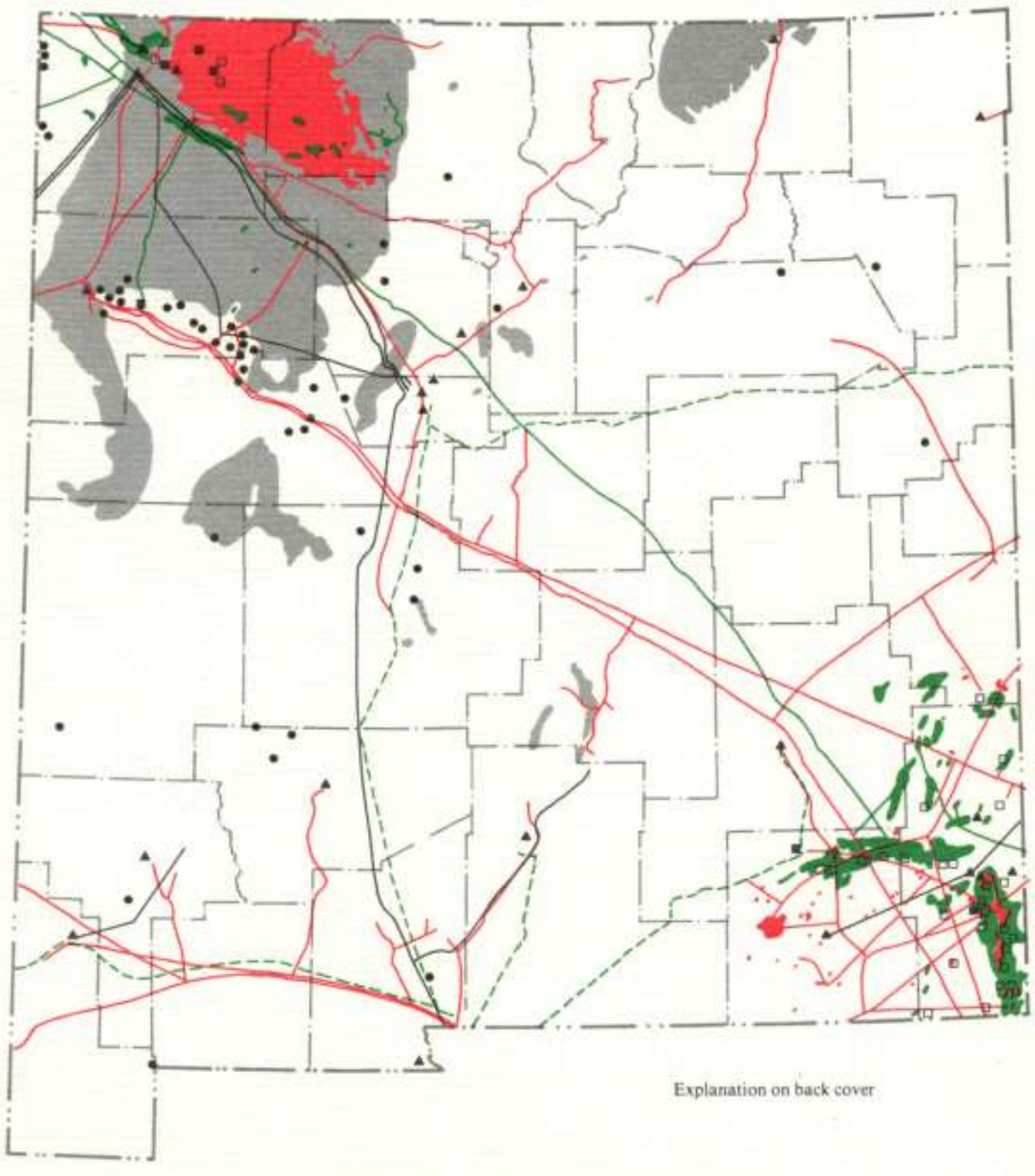
New Mexico's energy resources '79

—annual report of Bureau of Geology in the
Mining and Minerals Division of New Mexico
Energy and Minerals Department

compiled by Emery C. Arnold and
James M. Hill

Bruce King, Governor of New Mexico



New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

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—annual report of Bureau of Geology in the Mining and Minerals Division of New Mexico Energy and Minerals Department

compiled by

Emery C. Arnold, *Director, Mining and Minerals Division,*
and James M. Hill, *Chief, Bureau of Geology*

with contributions by

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Preface

I am privileged to present this report to the Governor of New Mexico and to members of the State Legislature for their use in formulating energy policy.

The Office of the State Geologist was established by Chapter 289 of the Laws of 1975. The Energy and Minerals Department Act, Chapter 255 of the Laws of 1977, became effective March 31, 1978. Under this act, the Office of the State Geologist became the Bureau of Geology, one of three bureaus in the newly formed Mining and Minerals Division of the Energy and Minerals Department. Permanent quarters are established at First Northern Plaza East in Santa Fe (Post Office Box 2860, Santa Fe, NM 87501; telephone 505/827-5621). The staff of the Mining and Minerals Division consists of:

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The Bureau of Geology is charged with 1) conducting geological studies aimed at determining reserves of known supplies of energy resources and 2) conducting geological studies of probable potential supplies. The Bureau is also charged with cooperating with the New Mexico Bureau of Mines and Mineral Resources in preparing maps, brochures, and pamphlets on known, probable, and potential sources of energy in New Mexico; cooperating with private, state, and federal agencies in the gathering of geological data concerning energy supplies; and assisting the Secretary of the Energy and Minerals Department in the maintenance of an inventory of all reserves and potential sources of fuel and power in New Mexico.

This is the fourth reserve and production summary published since the office was established and the second report to contain independently derived estimates of oil and gas reserves. Independently derived coal-reserve estimates have been prepared with the help of consultants. Reserve update studies for oil, gas, and coal are continuing.

Personnel from the New Mexico Bureau of Mines and Mineral Resources have contributed time, effort, and material to the preparation of this report, and their cooperation is appreciated. Betty Perkins, consultant to the Energy and Minerals Department, wrote the chapter on uranium. Robert D. Jebb, of Solo Writing and Editing, Santa Fe, provided a great deal of editorial assistance. Staff members from the Bureau of Surface Mining and the Bureau of Mine Inspection helped in compiling information. I also wish to express my appreciation for advice and assistance received from the New Mexico Oil Conservation Division, the New Mexico Oil and Gas Accounting Division, the New Mexico Revenue Division, the U.S. Bureau of Mines and the U.S. Department of Energy, as well as from the many industry personnel who contributed information and advice.

Emery C. Arnold
Director
Mining and Minerals Division
Energy and Minerals Department

Santa Fe
September 19, 1979

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Abstract

Production of crude **oil** in New Mexico continued to decline in 1978 with production of 78.7 million bbls (barrels), which was 3.9 million bbls or 5 percent less than that produced in 1977. **Condensate** production increased slightly over the previous year, but total crude oil and condensate production is expected to continue to decline. In early 1979 decline was due primarily to lower production rates in the Empire Abo Pool, the largest oil-producing pool in the state. **Natural gas** production decreased 25,169,926 thousand cu ft in 1978 from the previous year, although drilling set an eight-year record. Production projections have been revised to show differing decline rates through 2000. Crude **oil reserves** for 40 pools were calculated along with reserves for five gas pools. The state experienced a 7.5-percent **coal-production** increase over 1977 with 12.8 million tons extracted in 1978. Production is expected to increase 31 percent in 1979. **Coal reserves** are given according to the depth of coal beds. U_30, production of 9,400 tons in 1978 represented a 24-percent increase over the previous year, and New Mexico has over 50 percent of all forward-cost categories of uranium reserves. Possible **geothermal-energy** application has been designated in 46 low-temperature areas, and the U.S. Bureau of Land Management has issued 118 leases that are currently active.

New Mexico's role

by E. C. Arnold and J. M. Hill, *Bureau of Geology*

New Mexico has played and will continue to play a major role in energy-resource production in the nation. As the United States turns to more domestic production to offset oil imports, New Mexico will be expected to develop its vast resources to an even greater extent than in the past. The state is among the top dozen states in reserves of every major energy category. In the case of uranium, New Mexico not only leads the nation with almost half of U30, production and over half of reserves in every forward-cost category, but also supplies a significant proportion of global production.

New Mexico ranked fourth in the nation in total gas production and reserves, seventh in crude-oil production and reserves, 11th in coal reserves, and 14th in coal production. In addition, New Mexico is a national leader in geothermal potential and in initial steps toward its application. If an average is taken of the national rankings for New Mexico in production and reserves of oil, gas, coal, and uranium, the state would rank sixth in the nation.

Although production of oil and gas in New Mexico and adjacent states (table 1) has declined from previous years (with the rate of decline expected to accelerate because of diminishing supplies), production of coal and uranium has increased and is expected to increase even more dramatically in the near future. Total production of crude oil for New Mexico and the six adjacent states in 1976 was 1,471.30 million bbls (barrels) as compared with 1,327.85 million bbls in 1978 for the same states plus Missouri, Nevada, and Virginia. Production of total gas from New Mexico and four adjacent states declined from 10,005.6 billion cu ft in 1976 to 9,489.9 billion cu ft in 1978. Texas continues to lead the area in production and reserves of crude oil and total gas, but its production is also declining. Production of coal in New Mexico and five adjacent states reached 70,800,000 tons in 1978 compared to 55,000,000 tons in 1976. Texas continued as the leading state among adjacent states in coal production.

For growth in development, uranium has been the

TABLE 1—PRODUCTION AND RESERVES OF OIL, GAS, COAL, AND URANIUM FOR NEW MEXICO IN 1978 COMPARED TO ADJACENT STATES. Dashes indicate that statistics for individual states are not available. Oil-production figure for Arizona includes production in Missouri, Nevada, and Virginia. Uranium reserves listed are $50 forward-cost category. U_3O_8 reserves for Utah, Colorado, and Arizona totaled 83,200 tons. U_3O_8 production for Arizona, Colorado, Florida, Texas, Utah, Washington, and South Dakota totaled 4,600 tons (data from American Petroleum Institute; Keystone, 1979; U.S. Bureau of Mines; and U.S. Department of Energy, 1979b).

	Crude oil				Total gas				Coal				Uranium			
	Production		Reserves		Production		Reserves		Production		Strippable reserves		Production		Reserves	
State	Million bbls	U.S. rank	Million bbls	U.S. rank	Billion cu ft	U.S. rank	Billion cu ft	U.S. rank	Thousand tons	U.S. rank	Million tons	Nat. rank	Tons U_3O_8	U.S. rank	Tons U_3O_8	U.S. rank
New Mexico	78.13	7	485.6	7	1,068.9	4	13,261.49	4	13,000	14	2,400	11	8,560	1	473,900	1
Texas	1,044.94	1	7,690.0	2	6,528.7	2	54,600.24	1	17,600	11	3,200	10	--	-	49,600	3
Oklahoma	135.33	5	1,073.5	5	1,646.9	3	11,463.29	6	5,000	19	400	21	--	-	--	-
Colorado	36.28	11	198.0	9	185.6	8	1,965.77	11	13,300	13	3,800	8	--	-	--	-
Utah	31.48	13	155.4	14	59.8	15	698.66	18	10,200	17	300	-	--	-	--	-
Arizona	1.69	-	--	-	--	-	--	-	11,700	15	300	-	--	-	--	-

most significant energy resource in New Mexico. In the distribution of 1978 U_30_8 production by state, New Mexico accounted for 46 percent of the total, with 6,262,000 tons of ore and 9,400 tons U_30_8. The state with the closest production was Wyoming, with 27 percent of the total from 4,687,000 tons of ore mined and 5,500 tons U_30_8 produced. As of January 1, 1979, New Mexico had 66 percent of the nation's $15 reserves, 54 percent of the $30 reserves, and 52 percent of the $50 reserves. Favorable market conditions and other factors have caused an expanded search for low-grade deposits in Wyoming and elsewhere. Drilling in New Mexico accounted for 21.1 percent of the total with 9.9 million ft in 1978, while Wyoming accounted for 35.3 percent with 16.6 million ft. In New Mexico the continued emphasis was on drilling for mine development, rather than on drilling for exploration as was the case in Wyoming.

Taxes collected for energy resources have provided a significant portion of state revenue. Table 2 shows rates for tax receipts in 1978 comparing coal, oil, natural gas, and U_30_8. These rates were based on the calendar year 1978 for uranium and steam coal and on the first 6 months of 1978 for oil and gas. Dividing these receipts by the average prices of $8.84 per ton of steam coal, $9.77 per bbl of oil, $0.93 per thousand cu ft of gas, and $29.04 per lb of yellowcake yields effective tax rates of 10.79 percent for steam coal, 7.08 percent for oil, 8.97 percent for gas, and 6.60 percent for yellowcake.

TABLE 2—TAX RECEIPTS FOR ENERGY RESOURCES IN NEW MEXICO, 1978 (data from New Mexico Energy and Minerals Department).

Tax	1 ton steam coal	1 bbl of oil	1,000 cu ft natural gas	1 lb yellowcake
Property tax	$ 0.1133	$ --	$ --	$ 0.2025
Severance tax	0.3800	0.3130	0.0431	1.3846
Surtax	0.0250	0.0161	0.0024	0
School tax	--	0.2241	0.0214	--
Conservation tax	0.0165	0.0167	0.0016	0.0117
Ad Valorem (production)	--	0.1043	0.0103	--
Ad Valorem (equipment)	--	0.0177	0.0016	--
Natural gas processors	--	--	0.0030	--
Resource excise	0.0650	--	--	0.2177
Gross receipts	0.3536	--	--	0
Continued care	--	--	--	0.1000
	$ 0.9534	$ 0.6919	$ 0.0834	$ 1.9165

Oil and gas

by E. C. Arnold, J. M. Hill, and D. A. Donaldson, *Bureau of Geology*

Oil production

New Mexico's annual crude-oil production continued to decline in 1978, although condensate production increased slightly (table 3). The state's 1978 crude-oil and condensate production was 83,364,825 bbls (barrels). This production was 3,857,821 bbls less than that in 1977, and the 1977 crude-oil and condensate production was 4,906,229 bbls less than that in 1976. A breakdown of crude and condensate production shows that crude-oil production in 1978 was 78,748,818 bbls. This figure represented a 5-percent decline or 3,867,272 bbls less than that produced in 1977. The state's 1978 condensate production was 4,616,007 bbls—an increase of 9,451 bbls over the 1977 production. Condensate production for 1977 was 4,606,556 bbls. Table 4 compares oil production during 1977 and 1978.

Table 5 and fig. 1 show crude and condensate production for the eight oil-producing counties in New Mexico. The counties are listed in order by their percentage of the total state production. Lea County is the most prolific oil-producing county in New Mexico. It produced 52,067,258 bbls of the state's total 83,364,825 bbls of crude oil and condensate in 1978 (62.4 percent of the total).

Statewide oilj,roduction for the first three months of 1979 was down 8 percent from the same period in 1978. A great deal of this crude-oil decline is attributable to the lower production rates in the Empire Abo Pool for the first three months of 1979. The Empire Abo, located in Eddy County, is the largest oil-producing pool in the state. In 1978, its production was 14,368,103 bbls, which was slightly over 18 percent of the state's crude-oil production of 78,748,818 bbls. The lower production rates for the Empire Abo were caused by mechanical problems during severe cold weather in January and February and by a slightly lower formation pressure. Even if these problems are resolved by warmer weather and by increasing the volume of injected gas, the production decline might reach 20-30 percent in the next year or two because the Empire Abo unit is in the final stage of development.

Southeast New Mexico

Southeast New Mexico's crude and condensate production for 1978 was 77,288,162 bbls. Crude-oil production was 74,819,101 bbls, down 5.2 percent from 1977 production; condensate production was 2,469,061 bbls, up about 3 percent from 1977. Lea County continued to lead the state in crude and condensate production; it accounted for over 62 percent of the state's production. Eddy County ranked second in the state in crude and condensate production and produced 27 percent of the state's production. The other two oil-producing counties in the southeast are Chaves County, which ranked fifth in state production, and Roosevelt County. Chaves County ranked fourth in 1977 but was displaced by Rio Arriba County in 1978; Chaves County produced 1,498,835 bbls, or 1.8 percent of the production for 1978. Roosevelt County ranked sixth and produced 1,310,309 bbls, or 1.6 percent of the state's production.

Northwest New Mexico

Production of crude oil and condensate in northwest New Mexico for 1978 was 6,076,663 bbls. Production was up by 3 percent (150,028 bbls) from the previous year. Northwest New Mexico's crude-oil production for 1978 was 3,929,717 bbls, up from the 1977 production by 212,722 bbls. Condensate production was 2,146,946 bbls, down by 62,694 bbls. San Juan County ranked third in the state in crude and condensate production in 1978 with 2,987,830 bbls-3.6 percent of the state's total and 49 percent of the total San Juan Basin production. The other three oil- and condensate-producing counties in the northwest are Rio Arriba, which ranked fourth in state production for 1978 with 1,563,259 bbls; McKinley, which ranked seventh with 1,159,301 bbls; and Sandoval, which ranked eighth with 366,273 bbls. Table 6 shows production by county from 1961 through 1978.

Gas production

The state's natural gas production in 1978 was 1,159,148,334 thousand cu ft—a net decrease of 25,169,926 thousand cu ft from 1977. Both dry- and casinghead-gas production were down in the southeastern part of the state, but there were increases in the northwest. Table 4 shows a comparison of 1978 and 1977 gas production.

Northwest New Mexico

Northwest New Mexico's 1978 natural-gas production increased by 8,234,707 thousand cu ft over the 1977 production. Dry-gas production was 528,286,348 thousand cu ft, an increase of 6,486,057 thousand cu ft. Casinghead-gas production was 11,996,782 thousand cu ft, up by 1,748,650 thousand cu ft from 1977. As seen in the ranking by county below, San Juan County led the state in total gas production in 1978 according to the NMOCD (New Mexico Oil Conservation Division).

County (by rank)	Thousand cu ft	Percent of total state production
San Juan	374,797,579	32.33
Lea	371,274,780	32.03
Eddy	231,889,825	20.00
Rio Arriba	162,788,167	14.04
Chaves	12,106,616	1.04
Roosevelt	3,593,983	0.31
Sandoval	2,383,845	0.21
McKinley	298,925	0.03
Mora	14,614	0.01
Total state gas production	1,159,148,334	100.00

According to the NMOCD, San Juan County also led the state in 1978 in dry-gas production, with 371,362,243 thousand cu ft, 40.97 percent of the total

TABLE 3—PRODUCTION OF OIL AND NATURAL GAS IN NEW MEXICO, 1960 THROUGH 1978 (data from New Mexico Oil Conservation Division).

Year and area	Barrels				Thousand cubic feet		
	Oil	Condensate	Total oil and condensate	Water	Casinghead gas	Dry gas	Total gas
NW	13,430,845	1,374,351	14,805,196	915,768	31,266,992	342,133,828	373,400,820
SE	91,149,978	1,409,974	92,559,952	84,017,567	262,155,625	186,358,171	448,513,796
1960, total	104,580,823	2,784,325	107,365,148	84,933,335	293,422,617	528,491,999	821,914,616
NW	14,210,632	1,525,358	15,735,990	1,862,902	39,954,895	319,541,175	359,496,070
SE	95,596,439	1,220,972	96,817,411	97,512,336	269,373,304	157,725,609	427,098,913
1961, total	109,807,071	2,746,330	112,553,401	99,375,238	309,328,199	477,266,784	786,594,983
NW	9,181,861	1,659,507	10,841,368	3,839,406	35,895,143	304,909,639	340,804,782
SE	97,225,296	1,261,389	98,486,685	113,139,221	275,932,682	170,015,467	445,948,149
1962, total	106,407,157	2,920,896	109,328,053	116,978,627	311,827,825	474,925,106	786,752,931
NW	7,942,818	1,874,934	9,817,752	4,470,887	27,183,166	321,553,533	348,736,699
SE	98,794,993	1,370,312	100,165,305	127,283,521	272,556,376	171,932,132	444,488,508
1963, total	106,737,811	3,245,246	109,983,057	131,754,408	299,739,542	493,485,665	793,225,207
NW	7,443,260	2,550,525	9,993,785	7,131,448	20,991,913	405,718,222	426,710,135
SE	102,508,438	1,361,185	103,869,623	138,760,709	270,538,055	195,430,490	465,968,545
1964, total	109,951,698	3,911,710	113,863,408	145,892,157	291,529,968	601,148,712	892,678,680
NW	8,776,902	2,804,888	11,581,790	10,600,522	18,467,730	441,561,504	460,029,234
SE	105,966,181	1,618,506	107,584,687	150,261,064	276,863,641	208,128,648	484,992,289
1965, total	114,743,083	4,423,394	119,166,477	160,861,586	295,331,371	649,690,152	945,021,523
NW	8,159,673	3,196,280	11,355,953	13,533,781	15,222,739	483,275,803	498,498,542
SE	111,015,456	1,819,342	112,834,798	158,177,814	286,076,861	228,035,560	514,112,421
1966, total	119,175,129	5,015,622	124,190,751	171,711,595	301,299,600	711,311,363	1,012,610,963
NW	7,533,818	3,528,057	11,061,875	16,198,320	13,928,329	523,356,226	537,284,555
SE	113,060,912	1,879,664	114,940,576	167,575,219	281,722,938	236,644,443	518,367,381
1967, total	120,594,730	5,407,721	126,002,451	183,773,539	295,651,267	760,000,669	1,055,651,936
NW	6,732,250	3,673,081	10,405,331	17,020,379	13,140,201	580,374,026	593,514,227
SE	115,700,459	2,505,535	118,205,994	195,073,824	279,612,600	277,239,086	556,851,686
1968, total	122,432,709	6,178,616	128,611,325	212,094,203	292,752,801	857,613,112	1,150,365,913
NW	6,011,237	3,035,489	9,048,726	16,929,938	12,964,592	538,010,671	550,975,263
SE	117,722,236	2,455,899	120,178,135	210,505,804	282,222,689	280,642,531	562,865,220
1969, total	123,735,473	5,491,388	129,226,861	227,435,742	295,187,281	818,653,202	1,113,840,483
NW	5,780,167	2,905,943	8,686,110	18,593,311	11,066,422	513,961,890	525,028,312
SE	117,181,123	2,280,664	119,461,787	226,808,233	292,907,627	305,519,255	598,426,882
1970, total	122,961,290	5,186,607	128,147,897	245,401,544	303,974,049	819,481,145	1,123,455,194
NW	6,012,907	2,801,992	8,814,899	18,860,437	11,573,567	546,546,676	558,120,243
SE	107,708,035	1,887,036	109,595,071	206,386,656	291,253,975	298,056,323	589,310,298
1971, total	113,720,942	4,689,028	118,409,970	225,247,093	302,827,542	844,602,999	1,147,430,541
NW	5,730,714	2,874,298	8,605,012	20,415,149	12,314,515	574,019,873	586,334,388
SE	99,665,888	2,254,324	101,920,212	196,174,211	259,535,532	351,899,738	611,435,270
1972, total	105,396,602	5,128,622	110,525,224	216,589,360	271,850,047	925,919,611	1,197,769,658
NW	5,175,343	2,394,207	7,569,550	20,659,128	12,932,204	537,186,284	550,118,488
SE	91,233,655	2,182,481	93,416,136	199,979,510	250,718,587	398,702,355	649,420,942
1973, total	96,408,998	4,576,688	100,985,686	220,638,638	263,650,791	935,888,639	1,199,539,430
NW	5,599,465	2,401,954	8,001,419	26,544,506	14,612,336	532,780,048	547,392,384
SE	88,483,452	2,210,094	90,693,546	204,598,067	289,089,197	393,191,355	682,280,552
1974, total	94,082,917	4,612,048	98,694,965	231,142,573	303,701,533	925,971,403	1,229,672,936
NW	4,378,951	2,118,324	6,497,275	24,324,927	14,046,453	504,499,980	518,546,433
SE	86,374,571	2,190,689	88,565,260	208,391,779	291,662,510	392,897,887	684,560,397
1975, total	90,753,522	4,309,013	95,062,535	232,716,706	305,708,963	897,397,867	1,203,106,830
NW	3,721,564	2,274,973	5,996,537	26,825,257	10,157,080	517,649,826	527,806,906
SE	83,715,295	2,417,043	86,132,338	212,782,479	269,673,315	403,395,146	673,068,461
1976, total	87,436,859	4,692,016	92,128,875	239,607,736	279,830,395	921,044,972	1,200,875,367
NW	3,716,995	2,209,640	5,926,635	30,505,354	10,248,132	521,800,291	532,048,423
SE	78,899,095	2,396,916	81,296,011	219,653,564	256,711,369	395,558,468	652,269,837
1977, total	82,616,090	4,606,556	87,222,646	250,158,918	266,959,501	917,358,759	1,184,318,260
NW	3,929,717	2,146,946	6,076,663	37,902,386	11,996,782	528,286,348	540,283,130
SE	74,819,101	2,469,061	77,288,162	227,830,311	240,806,743	378,058,461	618,865,204
1978, total	78,748,818	4,616,007	83,364,825	265,732,697	252,803,525	906,344,309	1,159,148,334

TABLE 4—COMPARISON OF 1977 AND 1978 OIL AND GAS PRODUCTION IN NEW MEXICO (data from New Mexico Oil Conservation Division).

