Carbon	Amoco Production Company				478,583
Well Draw	Converse	McCulloch Oil Corporation	366,451	33,152		
Whitney Canyon	Uinta	Amoco Production Company			58,399,075	2,761,580
Worland	Washakie	Union Oil Company of California	6,001,791	257,828	4,467,211	215,189
TOTAL			299,467,735	10,528,240	641,337,620	17,920,421

[1] Name of plant in 1987 listed in parentheses where name has changed.

[2] Ownership of plant in 1987 listed in parentheses where ownership has changed or name of company has changed.

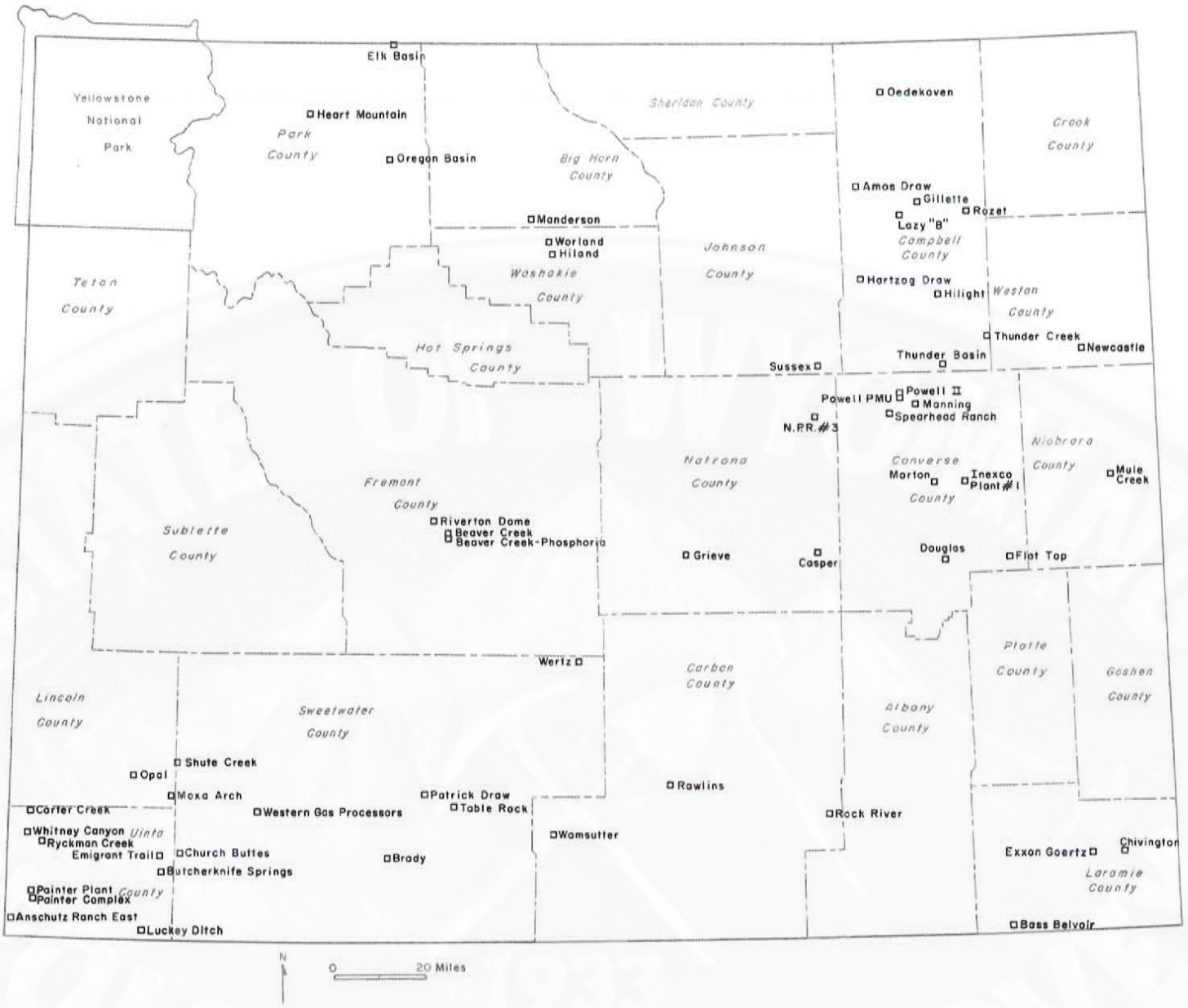

Figure 11. Locations of gas processing plants operating in Wyoming.