	Oil production (bbls)			
	1977	1978	Increases	Decreases
Crude oil				
Southeast	78,899,095	74,819,101		4,079,994
Northwest	3,716,995	3,929,717	212,722	
Total	82,616,090	78,748,818		3,867,272
Condensate				
Southeast	2,396,916	2,469,061	72,145	
Northwest	2,209,640	2,146,946		62,694
Total	4,606,556	4,616,007	9,451	
	Gas production (thousand cu ft)			
	1977	1978	Increases	Decreases
Dry				
Southeast	395,558,468	378,058,461		17,500,007
Northwest	521,800,291	528,286,348	6,486,057	
Total	917,358,759	906,344,309		11,014,450
Casinghead				
Southeast	256,711,369	240,806,743		15,904,626
Northwest	10,248,132	11,996,782	1,748,650	
Total	266,959,501	252,803,525		14,155,976
Total gas				
Southeast	652,269,837	618,865,204		33,404,633
Northwest	532,048,423	540,283,130	8,234,707	
Total	1,184,318,260	1,159,148,334		25,169,926

TABLE 5—NEW MEXICO CRUDE-OIL AND CONDENSATE PRODUCTION FOR 1978 RANKED BY COUNTY (data from New Mexico Oil Conservation Division).

Rank	County	Location	Bbls	Percent of total state production
1	Lea	SE	52,067,258	62.4
2	Eddy	SE	22,411,760	26.9
3	San Juan	NW	2,987,830	3.6
4	Rio Arriba	NW	1,563,259	1.9
5	Chaves	SE	1,498,835	1.8
6	Roosevelt	SE	1,310,309	1.6
7	McKinley	NW	1,159,301	1.4
8	Sandoval	NW	366,273	.4
Total state crude-oil and condensate production			83,364,855	100

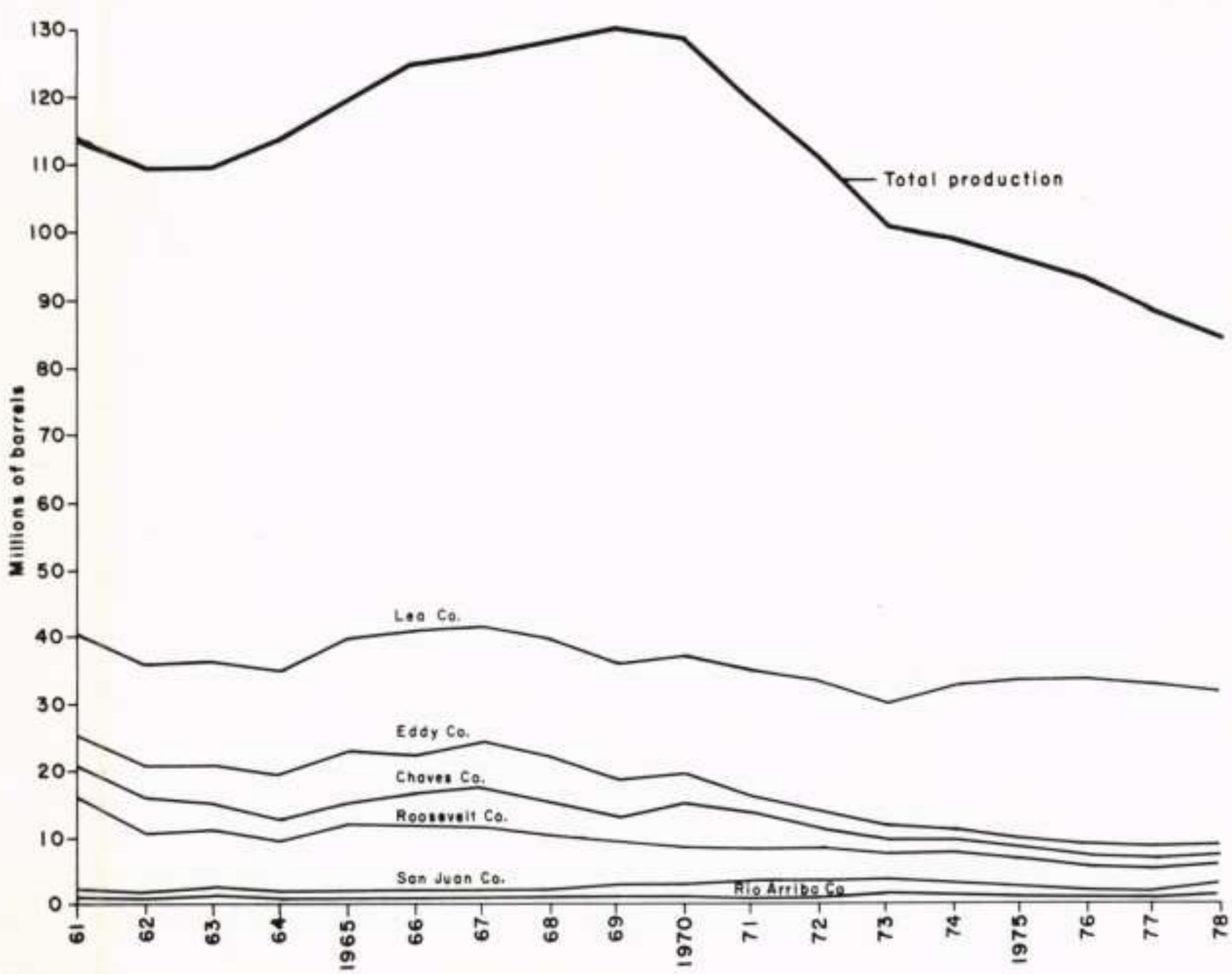

FIGURE 1—NEW MEXICO OIL AND CONDENSATE PRODUCTION BY COUNTY; Sandoval and McKinley production not shown (data from New Mexico Oil Conservation Division).

TABLE 6—SOUTHEAST AND NORTHWEST NEW MEXICO TOTAL CRUDE-OIL AND CONDENSATE PRODUCTION IN BBLS. 1961–1978 (data from New Mexico Oil Conservation Division).

County	1961	1962	1963	1964	1965	1966
Southeast						
Chaves	4,519,086	4,585,226	5,231,693	6,723,199	7,579,166	5,883,091
Eddy	14,340,933	14,996,520	15,602,848	15,270,064	16,662,831	18,380,161
Lea	74,093,103	74,254,645	76,324,276	79,751,863	80,999,582	84,063,544
Roosevelt	3,864,289	4,650,294	3,006,488	2,124,497	2,343,108	4,508,003
Total	96,817,411	98,486,685	100,165,305	103,869,623	107,584,687	112,834,799
Northwest						
McKinley	129,652	156,627	143,608	121,389	178,973	204,807
Rio Arriba	1,275,886	1,188,640	1,532,603	1,584,543	1,408,669	1,368,549
San Juan	14,307,469	9,481,304	8,130,766	8,276,071	9,984,098	9,776,051
Sandoval	22,983	14,797	10,775	11,782	10,050	6,546
Total	15,735,990	10,841,368	9,817,752	9,993,785	11,581,790	11,355,953

County	1967	1968	1969	1970	1971	1972
Southeast						
Chaves	6,394,571	6,751,493	5,806,920	4,480,469	2,973,841	2,304,271
Eddy	18,775,830	17,926,321	17,218,483	17,959,921	18,930,597	19,194,345
Lea	84,063,544	89,332,466	91,293,017	91,163,626	83,476,751	78,127,069
Roosevelt	4,508,003	4,195,714	3,981,523	5,857,771	4,213,882	2,294,527
Total	114,940,582	118,205,994	120,178,135	119,461,787	109,595,071	101,920,212
Northwest						
McKinley	311,451	482,344	821,549	1,213,563	1,754,036	1,852,557
Rio Arriba	1,341,869	1,298,263	1,296,935	1,497,704	2,037,791	1,895,013
San Juan	9,404,068	8,621,211	6,887,134	5,938,206	4,924,043	4,619,104
Sandoval	4,487	3,513	43,108	36,637	99,029	238,338
Total	11,061,875	10,405,331	9,048,726	8,686,110	8,814,899	8,605,012

County	1973	1974	1975	1976	1977	1978
Southeast						
Chaves	1,921,113	1,787,622	1,521,942	1,609,113	1,428,794	1,498,835
Eddy	18,040,298	21,504,533	23,649,874	24,049,803	23,498,167	22,411,760
Lea	71,834,891	66,028,464	62,152,972	59,110,851	55,105,577	52,067,258
Roosevelt	1,619,834	1,372,927	1,240,472	1,362,571	1,263,473	1,310,309
Total	93,416,136	90,693,546	88,565,260	86,132,338	81,296,011	77,288,162
Northwest						
McKinley	1,673,451	1,263,069	984,643	800,440	942,494	1,159,301
Rio Arriba	1,615,735	1,475,669	1,308,352	1,342,780	1,350,726	1,563,259
San Juan	4,079,956	4,998,550	3,934,275	3,396,844	3,107,352	2,987,830
Sandoval	200,408	264,131	270,005	456,473	526,063	366,273
Total	7,569,550	8,001,419	6,497,275	5,996,537	5,926,635	6,076,663

state dry-gas production. The total gas production in Rio Arriba County was 162,788,167 thousand cu ft, 14.04 percent of the state's 1978 natural-gas production. Sandoval County had production of 2,383,845 thousand cu ft, less than 1 percent of the state's total; and McKinley County produced 298,925 thousand cu ft.

County (by rank)	Thousand cu ft	Percent of total state production
San Juan	371,362,243	40.97
Eddy	215,108,001	23.73
Rio Arriba	155,583,374	17.17
Lea	154,108,714	17.00
Chaves	7,573,202	0.84
Sandoval	1,322,880	0.15
Roosevelt	1,268,544	0.14
Mora	14,614	—
McKinley	3,232	—
Total state dry-gas production	906,344,804	100.00

Southeast New Mexico

Dry-gas production in southeast New Mexico for 1978 was 378,058,461 thousand cu ft, which is 4.4 percent less than 1977 production. Casinghead-gas production was 240,806,743 thousand cu ft, 6.2 percent less than 1977 production. Additional data appear in the section about production projections.

Natural-gas liquid production

In 1978, 35 liquid-extraction plants were operating in New Mexico. Twenty-nine plants were located in southeast New Mexico and six were in the northwest section of the state. Total plant intake for the 35 plants was 969,930,363 thousand cu ft. Of this intake, 450,990,964 thousand cu ft went to the northwest, and 518,939,399 thousand cu ft went to the southeast. The total intake was 2.4 billion cu ft more than in 1977. Liquid production in 1978 was 31.4 million bbls, which was 7.2 million bbls less than 1977 liquid production. Most of the decrease was due to a drop of approximately 6.4 million bbls in gasoline production. The New Mexico Oil and Gas Engineering Committee (1978) reported New Mexico extraction plant production for 1978 as shown below.

	Southeast (29 plants)	Northwest (6 plants)	Total (35 plants)
Bbls gasoline	12,539,470	3,000,127	15,539,597
Bbls butane	3,480,494	3,555,629	7,036,123
Bbls propane	4,526,384	4,314,797	8,841,181

Drilling and development

The total number of wells drilled in the state in 1978 set an eight-year record high. This increase was attributed mainly to new gas-well completions. In 1978 1,543 new wells were drilled in New Mexico. This figure includes oil, gas, service, plugged-and-abandoned, and temporarily abandoned wells. Twelve wells fell under the classification of new footage in wells drilled deeper, and eight wells were classed as new footage in wells by reentry. According to the NMOCD (D. Stamets, personal communication), "new footage in wells by reentry" refers to wells that have been reentered after they were classed as "permanently abandoned." "New footage in wells drilled deeper" refers to all wells that have been drilled deeper except those that have been classed as "permanently abandoned" (table 7). In 1978, 444 new oil wells were drilled—an increase of 16 percent over 1977 drilling. In addition, 780 new gas wells were drilled in 1978—an increase of 14 percent over those drilled in 1977. Forty-six service wells, 259 permanently abandoned wells (dry holes), and 14 temporarily abandoned wells were drilled in 1978.

An examination of tables 7 and 8 shows that new well completions are not always the same as new wells drilled. The difference is that more than one completion can be made in a new well drilled. When a new well is drilled, the borehole can penetrate several productive zones; each productive zone would be a completion.

TABLE 7—OIL, GAS, SERVICE, DRY HOLES (PLUGGED AND ABANDONED), AND TEMPORARILY ABANDONED WELLS DRILLED IN NEW MEXICO IN 1978 (data from New Mexico Oil Conservation Division).

	Number drilled	Footage
Oil	444	2,187,051
Gas	780	4,657,776
Service	46	214,796
Plugged and abandoned	259	1,259,780
Temporarily abandoned	14	94,359
Subtotal	1,543	8,413,762
Wells drilled deeper	12	8,149
Wells by reentry	8	26,891
Subtotal	20	35,040
Total	1,563	8,448,802

Southeast New Mexico

Drilling and development in southeast New Mexico during 1978 continued to follow the development trend of the two previous years. Most of the oil and gas development was along known production trends, through infill drilling within existing pools, and in extensions to established pools.

According to the NMOCD (1978), 473 oil wells and 276 gas wells were completed during the year. In addition, 210 wells were completed as temporarily abandoned or plugged and abandoned. Of the 473 oil wells, 14 were wildcats and 459 were development completions. Gas wells included 54 wildcat completions and 222 development completions. In 1978 there were 54 more oil completions and 36 more gas completions than in 1977. Total footage drilled in southeast New Mexico for 1978 was 4,998,056 ft.

Northwest New Mexico

Both oil-well and gas-well completions in northwest New Mexico during 1978 were up from 1977. Table 8 shows 75 oil-well completions and 681 gas-well completions in 1978—an increase of 17 oil-well and 94 gas-well completions over 1977.

The greatest number of oil completions occurred in the Chacon Dakota Associated Pool, formerly Chacon Dakota Pool, which is located on the Jicarilla Apache Reservation along the Rio Arriba and Sandoval County line. As of January 1, 1979, the pool contained 56 pro-

TABLE 8—OIL, GAS, SERVICE, AND TEMPORARILY ABANDONED WELLS COMPLETED IN NEW MEXICO IN 1978; districts 1 and 2 are southeast New Mexico; district 3 is northwest New Mexico; and district 4 is Mora County (data from New Mexico Oil Conservation Division).

	Districts 1 and 2	District 3	District 4	Total state
Oil well completions				
New oil well completions	382	70	0	452
Oil wells drilled deeper	4	2	0	6
Oil wells plugged back	49	0	0	49
Oil wells reentry	15	3	0	18
Additional zone	23	0	0	23
Subtotal	473	75	0	548
Gas well completions				
New gas well completions	221	655	0	876
Gas wells drilled deeper	2	5	1	8
Gas wells plugged back	35	14	0	49
Gas wells reentry	6	0	0	6
Additional zone	12	7	0	19
Subtotal	276	681	1	958
Service well completions				
New service well completions	39	3	4	46
Service wells plugged back	2	0	0	2
Service wells reentry	0	0	1	1
Subtotal	41	3	5	49
Plugged & abandoned wells				
New P & A wells	175	69	17	261
P & A wells reentry	16	0	1	17
Subtotal	191	69	18	278
Temporarily abandoned wells				
New temporarily abandoned wells	14	1	0	15
Temporarily abandoned wells reentry	5	0	0	5
Subtotal	19	1	0	20
Total	1,000	804	24	1,828

ducing wells, with 37 in Rio Arriba County and 19 in Sandoval County.

The greatest number of gas completions occurred in the Blanco Mesaverde Pool with 313 wells, most being infill wells. The second largest number of gas completions occurred in the Blanco Pictured Cliffs Pool with 59 wells; other pools producing from Pictured Cliffs had 131 completions. The Basin Dakota Pool had 41 wells and ranked third in gas completions.

Additional drilling activity should occur in the Basin Dakota Pool in the next few years because of the New Mexico Oil Conservation Division order (in summer 1979) allowing Basin Dakota infill drilling. The order allows the optional drilling of an additional well on each 320-acre Dakota tract and potentially doubles the number of producing wells in each section.

Oil and gas industry in New Mexico

Geologic setting

The three major oil and gas provinces in New Mexico are the San Juan, Permian, and Delaware Basins. The Permian and Delaware Basins of southeast New Mexico and west Texas have long been among the major oil-and gas-producing provinces in the nation (fig. 2). Over 90 percent of the state's oil production has come from the two basins. Most of the oil and gas that has been produced in the San Juan Basin has come from reservoirs in the Pennsylvanian and Cretaceous Systems; the majority has come from the Cretaceous.

The first major oil discovery in the state was made in 1922 in the Hogback Oil Pool in San Juan County. The Gallup sands of the Cretaceous System have been the major oil producers discovered to date in the San Juan Basin. This production has come from sandbar-type stratigraphic traps and from fractured zones in the Mancos Shale. The first major discovery made in southeast New Mexico was in 1924 with the discovery of the Artesia Pool in Eddy County. Most of the early production in the southeast came from reservoirs in Permian strata. These reservoirs were relatively shallow, and production from many was prolific. Oil was later discovered in deep structures in Pennsylvanian, Mississippian, Devonian, Ordovician, and Silurian strata. Devonian beds in particular have been prolific oil producers.

The major sources of gas in the San Juan Basin are from two huge stratigraphic reservoirs: the Blanco Mesaverde and the Basin Dakota gas pools. The third major gas-producing zone in northwest New Mexico occurs in the Pictured Cliffs Sandstone, which, like the Dakota Formation and the Mesaverde Group, is of Cretaceous Age. Major reserves of dry gas in the southeast have been discovered in Pennsylvanian Formations. The Morrow Formation of Lower Pennsylvanian age has been the primary target in recent years. Many of these discoveries have been made in Eddy County.

Oil and gas sales

Table 9 shows oil and gas sales for New Mexico in 1978. According to the New Mexico Oil and Gas Accounting Division (1978), total oil sales amounted to $837,826,081 for 83,597,408 bbls—an average price of $10.02 per bbl. This sales figure compares to a lower value of $798,890,412 for a larger quantity of 86,701,836 bbls in 1977, but the average price per barrel in 1977 was $9.21. The largest volume of sales came from state land with 46 percent of total oil sales as compared with 48 percent in 1977.

Total gas sales in 1978 amounted to $1,154,502,027 for 1,137,853,045 thousand cu ft and an average price of $1.01 per thousand cu ft as compared with $960,169,087 for 1,192,760,410 thousand cu ft and an average price of $0.80 in 1977.

According to the New Mexico Employment Security Department (1979), 10,050 people were employed in oil and gas extraction in 1978. The majority (7,930) were employed as production and maintenance workers.

Projection of gas production

In spring 1976, the Legislative Energy Committee and the Energy Resources Board asked the Bureau of Geology to construct New Mexico oil- and gas-production projection curves that would show expected annual production through the year 2000. In response to this request, the Bureau of Geology staff constructed projection curves using several assumptions that produced differing rates of decline in production. The staff attempted to relate the varying rates to factors bearing on the decline rate—factors such as the history of past additions to reserves from new discoveries, assessments of discovery possibilities, decline rates in producing reservoirs, and economic factors affecting the oil and gas industry.

Since 1976, the Bureau of Geology has received requests for more current New Mexico oil and gas production projections. In response to this demand, the curves of the 1976 study were revised in fall 1978. The new revisions were based on the analysis of actual production and field development for 1976 and 1977, as well as on our best estimate of future development.

Production curves for statewide natural gas

In order to construct a statewide natural-gas curve, each major gas source in the state must be analyzed; from this analysis, a composite of the projected supplies and deliverability may be blended. New Mexico's natural-gas production consists of dry gas and casinghead gas, and it is produced in two separate oil and gas provinces, the San Juan Basin in the northwestern part of the state and the Permian/Delaware Basin in the southeastern part of the state. Casinghead or associated gas is that gas associated with oil production; dry or nonassociated gas occurs as dry gas in the reservoir and is produced independently of oil production.

The greater part of New Mexico's past casinghead-gas production has come from the southeastern part of the state in the Permian/Delaware Basin. In 1977, 96 percent of the casinghead production came from the southeast, and only 4 percent came from the northwest in the San Juan Basin, the only other casinghead gas-producing area in the state. The two areas are very different in their geology. Oil and gas production from the basins comes from strata of different ages and from dif-

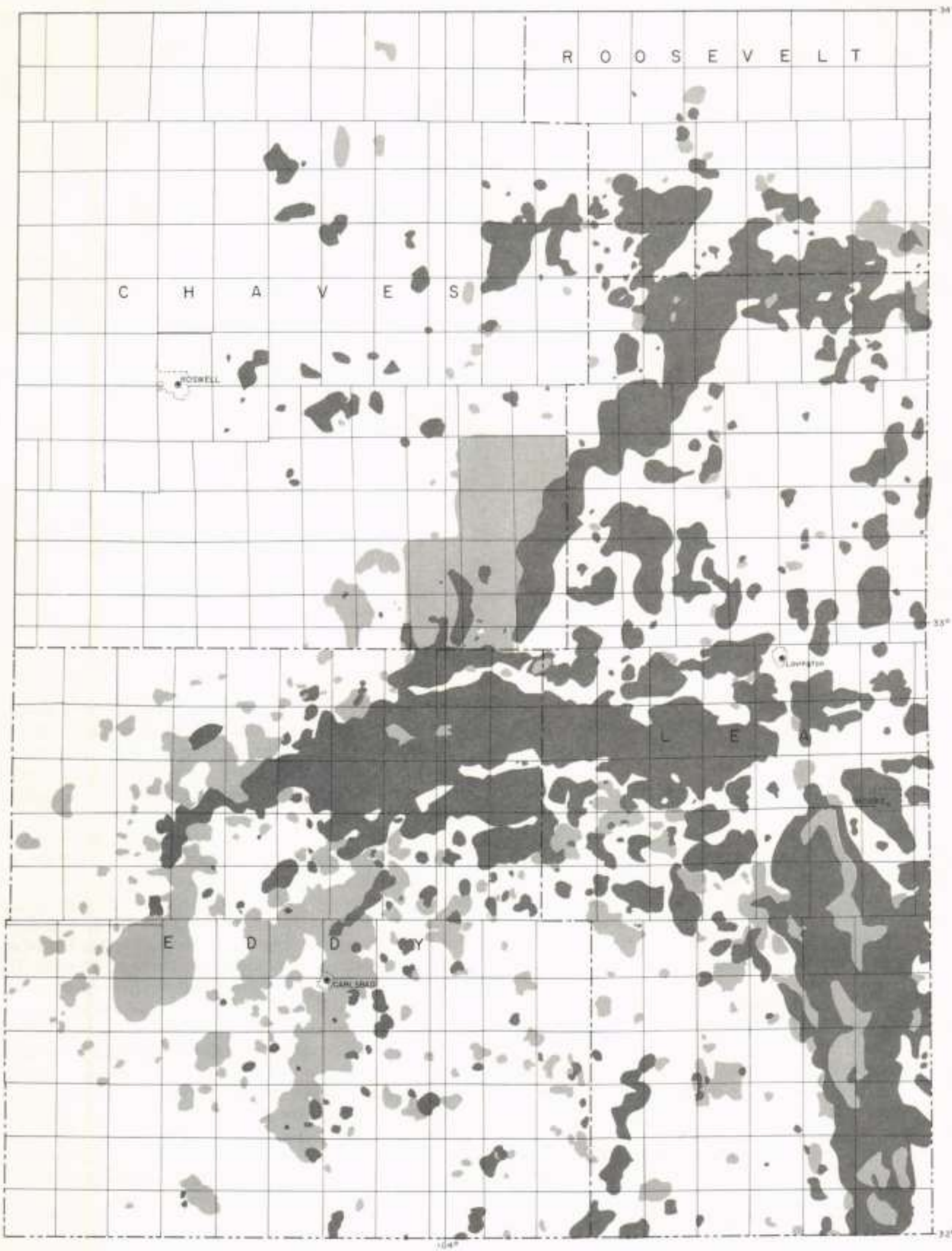

FIGURE 2—OIL- AND GAS-PRODUCING AREAS IN SOUTHEAST NEW MEXICO; darker areas represent oil fields; lighter areas represent gas fields (data from R. R. Chavez and R. A. Bieberman, New Mexico Bureau of Mines and Mineral Resources, November 1979).

TABLE 9—OIL AND GAS SALES IN NEW MEXICO, 1978 (New Mexico Oil and Gas Accounting Division, 1978).

Oil sales				Percent of sales volume				
County	Volume (bbls)	Value (dollars)	Price	State land	Federal land	Private land	Indian land	Percent of total
Chaves	1,507,902	18,488,659	12.26	40	43	17		2
Eddy	22,489,764	265,591,434	11.80	52	45	3		27
Lea	52,425,310	478,679,892	9.13	49	24	26		63
McKinley	1,159,427	12,076,869	10.41	5	53	17	25	1
Roosevelt	1,316,836	15,062,888	11.43	23	59	17		2
Rio Arriba	1,488,819	15,206,330	10.21	4	58	2	37	2
Sandoval	328,911	3,709,884	11.27		45		55	
San Juan	2,880,439	29,010,125	10.07	5	59	3	32	3
Total oil sales	83,597,408	837,826,081	10.02	46	33	18	2	100
Gas sales								
County	1,000 cu ft							
Chaves	10,794,559	11,183,727	1.03	41	55	4		1
Eddy	227,159,860	257,168,177	1.13	23	60	17		20
Lea	365,028,641	292,067,279	.80	39	23	38		32
McKinley	13,549	2,302	.16		100			
Roosevelt	3,408,312	3,106,118	.91	15	64	21		
Rio Arriba	153,513,383	166,796,007	1.08	6	74		19	13
Sandoval	2,172,404	3,909,326	1.79		5		95	
San Juan	374,668,655	420,157,282	1.12	9	85	3	3	33
Harding	1,081,311	94,284	.08			100		
Mora	12,371	17,525	1.41		25	75		1
Total gas sales	1,137,853,045	1,154,502,027	1.01	21	58	17	4	100
Total sales		$1,992,328,108						

ferent types of reservoirs. The Permian/Delaware Basin is a major oil province, whereas the San Juan Basin is a major dry-gas province.

Oil and casinghead-gas production in the southeast has come largely from reservoirs of Permian age, and much of the dry-gas production comes from reservoirs of Pennsylvanian age, principally the Morrow Formation. The Morrow gas reservoirs have greater porosity and permeability than the stratigraphic gas reservoirs of the San Juan Basin and are smaller in size. Consequently, the Morrow reservoirs are depleted at a faster rate than the gas reservoirs in the San Juan Basin. The average field life of a Morrow gas well is about seven years.

Most of the gas production in the northwest comes from reservoirs of Cretaceous age. About 80 percent of the gas production comes from two huge stratigraphic reservoirs, the Blanco Mesaverde and the Basin Dakota Pools. Permeabilities and resultant producing rates are low. As a result, the producing life of those reservoirs will be comparatively long; estimates range up to 40 years. New Mexico's 1977 gas production is shown below in thousands of cubic feet in figures compiled by the NMOCD:

	Production (thousand cu ft)		
	Casinghead	*Dry gas*	*Total gas*
Northwest	10,248,132	521,800,291	532,048,423
Southeast	256,711,369	395,558,468	652,269,837
State total	266,959,501	917,358,759	1,184,318,260

Forty-five percent of New Mexico's 1977 natural-gas production came from northwest New Mexico and 55 percent came from the southeast. A further breakdown shows 23 percent of the total production was casinghead gas, and 96 percent of this casinghead production came from the southeast. Seventy-seven percent of the state's production was dry gas, and 43 percent of this came from the southeast.

The production of dry gas is more evenly balanced between the two basins; but because of the difference in reservoir characteristics, this balance could shift considerably in the next few years. The average producing life of a well in a Permian/Delaware Basin Morrow Pool is seven years compared to the producing life of a San Juan Blanco Mesaverde Pool of around 35 years. If southeast New Mexico is to maintain its present share of total state dry-gas production, the new gas discovery and development rate will have to remain at a high level.

The task of determining gas reserves and projected production differs with gas type, reservoir characteristics, and region. The state's natural-gas projected production curves are a composite of three primary curves: dry gas northwest, dry gas southeast, and total casinghead gas. For additional information on the procedure used in this study, see Arnold and others (1976, 1977).

Projection for production of dry gas in northwest

When northwest New Mexico's dry-gas production was projected in spring 1976, the San Juan Basin's dry-gas production for that year was expected to increase by

2 percent over 1975 production, and 1977 production was expected to decline by 2 percent from that of 1976. Instead, 1976 production increased more than 2 percent (2.6 percent); and 1977 production, rather than declining by 2 percent, actually increased by 0.8 percent over 1976 production. These increases in production were caused by the very active drilling program, mainly infill drilling, that was brought on by higher gas prices. This additional drilling increased the deliverability from gas reservoirs in the San Juan Basin, thus boosting production.

In 1977, 587 gas wells were completed in northwest New Mexico; and, of these completions, many were Blanco Mesaverde infill wells. This active drilling program has continued through 1978 with an additional 656 gas wells completed in that year. With this additional drilling, dry-gas production for 1978 may again show a 1-2 percent increase over the previous year.

The increased production in the San Juan Basin is due to favorable economic incentives, mainly higher gas prices. This price rise led to the development of marginal areas in existing reservoirs. Improved prices also stimulated infill development in the Blanco Mesaverde Pool. This program has now been completed in the better portions of the Blanco Mesaverde Pool; and, unless substantial new production is discovered in other zones, the production will again start declining.

As shown in tables 10 and 11, two projections were constructed for northwest New Mexico. The high projection is based on a northwest gas-production rate that anticipates a 1-percent increase in 1979 and 1980, a 1-percent decline in 1981, a 2-percent decline from 1981 through 1983, and a 3-percent decline from 1984 through 2000. For this projection, the total production through 2000 would be 9.6 trillion cu ft of gas, and the annual production for 2000 would be 295.5 billion cu ft, or only 56 percent of the 1977 production. The low projection in table 10 is based on the same rate from 1979 through 1983, but the projection increases to a 5-percent decline rate from 1984 through 2000. This projection would result in total production of 8.6 trillion cu ft from 1978 through 2000, and production would be 207.4 billion cu ft for 2000.

Projection for production of dry gas in southeast

According to projection studies made in 1976, dry-gas production in southeast New Mexico was expected to increase by 6 percent over 1975 production and then to decrease 3 percent in 1977. Actually, the 1976 production increase was 2.7 percent above 1975, and 1977 production decreased by 2 percent from 1976. Current production figures show that 1978 dry-gas production declined 4.4 percent from 1977. Part of this decline could be the result of some production curtailment caused by a seasonal-demand variation in the Indian Basin (Upper Pennsylvanian) Gas Pool in Eddy County. Wells in this pool are highly productive and a large curtailment would affect the overall southeast production decline. Yearly dry-gas production in southeast New Mexico increased from 298 billion cu ft in 1971 to 399 billion cu ft in 1973 and has been near 400 billion cu ft yearly since 1973. This level of production was attained largely through an extensive drilling program in the portion of the Delaware Basin located in Eddy County. Primary targets were the Upper Pennsylvanian and the Atoka and Morrow Formations of the Lower Pennsylvanian.

Gas production is also affected by operators drilling an additional well on a gas-producing proration unit. Generally, the second well encounters different or additional gas-producing sand lenses not present in the first well (thus increasing the unit production) and recovers gas that otherwise would not be produced. Increased gas prices have helped maintain this activity despite higher drilling and completion costs. Many wells have been

TABLE 10—Lower projection for natural-gas production in New Mexico, 1978–2000; figures are in billions of cu ft (data from New Mexico Bureau of Geology).

Year	Percent decline	SE N.M. dry gas	Percent change	NW N.M. dry gas	Percent decline	Csghd gas statewide	Total gas
1978	- 4.4	378.1	+ 1	528.3	- 5	252.8	1,159.2
1979	- 4	363.0	+ 1	532.3	- 6	237.6	1,132.9
1980	- 5	344.8	- 1	527.0	- 6	223.4	1,095.2
1981	- 5	327.6	- 2	516.4	- 7	207.7	1,051.7
1982	- 6	307.9	- 2	506.1	- 7	193.2	1,007.2
1983	- 6	289.4	- 2	496.0	- 8	177.7	963.1
1984	- 6	272.1	- 5	471.2	- 8	163.5	906.8
1985	- 7	253.0	- 5	447.6	- 8	150.4	851.0
1986	- 7	235.3	- 5	425.3	- 10	135.4	796.0
1987	- 7	218.8	- 5	404.0	- 10	121.9	744.7
1988	- 7	203.5	- 5	383.8	- 10	109.7	697.0
1989	- 8	187.2	- 5	364.6	- 10	98.7	650.5
1990	- 8	172.3	- 5	346.4	- 10	88.8	607.5
1991	- 8	158.5	- 5	329.1	- 10	80.0	567.6
1992	- 8	145.8	- 5	312.6	- 10	72.0	530.4
1993	- 9	132.7	- 5	297.0	- 10	64.8	494.5
1994	- 9	120.7	- 5	282.1	- 10	58.3	461.1
1995	- 9	109.9	- 5	268.0	- 10	52.5	430.4
1996	- 9	100.0	- 5	254.6	- 10	47.2	401.8
1997	- 9	91.0	- 5	241.9	- 10	42.5	375.4
1998	- 9	82.8	- 5	229.8	- 10	38.2	350.8
1999	- 9	75.3	- 5	218.3	- 10	34.4	328.0
2000	- 9	68.6	- 5	207.4	- 10	31.0	307.0
Total projected production:							
1978-1985		2,535.9		4,024.9		1,606.3	8,167.1
1986-2000		2,102.4		4,564.9		1,075.4	7,742.7
1978-2000		4,638.3		8,589.8		2,681.7	15,909.8

TABLE 11—Higher projection for natural-gas production in New Mexico, 1978–2000; figures are in billions of cu ft (data from New Mexico Bureau of Geology).

Year	Percent decline	SE N.M. dry gas	Percent change	NW N.M. dry gas	Percent decline	Csghd gas statewide	Total gas
1978	- 4.4	378.1	+ 1	528.3		252.8	1,159.9
1979	- 4	363.0	+ 1	532.3	- 6	237.6	1,132.9
1980	- 4	348.5	- 2	527.0	- 6	223.4	1,098.8
1981	- 4	334.6	- 2	516.4	- 7	207.7	1,058.6
1982	- 5	317.9	- 2	506.1	- 7	193.2	1,017.1
1983	- 5	302.0	- 2	496.0	- 8	177.7	975.6
1984	- 6	283.9	- 3	481.1	- 8	163.5	928.4
1985	- 6	266.9	- 3	466.7	- 8	150.4	883.8
1986	- 6	250.9	- 3	452.7	- 10	135.4	838.8
1987	- 6	235.8	- 3	439.1	- 10	121.9	796.7
1988	- 6	221.7	- 3	425.9	- 10	109.7	757.1
1989	- 6	208.4	- 3	413.1	- 10	98.7	720.1
1990	- 6	195.9	- 3	400.8	- 10	88.8	685.4
1991	- 7	182.2	- 3	388.7	- 10	80.0	650.8
1992	- 7	169.4	- 3	377.1	- 10	72.0	618.4
1993	- 7	157.5	- 3	365.8	- 10	64.8	588.1
1994	- 7	146.5	- 3	354.8	- 10	58.3	559.5
1995	- 7	136.2	- 3	344.1	- 10	52.5	532.8
1996	- 7	126.7	- 3	333.8	- 10	47.2	507.7
1997	- 7	117.8	- 3	323.8	- 10	42.5	484.1
1998	- 7	109.6	- 3	314.1	- 10	38.2	461.8
1999	- 7	101.9	- 3	304.7	- 10	34.4	441.0
2000	- 7	94.8	- 3	295.5	- 10	31.0	421.2
Total projected production:							
1978-1985		2,594.9		4,053.9		1,606.3	8,254.4
1986-2000		2,455.3		5,534.0		1,075.4	9,063.5
1978-2000		5,050.2		9,587.9		2,681.7	17,317.9

drilled and completed recently that would not have been commercial at the old gas price.

There were 276 gas completions in 1978, with many in the formations mentioned above. Despite this number of completions, production declined 4.4 percent. The number of gas completions in Eddy County clearly must remain close to 1977-1978 levels to help offset the current 10-percent gas-production decline in Lea County. Compared to Eddy and Lea Counties, Chaves and Roosevelt Counties produce only minor amounts of dry gas. Several major discoveries in these two counties would be necessary to slow the current rate of decline in southeast New Mexico.

Tables 10 and 11 show that two projections were made for gas production in southeast New Mexico. The low projection is based on a discovery and completion rate in Eddy County through 1980 approximating the rate experienced during 1977 and 1978, with Lea County's production decline continuing about 10 percent per year. Drilling in Eddy County is expected to decline after 1980 but to remain fairly active for several years (approximately 50-60 percent of 1977-1980 activity). By 1985, many more of the Morrow wells drilled earlier will have been depleted, and new completions will not offset this loss of production. Unless major new discoveries of gas are made in southeast New Mexico and 'unless price controls are taken off natural gas, the percent_ decline could approach 15 percent or more after 1990. The high projection is similar to the low except that it anticipates some significant discoveries, possibly in deeper horizons than the Pennsylvanian, and the lifting of gas price controls in the 1980's, which would induce development of marginal zones discovered previously.

Projection for production of casinghead gas

Casinghead, or associated gas, is that gas which is produced along with oil. Because this gas is tied to the production of oil, a basic decline in oil production would signal a decline in casinghead-gas production. Therefore, casinghead-gas projections are based on our estimate of projected oil production.

Casinghead-gas production has provided a substantial segment of total gas production in the state. Production in 1978 was 252.8 billion cu ft, 23 percent of the state's total gas production. Many of the large oil pools in the state are now declining in production, and waterflooding projects have been instituted in a large number of them. Casinghead-gas production from these pools is also declining, and the rate of decline will probably increase. The decline can be arrested or reversed only by the discovery of significant new oil pools.

Tables 10 and 11 show that casinghead-gas production, which showed a 5-percent decline in 1978, will continue to decline but at a faster rate. By 1986, the rate of decline is estimated to be 10 percent per year and will continue at that rate through 2000.

Projection for production of natural gas

As shown in tables 10 and 11, high and low statewide gas projections were made. The two tables were constructed by combining yearly projected volumes of dry gas from northwest New Mexico, dry gas from southeast New Mexico, and statewide casinghead-gas production.

If production equals that indicated by the low projection in table 10, total state production for the period 1978 through 1985 would be 8.167 trillion cu ft, and the production in 1985 would be 851.0 billion cu ft. Production from 1986 through 2000 would be 7.743 trillion cu ft, and the production in 2000 would be 307 billion cu ft. Total production for 1978 through 2000 would be 15.91 trillion cu ft.

As shown in table 11, the high projection for total state production for the period 1978 through 1985 would be 8.254 trillion cu ft, and the production in 1985 would be 883.8 billion cu ft. Assuming the high projection, production from 1986 through 2000 would be 9.064 trillion cu ft, and production in 2000 would be 421.2 billion cu ft. Total production, using the high production figures, for the period 1978 through 2000 would be 17.318 trillion cu ft.

Projection for production of crude oil

In table 12, column 2 lists actual yearly crude-oil production in southeast New Mexico from 1969 through 1978 and projects yearly crude-oil production from 1979 through 2000. Column 4 shows historical crude-oil production in the Empire Abo Pool from 1969 through 1978, yearly production estimates from 1979 through 1990 (furnished by Atlantic Richfield Company early in 1979), and projected production from 1991 through 2000 using a yearly 6-percent production decline. Column 5 shows southeast yearly production (less Empire Abo Pool yearly production) from 1969 through 1978 and projected southeast yearly production (less projected Empire Abo yearly production) from 1979 through 2000 using a 5-percent production decline in 1979 and 1980 and a 6-percent decline from 1981 through 2000. By combining projected yearly production in column 5 with the corresponding yearly production in column 4, total southeast projected yearly production is obtained in column 2. Column 2 is believed to represent the best current estimate of the decline rate for crude-oil production in southeast New Mexico from 1979 through 2000. The higher decline rates shown for the years 1980 through 1982 are expected to be a result of a sharp decrease in production from the Empire Abo Pool, the largest oil-producing pool in New Mexico.

The production projection for 1979 may be optimistic because the production decline in the Empire Abo Pool has been greater in the first quarter than anticipated. The production decline in the first quarter was 21 percent for the Empire Abo and 8.25 percent for all southeast New Mexico. Should the Empire Abo Pool have a 20-percent production decline in 1979, 11.49 million bbls would be produced instead of 13.18 million bbls. Assuming all other southeast crude-oil production declines at the projected 5-percent rate, total southeast crude-oil production would be 68.92 million bbls—an 8-percent decline in 1979 from 1978 instead of the projected 5.6 percent decline. Table 13 shows projected production of crude oil from 1979 through 2000 for all of New Mexico with both a 5-percent decline and a 10-percent decline.

TABLE 12—SOUTHEAST NEW MEXICO CRUDE-OIL PRODUCTION IN BBLS: ACTUAL PRODUCTION, 1969–1978, AND PROJECTED PRODUCTION, 1979–2000. In 1971 Jalmat Oil Pool was reclassified as a gas pool. In 1974 Blinebry Gas Pool was reclassified as Blinebry Oil and Gas Pool. Empire Abo production figures for 1979 through 1990 are estimates furnished by Atlantic Richfield. Projected production for Empire Abo from 1991 to 2000 uses a yearly 6-percent production decline.

Year	Southeast New Mexico	Percent decline	Empire Abo Pool	S.E. minus Empire Abo	Percent decline
1969	117,722,236		8,399,860	109,322,376	
1970	117,181,123	1	9,136,850	108,044,273	1.2
1971	107,708,035	8.1	9,279,472	98,428,563	8.9
1972	99,665,888	7.5	9,374,822	90,291,066	8.3
1973	91,233,655	8.5	9,743,628	81,490,027	9.8
1974	88,483,452	3	13,380,370	75,103,082	7.8
1975	86,374,571	2.4	15,219,800	71,154,771	5.3
1976	83,715,295	3.1	15,296,442	68,418,853	3.9
1977	78,899,095	5.8	15,168,864	63,730,231	5.2
1978	74,819,101	5.2	14,368,103	60,450,998	5.2
1979	70,604,948	5.6	13,176,500	57,428,448	5
1980	63,426,526	10.2	8,869,500	54,557,026	5
1981	56,977,604	10.2	5,694,000	51,283,604	6
1982	52,039,088	8.7	3,832,500	48,206,588	6
1983	48,051,693	7.7	2,737,500	45,314,193	6
1984	44,748,841	6.9	2,153,500	42,595,341	6
1985	41,572,621	7.1	1,533,000	40,039,621	6
1986	38,841,744	6.6	1,204,500	37,637,244	6
1987	36,364,509	6.4	985,500	35,379,009	6
1988	34,059,268	6.3	803,000	33,256,268	6
1989	31,808,392	6.6	547,500	31,260,892	6
1990	29,823,239	6.2	438,000	29,385,239	6
1991	28,033,845	6	411,720	27,622,125	6
1992	26,351,815	6	387,017	25,964,798	6
1993	24,770,706	6	363,796	24,406,910	6
1994	23,284,463	6	341,968	22,942,495	6
1995	21,887,395	6	321,450	21,565,945	6
1996	20,574,152	6	302,163	20,271,989	6
1997	19,339,702	6	284,033	19,055,669	6
1998	18,179,320	6	266,991	17,912,329	6
1999	17,088,561	6	250,972	16,837,589	6
2000	16,063,247	6	235,913	15,827,334	6
Total projected production					
1979–1990	548,318,473		41,975,000	506,343,473	
1991–2000	215,573,206		3,166,023	212,407,183	

Reserves

Southeast New Mexico

The Bureau of Geology calculated primary and secondary crude-oil reserves for 40 pools in southeast New Mexico to be 779 million bbls as of January 1, 1978. API (American Petroleum Institute and others, 1978) proved and indicated additional crude-oil reserves for all pools in southeast New Mexico to be 842.6 million bbls as of January 1, 1978.

Using data and information generated and gathered by the Bureau of Geology, the first of several continuing projects was initiated in 1976 to help determine oil and gas reserves in southeast New Mexico. Data included historical oil and gas production from 30 oil pools and the five highest producing gas pools, oil- and gas-pool location plats showing boundaries of each pool and their associated secondary recovery units, production performance of the secondary recovery projects, and other pertinent information pertaining to production and reserves. Sipes, Williamson and Aycock, Inc., an engineering-consulting firm, was placed under contract to calculate remaining oil reserves in 30 pools containing approximately 75 percent of the secondary recovery projects in southern New Mexico (table 14). Engineering techniques and procedures used to calculate total remaining reserves for the 30 pools were published in January 1978 in Arnold and others (1978). Individual pool reserves, plus a brief description of the producing horizons, are available in a report furnished by Sipes, Williamson and Aycock, Inc. (1979).

The next project consisted of updating and refining studies of the original 30 pools for 1977 and calculating reserves for 10 additional oil pools in southeast New Mexico (table 15). According to the 1977 Annual Report of the New Mexico Oil and Gas Engineering Committee, production from these 40 pools was 61,704,123 bbls or 75 percent of the statewide production total of 82,619,090 bbls. The updating and additional studies of the 30 pools previously mentioned, also conducted by Sipes, Williamson and Aycock, Inc., resulted in some changes of remaining oil reserves in a few pools, with total reserves being increased from 661 million bbls to 678 million bbls as of January 1, 1978. Remaining reserves of the 10 additional pools were calculated to be 101 million bbls as of January 1, 1978.

Because the 40 pools mentioned above produced 75 percent of the oil in 1977, one might assume that these

TABLE 14—EVALUATION OF REMAINING OIL RESERVES FOR 30 POOLS IN SOUTHEAST NEW MEXICO, January 1, 1978; cumulative production corrected from New Mexico Oil and Gas Engineering Committee Annual Report dated January 1, 1959. Cumulative production brought forward (data from New Mexico Bureau of Geology).

No.	Pool name	Primary ultimate recovery oil, bbl	Secondary ultimate recovery oil, bbl	Total ultimate recovery oil, bbl	Cumulative production at 1-1-78, oil, bbl	Remaining reserves oil, bbl
1	Artesia (Queen-Grayburg-San Andres)	17,995,000	13,673,000	31,668,000	23,921,892	7,746,108
2	Caprock (Queen)	38,178,000	34,644,000	72,822,000	71,741,353	1,080,647
3	Cato (San Andres)	13,032,000	2,993,000	16,025,000	13,835,892	2,189,108
4	Chaveroo (San Andres)	18,133,000	2,982,000	21,115,000	18,359,125	2,755,875
5	Denton (Wolfcamp)	33,136,000	6,428,000	39,564,000	33,317,962	6,246,038
6	Dollarhide (Devonian)	2,798,000	5,081,000	7,879,000	6,004,709	1,874,291
7	Dollarhide (Tubb-Drinkard)	14,452,000	6,969,000	21,421,000	15,846,528	5,574,472
8	Drinkard	79,313,000	47,588,000	126,901,000	73,361,709	53,539,291
9	Empire (Abo)	161,170,000	54,798,000	215,968,000	158,155,279	57,812,721
10	Eumont (Yates-Seven Rivers)	66,800,000	10,650,000	77,450,000	68,517,052	8,932,948
11	Eunice Monument (Grayburg-San Andres)	376,181,000	75,236,000	451,417,000	333.395,463	118,021,537
12	Eunice, South (Seven Rivers-Queen)	23,138,000	17,067,000	40,205,000	24,358,989	15,846,011
13	Flying "M" (San Andres)	2,917,000	6,795,000	9,712,000	5,681,050	4,030,950
14	Grayburg Jackson (Queen-San Andres)	65,999,000	21,475,000	87,474,000	75,767,915	11,706,085
15	Hobbs (Grayburg-San Andres)	270,000,000	79,168,000	349,168,000	234,053,742	115,114,258
16	Jalmat (Yates-Seven Rivers)	61,080,000	30,540,000	91,620,000	57,819,325	33,800,675
17	Langlie Mattix (Seven Rivers-Queen)	78,815,000	59,899,000	138,714,000	97,692,420	41,021,580
18	Loco Hills(Queen-Grayburg-San Andres)	28,159,000	17,473,000	45,632,000	42,016,094	3,615,906
19	Lovington (Paddock)	11,176,000	4,471,000	15,647,000	12,041,980	3,605,020
20	Maljamar (Grayburg-San Andres)	88,629,000	53,177,000	141,806,000	112,091,908	29,714,092
21	Paddock (Paddock)	27,231,000	0	27,231,000	22,426,932	4,804,068
22	Paduca (Delaware)	7,000,000	8,914,000	15,914,000	10,603,467	5,310,533
23	Pearl (Queen)	10,198,000	12,102,000	22,300,000	18,320,876	3,979,124
24	Penrose-Skelly (Grayburg)	18,714,000	1,533,000	20,247,000	18,179,270	2,067,730
25	Scarborough (Yates-Seven Rivers)	15,794,000	948,000	16,742,000	14,584,234	2,157,766
26	Shugart(Yates-7 Rivers-Queen-Grayburg)	14,342,000	7,888,000	22,230,000	16,104,879	6,125,121
27	Square Lake (Grayburg-San Andres)	17,524,000	17,243,000	34,767,000	22,265,113	12,501,887
28	Vacuum (Grayburg-San Andres)	216,631,000	24,033,000	240,664,000	171,007,707	69,656,293
29	Vacuum, North (Abo)	20,553,000	20,034,000	40,587,000	16,594,458	23,992,542
30	Vacuum (Abo Reef)	79,326,000	15,952,000	95,278,000	72,123,516	23,154,484
	GRAND TOTAL	1,878,414,000	659,754,000	2,538,168,000	1,860,190,839	677,977,161

pools could contain 75 percent of the statewide oil reserves. If so, the reserve figure of 779 million bbls would be expanded to 974 million bbls to represent statewide primary and secondary oil reserves. API's statewide proved and indicated oil reserves were 864.6 million bbls as of January 1, 1978.

According to API (1978), proved oil reserves for southeast New Mexico were 471.7 million bbls and indicated additional reserves from known reservoirs were 370.9 million bbls as of January 1, 1978. API reserves are based on reservoir studies that do not take into account all potential development of existing pools. Indicated additional reserves are reserves expected from existing secondary recovery projects that have experienced a positive response to waterflooding (S. Smith, personal communication). The Sipes, Williamson and Aycock reserve studies do not separate secondary-recovery production actually occurring in an active waterflood project within a pool from the secondary reserves which are believed to be obtainable from current primary producing areas (areas that contain no waterflood projects or areas with waterflood projects

TABLE 15—Evaluation of remaining oil reserves for 10 pools in southeast New Mexico, January 1, 1978. Pool acres calculated from location plats furnished by New Mexico Oil Conservation Division. Cumulative production corrected from New Mexico Oil and Gas Engineering Committee Annual Report dated January 1, 1959. Cumulative production brought forward. Secondary projects have not yet begun for Blinebry, Justis, and Vacuum Pools (data from New Mexico Bureau of Geology).