southwestern Wyoming (**Figure 13**). Production of helium is around 2.2 million cubic feet per day or about 800 million cubic feet per year. This production represents a significant increase in the world's supply of that element (Hunter and Bryan, 1987). If Exxon's plant runs at capacity throughout its planned 50-year life, over 40 billion cubic feet of helium will be produced there. If demand for carbon dioxide increases (carbon dioxide is the main product from Exxon's plant), there is a strong possibility that the plant's production capacity could be doubled. In that event, helium production could increase to as much as 4.4 million cubic feet per day, 1.6 billion cubic feet per year, and 80 billion cubic feet over the life of the project. The helium processed at Exxon's plant is coming from natural gas produced from the Madison Limestone at Lake Ridge, Fogarty Creek, and Graphite Fields (**Figure 13**). Average helium content of the gas at these fields is 0.5 percent.

Other fields with the potential to produce significant amounts of helium include Dry Piney, Hogsback, Riley Ridge, and Tip Top. All of these fields are located in the vicinity of the fields that are producing helium for Exxon's plant (**Figure 13**). Estimates of recoverable helium in the Madison Limestone are shown in (**Table 18**).

Table 17. Production of by-product sulfur from Wyoming gas processing plants in 1980 and 1987 by plant or field area (modified from Wyoming Oil and Gas Conservation Commission, 1981b and 1988a).

Plant or field area	Plant operator	1980 Production (tons)	1987 Production (tons)
Elk Basin	Amoco Production Company	26,494	21,351
Table Rock	Colorado Interstate Gas Company	20,254	3,678
Beaver Creek-Phosphoria	Amoco Production Company	None	6,650
Carter Creek	Chevron, U.S.A.	None	325,052
Shute Creek	Exxon Corporation	None	430,303
Oregon Basin	Marathon Oil Company	None	1,549
Whitney Canyon	Amoco Production Company	None	404,940
TOTAL		46,748	1,193,523

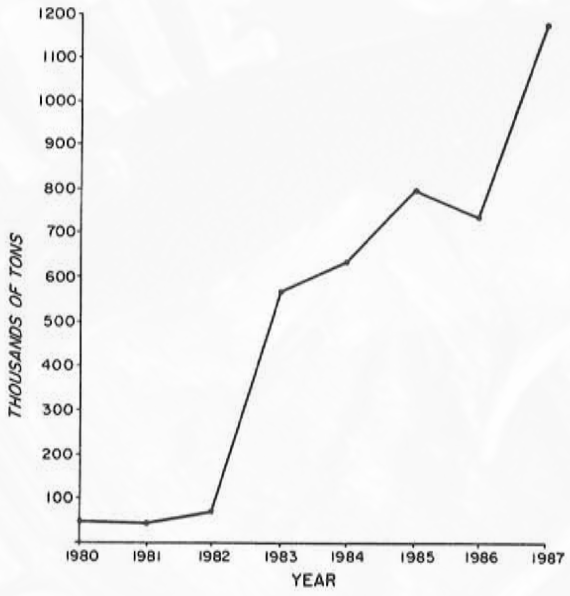

Figure 12. Production of by-product sulfur in Wyoming 1980-1987 (modified from Wyoming Oil and Gas Conservation Commission, 1981-1988). Exxon produced an estimated 70,000 tons of sulfur in 1986 that was not reported to the Oil and Gas Conservation Commission. This production and Exxon's production for 1987 is included in the graph above.

Church Buttes Field in southwestern Wyoming (**Figure 13**) also contains a large amount of helium. Using information from two wells drilled in the field in 1964 and 1967, Carr and Madden (1975) estimated natural gas in the Madison Limestone averages 0.24 percent helium and helium reserves are slightly over 17 billion cubic feet.

These helium reserves in Wyoming total 217 billion cubic feet of helium, more than enough to supply the United States' demand for that element well into the next century.