No.	Pool name	Pool acres	Secondary recovery acres	Percent of total acreage not on secondary recovery	Primary ultimate recovery oil, bbl	Secondary ultimate recovery oil, bbl	Total ultimate recovery oil, bbl	Cumulative production at 1-1-78 oil, bbl	Remaining reserves oil, bbl
1	North Bagley (Penn)	18,960			48,079,678		48,079,678	41,238,741	6,840,937
2	Blinebry Oil & Gas	44,440			41,619,581	6,287,000	47,906,581	36,823,181	11,083,400
3	Corbin (Abo)	3,360			14,746,144		14,746,144	12,535,404	2,210,740
4	Crossroads (Siluro-Devonian)	3,840			40,120,219		40,120,219	38,871,871	1,248,348
5	Denton (Devonian)	10,400			99,304,991		99,304,991	91,851,473	7,453,518
6	Justis (Blinebry)	10,480			26,333,681	10,533,472	36,867,153	23,076,459	13,790,694
7	Rhodes (Yates-Seven Rivers)	10,341	2,120	79.5	11,684,000	13,144,500	24,828,500	9,564,595	15,263,905
8	Vacuum (Glorieta)	8,320			63,793,028	15,948,257	79,741,285	43,727,628	36,013,657
9	Vada (Penn)	58,240			50,634,438		50,634,438	45,538,052	5,096,386
10	Wantz (Granite Wash)	6,240			4,922,389		4,922,389	2,459,229	2,463,160
					410,238,149	45,913,229	447,151,378	345,686,633	101,464,745

that have not had a positive response). The secondary reserves believed to be obtainable from current, primary producing areas are based on analogy to existing secondary-recovery performance nearby or in an adjoining pool producing from the same formation. Analogy to existing secondary-recovery performance refers to the similarities of geological and reservoir parameters of the producing interval in a primary producing area to a producing interval in an active waterflood project that has shown a positive response.

Another project that has been completed for southeast New Mexico involves the volumetric calculations of the reserves in 172 oil and gas wells completed in the fourth quarter of 1977. This entailed a quantitative electric-log interpretation to determine each well's net pay, average porosity, water saturation, hydrocarbon saturation, original oil or gas in place, and estimated ultimate recoveries from the completed intervals. Calculated oil reserves in 111 oil completions for the fourth quarter of 1977 amounted to approximately 3.43 million bbls, and gas reserves in 61 gas completions amounted to 85.67 billion cu ft. Volumetric reserve calculations may require adjustment either up or down after a production history is established. Reserve studies are presently underway for oil and gas wells completed in the first half of 1978.

Reserve studies have been conducted to determine remaining as reserves for five major gas pools in southeast New Mexico. The five pools are the Indian Basin (Upper Pennsylvanian), Burton Flat (Morrow), Jalmat (Tansill-Yates-Seven Rivers), South Carlsbad (Morrow), and the Tubb. Results of the gas-reserve studies are shown in table 16 and figs. 3-7. Production from the five pools was 148,955,137 thousand cu ft in 1977, an average of 408,096 thousand cu ft per day, which was 38 percent of the dry gas produced in southeast New Mexico for 1977. Production in 1978 was 122,304,420 thousand cu ft, down 18 percent from 1977. API's estimate of dry-gas reserves in southeast New Mexico was 1,382 billion cu ft as of December 31, 1978, and total gas was 3,615 billion cu ft.

Basin Dakota reserves

The Basin Dakota Gas Pool is the second most prolific producer in the San Juan Basin. The pool is a huge stratigraphic trap with structure playing little part in gas accumulation. The Dakota is productive over much of the area occupied by the Blanco Mesaverde Pool. In addition, Dakota productive limits extend 12-15 mi southwest and 20 mi southeast of the Blanco Mesaverde Pool boundary. Productive sands in the Dakota Pool, however, are less continuous. Dakota reservoir quality is also inferior to that of the Mesaverde and average per-acre reserves are smaller.

As of January 1, 1979, 2,461 gas wells were producing from the Basin Dakota Gas Pool. Of these, 1,641 are located in San Juan County and 820 in Rio Arriba County. Production from the Basin Dakota Pool totaled 3.03 trillion cu ft with 2.24 trillion cu ft coming from San Juan County and 791 billion cu ft coming from Rio Arriba County.

The Bureau of Geology completed a reserve study of the Basin Dakota Gas Pool. The reserve for the pool

TABLE 16—Evaluation of remaining reserves for five major gas pools in southeast New Mexico, January 1, 1979 (New Mexico Oil and Gas Engineering Committee, 1978; Sipes, Williamson and Aycock, Inc., 1979).

County POOL (Reservoir)	Cumulative production, million cu ft	Estimated remaining reserves, million cu ft	Estimated ultimate recovery, million cu ft
Eddy County			
BURTON FLAT (Morrow)	123,465	44,822	168,287
CARLSBAD, SOUTH (Morrow)	161,394	72,403	233,797
INDIAN BASIN (Upper Penn)	792,216	268,823	1,061,039
Lea County			
JALMAT (Tansill-Yates-Seven Rivers)	1,580,696	184,737	1,765,433
TUBB	400,798	90,446	491,244
Totals	3,058,569	661,231	3,719,800

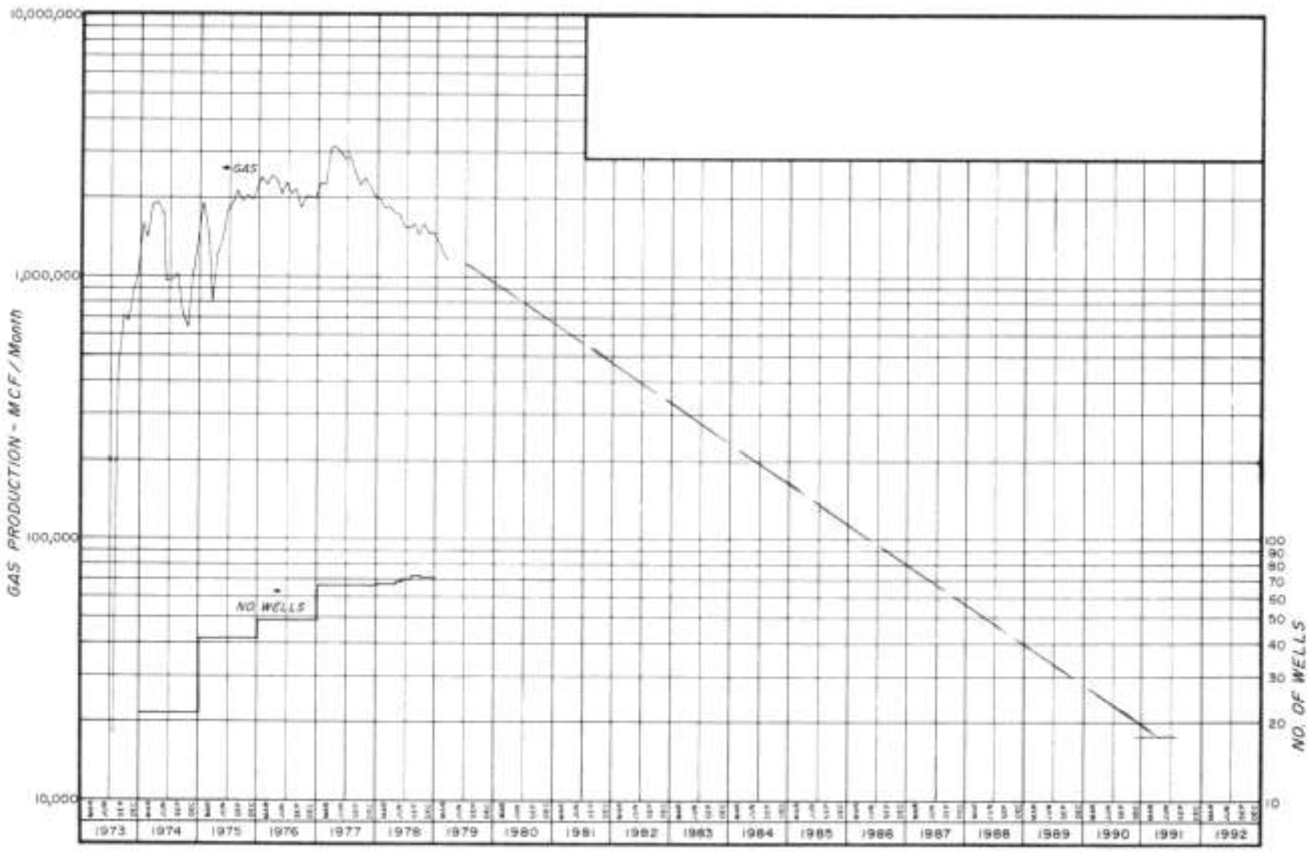

FIGURE 3—TOTAL POOL PRODUCTION FOR BURTON FLAT GAS FIELD (Sipes, Williamson and Aycock, Inc., 1979).

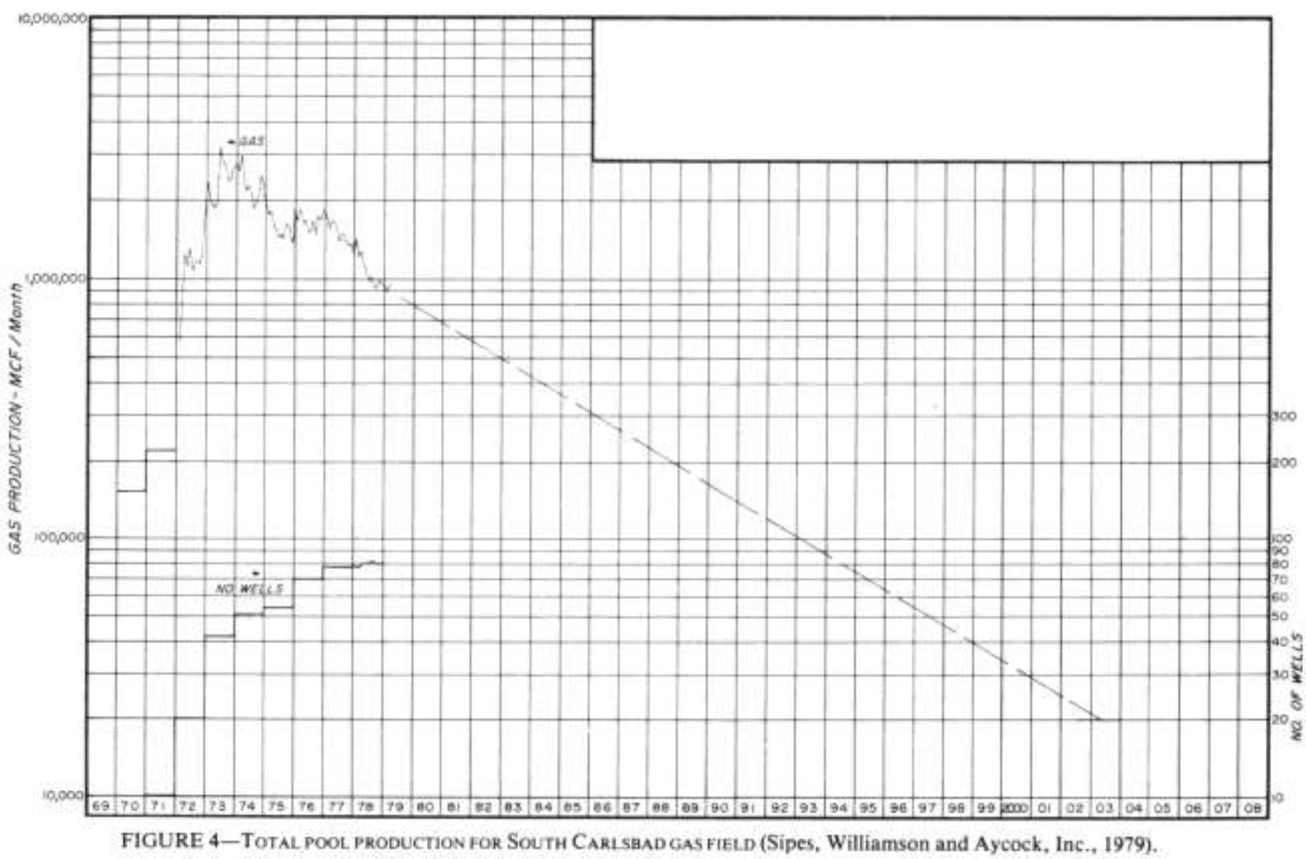

FIGURE 4—TOTAL POOL PRODUCTION FOR SOUTH CARLSBAD GAS FIELD (Sipes, Williamson and Aycock, Inc., 1979).

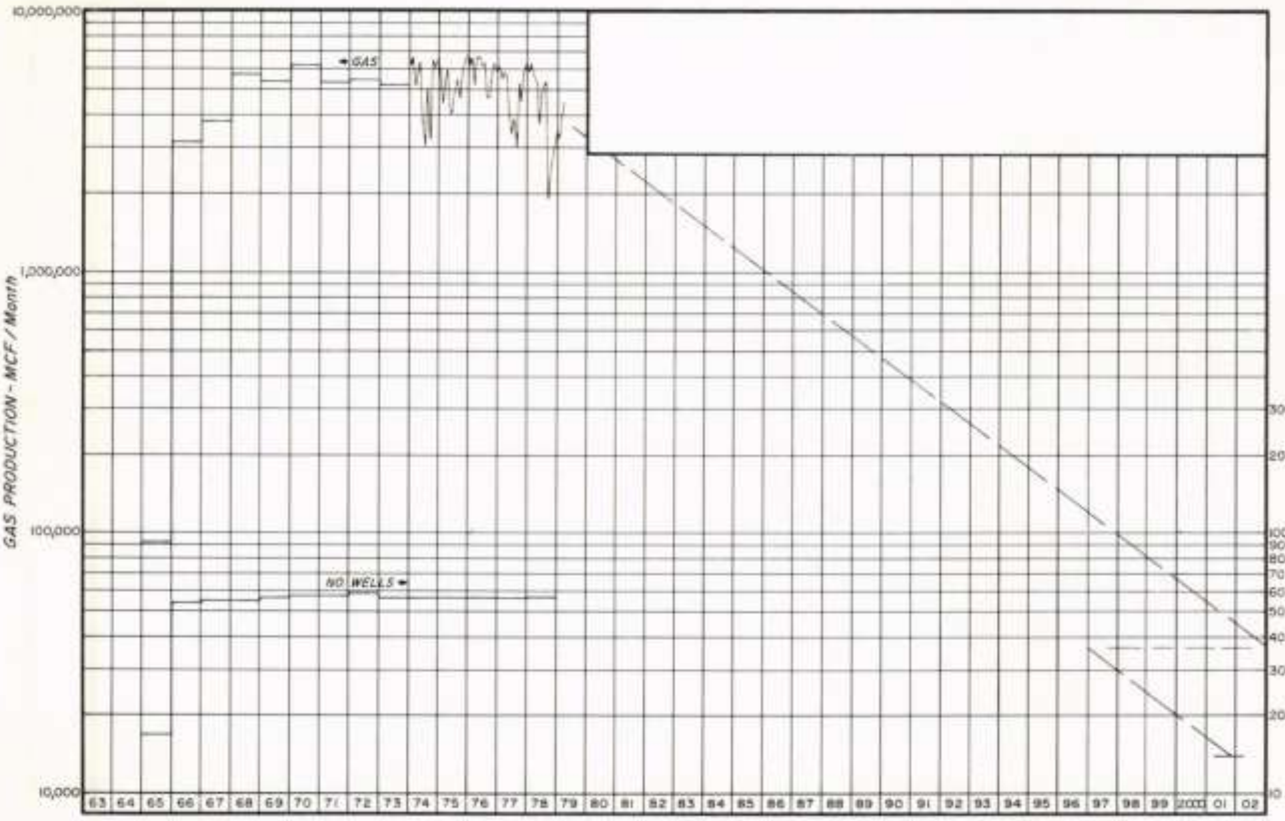

FIGURE 5—TOTAL POOL PRODUCTION FOR INDIAN BASIN GAS FIELD (Sipes, Williamson and Aycock, Inc., 1979).

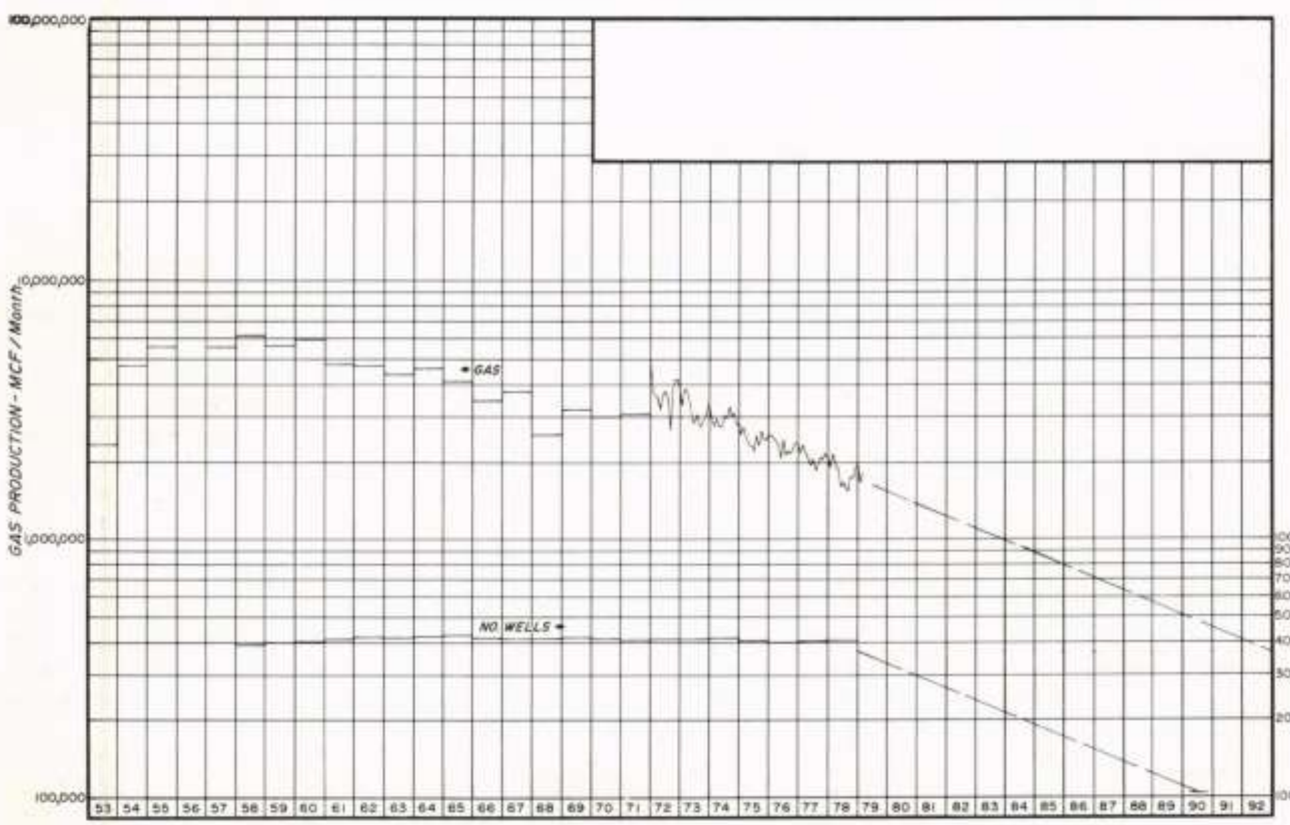

FIGURE 6—TOTAL POOL PRODUCTION FOR JALMAT GAS FIELD (Sipes, Williamson and Aycock, Inc., 1979).

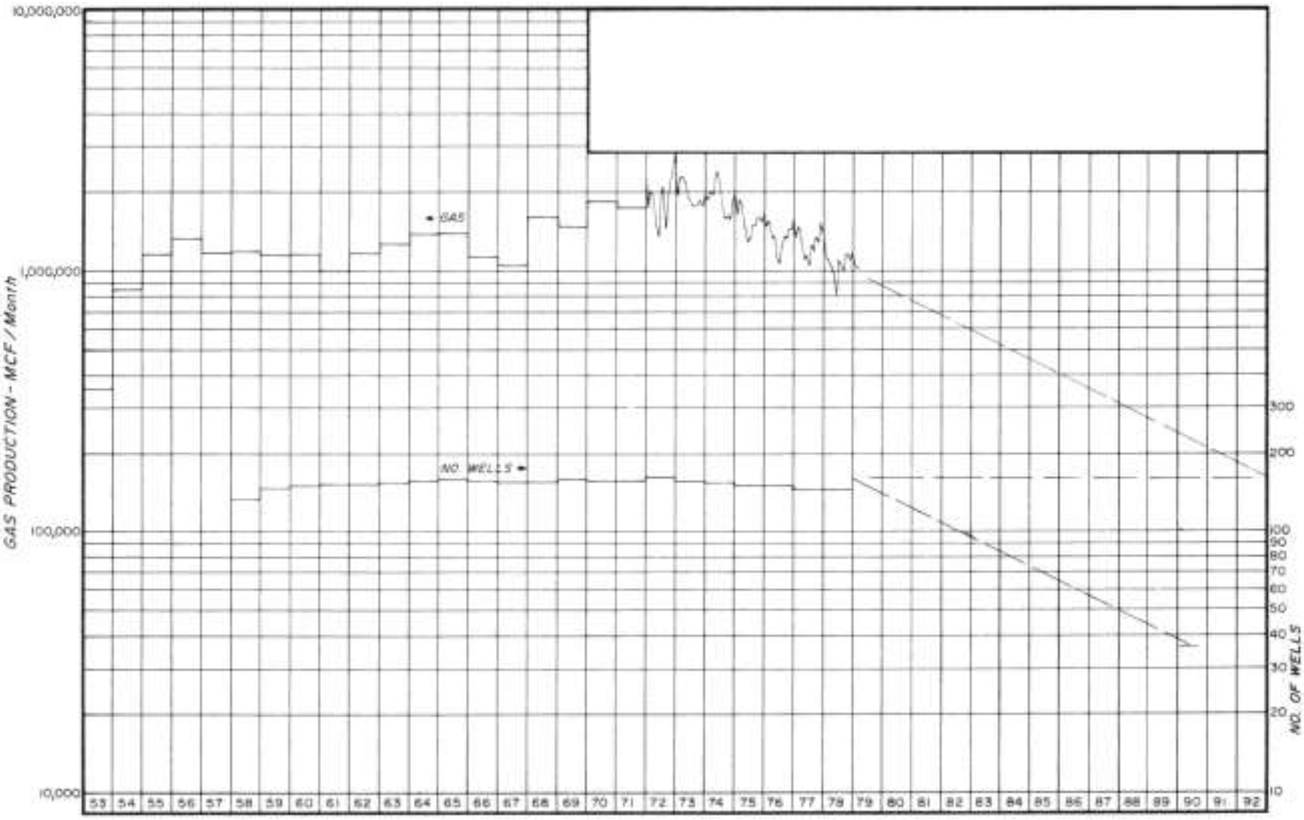

FIGURE 7—TOTAL POOL PRODUCTION FOR TUBB GAS FIELD (Sipes, Williamson and Aycock, 1979).

was determined by plotting the pressure decline for each well or the average of wells against the accumulative production for each well or of wells in a township. This same method was used in the Blanco Mesaverde Gas Pool reserve study. A review of the Blanco Mesaverde reserve study appeared in Arnold (1978).

Two approaches were used to calculate the pool reserves. The first approach entailed averaging the bottom-hole pressure of all the wells located in a township in order to determine an average initial pressure and an average annual pressure for 1970 through 1974. The pressure was plotted against production to determine original and remaining reserves for each township in the pool. The second study used the same method except that the original and remaining reserve for each well in the pool was determined.

The bottom-hole pressure and annual production figures were provided by NMOCD. The bottom-hole pressures were available on most of the wells and they provided usable pressure-decline data, although interpretation of some of the curves might lead to disagreement. The annual shut-in pressure was measured by the operators after a seven-day shut-in period as required by NMOCD testing regulations. The result of the study is:

Basin Dakota Gas Pool	(billions of cu ft, 320-acre well density)
Total original recoverable reserves	4,753.32
Accumulative production through January 1, 1979	3,030.08
Remaining reserves	1,723.24

The 1.723 trillion cu ft of remaining reserves in the Basin Dakota Gas Pool is based on a 320-acre well density. Additional reserves that may be added through in-fill drilling or a 160-acre well density are not included in the above figure.

Projections of oil production and revenue for New Mexico, 1979-1985

by R. W. Foster, *Petroleum Recovery Research Center, New Mexico Institute of Mining and Technology*

In 1976 R. W. Foster and others at the New Mexico Bureau of Mines and Mineral Resources undertook studies to estimate future yearly crude oil production and recoverable reserves. Results of these studies were published in 1978 (Arnold and others, 1978; Foster and others, 1978), and included projections for the period from 1977 to 2026, when the estimated economic limit would be reached. Various decline-curve methods were used to determine recoverable reserves for the state, the northwest and southeast producing areas, and the 50 largest pools based on their production during 1975. The methods used are discussed in Arnold and others (1978) and Foster and others (1978). For this paper (an update of the previous studies) an exponential curve fit was employed. This method gives essentially the same results as the multiple-regression program used for most of the previous projections and can be done with a programmable pocket calculator.

As noted in the 1978 reports, projections of future production should be fairly good for short periods of one to two years. Longer range predictions are subject to greater error. This assumption is supported by the earlier predictions for 1977 and 1978 where the error was only 1.2 and 1.9 percent. Foster and others (1978) noted that estimates of state revenues from crude-oil production should be reliable enough for advance planning for one or two years. In this update, projections for crude-oil production, crude-oil plus lease condensate production, production value, average price per barrel, and state revenues have been projected to 1985.

Many factors could affect the revenue projections even for short periods of time such as for 1979 and 1980. In particular, passage of the Carter administration's National Energy Plan would have a profound effect on the price of a barrel of oil and resulting state revenues. With the realization that oil prices will very likely increase rapidly in the near future, the estimates presented here are considered conservative. The rather rapid production decline in New Mexico should be more than offset by increasing prices at least for the next few years.

Oil revenues are expected to increase from $103.9 million in 1978 to $113.7 million in 1979 and $183.8 million in 1985. Revenues for the projected seven years from 1979 to 1985 are estimated to be $1.0 billion.

Projected production of crude oil

In 1976 projections of crude-oil production and recoverable reserves were made for the period from 1977 to 2026, when the economic limit would be reached (Arnold and others 1978; Foster and others, 1978). The earlier projections for the period 1979 through 1985 are given in table 17. Also shown are the actual production figures for 1977 and 1978, the error in the predicted production for these two years, and revised estimates for the period 1979 through 1985. The base period used for the earlier projections was from February 1975 to December 1976. The decline rate during this period was 3.8 percent overall but had increased to 5.4 percent in 1976. For the revised projections, the data base is the monthly average daily production for 1978 and the decline rate is 6.2 percent.

TABLE 17—PROJECTED CRUDE-OIL PRODUCTION IN BBLS, 1979–1985.

Year	Predicted	Actual	%Error	Revised estimates
		State		
1977	83,593,213	82,616,090	1.2	-
1978	80,250,725	78,748,818	1.9	-
1979	77,088,548	-	-	73,810,282
1980	74,293,059	-	-	69,374,150
1981	71,241,248	-	-	64,840,114
1982	68,530,028	-	-	60,772,518
1983	65,945,098	-	-	56,960,091
1984	62,740,452	-	-	53,563,688
1985	60,356,035	-	-	50,037,732
		Northwest area		
Year	Predicted	Actual	%Error	Revised estimates
1977	3,087,718	3,716,995	16.9	
1978	2,592,595	3,929,717	34.0	
1979	2,177,043			
1980	1,832,928			
1981	1,534,825			
1982	1,288,815			
1983	1,082,043			
1984	Economic limit			
1985				
		Southeast area		
Year	Predicted	Actual	%Error	Revised estimates
1977	80,505,495	78,899,095	2.0	
1978	77,658,180	74,819,101	3.7	
1979	74,911,505			
1980	72,460,131			
1981	69,706,423			
1982	67,241,213			
1983	64,863,055			
1984	62,740,052			
1985	60,356,035			

Table 17 shows that the 3.8 percent decline rate used in the projections resulted in an error of 1.2 percent in predicted production for 1977 and 1.9 percent in 1978. In both cases predicted production was higher than actual production although the error is small enough so that revenue projections would be reasonable. However, at the current rate of decline the error will increase each year. Arnold and others (1978) and Foster and others (1978) anticipated that reliability of the predictions would be good for one or two years, but less so with increasing time. The reports recommended that the predictions be updated on a regular basis in order to maintain as little error as possible.

In the original studies, estimates of future production also were made for the northwest and southeast producing areas. These predictions are not updated here, but a comparison of predicted and actual production is important in assessing the reliability of the projection methods.

The northwest area (San Juan Basin) includes McKinley, Rio Arriba, Sandoval, and San Juan Counties. The amount of crude oil produced in this area is only about 5 percent of the oil produced in the state. In the previous reports, the decline rate for the base period, January 1975 to December 1976, was 16 percent. Projected, this decline rate indicated that the economic limit would be reached by 1984 and that recoverable reserves amounted to only 13.6 million bbls. The steep decline continued into early 1977; fortunately, production then began to stabilize. Although the oil produced in 1977 was less than in 1976, the decline was below 1 percent and actual production was 17 percent above that predicted. In 1978 the decline was reversed and production increased 5 percent to 3,929,717 bbls of oil.

As noted earlier (Foster and others, 1978, p. 7), "Because of the small amount of oil being produced, discoveries, development, and enhanced recovery programs can cause considerable fluctuation in total production figures. . . . New discoveries are the important factor in slowing or reversing the current rate of decline." The importance of new discoveries in this area is borne out by the fact that two pools, Chacon Dakota and Papers Wash Entrada, accounted for an increase of 388,236 bbls of oil in 1978 compared with 1977. The Chacon Dakota Pool was discovered in September 1974 but was not designated as a pool or developed until 1976. Papers Wash was discovered in January 1977. Five additional pools were established in 1978 and 12 in 1977. Production from these new pools has more than offset the continuing decline for most of the older pools.

As shown in table 17, predicted production for the southeast area of Chaves, Eddy, Lea, and Roosevelt Counties has been higher than actual production. The error is small as would be expected where large volumes are involved, but the rate of decline will be steeper than previously projected. In the earlier reports projections also were made for the 50 largest pools in the state, based on production of crude oil in 1975. For this report projections are made of the combined estimated production through 1985 for the 12 largest pools based on the amount of oil produced in 1978 (table 18). All of these pools are located in the southeast producing area. Production from these pools amounted to 1 million bbls of oil or more during 1978. They also were the first 12 pools in production in the earlier reports, although some changes in ranking occurred. These 12 pools accounted for 55 percent of the crude oil produced in New Mexico in 1978.

In table 18 the data base used for the projections is the same as that used for the state projections. Empire Abo supplied 18 percent of the crude oil produced in New Mexico in 1978 even though production declined by 800,000 bbls from 1977. From 1977 to 1978, the state decline was 3,867,272 bbls. Thus, Empire Abo accounted for almost 21 percent of the decline. The rate of decline at Empire was 5.3 percent for 1978, but, from May through December, the rate of decline was at 13.5 percent. With minor fluctuations, the rate of decline is expected to remain quite steep. Because of the amount of oil produced from this pool, an increase in the rate of decline would have a considerable effect on the projections made in this report. The Abo reservoir originally contained an estimated 401.6 million stock tank bbls of oil, of which 212.8 million bbls or 53 percent would be recovered under primary production and the gas-pressure maintenance program. Through 1978 reported cumulative production has been 172.6 million bbls. Based on the current rate of decline and current conditions, an estimated additional 60.2 million bbls will be recovered. This amount would be about 58 percent of the original oil in place leaving an estimated 168.8 million bbls in the reservoir.

Of the 12 largest pools, all but two, Hobbs and Langlie-Mattix, had production declines in 1978. In addition to Empire, significant declines occurred at Vacuum Grayburg-San Andres, Maljamar, Vacuum Abo Reef, and North Bagley. The decline of almost 2.4 million bbls for the 12 largest pools accounted for 61 percent of the state's decline from 1977 to 1978.

Revenue projections

Including imports, the total United States supply of crude oil and lease condensate in 1978 amounted to 5.4 billion bbls or 14.8 million bbls per day. Of this, New Mexico provided 1.5 percent or a 5.6-day supply. Although seemingly unimportant, this amount is a significant contribution to the nation's energy base and of considerable importance to New Mexico from a revenue standpoint. To import the oil produced in New Mexico in 1978 would have cost approximately $0.8 billion more than the reported value.

Reported production, sales, value, price per barrel, and revenues for the period 1962-1978 and projections to 1985 are given in table 19. The data through 1978 is based on reports of the New Mexico Oil and Gas Accounting Division of the Taxation and Revenue Department and of the New Mexico Oil and Gas Engineering Committee. The past production and sales and the projections are based on the combined production of crude

TABLE 18—Production in 1978 and projected production in bbls for 12 largest oil pools, 1979–1985.

Rank 1975	Rank 1978	Pool	1978 Production	± 1977	% State Production
1	1	Empire Abo	14,368,103	-800,761	18.3
2	2	Vacuum Grayburg-San Andres	5,128,595	-304,652	6.5
4	3	Hobbs Grayburg-San Andres	4,087,446	+392,082	5.2
3	4	Maljamar Grayburg-San Andres	3,643,846	-324,688	4.6
5	5	Eunice Monument Grayburg-San Andres	3,334,538	- 97,883	4.2
6	6	Langlie Mattix Yates-Seven Rivers-Queen	2,839,819	+ 24,411	3.6
12	7	North Vacuum Abo	2,135,503	- 33,091	2.7
8	8	Vacuum Glorieta	2,132,081	-182,202	2.7
7	9	Vacuum Abo Reef	1,785,044	-380,781	2.3
11	10	Drinkard	1,579,957	- 22,039	2.0
10	11	Grayburg Jackson Queen-Grayburg-San Andres	1,462,753	-166,101	1.9
9	12	North Bagley Pennsylvanian	1,094,689	-461,505	1.4
		Totals	43,405,408	-2,360,210	55.1

Projected production

1979	40,777,858
1980	38,066,244
1981	35,534,945
1982	33,171,971
1983	30,966,127
1984	28,906,966
1985	26,984,733

TABLE 19—PROJECTED SALES AND REVENUES FROM OIL, 1979-1985.

Year	Reported Production (bbls)	Reported Sales (bbls)	Reported Value	Average Price Per Barrel	Reported State Revenues
1962	109,328,053	109,850,148	$311,702,831	$ 2.84	$ 31,657,001
1963	109,983,057	110,837,782	312,491,996	2.82	34,060,686
1964	113,863,408	120,501,860	323,498,246	2.68	36,446,170
1965	119,166,477	119,378,891	335,604,620	2.81	37,833,954
1966	124,190,751	125,754,822	352,861,604	2.81	40,471,124
1967	126,002,451	125,726,611	366,766,663	2.92	43,080,502
1968	128,611,325	128,322,505	381,688,854	2.97	45,584,137
1969	129,226,861	128,714,872	403,599,969	3.13	47,953,736
1970	128,147,897	128,096,788	407,143,993	3.17	46,967,276
1971	118,409,970	118,131,653	401,271,514	3.39	46,789,020
1972	110,525,224	108,794,711	375,573,806	3.45	43,603,811
1973	100,985,686	99,902,903	411,622,239	4.12	47,666,909
1974	96,694,965	96,668,899	700,168,008	7.24	84,738,196
1975	95,062,535	94,395,858	788,340,493	8.35	100,448,395
1976	92,128,875	91,060,806	805,224,309	8.84	102,916,337
1977	87,222,646	86,167,809	792,710,295	9.20	100,224,479
1978	83,364,825	83,300,953	834,357,935	10.01	103,891,616
			PROJECTED		
1979	78,138,472	77,747,780	$ 909,649,026	$11.70	$113,706,128
1980	73,440,876	73,073,672	984,302,362	13.47	123,037,795
1981	68,639,806	68,296,607	1,064,744,103	15.59	133,093,013
1982	64,332,675	64,011,012	1,154,118,546	18.03	144,264,818
1983	60,295,815	59,994,336	1,250,881,906	20.85	156,360,238
1984	56,669,898	56,386,549	1,360,043,562	24.12	170,005,445
1985	52,966,136	52,701,305	1,470,366,410	27.90	183,795,801

oil and lease condensate. State revenues from oil include the school, reverence, conservation, and ad valorem taxes, and royalties from production on state lands.

Since 1967 annual sales have averaged about 0.5 percent below reported production. Projected sales are based on this percentage factor. Projected revenues were obtained from the current average of 12.5 percent of the sales value. The projected average price for a barrel of oil is based on the rate of increase in the average monthly price from January 1978 to June 1979.

From 1962 through 1972 the average price for a barrel of oil in New Mexico had increased only $0.61. When production began to decline in 1970 revenues also declined. The decrease in revenues continued through 1972. Following the oil embargo that began in November 1973, the price of a barrel of oil rose by almost 78 percent in 1974 to an average price of $7.24. Although production declined by more than 4 million bbls in that year, state revenues increased by some $37 million. Since then, with the exception of 1977, revenues have increased yearly despite the continuing decline in production. The decrease in revenues in 1977 resulted from a higher rate of decline in production and a smaller increase in the average price for a barrel of oil than the normal yearly increase for the period from 1974 to 1978.

Revenue projections for the period through 1985 are considered conservative. If the proposed legislation in the National Energy Plan is implemented and "windfall" taxes do not affect state taxes, a substantial increase in the average price for a barrel of oil and, therefore, in state revenues would occur. An increase in revenues would occur even if the rate of decline in production were somewhat greater than projected. A substantial increase in the price of a barrel of oil has already taken place in 1979. Through June the increase has been almost 31 percent compared to the average price in 1978. Revenues received through June 1979 total almost $53 million. If the June average price of $13.10 per bbl remains in effect for the rest of the year, revenues would exceed $120 million based on projected sales.

Coal

by L. B. Martinez, *Bureau of Geology*

Production

Historic coal production

New Mexico has had an active coal industry except for the 1950's and early 1960's when natural gas was experiencing a period of enormous growth and development. During the early 1950's the growth of the coal industry was slowed when the railroads completed the change from coal to diesel power. In the 1940's and earlier, coal was largely produced from underground mines in areas that are now unproductive or are just now beginning to attract new interests. These areas are Dawson, Madrid, and Mentmore-Gamerco, along with Hagan, Riley, Carthage, and Monero-Lumberton. The small coal-mining-community concept connected with these mines is gone. The large strip mines that have appeared in the last 15 years draw their labor forces from the larger, established communities of Gallup, Farmington, and Raton.

F. E. Kottlowski, D. E. Tabet, and S. J. Frost of New Mexico Bureau of Mines and Mineral Resources have related New Mexico coal production to national or local events throughout the period from 1890 to 1978. This development is reproduced in fig. 8. Note the profound found effect of the opening of the large strip mines in the 1960's. This significant increase represents the first large-scale use of New Mexico's coal in electrical generation. Annual production figures from 1957 through 1977 are given in table 20.

Statewide production

New Mexico ranked 14th among coal and lignite producers in the United States for 1977 with 11,895,411

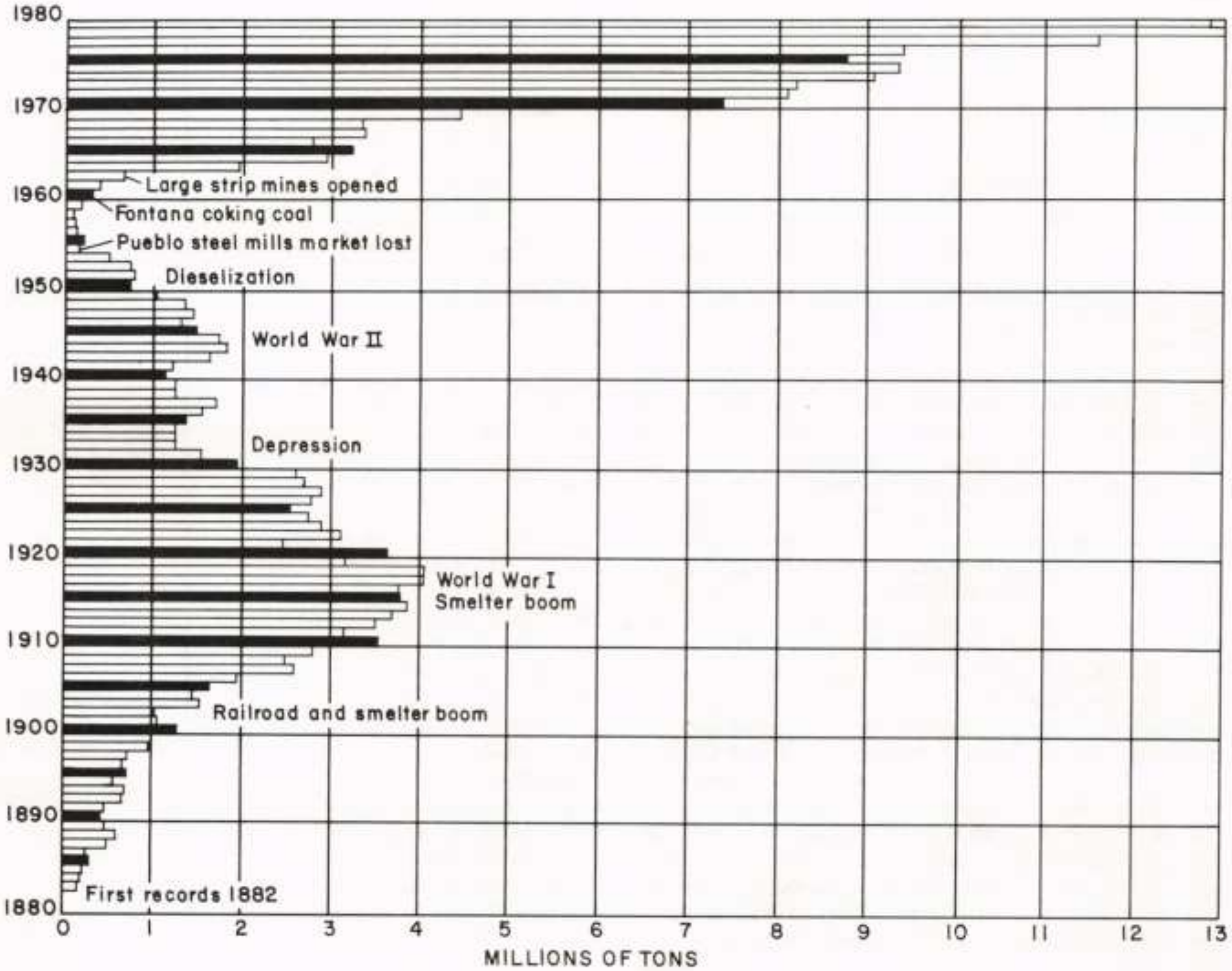

FIGURE 8—AMOUNTS OF COAL MINED YEARLY IN NEW MEXICO in millions of tons (data from F. E. Kottlowski, D. E. Tabet, and S. J. Frost, New Mexico Bureau of Mines and Mineral Resources, November 1979).

TABLE 20—ANNUAL COAL PRODUCTION IN NEW MEXICO, 1957 THROUGH 1978 (data from New Mexico Bureau of Mine Inspection).

Year	Short tons mined	Year	Short tons mined
1957	128,354	1968	3,582,793
1958	85,512	1969	5,130,653
1959	113,046	1970	7,643,319
1960	235,068	1971	8,175,059
1961	279,021	1972	8,248,745
1962	592,869	1973	9,350,156
1963	2,260,303	1974	9,668,700
1964	3,354,917	1975	9,559,920
1965	3,519,265	1976	9,980,322
1966	2,933,757	1977	11,895,411
1967	3,596,488	1978	12,787,932

TABLE 21—COAL AND LIGNITE PRODUCTION IN 1978 FOR NEW MEXICO AND RANK AMONG ADJACENT STATES (Keystone, 1979; New Mexico Bureau of Mine Inspection).

State	Tons	Rank
Texas	17,600,000	1
Colorado	13,345,000	2
NEW MEXICO	12,787,932	3
Arizona	11,700,000	4
Utah	10,200,000	5
Oklahoma	5,000,000	6

tons mined and again ranked 14th in 1978 with 12,787,932 tons extracted—a 7.5-percent production increase over 1977. A comparison of coal production with adjacent states shows Texas and Colorado ranking ahead of New Mexico (table 21). The value of New Mexico's coal production jumped significantly from $87,841,748 (1977) to $123,440,601 (1978), a 40.5 percent increase. In view of the large increases, use of a "dollar inflation index" may now be necessary to evaluate the total value. The 1978 average price per ton was approximately $9.65, according to the State of New Mexico's Bureau of Mine Inspection, with prices ranging from $5.04 to $20.92 per short ton.

Steam-coal production in 1976 was 91 percent of New Mexico's total coal output, and coking (metallurgical) coal accounted for 9 percent (Anderson, 1978). Production was 90-percent steam coal and 10-percent coking coal in 1977 and changed only slightly in 1978 to 92-percent steam coal and 8-percent coking coal.

Production by mine

The Navajo mine, fourth largest coal strip mine in the United States (Keystone, 1979) and operated by Utah International, continued to be the leading producer with 6,100,000 tons reported in 1978. New Mexico's second largest producer was Pittsburg and Midway's McKinley mine with 2,992,958 tons. Other large producers were Western Coal Company's San Juan mine with 2,617,818 tons; Kaiser Steel Corporation's York Canyon West Ridge strip with 134,000 tons of steam coal and York Canyon underground mines with 803,056 tons of metallurgical coal, respectively; Amcord's Amcoal mine No. 1 with 100,000 tons; and the Carbon Coal Gamerco mine, a Hamilton Brother's subsidiary, with 40,000 tons. In 1978, only Kaiser Steel's York Canyon West Ridge strip and Pittsburg and Midway's McKinley mine showed increases in production over 1977 (table 22). Kaiser Steel's West Ridge strip production marks the company's entry into the steam-coal market. Decreasing production from Kaiser's York Canyon mine is attributed to the United Mine Workers of America nationwide strike in 1978. Production from other New Mexico mines was not affected by the workers on strike because these mines are not represented by the United Mine Workers. The decrease of over 1.3 million tons in 1978 from the previous year at Utah International's Navajo mine is attributed to plant outages.

Five coal strip mines and one underground mine were operating in the state in 1977. In 1978 the trend to large strip mine operations that began in 1962 continued to materialize as Carbon Coal Company completed a major strip mine and began to stockpile coal to meet 1979 contracts.

Destination

As power demand in neighboring states grows, this demand will be met by utilization of coal from New Mexico. New Mexico coal producers already export over 4 million tons annually. Although much of the coal produced within the state's borders is burned here, considerable amounts of the mine-mouth generated electric power is ultimately consumed in Arizona and California. Projected firm markets also exist in Arizona and Texas. Raw coal that is earmarked for Texas cannot be shipped until rail and power lines are built to service the Bisti-Star Lake coal fields. These lines are being delayed

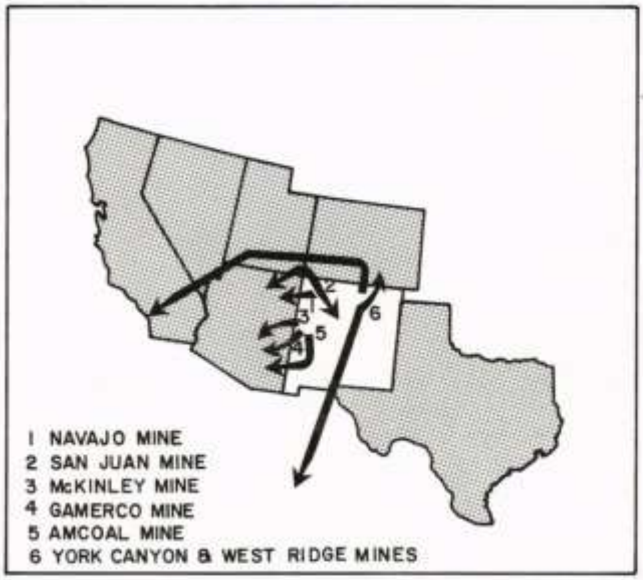

FIGURE 9—NEW MEXICO'S COAL-SHIPMENT PATTERNS (data from Bureau of Geology).

by a federal EIS (Environmental Impact Statement). Opposition to the proposed lines has been expressed by the Navajo Indians, who possess surface-ownership rights in the area. The Navajo are also withholding approval of a rail line to service a proposed mine on the reservation. Fig. 9 shows current consumption and shipment patterns for New Mexico's coal. The following list shows the destinations of New Mexico's coal:

Mine and Company	**Destination**
Navajo mine—Utah International; affiliate of General Electric and Arizona Public Service	7.4 million tons per year to Arizona and California as electricity
San Juan mine—Western Coal Company and New Mexico Public Service Company (50 percent) and Tucson Gas and Electric Company (50 percent)	1.8 million tons per year to New Mexico and Arizona
Gamerco mine—Carbon Coal Company and Hamilton Brothers; Arizona Electric Power Cooperative	1.2 million tons per year to Benson Power Plant, Cochise, Arizona
McKinley mine—Pittsburg and Midway; subsidiary of Gulf Mineral Resources	2.6 million tons per year to 1) Cholla Generating Plant (116 mw), Joseph City, Arizona, operated by Arizona Public Service Company; 2) Flintkote Company, Arizona; 3) Southwest Forest Industries; 4) Kaiser Cement and Gypsum; 5) Texas Utilities, Texas; 6) Union Electric, Missouri; 7) Arizona Electric Power, Benson Plant, Cochise, Arizona; 8) Kerr-McGee Chemicals; 9) Arizona Salt River Authority (Salt River project), Arizona
York Canyon mine—Kaiser Steel Corporation	0.93 million tons per year to 1) Kaiser Steel, Fontana, California; 2) Arizona Salt River Authority, (Salt River project), Arizona; 3) Colorado Fuel and Iron Company, Pueblo, Colorado; 4) Ciudad Fundidora de Fierro Y Acero de Monterey, Monterey, Mexico

TABLE 22—New Mexico coal production in tons for 1976, 1977, and 1978; s = strip mine, u = underground mine (data from Keystone Coal Industry Manual, 1976, 1977, and 1978).

County	1976	1977	Percent Change	1978	Percent Change
Colfax					
West York (s)	0	95,641	+100	134,100	+40
York Canyon (u)	845,000	1,005,123	+ 19	803,056	-20
York Canyon prospect (u)	Test Production	0	-	0	-
Total	845,000	1,100,764	+ 23	937,156	-15
McKinley					
Amcoal #1 (s)	?	160,000	+100	100,000	-38
McKinley (s)	842,338	1,369,200	+ 38	2,992,958	+11
Gamerco (s)	-	-	-	40,000	+100
Total	842,338	1,529,200	+ 81	3,132,958	+105
San Juan					
Navajo (s)	6,756,236	7,420,066	+ 8	6,100,000	-18
San Juan (s)	1,223,670	1,843,076	+ 34	2,613,038	+42
San Juan test (u)	0	2,305	+100	0	-100
Total	7,930,006	9,265,447	+ 17	8,713,030	- 6
Grand total	9,667,344	11,895,411	+ 23	12,783,144	+ 7

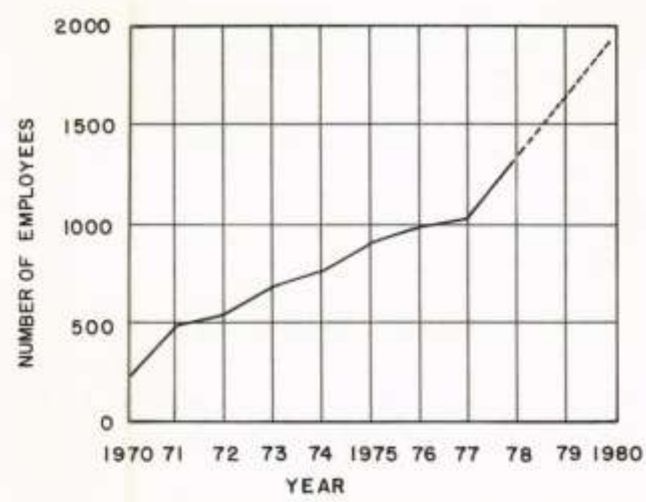

FIGURE 10—NEW MEXICO COAL-INDUSTRY ANNUAL EMPLOYMENT LEVELS FOR YEARS 1970 THROUGH 1980 (data from New Mexico Bureau of Mine Inspection).