Carbon dioxide

One of the most significant events of the decade in the Wyoming oil and gas industry was the opening of Exxon's 480-million-cubic-feet-per-day Shute Creek gas processing plant in southwestern Wyoming (**Figure 14**). Plant construction started in May, 1984, and the plant was completed in September, 1986. To date, 24 producing wells in the Madison Limestone in Exxon's Lake Ridge, Fogarty Creek, and Graphite units (**Figure 14**) are supplying natural gas to the Shute Creek plant. The composition of the natural gas averages 66 percent carbon dioxide, 22 percent methane, 7 percent nitrogen, 4.5 percent hydrogen sulfide, and 0.5 percent helium (Hunter and Bryan, 1987). Nineteen wells in the Fogarty Creek unit produced around 124 billion cubic feet of natural gas in 1987 or 69 percent of the total gas supplied to the Exxon plant. Average production per well at Fogarty Creek was nearly 18 million cubic feet of natural gas per day. In 1987, the first full year of operation for the plant, nearly 180 billion cubic feet of natural gas were separated into the various components (Wyoming Oil and Gas Conservation Commission, 1988a). Of the total, nearly 120 billion cubic feet were carbon dioxide.

While the solid form of carbon dioxide is dry ice and its gaseous form is most commonly associated with the fizz in soft drinks, the significance of carbon dioxide for Wyoming is its use in enhanced oil recovery projects. Presently, Exxon is supplying carbon dioxide to Chevron for an enhanced oil recovery project at Rangely Field in Colorado and to Amoco for a project at Wertz Field north of Rawlins. Amoco will also begin injection of carbon dioxide at its nearby Lost Soldier Field early in 1989.

The three Exxon units producing carbon dioxide-rich gas comprise only 40,000 acres out of a total of 160,000 acres considered productive for this type of gas from the Madison Limestone. Other units include Riley Ridge, Dry Piney, Tip Top, and Hogsback (**Figure 14**). Part of the acreage has not yet been unitized.

There is some controversy over how much carbon dioxide exists in this area. Unpublished estimates of total resources are in the neighborhood of 115 trillion cubic feet while the National Petroleum Council (1984) estimates 20 to 25 trillion cubic feet. The U.S. Bureau of Land Management and others (1983) estimated recoverable reserves for the area (**Table 19**) of over 13 trillion cubic feet.

Amoco discovered Raptor Field (**Figure 14**) in 1986. Initial potential of the discovery well was 13 million cu-

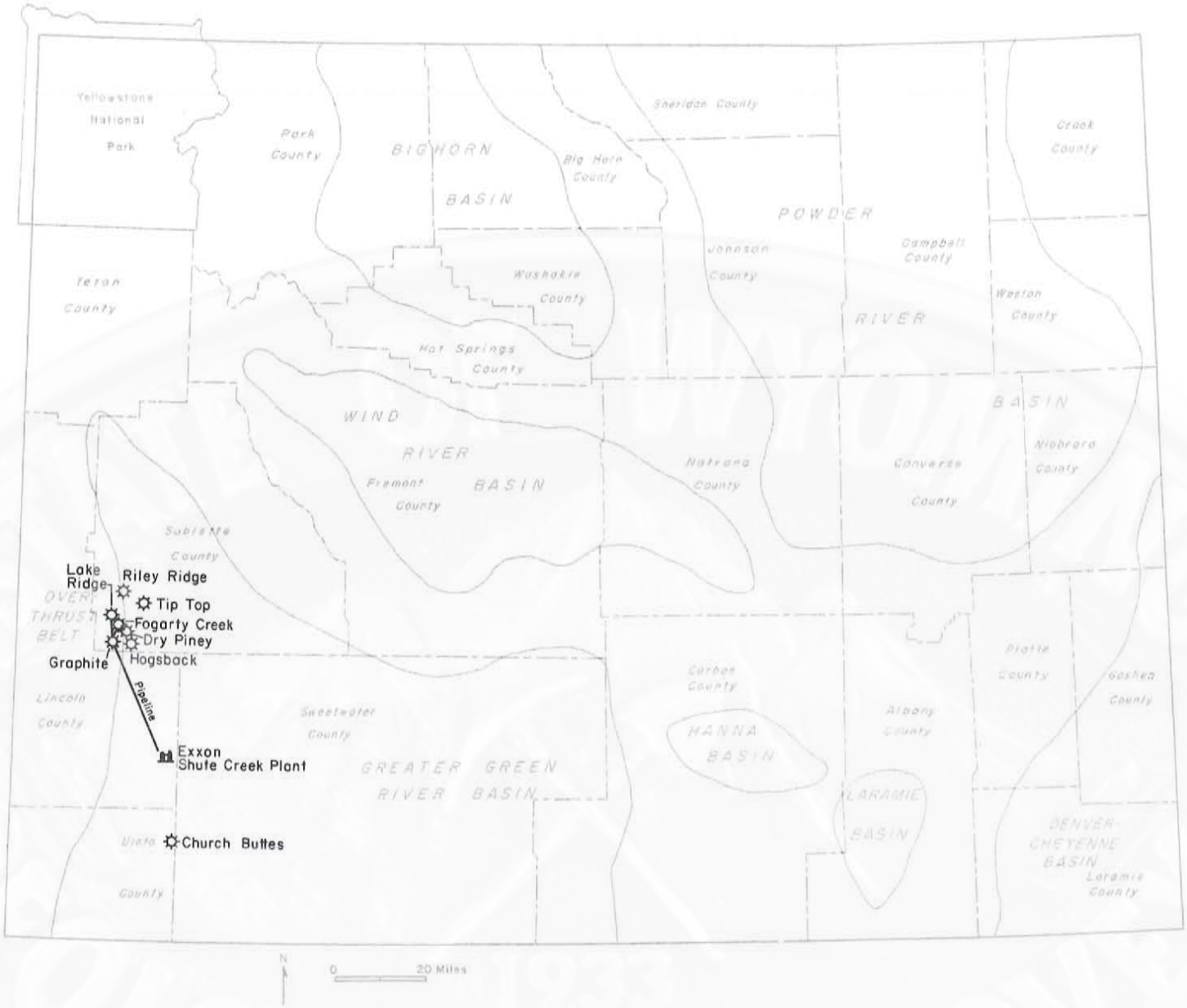

Figure 13. Fields with major reserves of helium and Wyoming's only helium recovery plant, the Shute Creek plant.

bic feet of gas per day (95 percent carbon dioxide) from the Madison Limestone. If Amoco decides to develop the Raptor Field, they would build a 200-million-cubic-feet-per-day processing plant at Fontenelle, near Exxon's Shute Creek plant (**Figure 14**). Amoco would use the carbon dioxide separated at their plant for enhanced oil recovery projects planned in Wyoming. Although no reserves have been published for Raptor field, Amoco needs 565 billion cubic feet of carbon dioxide for their projects, so recoverable reserves would have to equal that amount.

Table 18. Wyoming fields with major recoverable reserves of helium (modified from U.S. Bureau of Land Management and others, 1983; Carr and Madden, 1975).

Field	Recoverable reserves[1]
Graphite[2]	5
Dry Piney	9
Hogsback	14
Fogarty Creek[2]	20
Riley Ridge	20
Lake Ridge[2]	26
Tip Top	40
Nonunitized lands adjacent to above fields	66
Church Buttes	17
TOTAL	217