Employment

Coal companies operating in New Mexico in 1978 employed 1,384 persons. This figure represented a 28-percent increase over the 1977 total of 1,081 persons. Of the new employees, 140 were employed at the new Gamerco strip mine. All mines, with the exception of Amcord's Amcoal mine, had increases in employment for 1978. If employment in the coal industry grows proportionately with anticipated production, the number of permanent employees will increase in 1979 by 300. Fig. 10 shows the trend of employment in New Mexico's coal industry from 1970 through 1978 and projected employment for 1979 and 1980.

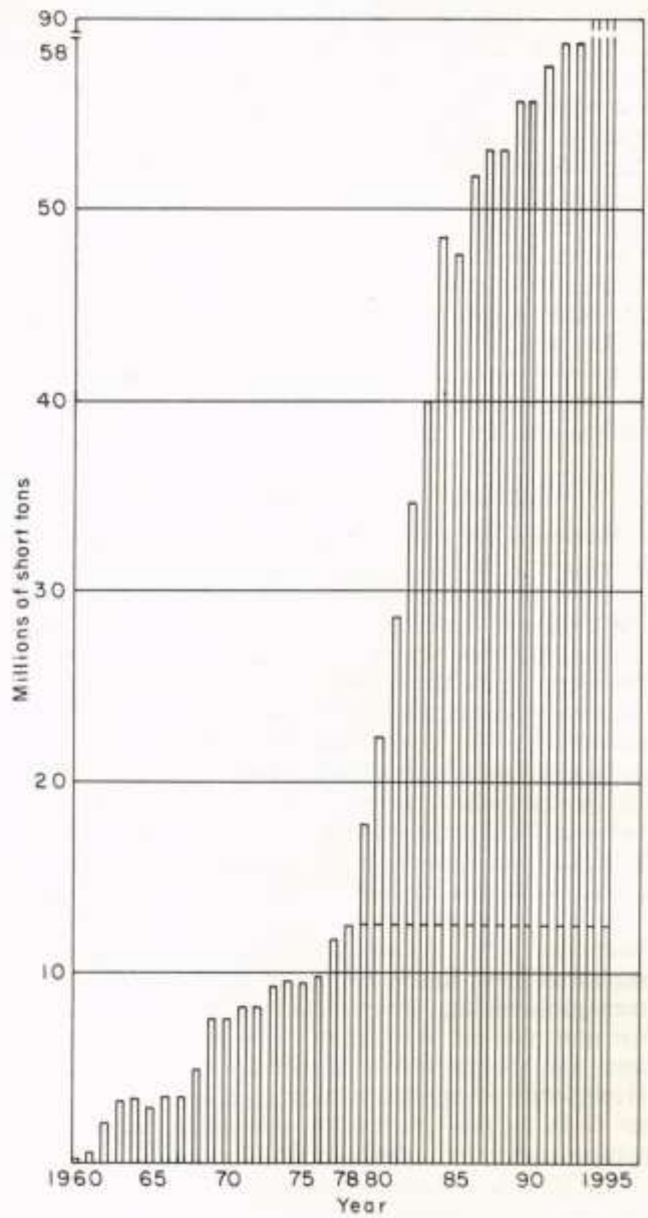

FIGURE 11—NEW MEXICO PROJECTED COAL PRODUCTION (data from Bureau of Geology).

Production projections

A Bureau of Geology study has indicated a substantial increase for coal production in 1979 (a 31-percent increase over 1978) that will push New Mexico's annual production to approximately 18 million tons in 1979 (fig. 11). This increase will be the result of a variety of causes, including new mines, expansion of existing mines, and the shift in fuels from gas to coal in generation plants. As shown in fig. 11, under certain conditions New Mexico's annual coal production may increase in 1985 to 47 million tons per year and may exceed 50 million tons per year by 1990.

Estimates beyond 1990 are unreliable, but reviews of mining plans and coal-industry surveys submitted to the Bureau of Geology reveal that annual production may reach 90 million tons by 2000. *Coal Age* (Nielson, 1979) foresees New Mexico reaching an annual coal-production level of 64.4 million tons by 1987. This survey indicates that the overwhelming portion of coal production will come from strip mining and that an estimated 93 percent will be used as steam coal. Of all the coal-producing states in the United States, only Wyoming, Montana, and Texas may show a faster growing coal industry than New Mexico by 1987. This general focus on western coal comes as the result of changing national energy policies to reduce oil imports, a heightened domestic awareness that a cleaner environment would result from utilization of low-sulfur western coals, curtailed nuclear projects, and uncertainties in the future use of nuclear energy to meet fuel demands.

Future coal development

Bisti project

Western Coal Company, a subsidiary of Public Service Company of New Mexico, has plans for a new underground mine (2,565.5 acres), an extension of their present operations, and the opening of a new strip mine in the Bisti coal field. Western Coal has announced the submission of plans for a surface mine with a life expectancy of 25 years and with 87 million tons of reserves. The coal will be used in the proposed 2,000-megawatt New Mexico station on a 5,795-acre lease in the Bisti coal field. The station will be owned jointly by Tucson Gas and Electric and Public Service Company of New Mexico. The mining schedule calls for production of 255,000 tons per year between 1979 and 1985. In 1985 production will go to 1.2 million tons per year and to 2.4 million tons per year in the period from 1986 to 1987. By 1992 production is expected to reach a level of 5.1 million tons per year.

San Juan underground extension

Western Coal Company has nominated federal coal acreage in T. 30 N., R. 15 W. under the BLM's (Bureau of Land Management's) Short Term Emergency Leasing Program. Under the prior federal leasing moratorium, no new leases on federal land were being awarded in New Mexico except in those cases where the operator requires additional coal reserves in order to continue existing operations. These leases will receive consideration to be processed before the 1983 lease date set by the federal government. Environmental statements are still required before any leasing on federal lands can occur. Leases will be awarded through competitive bidding for the new acreage, and operators other than Western Coal Company may bid. Although in this case only Western Coal Company can meet requirements set forth in the emergency leasing program for contiguous mining, which includes a demonstrated need for new reserves in order to continue operations, the lease will not necessarily be awarded to Western Coal. Henceforth, all applicants must meet the minimum bid set forth by the USGS (U.S. Geological Survey) and comply with environmental regulations.

The USGS, in response to a request by the BLM, has conducted a coal-resource evaluation study for this area using drilling, coring, and logging methods. The results of this evaluation are described by Beach and Jentgen (1978). When operations begin, this Western Coal operation will be the only underground mine utilizing the Fruitland Formation. The coal will be mined at depths ranging from 150 ft to 750 ft, from one principal bottom seam that reaches a thickness of 14 ft and from a thinner, overriding seam that reaches a thickness of 3 ft.

Amcoal

Amcoal has also applied for additional coal acreage under the Short Term Emergency Leasing Program. The acreage is adjacent to its Amcoal mine located in McKinley County. The company has applied for one federal section located in sec. 8, T. 19 N., R. 17 W. Key federal administrators in the reviewing process are the USGS, BLM, and Office of Surface Mining. Although the company has applied for an entire section, only one-half of the section has been designated suitable for mining. The scheduled lease sale was postponed by the order of the Secretary of the Interior. One hundred sixty acres of this half section (surface ownership) is held in trust by the BIA for the Navajo Tribe. However, the underlying coal is reserved to the federal government and administered by the BLM. The BIA is challenging the BLM's authority to lease the coal without prior consent of the surface owner. The surface owner being represented by the BIA. Conflict in the authority of federal control of these lands is being settled at the departmental level.

Pittsburg and Midway expansion

The Pittsburg and Midway Coal and Mining Company, a wholly owned subsidiary of Gulf Mineral Resources, is expanding its operations to the southern portion of its lease. The McKinley strip mine, which is located in western McKinley County, has grown from 500,000 tons in 1976 to 2,972,958 tons in 1978. The company plans to mine 4,800,000 tons in 1979.

Carbon Coal Company

Carbon Coal Company is a subsidiary of Hamilton Brothers. Its Gamerco mine began operations in late 1978 and is now reaching full capacity of 1.2 million tons per year. The main seams are in the Gibson Coal Member of the Mesaverde Formation, and they range in thickness from 12 inches to 48 inches. Stacked (aggregate) seam thickness may total 7 ft to an overburden depth of 150 ft. The coal is ranked as subbituminous with 20-30 percent ash and less than 0.6-percent sulfur. The coal is being contracted by the Arizona Electric Power Cooperative in Benson, Arizona. Strippable coal reserves for the area are believed to be between 12 and 18 million tons. This development, however, involves some unique, complex mining methods; and mining plans may be revised several times before the most efficient method and plan are realized. An estimated additional 60 million tons of deep coal reserves are under lease. The land, totaling 50,000 acres, is leased from the Gamerco Associates, Ltd. (formerly the Gallup Gamerco Coal Company) to Carbon Coal and Arizona Electric Power Cooperative. The lease is located in parts of Tps. 14, 15, and 16N., Rs. 18 and 19W.

WESCO

WESCO's plans for a coal-gasification plant on the Navajo Indian Reservation have been dropped. Navajo tribal officials rejected the firm's rental, royalty, and tax proposals.

WESTCO

WESTCO, not to be confused with WESCO, recently announced plans to open a mine in Lincoln County near White Oaks. Quantities of coal to be mined will reach approximately 10,000 tons per month.

Alamito Coal Company

Alamito Coal Company, a subsidiary of Tucson Gas and Electric is scheduled to begin operation of the Gallo Wash mine in 1981. The life expectancy of the mine is approximately 40 years with production eventually reaching 5 million tons per year. The schedule of coal development will be tied to the requirements of the three generating units being committed for construction in mid-1981 at the Tucson Gas and Electric Springville Generating Station, but firm plans will begin to be formulated in mid-1979.

Reserve estimates range from 128 to 142 million tons of coal minable by stripping. The coal is owned by Santa Fe Industries and by the state and has been leased to Tucson Gas and Electric. The surface ownership is Indian except sec. 16, T. 21 N., R. 9 W., which is state owned.

Consolidation Coal Company

Consolidation Coal Company, acting in a complex partnership agreement with El Paso Natural Gas Company, is planning a joint-venture coal-mining operation on the Navajo Reservation along the Fruitland Formation outcrop. The complexity of the venture is the result of antitrust laws that forced the two companies to dissolve their partnership. Because of contracts negotiated prior to the antitrust ruling, the joint venture was allowed to proceed with certain stipulations that delegated quite different responsibilities to each company. A stipulation of the judgment was that each company would market its share of the coal without discussing market contract prices received for the coal with the other. The judgment also resulted in the lease being divided into three portions: 1) the joint venture (northern area of the lease), 2) the El Paso portion, and 3) the Consolidation portion. The entire lease area as negotiated in 1968 encompasses some 40,287 acres with calculated total reserves of 825 million tons. On this lease, the coal in the Fruitland Formation is ranked as high-volatile bituminous B and high-volatile bituminous C (8,300 Btu per lb, moisture free) with 788 million tons of the reserves at a strippable depth of 150 ft. This coal is 0.72 percent sulfur and 22.5 percent ash. The Con Paso mine on the joint-venture portion of the lease is slated to have production levels beginning with 250,000 tons per year and reaching 5 million tons per year by 1983. The coal will be used principally for off-site power generation, possibly at the San Juan generating plant.

Arizona Salt River Authority

The Salt River project involves scattered state leases in San Juan County with a potential for deep mining. The coal will be used at the Cholla Electrical Generation Plant, St. Johns, Arizona, to supply part of the needed 3.5 million tons of coal for a planned 1,000-megawatt expansion. Mine production schedules that have been announced informally show a 2.9 million-ton-per-year mine by 1990 and a second mine by 1992 that would bring total output to approximately 5.4 million tons per year.

Newmont Exploration Ltd.

Consulting firms from Albuquerque have been actively evaluating coal reserves on property leased from the state and a private owner in Lincoln County. The Mesaverde coal deposits are at shallow depths and may be economically mined. The coal lies in a small syncline along the western face of Carrizo Mountain between the towns of White Oaks and Carrizozo. Many favorable aspects for development exist: 1) the area is bisected by the railroad, 2) it is located on state and private lands and offers a three-year advantage over federally owned coal that is leased, 3) the coal is at shallow depths, and 4) deposits reach an aggregate thickness of 13 ft to depths of 200 ft or less. The coal is designated to be used for smelters owned by Newmont in southern Arizona.

Santa Fe Industries

Santa Fe Industries, with extensive coal holdings in the San Juan Basin and smaller holdings in the Raton Basin, has subleased much of its coal acreage in the San Juan Basin to several investors. In addition to its leased acreage, however, the company still possesses a substantial amount of unleased, valuable coal acreage. A program to evaluate the coal resources is being carried out by a newly formed subsidiary, Santa Fe Mining Company. No immediate coal developments are planned.

Coastal States Energy

Coastal States Energy has been acquiring state and private leases in the Zuni-Salt Lake coal areas and engaging in a drilling program to evaluate resources. No developments have been announced.

Chaco Energy

Chaco Energy, a wholly owned subsidiary of Texas Utilities, has leased 7,800 acres of coal rights for its South Hospah mine from Santa Fe Industries; the acreage has reported strippable Mesaverde coal reserves ranging between 80 and 125 million tons to the 150-ft overburden limit. Chaco Energy has received a mining permit from the New Mexico Mining and Minerals Division to mine 2 million tons of coal in 1980, escalating to 3.2 million tons in 1981 and 1982, and reaching 6 million tons annually by 1985. Mine development is hinging on approval of the proposed railroad spur from Prewitt northward to the Star Lake coal area. The mine is located in McKinley County.

Gallo Wash project

Although Chaco Energy has postponed mining in this area indefinitely, it has acquired state leases and holds federal PRLA's (Preference Right Lease Applications) totaling 7,511 acres.

Ideal Basic

Ideal Basic has purchased federal coal rights from Consolidation Coal Company in the La Ventana area, southeast of Cuba. The coal is amenable only to underground mining. An extensive, 180-well drilling program, ranging at depths from 100 to 1,500 ft, has delineated reserves of 60 million tons and estimated recoverable reserves of 120 million tons. Production will begin in 1980 in at least one of the several individual underground mining units at 77,500 tons per year and is expected to reach 1.5 million tons per year in 1985. The coal will be burned at the Ideal Basic Cement Plant in Tijeras, New Mexico.

Resources and reserves

The San Juan Basin, a geologic-geographic region in northwest New Mexico, covers more than 26,000 sq mi, contains most of the state's reserves of subbituminous coal, and now accounts for approximately 90 percent of the state's coal production. The two main coal-bearing formations are the Fruitland and the Mesaverde Formations, with perhaps 88 percent of the identified resources located in the Fruitland. Fig. 12 shows the distribution of New Mexico coal resource areas.

It is important to note that there is a difference between the terms *reserves* and *resources.* As commonly used by geologists, *coal resource* is the amount of coal that reasonable interpretation of data suggests is in place. *Coal reserve* is the portion of the total coal resource that is recoverable by existing technology under present economic conditions. The USGS and U.S. Bureau of Mines, in an effort to simplify and clarify classification terms, define *reserves* as that portion of the identified coal resource that can be economically mined at the time of determination. The reserve is derived by applying a *recovery factor* to that component of the identified coal resource designated as the reserve base. *Resource* is defined as the concentration of coal in

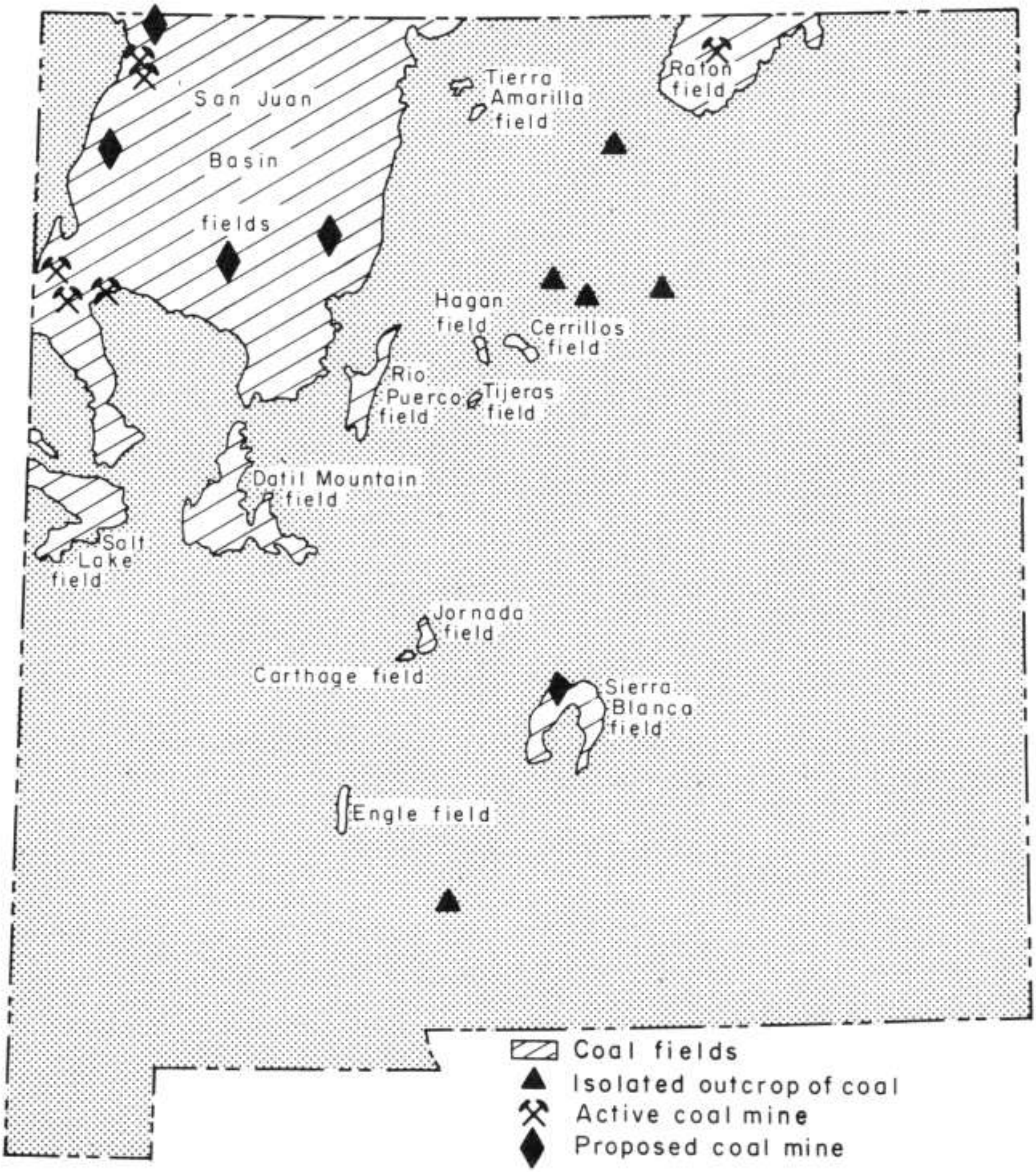

FIGURE 12—COAL IN NEW MEXICO (Kottlowski and Thompson, in press).

such forms that economic extraction is currently or may become feasible. *Identified resources* are specific bodies of coal whose location, rank, quality, and quantity are known from geologic evidence supported by engineering measurement. *Reserve base* is that portion of the identified coal resource that can be economically mined at the time of determination. *Recovery factor* is the percentage of total tons of coal estimated to be recoverable from a given area in relation to the total tonnage that, in turn, is estimated to be in the reserve base in the ground. The USGS commonly applies a 75-90-percent recovery factor.

When assessing coal resources, geologic factors relative to occurrences of the coal beds (seams) regulate the mining methods and influence the amount of *recoverable reserves.* The primary geologic factors limiting extraction of New Mexico coal at present are overburden thickness and coal-seam thickness. Coal seams 3 ft thick or more and at depths shallower than 150 ft are considered recoverable by strip mining. Coal occurring at greater depths is extractable, considering present mining technology, only through deep mining. In further refining coal-reserve data, the categories of *measured* or *inferred* reserves are used. Measured reserves are calculated using information obtained from outcrop observations and/or drill-hole data from holes spaced less than 1 mi apart. Inferred reserves are determined from similar geologic observations and from drill-hole data spaced more than 1 mi apart.

Coal is New Mexico's long-range energy commodity. The only resource that might exceed coal in longevity is geothermal energy, but it is not thoroughly proven as yet. Fig. 13 illustrates coal's importance.

Coal-reserve estimates

The San Juan Basin's strippable coal reserves (those reserves beneath less than 150 ft of overburden) in the Fruitland Formation alone total more than 3 billion tons. Adding the reserves in the 150-ft to 250-ft overburden category raises the total to 5.7 billion tons (table 23). Estimates are based on data gathered from all available sources: geologic evaluation, private consultants' reports, and drill-hole information (including oil and gas test wells). At present, thorough geologic field work clearly remains the best method to measure coal deposits. In the 150-ft overburden category, all coal beds 3 ft thick or more were included. In the deeper category (150-250 ft overburden), all coal beds 5-ft thick or more were included in the reserve estimates. Recent field work by Tabet and Frost (1979) in the San Mateo and Chacra Mesa coal fields has allowed upward revisions in the 150-ft overburden category for these two fields (table 24). Only small additions to Fruitland reserves have been made since the 1977 annual report of the Office of the State Geologist.

Strippable reserves in the 150-ft to 250-ft category are listed by Beaumont and others (1978) and by Tabet and Frost (1979) as 2.6 billion tons (table 24). Even though the term *reserve* refers to that portion of an identified resource that can be economically mined at the time of determination with the recovery factor applied, no operation in New Mexico is currently stripping to such depths. Therefore, considering minable coal only, the 2.6 billion tons would be an accurate reserve figure only if the coal is amenable to strip mining at depths to 250 ft. If an annual extraction rate of 20 million tons (present rate in the San Juan Basin is 10 million tons) is applied to the 3 billion tons of strippable reserves to a depth of 150 ft, the reserves would last over 150 years.

In the deep-coal resource category, Shomaker and Whyte (1977) listed Fruitland Formation coal resources as follows:

Overburden (ft)	Coal resource (millions of short tons)
0- 500	14,638.3
500-1,000	13,868.2
1,000-2,000	27,937.2
2,000-3,000	58,808.2
3,000-4,000	82,824.1
4,000+	3,060.8
Total	201,136.8

Mesaverde Formation strippable coal reserves in the San Juan Basin total 618 million tons to a depth of 150 ft. In the 150-ft to 250-ft range are another 169.3 million tons, making a total Mesaverde reserve of approxi-

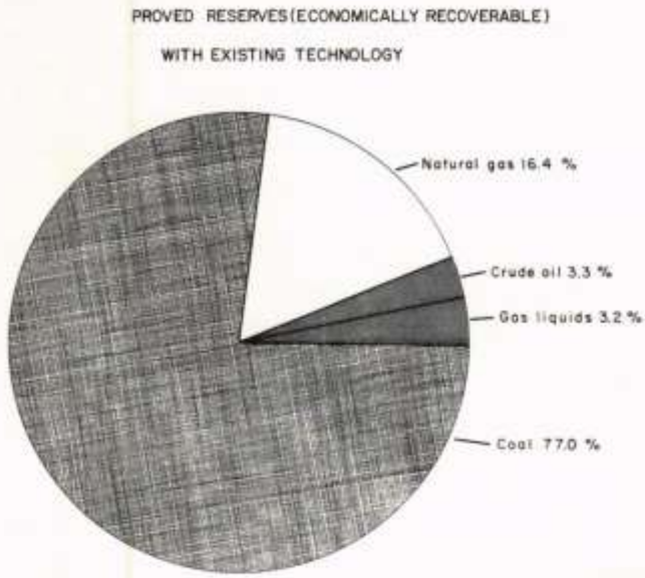

FIGURE 13—Proved reserves of fossil fuels in New Mexico that are economically recoverable with existing technology (data from Bureau of Geology, 1979).

TABLE 23—Total strippable Fruitland and Mesaverde coal in New Mexico in millions of tons (Beaumont and others, 1978; Tabet and Frost, 1979).

	Overburden category 150'	150'- 250'	Total to 250'
Fruitland	3,116	2,600	5,716
Mesaverde	618	170	788
Totals	3,734	2,770	6,504

TABLE 24—Original strippable coal reserves in New Mexico in millions of tons. Combined category includes both measured and inferred overburden (Beaumont and others, 1978; Tabet and Frost, 1979).