[1] Billion cubic feet
[2] Presently producing helium

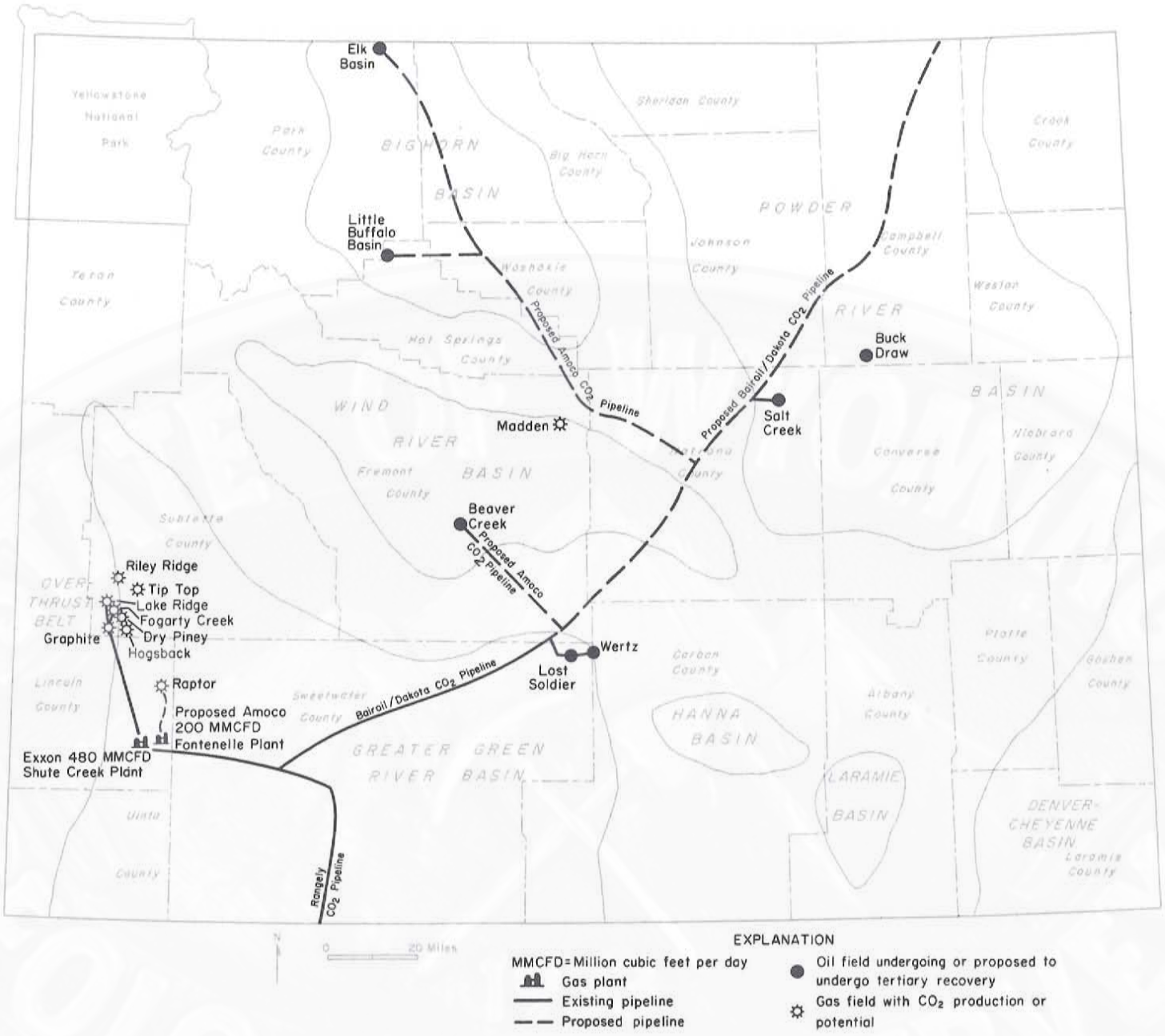

Figure 14. Important fields and facilities in Wyoming related to carbon dioxide production in the State and locations of major current and planned enhanced oil recovery activities in Wyoming.

Pipelines

Several new major pipelines have been constructed in Wyoming during the 1980s. The Trailblazer pipeline system was completed late in 1982 to transport natural gas from Whitney Canyon-Carter Creek Field in the Overthrust Belt to existing pipelines at Beatrice, Nebraska, for distribution of natural gas in the Midwest. The 36-inch pipeline has a total length of nearly 800 miles and can carry 526 million cubic feet of gas per day. The Frontier pipeline was completed late in 1983 and is designed to carry up to 200,000 barrels of oil per day from Anschutz and East Anschutz Fields in the Overthrust Belt to Casper, Wyoming. Another major pipeline is owned by Exxon and transports gas from the Lake Ridge, Fogarty Creek, and Graphite units to the Shute Creek gas processing plant. A 24-inch pipeline from the plant carries carbon dioxide to Rock Springs. One 16-inch branch at Rock Springs carries carbon dioxide to Chevron's Rangely Field in Colorado and another 20-inch branch between Exxon's plant and Rock Springs carries carbon dioxide to Amoco's Bairoil proj-

ect north of Rawlins. The carbon dioxide is being used in enhanced oil recovery projects.

One of the most important developments for the Wyoming oil and gas industry in several years is the emergence of a completely new market for natural gas in southern California. The demand would start at 700 million cubic feet per day and could reach a maximum of over 1 billion cubic feet per day. The natural gas would be used to generate steam for electricity and for use in steam floods in several heavy-oil fields. At this time, there are three pipeline companies vying for approval to supply that market. As a significant indication of support for such a pipeline, the Wyoming State Legislature passed a bill in March of 1988, authorizing a $250 million State loan at 4 percent interest. This low-interest loan would have the effect of lowering transportation costs for natural gas from Wyoming. In order to keep the loan at a low interest rate, the pipeline would have to transport at least 350 million cubic feet per day of natural gas produced in Wyoming. Both the proposed Kern River and WyCal pipelines would originate in southwestern Wyoming and tie into other existing pipelines from either Canada or the southwestern United States. The Mojave Pipeline is designed to supply southern California's natural gas needs for cogeneration mainly from the southwestern United States.

Table 19. Wyoming fields with major recoverable reserves of carbon dioxide (modified from U.S. Bureau of Land Management and others, 1983).

Field	Recoverable reserves[1]
Graphite[2]	.3
Dry Piney	.6
Hogsback	.9
Fogarty Creek[2]	1.3
Riley Ridge	1.3
Lake Ridge[2]	1.8
Tip Top	2.7
Non-unitized lands adjacent to above fields	4.4
TOTAL	13.3

[1] Trillion cubic feet

[2] Presently producing carbon dioxide

Secondary and enhanced oil recovery

In 1987, there were 206 separate secondary recovery waterflood projects in Wyoming (Wyoming Oil and Gas Conservation Commission, 1988a). Most of the top 25 oil producing fields as well as many of the smaller fields are undergoing waterflood operations. An estimated 50 percent of Wyoming's current oil production is directly related to waterflood projects in the State (Rick Marvel, personal communication, 1988).

There were also seven pressure maintenance projects in the State in 1987 where gas was injected into producing formations to keep reservoir pressures above the bubble point.

Most tertiary recovery projects in the State in 1987 were fairly small-scale polymer-augmented waterfloods. Four of the largest water-polymer projects were at Oregon Basin, Byron, Grass Creek, and Frannie Fields.

A study by Varma (1985) estimated that 500 million additional barrels of oil could be recovered in Wyoming over the next 30 years using enhanced oil recovery techniques. The study shows that the average additional recovery of crude oil from carbon dioxide floods should be 7.9 percent of the original oil in place, while additional recovery from polymer-augmented waterfloods should average 4.4 percent of the original oil in place. The study used $1.25 per MCF of carbon dioxide as the basis for its assumptions. Using these assumptions, Varma concluded that polymer-augmented waterfloods will be the most widely used type of enhanced oil recovery project and miscible gas (chiefly carbon dioxide) will be less popular (less economical). However, at a price lower than $1.25 per MCF, the carbon dioxide floods become more attractive. If carbon dioxide is chosen over polymer-augmented waterfloods in a number of fields, the total enhanced oil recovery in Wyoming could rise substantially above the 500 million barrels that Varma's study predicts as recoverable during the next 30 years. The construction of the Exxon plant and the possible competition from Amoco with carbon dioxide processed from their Raptor Field could lower carbon dioxide prices into the $.75 per MCF range, with even lower prices for high-volume consumers.

Lower carbon dioxide prices, along with presently lower drilling costs convinced Amoco to proceed with the Bairoil project. The Tensleep Sandstone at Wertz Field has been injected with carbon dioxide since late 1986, and the excellent results obtained so far have influenced Amoco to proceed with the Lost Soldier Field portion of the project. The operator of Wertz and Lost Soldier Fields estimates that an additional 31 million barrels of oil will be recovered from the Tensleep Sandstone by injecting carbon dioxide at these two fields. Another 7 million barrels could be recovered at these fields by injecting carbon dioxide into the Madison Limestone and Darwin Sandstone. Total carbon dioxide

requirements for these reservoirs would be 375 billion cubic feet. Of that total, about 195 billion cubic feet will be purchased from Exxon. The rest will be recovered with the crude oil and will be recycled. These figures suggest that a little over 5 MCF of carbon dioxide will have to be purchased for each barrel of oil recovered. In addition, another 5 MCF of recycled carbon dioxide would be needed for each produced barrel. Smaller fields that may be candidates for carbon dioxide floods may not be able to use this recovery method unless the price of carbon dioxide is lowered, the price of crude oil increases, or operators in several nearby fields are able to pool their resources and build a carbon dioxide recycling plant that can serve several fields.

The operator of Buck Draw Field estimates that a miscible gas flood (lean hydrocarbon gas and nitrogen) in the Dakota Formation will recover an additional 10.8 million barrels of oil and will extend the producing life of the field at least three years. Kerr-McGee Corporation resumed production at five wells in Buck Draw Field in December, 1988, after installation of the miscible gas flood. The five wells are currently producing a total of 8,400 barrels of oil per day. When combined, the tertiary projects either already started or proposed at Wertz, Lost Soldier, and Buck Draw Fields (**Figure 14**) could recover an additional 49 million barrels of oil over the next 15 to 20 years. In a related item, Amoco announced that it is planning to inject carbon dioxide into Little Buffalo Basin and Elk Basin Fields in the Bighorn Basin, Beaver Creek Field in the Wind River Basin, and Salt Creek Field in the Powder River Basin (**Figure 14**). Additional recoverable oil, derived from Amoco's estimated percentages of original oil in place, is between 115 million and 200 million barrels from these four fields. Carbon dioxide for these projects will come from either the Exxon Shute Creek plant or from Amoco's proposed Fontenelle plant, which would utilize carbon dioxide gas from the Raptor Field discovery. Purchased carbon dioxide requirements for these four projects would be 565 billion cubic feet. Amoco estimated that carbon dioxide injection could begin as early as the first quarter of 1990 in Elk Basin Field (U.S. Department of the Interior, 1987a).