Coal field or area	Overburden less than 150 ft: Measured (column 1)	Combined	Inferred (column 2)	Overburden 150 ft to 250 ft: Measured (column 3)	Combined	Inferred (column 4)	Total
Mesaverde Group							
Gallup		270.0			88.0		358.0
Newcomb			78.5			6.3	84.8
Chaco Canyon			31.0				31.0
Chacra Mesa		34.7					34.7
San Mateo		82.3	21.2				103.5
Standing Rock			63.5			75.0	138.5
Zuni			6.2				6.2
Crownpoint			15.0				15.0
South Mount Taylor			1.4				1.4
East Mount Taylor							
Rio Puerco							
La Ventana			15.0				15.0
Mesaverde total		618.8			169.3		788.1
Fruitland Formation							
Fruitland	93.0		16.5	65.0			174.5
Navajo		1,934.5			1,352.8		3,287.3
Bisti			617.0			912.0	1,529.0
Star Lake			455.0			270.0	725.0
Fruitland total		3,116.0			2,599.8		5,715.8
Total		3,734.8			2,769.1		6,503.9

mately 788.1 million tons. Table 24 shows a summary of strippable coal reserves in the San Juan Basin.

The extent of strippable reserves outside the San Juan Basin is not well known, but a study now being initiated by this office should refine much of the published data. Arnold and others (1976) listed combined strippable and deep resources for the Raton Basin as 4.7 billion tons (including all coal below more than 250 ft of overburden). Maximum cut-off depth for this figure is not known but is probably 4,000 ft. The U.S. Bureau of Mines published a reserve base figure of 1.38 billion tons for bituminous coal in Colfax County (fig. 14). This figure includes only coal in beds 28 inches or more in thickness, down to a depth of 1,000 ft, and excludes strippable coal to 120 ft. All of this coal is under the control of private companies (Kaiser Steel, Pennzoil Corporation, Phelps-Dodge, and Santa Fe Railroad) who plan to develop it as expeditiously as marketing and economic conditions permit. On the other hand, nearly 90 percent of the readily available coal (strippable) in the San Juan Basin is under federal or Indian ownership (table 25).

The only other areas where significant coal deposits occur are the Datil Mountain area, the Sierra Blanca-Capitan coal fields, and the Cerillos field. Large-scale development in these areas is very unlikely over the next five years, although there are indications that small-scale mines may be opened.

Coal-leasing management

Federal coal leasing

Because of New Mexico's unique coal-ownership patterns, the state will not be affected by federal coal-leasing policies to the same extent as other western states. More than 50 percent of the strippable coal in the 150-ft overburden category is on the Navajo Indian Reservation and is under lease. An additional 10 percent is under fee land, and about 3 percent is under state land; just over 25 percent of the strippable coal in this category is under federal land (table 24). A large portion of this federal land in strippable areas is already under lease or under PRLA's.

Much of the mining that occurs in New Mexico during the next 5-10 years will occur independently of constraints placed by federal coal-leasing policy. Transportation constraints in many of the roadless areas where strippable coal occurs will affect coal production more than leasing constraints. Railroad construction into these areas has been delayed by federal EIS's (Environmental Impact Statements) and by lack of approval by the Navajo nation. Unleased federal coal land is interspersed with fee, state, and Indian-allotted land

TABLE 25—Fruitland Formation coal ownership and reserve statistics to a depth of 150 ft as of September 1977 (data from New Mexico Bureau of Geology).

Ownership category	Coal reserves (millions of tons)	Percent of reserves in each ownership category
Indian	1,934	62.0
Federal	796	25.6
Fee	280	9.0
State	106	3.4
Total	3,116	100.0

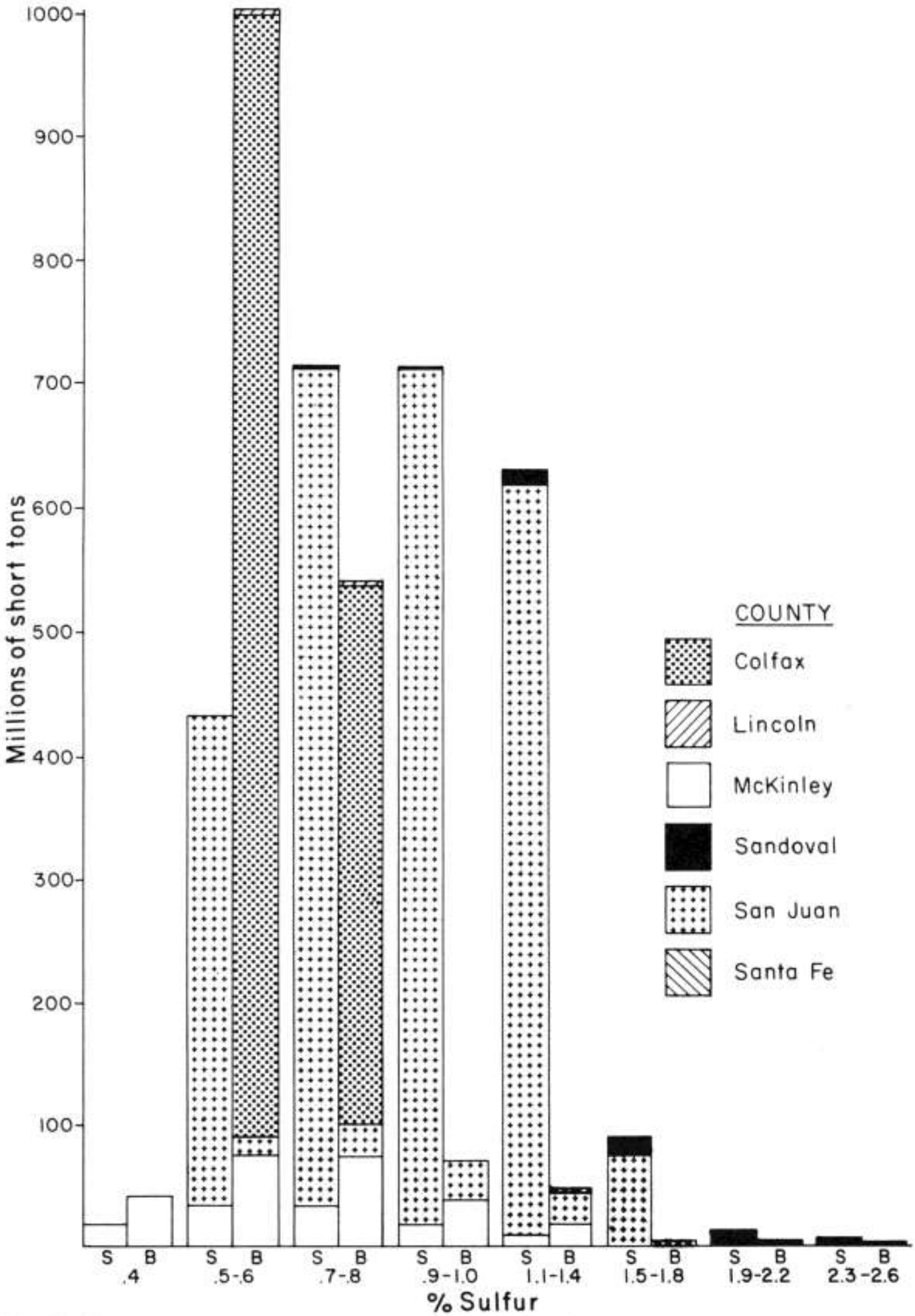

FIGURE 14—NEW MEXICO RESERVE BASE FOR COAL BY PERCENTAGE OF SULFUR; S = subbituminous, B = bituminous (data from U.S. Bureau of Mines).

and is commonly referred to as the "checkerboard area." The formulation of a federal coal-leasing policy will facilitate the formation of logical mining units in areas where this is not now possible.

Preference Right Lease Applications

According to the Albuquerque office of the BLM, 175,000 of the 456,000 acres contained within the Bisti-Star Lake EIS were in the active (leases being mined) or proposal category of leases at the beginning of 1977. Of these 175,000 acres, 137,089 acres are federal land divided as follows:

Leased	29,850 acres (21.8 percent)
PRLA	69,991 acres (51.1 percent)
Nominated	33,768 acres (24.6 percent)
Other	3,480 acres (2.5 percent)

This distribution indicates that New Mexico will be heavily affected by that portion of the federal coal-leasing policy which affects PRLA's. Substantial areas of this acreage probably will be uneconomic for mining at the present time, and much of it will be located in areas that cannot be strip mined because of excessive overburden. Nevertheless, an estimated 340 million tons of strip reserves in the 150-ft-or-less overburden category has been calculated. Some PRLA's probably will be canceled because of legal defects caused by the failure of applicants to perform according to lease stipulations. Some of these leases also are located in areas that may be classed as "unsuitable for mining" according to criteria proposed by the BLM (such as criteria relating to areas containing "rare geological and paleontological values" or other environmental considerations). Distinctions can be made between areas that will be strip mined and areas where coal will be removed by deep-mining methods, because deep mining may be carried out without disturbing a significant amount of surface area. An area judged to be unsuitable for surface mining on environmental grounds could be deemed acceptable for deep mining.

The Western Interstate Energy Board has a coal committee that coordinates the various policy positions of western coal-producing states. New Mexico is taking an active part in this effort. The immediate task being addressed by this group is effective western-state input into the new federal coal-leasing policy that the U.S. Department of the Interior is now forming.

Beginning in 1970, an analysis of coal-leasing activity by the BLM indicated serious deficiencies in the federal coal-leasing program. This study forced the Secretary of the Department of the Interior to announce a moratorium on coal leasing. In 1979, however, the seven-year freeze on federal coal leasing was lifted. Nonetheless, the earliest date that New Mexico coal leases on federal lands will be processed is set for 1983. Despite guarantees to lease land, exploitation of the coal still carries many uncertainties. The stalemate that has developed between mining interests and environmental groups and key federal agencies administering coal resources may further extend the delay.

State coal leasing

As of March 20, 1979, 85,529 acres of state trust land were leased in New Mexico. Although no coal production yet occurs on state trust land, the state is accruing royalties from its leases because advance royalties are required by lease stipulations. As of November 1977, state coal leases have been issued with 12 1/2-percent royalty provisions. Prior to November 1977, royalties were set at 8 percent; and, prior to 1973, they were $0.20 per ton. If leases currently out at 8 percent or less expire before production begins, they will, by law, have to be renegotiated at the new 12 1/2-percent royalty rate. If judicial intervention continues to delay federal coal leasing, state acreage will play a significant role in expanding New Mexico's production. Mining plans for a mine near Carrizozo, Chaco Energy's mine near Star Lake, and Western Coal's Bisti development, as well as the expansion of Pittsburg and Midway's McKinley mine, involve the development of state-owned coal.

State revenue

In 1978 the state collected $6,539,519 from the severance, resource excise, and conservation taxes, and $455,887 from rental bonus bids and royalties on state trust lands. The state also receives a portion of the royalties collected by the federal government on public lands (table 26).

Total state revenue was $6,995,406 in 1978, up from $5,780,076 in 1977. This figure does not include the royalties from the federal government. The state does not receive royalties from coal extracted from Indian lands.

Table 26, compiled by the Bureau of Geology, shows the amounts collected from taxes and royalties for the past two years.

TABLE 26—REVENUE FROM TAXES AND ROYALTIES FROM COAL FOR NEW MEXICO, 1977 AND 1978. Royalties from state lands include bonus payment and rental payment; no state leases are in production, but royalties are accruing as stipulated by state-lease regulations. Years are fiscal years; 1978 is July 1, 1977-June 30, 1978, and 1977 is July 1, 1976, to June 30, 1977. Only a portion of federal royalties is returned to the state (data from New Mexico Taxation and Revenue Department and U.S. Geological Survey).

	1978	1977
Severance tax	$5,115,621	$4,020,151
Resource excise tax	1,135,260	795,710
Conservation tax	288,638	215,533
Total	$6,539,519	$5,031,394
	1978	1977
Royalties - state land	$ 455,887	$ 748,682
Total	$ 455,887	$ 748,682
Totals	$6,995,406	$5,780,076

Royalties - federally owned coal

	1978 Tons	1978 Value	Tons	Value
Indian	6,279,840	$1,088,476	6,953,310	$1,088,832
Public Domain	4,261,690	958,880	2,335,981	525,596
Total	10,541,530	$2,047,356	9,289,291	$1,614,428

	1978	1977
Grand totals	$9,042,762	$7,394,504

Uranium

by B. L. Perkins, *Consultant to Energy and Minerals Department*

Production

In 1978 a record 6,262,000 tons of uranium ore were weighed and sampled by New Mexico mills. This amount represented an increase of 49 percent from 1977. The amount of U_3O_8 contained in the ore was 9,400 tons or a 24-percent increase over 1977. The smaller increase in U_3O_8 content is due to a drop in ore grade. Table 27 lists data for the past five years. New Mexico continued to lead the nation in 1978 with 46 percent of total United States concentrate production. In 1978, 8,560 tons of U_3O_8 were produced in New Mexico; this figure represents an increase of 26 percent over 1977. The difference between the amount of U_3O_8 contained in the weighed ore and the amount actually produced is a result of U_3O_8 lost in the milling process and differences in amounts stockpiled. Concentrate production since 1966 is shown in table 28.

Most of the 1978 production came from sandstone deposits in the Morrison Formation. The only exception was a small amount of ore produced from the Todilto Limestone. Most of the New Mexico ore production has always come from the Morrison Formation in the San Juan Basin. The 1978 production came predominantly from the Ambrosia Lake, Smith Lake, Church Rock, and Laguna areas, with a very small amount being produced from the Shiprock area. Northwest New Mexico has always been dominant in uranium production (table 29).

Mining

As of December 1978, 33 mines were producing ore in New Mexico. By July 1979, 37 mines were in production (table 30). Two mines were undergoing mine-water recirculation only as of July 1979, and several producing mines were also undergoing mine-water recirculation.

New Mexico ore weighed by mills in 1978 would average 189,758 tons per year per mine. In actual practice, however, several large mines producing 1,000 tons or more per day dominated production. Production in 1978 from United States mines outside New Mexico was approximately 9,928,000 tons from 335 mines for an average of 29,636 tons per year per mine. Thus, New Mexico mines have a greater average production per mine than elsewhere in the United States.

As of November 1978, approximately 15,250 gpm (gallons per minute) of water were being discharged (including water being recirculated) from all active mines. Excluding water being recirculated, minedewatering discharge was approximately 13,345 gpm. If the Mount Taylor operation (where an experimental ore production program is underway) is included in the July 1979 inventory, discharge at that time due to mine dewatering from active mines was approximately 17,345 gpm. Dewatering data since 1956 is given in table 31.

Total employment in mining in 1978 was 6,021 as compared to 5,264 in 1977, 3,833 in 1976, and 2,857 in 1975. The 1978 total consisted of 1,961 miners and 1,766 service and support personnel employed in underground mines; 325 miners and 411 service and support personnel employed in open-pit mines; 579 technical personnel; 602 supervisory personnel, and 377 other personnel.

Milling

During 1978, five mills were in operation in New Mexico (table 32). New Mexico mills were running at 10-20 percent of full capacity during 1978. Lack of capacity and declining ore grade may be the limiting factors in New Mexico concentrate production until other mills are licensed and constructed.

Yellowcake was recovered from ore produced by New Mexico mines and from either loaded resins or pregnant solutions from ion-exchange facilities (which accounted for only a small amount of the total).

TABLE 27—Uranium ore weighed and sampled by mills and buying stations in New Mexico, 1974–1978 (U.S. Energy Research and Development Administration, 1975, 1976, 1977; U.S. Department of Energy, 1978a, 1979b).

Year	Ore (tons)	U_3O_8 (tons)	Ore grade %	% of total U.S. U_3O_8 production
1974	2,997,000	5,400	0.180	43
1975	2,985,000	5,500	0.184	45
1976	3,401,000	6,500	0.191	46
1977	4,209,000	7,600	0.181	46
1978	6,262,000	9,400	0.150	47

TABLE 28—Uranium-concentrate production in New Mexico, 1966–1978; because of a prolonged labor strike at Kerr-McGee in 1973, concentrate production for that year is not included in average (U.S. Department of Energy, 1979b).

Year	U_3O_8 (tons)	% of total U.S. production
1966	5,076	48
1967	5,933	53
1968	6,192	50
1969	5,943	51
1970	5,771	45
1971	5,305	43
1972	5,464	42
1973	4,634	35
1974	4,951	43
1975	5,191	45
1976	6,059	48
1977	6,780	45
1978	8,560	46
Average (excluding 1973)		47

TABLE 29—AREAS OF URANIUM PRODUCTION IN NEW MEXICO, 1948–1978. Production categories: 1 = less than 1 ton U_3O_8, 2 = 1–100 tons U_3O_8, 3 = 101–1,000 tons U_3O_8, 4 = 1,001–10,000 tons U_3O_8, 5 = greater than 10,000 tons U_3O_8 (U.S. Department of Energy, 1979a).

Area	No. of properties that have produced	Production category
Shiprock	41	3
Gallup	17	3
Black Jack	15	4
Ambrosia Lake	101	5
Laguna	9	5
Red Basin	3	1
Socorro	6	2
Burro Mountains	3	1
Petaca	3	1
Chama	1	1
Jemez	6	1
Nacimiento	2	1
Las Vegas	2	1
Santa Fe	1	2
Tucumcari	6	1

TABLE 30—NEW MEXICO URANIUM MINES IN PRODUCTION AS OF JULY 1, 1979. Kerr-McGee sec. 33 and sec. 22 mines are mine-water recirculation only; Gulf Mount Taylor mine is an experimental ore-production program (data from New Mexico Energy and Minerals Department).

Mine	Company	Location Sec., Twp., Rge.	Depth (ft)
Section 17	Kerr-McGee	17, T.14 N., R.9 W.	1,094
Section 19	Kerr-McGee	19, T.14 N., R.9 W.	779
Section 22	Kerr-McGee	22, T.14 N., R.10 W.	827
Section 24	Kerr-McGee	24, T.14 N., R.10 W.	837
Section 30	Kerr-McGee	30, T.14 N., R.9 W.	750
Section 30W	Kerr-McGee	30, T.14 N., R.9 W.	810
Section 33	Kerr-McGee	33, T.14 N., R.9 W.	848
Section 35	Kerr-McGee	35, T.14 N., R.9 W.	1,398
Section 36	Kerr-McGee	36, T.14 N., R.9 W.	1,473
Church Rock No. 1	Kerr-McGee	35, T.17 N., R.16 W.	1,851
Ann Lee	UNC (United Nuclear Corp.)	28, T.14 N., R.9 W.	720
Section 27	UNC	27, T.14 N., R.9 W.	850
Sandstone (John Billy Shaft)	UNC	34, T.14 N., R.9 W.	940
Church Rock	UNC	35, T.17 N., R.16 W.	1,800
St. Anthony (pit)	UNC	19&30, T.11 N., R.4 W.	150–200
Section 25	United Nuclear-Homestake Partners	25, T.14 N., R.10 W.	811
Section 13	UN-HP	13, T.14 N., R.10 W.	618
Section 15	UN-HP	15, T.14 N., R.10 W.	623
Section 23	UN-HP	23, T.14 N., R.10 W.	850
Section 32	UN-HP	32, T.14 N., R.9 W.	595
Johnny M	Ranchers Exploration	7&18, T.13 N., R.8 W.	1,380
Hope	Ranchers Exploration	19, T.13 N., R.9 W.	400
Poison Canyon (connects to Gossett)	Reserve Oil & Minerals Corp.	19, T.13 N., R.9 W.	200
Section 12 (connects to Dysart No. 2)	Cobb	12, T.14 N., R.10 W.	665
Section 14	Cobb	14, T.14 N., R.10 W.	384
Westranch (portal sec. 33)	Cobb	32, T.15 N., R.11 W.	320
Ruby No. 1 (connects by tunnel to Ruby No. 2)	Western Nuclear	21, T.15 N., R.13 W.	300–400
Mariano Lake	Gulf	12, T.15 N., R.14 W.	519
JJ No. 1	Sohio	13, T.11 N., R.5 W.	672
PW-2/3	Anaconda	33, T.11 N., R.5 W.	adit
P-10	Anaconda	4, T.10 N., R.5 W.	450
Jackpile-Paguate	Anaconda	33,34&35, T.11 N., R.5 W.; 2,4&5, T.10 N., R.5 W.	150
Haystack	Todilto Exploration & Development Corp.	19&18, T.13 N., R.10 W.; 13, T.13 N., R.11 W.	150
Piedra Triste (connects to Roundy & Barbara J No. 2)	Todilto Exploration & Development Corp.	30, T.13 N., R.9 W.	
Isabella and	Koppen	6, T.13 N., R.9 W.	
Spencer Shaft No. 1	Koppen	8, T.13 N., R.9 W.	300
Spencer Shaft No. 2	Koppen	6, T.13 N., R.9 W.	
Enos Johnson	Ray Williams	9 mi w. Sanostee Boarding School	adit
Section 21 (Doris extension connects to Flea)	M&M	21, T.13 N., R.9 W.	adit
St. Anthony Shaft	UNC	24, T.11 N., R.5 W.	320

TABLE 31—HISTORICAL APPROXIMATE WATER PRODUCTION FROM NEW MEXICO URANIUM MINES, 1956–1978. Figures do not include water produced during shaft sinking (data from Phillips Uranium Company exhibit, Hearing before the State Engineer, July 31–August 2, 1979).

Year	Approximate gallons per minute: Laguna	Smith Lake	Church Rock	Ambrosia Lake	Total gallons per minute	Total (millions of gallons)
1956				500	500	262.8
1957				4,500	4,500	2,365.2
1958				8,500	8,500	4,467.6
1959				11,500	11,500	6,044.4
1960			400	11,500	11,900	6,254.6
1961		60	400	12,000	12,460	6,549.0
1962		85		11,600	11,685	6,141.6
1963		85		11,400	11,485	6,036.5
1964				11,300	11,300	5,939.3
1965				11,000	11,000	5,781.6
1966				9,500	9,500	4,993.2
1967			2,400	8,500	10,900	5,729.0
1968			2,300	8,300	10,600	5,571.4
1969			2,000	8,000	10,000	5,256.0
1970			3,500	8,500	12,000	6,307.2
1971			3,600	8,000	11,600	6,097.0
1972	30		4,000	8,000	12,030	6,323.0
1973	30		4,000	7,500	11,530	6,060.2
1974	100		4,000	7,000	11,100	5,834.2
1975	100		4,250	7,000	11,350	5,965.6
1976	150		4,250	7,400	11,800	6,202.1
1977	200	50	4,500	7,000	11,750	6,175.8
1978	225	200–300	5,400	7,420	13,345	7,014.1
				Total withdrawal		127,371.4 (0.39 million acre-ft)

One pilot plant, an in situ leach project, was licensed by the state but had not begun active operation by July 1979. Another in situ leach pilot-plant location was undergoing formation studies. Seven ion-exchange facilities were in operation in the state as of July 1979 and are listed below:

Company	Location
United Nuclear Corp.	Church Rock (mine)
United Nuclear Corp.	Ambrosia Lake (mines)
United Nuclear-Homestake Partners	Ambrosia Lake (mines)
Kerr-McGee	Ambrosia Lake (sec. 35)
Kerr-McGee	Ambrosia Lake (western section of mines)
United Nuclear-Homestake Partners	Milan (mill-tailings pond recirculation)
Gulf	Mariano Lake (mine)

United Nuclear had an ion-exchange facility at its Old Church Rock mine, but it was used very little because of lack of water flowing from the mine. Gulf is building an ion-exchange facility for its Mount Taylor mine.

Mobil had not yet begun uranium recovery for an in situ project at Crownpoint, but the equipment was mounted on the property by July 1979. A discharge permit for a small pilot plant for a heap-leach facility was obtained by United Nuclear Corporation from the state but construction had not been completed as of July 1979.

Estimated water use in milling for 1979 was 1.886 billion gallons. Most of this water was discharged into tailing ponds, where it either evaporated, was incorporated into the tailings, or seeped out of the tailings area. Electrical consumption for milling in 1978 was estimated at 219 million kilowatt-hours. In 1978, 1,127 persons were employed in milling in New Mexico: 428 in operations, 362 in maintenance, 121 in technical posi-

TABLE 32—LICENCED NEW MEXICO URANIUM MILLS AS OF JULY 1, 1979; excludes ion-exchange facilities (data from New Mexico Health and Environmental Department).

Company	Location	Licensed capacity (tons/day)	Normal operating throughput (tons/day)
Sohio Oil-Reserve Oil	Seboyeta	1,660	1,500
Kerr-McGee Nuclear	Ambrosia Lake	7,000	7,000
United Nuclear-Homestake Partners	Milan	3,500	2,500
Anaconda	Bluewater	6,000	6,000
United Nuclear	Church Rock	4,000	4,000
Mobil*	Crownpoint	contains maximum 30,000 lb yellowcake slurry (maximum 30% U_3O_8 by weight)	not yet in operation

* In Situ

TABLE 33—SURFACE DRILLING FOR URANIUM IN NEW MEXICO BY COUNTY, 1978. "Other" includes Luna, Sierra, and Socorro Counties and undisclosed locations (W. L. Chenoweth, U.S. Department of Energy, personal communication).

County	Exploration		Development	
	No. of holes	Footage	No. of holes	Footage
Catron	611	369,245	0	0
McKinley	2,015	2,501,433	3,144	4,837,494
Sandoval	244	115,842	118	207,408
San Juan	184	379,905	0	0
Valencia	96	108,741	2,641	1,129,489
Other	140	208,221	141	64,602
Totals	3,290	3,683,387	6,044	6,238,993

tions, 155 in supervisory positions, and 61 in other positions. Employment distributions appear to be similar to mill operations outside New Mexico.