Revenue to the State

The assessed valuation of Wyoming's taxable oil and gas production is tied into both production and price. The large decreases in assessed valuation for oil and natural gas production in 1987 (**Figures 15** and **16**) were partly caused by declines in production as well as by large price decreases for both commodities in 1986. Assessed valuation of taxable oil increased somewhat in 1988 due to slightly higher production and prices in 1987. Assessed valuation of taxable natural gas decreased because lower prices more than offset increased production in 1987.

Table 20 gives a summary of taxes and royalties paid by oil and gas producers on production in 1980 through 1987. These figures reflect the relatively high prices received for oil and gas production during 1981 through 1985. They also reflect increases in production, especially in 1984 and 1985 for oil and in 1983, 1984,

Figure 15. Annual taxable production and assessed valuation of Wyoming's oil production, calendar years 1980-1988 (Wyoming Legislative Service Office, 1988). Assessed valuation is based on the previous year's taxable production.

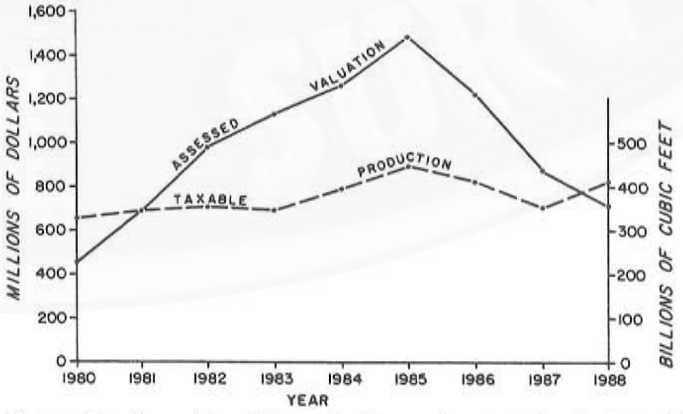

Figure 16. Annual taxable production and assessed valuation of Wyoming's natural gas production, calendar years 1980-1988 (Wyoming Legislative Service Office, 1988). Assessed valuation is based on the previous year's taxable production.

Table 20. Summary of taxes and royalties in millions of dollars paid by oil and gas producers on production from 1980 through 1987 (U.S. Department of Interior, 1988; Wyoming Department of Public Lands and Farm Loans, 1988; Wyoming Economic Development and Stabilization Board, 1988).

Production Year	State ad valorem tax[1]		State severance tax[1]		Total ad valorem and severance tax on production[1]		Wyoming share of Federal royalty[2]		State royalty[2]		Total State and Federal royalty on production[2]		Total ad valorem and severance tax and State and Federal Royalty[1, 2]		Grand total each year[1, 2]
	Oil	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil & Gas
1980	141.07	42.83	*	*	141.07	42.83	95.83	23.21	19.41	6.26	115.24	29.47	256.31	72.30	328.61
1981	221.42	62.55	212.49	58.68	433.91	121.23	138.30	30.44	29.26	11.06	167.56	41.50	601.47	162.73	764.20
1982	214.32	75.10	186.93	67.85	401.25	142.95	120.41	41.43	25.55	11.79	145.96	53.22	547.21	196.17	743.38
1983	199.13	83.48	175.25	75.49	374.38	158.97	121.57	50.26	24.08	12.16	145.65	62.42	520.03	221.39	741.42
1984	203.05	98.63	183.66	89.16	386.71	187.79	122.06	60.27	26.40	14.57	148.46	74.84	535.17	262.63	797.80
1985	184.53	86.59	169.31	74.41	353.84	161.00	115.96	47.95	26.20	11.02	142.16	58.97	496.00	219.97	715.97
1986	95.33	60.99	84.49	53.34	179.82	114.33	62.01	35.94	13.36	9.12	75.37	45.06	255.19	159.39	415.58
1987	112.26	48.43	100.07	43.06	212.33	91.49	68.04	29.53	15.93	7.34	83.97	36.87	296.30	128.36	424.66
TOTAL	1,371.11	558.60	1,112.20	461.99	2,483.31	1,020.59	844.18	319.03	180.19	83.32	1,024.37	402.35	3,507.68	1,422.94	4,930.62

* Severance taxes were not collected on 1980 mineral production due to changes in the way severance taxes were paid.

[1] The State receives these taxes between July 1 of the calendar year of production and June 30 of the next calendar year.

[2] State and Federal royalties are paid on a calendar year basis.

and 1985 for gas. The oil and gas industry in the State has contributed very substantially to Wyoming's revenue. Taxes and royalties paid on production during the first eight years of the decade (1980-1987) amounted to $3.5 billion for oil and $1.4 billion for natural gas.

In fiscal year 1987 (July 1, 1986-June 30, 1987), the oil and gas industry paid almost 38 percent of all property taxes levied in Wyoming ($271.1 million) and over 65 percent of the property tax paid by all mineral industries. In fiscal year 1987, the industry also paid $137.8 million in severance taxes, which was about 53 percent of all severance taxes paid by Wyoming's mineral industries. Royalties from production on State land were $24.5 million and Wyoming's 50 percent share of Federal royalties on production was $111.5 million. Over $400 million was spent by the oil and gas industry in Wyoming during 1987 on drilling projects and the industry employed 15,000 people with an annual payroll over $375 million (Petroleum Association of Wyoming, 1988).

Summary and forecast

The collapse of the price of oil, coupled with surplus gas supplies, reduced drilling to pre-World War II levels in the United States and Wyoming during 1986, 1987, and 1988. Consequently, with the exception of 1984 and 1987, the rig count has shown a steady decrease since 1981 (**Figure 17**). Preliminary figures show that even fewer wells were completed in 1988 than in 1987. With OPEC seemingly content to maintain what they perceive as their share of the market by producing enough oil to keep prices relatively low, crude prices will probably be in the $15 to $20 range for at least the rest of the decade. Even lower crude prices are possible if OPEC is unable to prevent cheating on production quotas by its members. Natural gas prices will probably not get above $2.50 per MCF in this decade because of the current surplus. With this scenario for oil and gas prices, drilling in Wyoming will not increase enough in the next few years to keep crude oil production from declining. Natural gas production in Wyoming is capable of very large increases; however, with low prices and surplus supplies, production gains will be held to a minimum unless new markets like those in southern California are developed. Construction of a major pipeline to California would stimulate a tremendous increase in gas exploration in the State, especially in the Greater Green River Basin, where the majority of Wyoming's undeveloped gas supplies are located.

The most promising method for keeping oil production declines to a minimum is tertiary recovery. Around

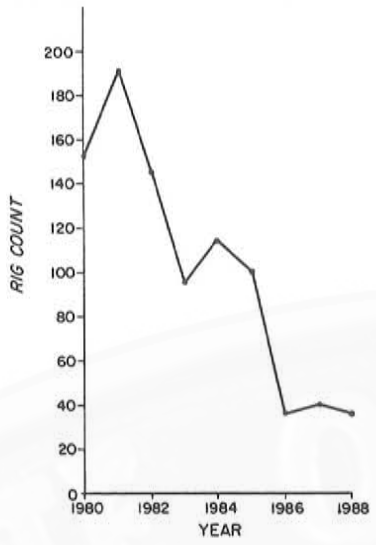

Figure 17. Weekly average Wyoming rig count, calendar years 1980-1988 (data from Huges Rig Count, *in* Oil and Gas Journals, 1980-1988).

50 percent (10 billion barrels) of the discovered original oil in place in Wyoming is considered immobile oil and can only be recovered with tertiary techniques. Tertiary projects in Wyoming involving gas injection (mainly carbon dioxide) that have already started (Wertz and Buck Draw Fields) or are planned for the near future (Lost Soldier, Elk Basin, Little Buffalo Basin, Beaver Creek, and Salt Creek Fields) could add as much as 250 million barrels to State production totals over the next 20 years. Production of most of the remaining immobile oil will probably have to wait until prices recover to at least $30 per barrel and for the development of technology that will mobilize more than 5 to 8 percent of the estimated 10 billion barrels of discovered immobile oil in Wyoming reservoirs.

Secondary recovery will continue to add significant amounts of oil to Wyoming's production total and should contribute around 50 percent to total production in the future. Old large fields will continue waterflood operations and newer discoveries will begin waterflood operations as primary production declines.

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