Exploration and development

Drilling

In 1978 exploration and development drilling was 9,922,380 ft compared with approximately 9,100,000 ft in 1977; the 1977 figure may be too low by about 1 million ft and the United States total may be too low by 4 million ft. Drilling in New Mexico in 1978 was 21.1 percent of the United States total, 22.2 percent in 1977, 32.4 percent in 1976, and 21.9 percent in 1975. In 1976, a total of 11,020,000 ft was drilled in New Mexico; 5,698,000 ft were drilled in 1975. The 1978 total includes 3,290 exploration drill holes (a total of 3,683,387 ft) and 6,044 development drill holes (a total of 6,238,993 ft). The greatest amount of exploration and development drilling took place in McKinley County. Table 33 shows New Mexico surface drilling in 1978. During 1978 and through June 1979, 40 companies were engaged in drilling activities in New Mexico (table 34). Areas of interest outside the San Juan Basin included Pietown-Quemado, Chama, Truth or Consequences, the Hagan Basin, Datil, and Socorro. The San Juan Basin, however, continued to be the dominant area of activity.

In 1978, 988 man-years of employment went into exploration in New Mexico.

Exploration and mine development

Along with the 37 mines in production as of July 1979, eight mines, one new shaft for a mine in active production, and one in situ pilot project were under development (table 35). Land held for uranium exploration and mining in New Mexico as of January 1, 1979, consisted of 4,279,000 acres, which amounted to 13 percent of the total land held for uranium exploration and mining in the United States. On January 1, 1978, by comparison, 3,855,000 acres were held for exploration and mining (13 percent of the United States total). Although the amount of acreage held has increased over the past six years, the percent of the United States total has been decreasing. On January 1, 1974, 3,158,000 acres (17 percent of total United States land) were held for exploration and mining. Table 36 shows acres held for uranium exploration and development by county and land category at the second half of 1978.

During 1978 the target Morrison Formation host rock located slightly more than 3,000 ft below the surface was intercepted by Gulf Minerals at its Mount Taylor facility. The sandstone proved to be competent, and by July 1979 an experimental mining program had begun. The major mining problem may prove to be the high rock temperature (the rock face runs about 130°F).

Other new developments included continued shaft sinking combined with use of dewatering wells at Phillips' Nose Rock mine. A head frame was installed at the third shaft, and by July 1979 shaft sinking on the third shaft had progressed several hundred feet while shaft sinking continued at locations one and two. A new mine was constructed in the Poison Canyon area (Piedra Triste) by Todilto Exploration and Development. The reentry of the Spencer shaft, Isabella (by tunnel from Spencer shaft), and Section 14 resulted in active ore production by July 1979 for these mines. Reentry of the Old Church Rock mine and Section 10 was also underway as of July 1979.

Construction of a shaft by slabbing down at Kerr-McGee Nuclear's Church Rock 1E progressed well during 1978 and had been completed except for work on the last station by July 1979. Also by July, a tunnel from Ruby No. 1 to the orebody of Ruby No. 2 was progressing and the separate entry for Ruby No. 3 and Ruby No. 4 was under construction. The operation of Rio Puerco was almost ready to be turned over to the production crew by July 1979, and during 1978 adits were developed off the main Paguate (Anaconda) pit to allow for ore recovery in a region adjacent to the pit. Also during 1978, dewatering problems in the shaft of Bokum's Marquez mine hindered development. Lawsuits and permit approval delayed start-up of Mobil's in situ leach pilot project at Crownpoint. Mobil was also testing the Morrison Formation (July 1979) at its Monument property (sec. 28, T. 17 N., R. 12 W.) and a possible second in situ leach project may be located there. Kerr-McGee announced a new mine at Marquez, and the Tennessee Valley Authority agreed to pay Kerr-

TABLE 34—New Mexico uranium drilling, companies and locations, January 1978 through June 1979. Some drilling may not be included (data from E. N. Saucier, New Mexico Uranium Newsletter).

Company	Area	Section, township, range
Anaconda	Smith Lake	T.16 N., R.13 & 14 W.
	Datil	N/A
	Jackpile Paguate	Sec. 26,33,34,35,36, T.11 N., R.5 W.
	Jackpile Paguate	Sec. 4,5,8,9,16, T.10 N., R.5 W.
	Chama Basin	T.25 N., R.5 E.
	Chama Basin	T.26 N., R.5&6 E.
	Lee Ranch	T.16 N., R.7 W.
	Lee Ranch	T.17 N., R.6&7 W.
Ashland	Hagan Basin	T.14 N., R.5,6&7 E.
Bokum	Marquez	Sec. 36, T.13 N., R.5 W.
	Marquez	Sec. 31,32,33, T.13 N., R.4 W.
	Marquez	Sec. 5, T.12 N., R.4 W.
Cobb	Ambrosia Lake	Sec. 28, T.14 N., R.11 W.
	Ambrosia Lake	Sec. 12,14, T.14 N., R.10 W.
	Pinedale	Sec. 17,18,19,30, T.16 N., R.15 W.
	Thoreau	Sec. 8, T.14 N., R.12 W.
	Rio Puerco	Sec. 8,18,20, T.11 N., R.3 W.
	Rio Puerco	Sec. 12,24, T.11 N., R.4 W.
Conoco	Hosta Butte	Sec. 3,9,11, T.16 N., R.13 W.
	Borrego Pass	Sec. 2,13, T.16 N., R.11 W.
	Borrego Pass	Sec. 18,20,28,34, T.16 N., R.10 W.
	San Mateo	Sec. 11, T.14 N., R.8 W.
	San Mateo	Sec. 25, T.13 N., R.9 W.
	San Mateo	Sec. 2,11, T.13 N., R.8 W.
	Crownpoint	Sec. 20,32,36, T.18 N., R.13 W.
	Crownpoint	Sec. 30, T.18 N., R.12 W.
	Crownpoint	Sec. 8,29, T.17 N., R.12 W.
	Crownpoint	Sec. 23, T.17 N., R.13 W.
	Bernabe Montano	Sec. 31, T.12 N., R.1 W.
	Bernabe Montano	Sec. 23,27, T.12 N., R.2 W.
	Whitehorse	Sec. 20, T.20 N., R.10 W.
	Whitehorse	Sec. 24, T.19 N., R.9 W.
	Nose Rock	Sec. 4,14, T.20 N., R.13 W.
	Nose Rock	Sec. 4, T.20 N., R.12 W.
Energy Fuels	Evelyn Mine	Sec. 8,9, T.14 N., R.11 W.
	Evelyn Mine	Sec. 35, T.15 N., R.11 W.
	Cubero	T.10 N., R.7 W.
Energy Reserves	Quemado-Pietown	N/A
	Truth or Consequences	N/A
	Datil	T.2 N., R.12 W.
Exxon	Sanostee	T.26 N., R.18 W.
	Sanostee	T.25 N., R.18 W.
	Mt. Taylor	Sec. 19,29, T.12 N., R.6 W.
Frontier Mining		Sec. 4,8,24, T.15 N., R.8 W.
		Sec. 10,14,22,26,28,30,32,34, T.16 N., R.9 W.
		T.15 N., R.7 W.
		Sec. 28,34, T.16 N., R.8 W.
		T.16 N., R.7 W.
Getty	Chaco	T.22 N., R.9 W.
Gulf	Mt. Taylor	Sec. 25,26,28,31, T.13 N., R.7 W.
	San Mateo (Mt. Taylor)	Sec. 25, T.13 N., R.8 W.
		Sec. 26, T.13 N., R.9 W.
	West Largo	Sec. 20,28, T.15 N., R.10 W.
	West Largo	Sec. 14,30, T.15 N., R.11 W.
	Chama	Sec. 9, T.22 N., R.3 E.
	Thoreau	Sec. 24, T.15 N., R.13 W.
	Mariano Lake	Sec. 13, T.15 N., R.14 W.
	Aguila	Sec. 10, T.16 N., R.10 W.
	Cabezon	Sec. 19,17, T.16 N., R.4 W.
Homestake	Rio Puerco	Sec. 16, T.12 N., R.3 W.
	Ambrosia Lake	Sec. 2, T.13 N., R.9 W.
	Smith Lake	Sec. 32, T.15 N., R.11 W.
	Church Rock	Sec. 24,28, T.16 N., R.17 W.
	San Mateo	Sec. 31, T.14 N., R.8 W.
Houston Oil	Datil	Sec. 33, T.2 N., R.11 W.
	San Mateo	T.14 N., R.8 W.
Keradamex	San Mateo	Sec. 33,35, T.13 N., R.8 W.
	N. of Ambrosia Lake	Sec. 30,31, T.16 N., R.9 W.
	North Ranch	Sec. 5,31, T.15 N., R.8 W.
	North Ranch	Sec. 5,7,17, T.16 N., R.8 W.
Kerr-McGee	Ambrosia Lake	Sec. 4,18,19,20,26,29,30,35,36, T.14 N., R.9 W.
	Ambrosia Lake	Sec. 2,12,22,24,26, T.14 N., R.10 W.
	Ambrosia Lake	Sec. 4,12, T.13 N., R.9 W.
	Rio Puerco	T.12 N., R.2&3 W.
	Church Rock	Sec. 22,23,25,26, T.17 N., R.16 W.
	Pina Ranch	T.15 N., R.9 W.
	Datil	N/A
	Roca Honda	Sec. 8,17, T.13 N., R.8 W.
Koppen	Hosta Butte	Sec. 10, T.16 N., R.13 W.
Mobil	Crownpoint	Sec. 3,4,5,7,8,9,12,15,16,18,23, 24, T.17 N., R.13 W.
	Crownpoint	Sec. 26,28, T.17 N., R.12 W.
Lucky Mc (became Pathfinder)	Crownpoint	Sec. 22, T.17 N., R.11 W.
	Ambrosia Lake	Sec. 29, T.15 N., R.10 W.
	Ambrosia Lake	Sec. 9, T.14 N., R.10 W.
New Cinch	Mesa Portales	T.20 N., R.2,3,4 W.
	La Ventana	T.19 N., R.2,3 W.
Noranda	San Mateo	Sec. 19, T.13 N., R.8 W.
North-South Exploration	Ojo Encino	T.20 N., R.5,6 W.
Pathfinder	Crownpoint	Sec. 32, T.17 N., R.13 W.
	Crownpoint	Sec. 28, T.19 N., R.13 W.
	Borrego Pass	Sec. 22, T.16 N., R.10 W.
		Sec. 5,21,29, T.15 N., R.10 W.
	East Crownpoint	Sec. 14, T.17 N., R.11 W.
Phillips	Nose Rock	T.19 N., R.11 W.
	Nose Rock	T.20 N., R.11 W.
	Datil	T.3 N., R.13 W.
	Cabezon	Sec. 5,7,10,13,23, T.16 N., R.5 W.
Pioneer	Datil	Sec. 18,25, T.2 N., R.12 W.
	Datil	Sec. 32, T.3 N., R.12 W.
	Chama	T.27 N., R.2,3 E.
	Ambrosia Lake	Sec. 2, T.13 N., R.10 W.
	Tierra Amarilla	T.28 N., R.3,4 E.
	Dalton Pass	Sec. 5, T.16 N., R.13 W.
Ranchers	Pinedale	T.16 N., R.15 W.
	Hope Mine	Sec. 19, T.13 N., R.9 W.
	Hope Mine	Sec. 24, T.13 N., R.10 W.
	Johhny M	Sec. 7,13, T.13 N., R.9 W.
		T.13 N., R.8 W.
	Datil	N/A
	Rio Puerco	T.12 N., R.3 W.
	Ambrosia Lake	T.14 N., R.9 W.
	West Ranch	T.14 N., R.11 W.
	West Ranch	Sec. 33, T.15 N., R.11 W.
	Crownpoint	T.16 N., R.12 W.
	Isabella (Ambrosia Lake)	Sec. 7, T.13 N., R.9 W.
	Faith	Sec. 29, T.13 N., R.9 W.
	Near Poison Canyon	Sec. 24, T.13 N., R.10 W.
Reserve		Sec. 8, T.11 N., R.9 W.
	Poison Canyon	Sec. 10,20, T.13 N., R.9 W.
	Poison Canyon	Sec. 12, T.13 N., R.10 W.
Rocky Mt.	Socorro	N/A
	Hospah	T.17 N., R.10,11 W.
Santa Fe RR	Ambrosia Lake	Sec. 5,11, T.13 N., R.9 W.
	Poison Canyon	Sec. 17, T.13 N., R.9 W.
Saint Joe	Datil	T.1 N., R.13 W.
Sohio	L-Bar	Sec. 12,13,23,24, T.11 N., R.5 W.
Teton	Crownpoint	Sec. 16, T.17 N., R.12 W.
	Crownpoint	Sec. 34, T.17 N., R.13 W.
	Crownpoint	Sec. 2, T.16 N., R.13 W.
	Church Rock	Sec. 13, T.16 N., R.17 W.
	Torreon	Sec. 1,13,35, T.17 N., R.4 W.
	Torreon	Sec. 14, T.17 N., R.5 W.
	Hosta Butte	Sec. 4, T.16 N., R.13 W.
	San Mateo	Sec. 31, T.13 N., R.8 W.
	Chama	Sec. 35, T.26 N., R.5 E.
Thermal Energy	Borrego Pass	Sec. 30, T.16 N., R.10 W.
	Borrego Pass	Sec. 26, T.16 N., R.11 W.
Todilto	Poison Canyon	Sec. 30, T.13 N., R.9 W.
	Haystack	Sec. 13, T.13 N., R.11 W.
	San Mateo	Sec. 30, T.13 N., R.9 W.
United Nuclear	St. Anthony	Sec. 25, T.11 N., R.5 W.
	Church Rock	Sec. 34,35, T.17 N., R.16 W.
	Church Rock	Sec. 3,7, T.16 N., R.16 W.
	Church Rock	Sec. 12, T.16 N., R.17 W.
	Dalton Pass	Sec. 30, T.17 N., R.13 W.
	Dalton Pass	T.17 N., R.14 W.
	Crownpoint	Sec. 34, T.17 N., R.13 W.
	West Ranch	Sec. 12, T.14 N., R.11 W.
United Nuclear-Homestake Partners	Ambrosia Lake	Sec. 13,23,25, T.14 N., R.10 W.
Union Carbide	Hagan Basin	Sec. 16, T.13 N., R.6 E.
	La Bajada	Sec. 15, T.15 N., R.7 E.
Urania	Pietown	T.2 N., R.11 W.
Uranium King	Church Rock	Sec. 14,20, T.16 N., R.17 W.
	Church Rock	Sec. 18, T.16 N., R.16 W.
Western Nuclear	Ruby Well	Sec. 20,25,26,27, T.15 N., R.13 W.
	Ruby Well	Sec. 30, T.15 N., R.12 W.
	Mariano Lake	Sec. 35, T.16 N., R.14 W.
	Truth or Consequences	N/A
WESCO	Smith Lake	Sec. 23, T.15 N., R.12 W.
	Crownpoint	T.16 N., R.12 W.

TABLE 35—NEW MEXICO URANIUM MINES UNDER DEVELOPMENT, JULY 1979; Kerr-McGee's Church Rock 1E and Rio Puerco are almost complete (data from New Mexico Energy and Minerals Department).

Mine	Company	Location	Target depth
Marquez	Bokum Resources	Sec.25,T.13N.,R.5W.	2,100
Church Rock 1E (part of Church Rock No.1)	Kerr-McGee	Sec. 36, T.17N.,R.16W.	1,545
Mt. Taylor	Gulf	Sec.24,T.13N.,R.8W.	3,370
Rio Puerco	Kerr-McGee	Sec.18,T.12N.,R.3W.	850
Nose Rock No.1 (3 shafts)	Phillips Uranium Co.	Sec.31,T.19N.,R.11W. Sec.36,T.19N.,R.12W.	3,400
Old Church Rock	United Nuclear	Sec.17,T.16N.,R.16W.	900
Ruby No.3 & No.4	Western Nuclear	Sec.26,T.15N.,R.13W. Sec.25,T.15N.,R.13W.	~360
Section 10	Cobb	Sec.10,T.14N.,R.10W.	not known
Ruby No.2 (connects to No.1)	Western Nuclear	Sec.27,T.15N.,R.13W.	~360
Crownpoint in situ leach	Mobil Oil	Sec.9,T.17N.,R.13W.	~2,000

McGee for half interest in the mining lease. The venture is expected to yield the Tennessee Valley Authority about 5 million lbs of U_3O_8. Kerr-McGee also announced plans to develop the Roca Honda mine near San Mateo (1,675 ft deep, production estimated at 600 tons per day). Conoco filed a mining plan with the USGS (U.S. Geological Survey) for a mine at Borrego Pass.

A report on radon emissions from mine vents was issued in March 1979 (Jackson and others, 1979). The data obtained for radon emissions from seven mines were: mine 1, 4 curies per day; mine 2, 16 curies per day; mine 3, 22 curies per day; mine 4, 40 curies per day; mine 5, approximately 23 curies per day; mine 6, 12 curies per day; and mine 7, 12 curies per day. The average emission in terms of Radon-222 emissions per annual fuel requirement (annual 1,000-megawatt fuel requirement defined as 245 metric tons U_3O_8) was 4,130 excluding mine 5.

Mill development and applications

In addition to the five mills in operation, three mill license applications were received by the State of New Mexico during 1978 and early 1979. Bokum Resources requested a license for a 2,200-ton-per-day capacity mill at Marquez. Bokum began construction of a new mill and tailings pond and proceeded with construction without a ground-water-discharge permit or a mill license. The discharge-permit application was denied, and on August 1, 1979, the New Mexico Supreme Court declined jurisdiction at that point in the proceedings. Bokum consequently has modified the tailings-disposal plan. Gulf Mineral Resources requested a license for a mill at San Mateo for a capacity of 4,200 tons per day,

TABLE 36—NEW MEXICO LAND HELD FOR URANIUM EXPLORATION AND DEVELOPMENT, SECOND HALF 1978. Parentheses indicate lease termination and claim abandonments (Bendix Field Engineering Corporation, 1979).

	Acres held by county and land category (approximate)					
Period	State	Claim	Federally acquired	Indian	Fee	Total
Cumulative total to January 1, 1978	328,806	1,768,775	608	386,215	1,370,213	3,854,617
Total January 1 to June 30, 1978	43,002	150,400	—	—	(69)	193,333
Land transactions, July 1 to December 31, 1978 by county						
Bernalillo		1,260				1,260
Catron	29,848					29,848
Chaves	2,080					2,080
DeBaca	6,386					6,386
Dona Ana	(49)					(49)
Grant	16,911					16,911
Guadalupe	1,506					1,506
Hidalgo	(1,262)					(1,262)
Lincoln	250					250
Luna	377					377
McKinley	1,055	58,000			240	59,295
Quay	1,280					1,280
Rio Arriba	3,251	(480)			(10,607)	(7,836)
Sandoval	(840)	14,540			2,533	16,233
San Juan	1,278	71,380				72,658
Sierra	410					410
Socorro	(1,548)	9,280			80	7,812
Valencia	(1,280)	25,360				24,080
Total July 1 to December 31, 1978	59,653	179,340	—	—	(7,754)	231,239
Total for calendar year 1978	102,655	329,740	—	—	(7,823)	424,572
Cummulative total to December 31, 1978	431,461	2,098,515	608	386,215	1,362,390	4,279,189

and Phillips Uranium Co. requested a license for a mill at Nose Rock for a capacity of 2,750 tons per day. The Gulf and Bokum mill applications have been accepted for review by the New Mexico Environmental Improvement Division.

Probably one of the major reasons for the 1978 increase in ore sampled by mills and the decrease in ore grade was the upgrading of the Anaconda mill to handle more ore, a process that gave Anaconda the capability of milling more lower grade ore from stockpiles at the Jackpile-Paguate mine. The Anaconda mill is expected to continue to obtain lower grade ores from the Jackpile-Paguate stockpiles until those stockpiles are depleted, perhaps sometime in the mid-1980's. Anaconda is also considering a heap-leach operation at the Jackpile-Paguate mine.

In late August 1979, Conoco, Inc., and Westinghouse Electric Corporation announced that they will jointly develop a uranium mine and mill near Crownpoint. Westinghouse will finance construction estimated at $120 million (1979 dollars), and target output is approximately 1 million lbs of U_30_8 annually (with a mill capacity of about 1,000 tons per day). Exxon may submit plans in the next year for an in situ leach project also in the Laguna-Marquez area.

In July 1979, the tailings dam of the United Nuclear Corporation mill at Church Rock developed a hole that resulted in discharging mill-spent processing liquor and tailings into the Rio Puerco (Puerco of the West). United Nuclear has estimated that 94 million gallons of liquid and 1,100 tons of solids were lost. While final sampling results (August 15, 1979) are not complete, measurements of lower than normal pH and increased conductivity for the water downstream in the Puerco indicate fairly extensive movement of the waste materials. The banks of the Puerco were yellow, indicating the level of the flow. Thorium was probably one of the principal radioactive nuclides discharged. Officials are trying to determine the failure mechanism and to implement a plan for cleanup.

Reserves

The DOE (U.S. Department of Energy) Grand Junction Office estimates that, as of January 1, 1979, there were 85,700,000 tons of ore and 190,900 tons of U_30_8 at 0.22 percent U_30_8 in the $15-per-lb forward-cost category or 66 percent of total United States reserves in that category. Reserves at that date for the $30-per-lb forward-cost category were estimated to be 309,700,000 tons of ore to yield 375,000 tons of U_30, with an ore content of 0.12 percent $U30_8$ or 54 percent of total United States reserves for this category. Reserves for the $50-per-lb forward-cost category were estimated to be 539,000,000 tons of ore containing 473,900 tons of U308 (ore content of 0.09 percent U_30_8), or 52 percent of total United States reserves for this category. Table 37 shows comparisons with previous years.

The Grand Junction Office indicates that uranium reserve estimates are derived from drill-hole and other data made available by the uranium companies. The Grand Junction Office also states (U.S. Department of Energy, 1979b):

TABLE 37—NEW MEXICO URANIUM RESERVES BY COST CATEGORIES, 1976-1979; $10/lb forward-cost category dropped in 1978 (U.S. Energy Research and Development Administration, 1976, 1977; U.S. Department of Energy, 1978a, 1979b).

Forward cost category	Year	Tons ore	Percent U_30_8	Tons U_30_8	Percent of total U.S. reserves	Number of deposits
$10/lb	1/1/76	57,100,000	0.26	151,000	56	73
	1/1/77	55,800,000	0.27	152,700	61	70
	1/1/78					
$15/lb	1/1/76	115,900,000	0.18	206,200	48	106
	1/1/77	120,000,000	0.19	225,500	55	112
	1/1/78	111,300,000	0.20	222,000	60	106
	1/1/79	85,700,000	0.22	190,900	66	89
$30/lb	1/1/76	302,000,000	0.10	302,700	47	173
	1/1/77	327,900,000	0.11	357,000	53	175
	1/1/78	318,000,000	0.12	367,700	53	174
	1/1/79	309,700,000	0.12	375,000	54	155
$50/lb	1/1/76	Not included				
	1/1/77	Not included				
	1/1/78	547,100,000	0.09	465,000	52	177
	1/1/79	539,000,000	0.09	473,900	52	175

Separate evaluations are made of the quantities of uranium in cost categories of $15, $30, and $50 per lb U30, to cover the range of current economic interest. The costs used to assign the uranium reserves to these cost categories are "forward costs" comprising operating and capital costs, in present dollars, that will be incurred in production of the uranium.

Not only does New Mexico hold a dominant position in United States domestic production with more than half of total reserves in all categories, but the state also plays an important role in relation to international reserves. Reasonable assured world uranium resources, excluding the People's Republic of China, the U.S.S.R., and associated countries, in the $50-per-lb category were 2,900,000 tons U_30_8 as of 1977. Thus, New Mexico reserves represent approximately 16 percent of this total.

As of January 1, 1979, private lands (including railroad lands) accounted for 54 percent of the $50 reserve category with 257,500 tons U_30_8. Next were federal lands with 27 percent and 128,400 tons U_30_8, Indian lands with 79,000 tons U308 or 17 percent, and state lands with 2 percent and 9,000 tons U_30_8. The location by county of the $50 reserve category as of January 1, 1979, consisted of 348,300 tons U_30_8 in McKinley County, 99,500 tons U_30_8 in Valencia, and 26,100 tons for all others (Carron, Grant, Rio Arriba, Sandoval, San Juan, Santa Fe, and Socorro). All but 3,100 tons of the $50-per-lb forward-cost reserves are in the Morrison Formation. These 3,100 tons are in the Mesaverde Group; Baca, Dakota, Espinaso, Galisteo, Popotosa, and Todilto Formations; and in Precambrian rocks.

Data on New Mexico preproduction and postproduction inventories are given in table 38. According to the Department of Energy, the term "inventory" refers to all material equal to or greater than a grade of 0.01 percent U_30_8; economic availability is not considered. In addition to reserves, the inventory includes material that meets minimum mining thickness criteria but not the criteria for reserves. Such material would be available at higher costs than current reserves (U.S. Department of

TABLE 38—PREPRODUCTION AND POSTPRODUCTION IN NEW MEXICO URANIUM INVENTORY, JANUARY 1, 1979. The preproduction inventories of U_3O_8 are cumulative tonnage-grade distributions of individual properties prior to production. The postproduction inventories reflect in-place distributions of U_3O_8 after substracting all production prior to January 1, 1979 (U.S. Department of Energy, 1979b).

Minimum grade (% U_3O_8)	Preproduction			Postproduction		
	Cumulative tons of ore (millions)	Average grade (% U_3O_8) of cumulative tons	Cumulative tons U_3O_8 (thousands)	Cumulative tons of ore (millions)	Average grade (% U_3O_8) of cumulative tons	Cumulative tons U_3O_8 (thousands)
0.01	1,202	0.06	749	1,134	0.05	610
0.02	913	0.08	707	846	0.07	568
0.03	679	0.10	653	612	0.08	514
0.04	526	0.12	604	459	0.10	465
0.05	422	0.13	559	354	0.12	420
0.06	348	0.15	521	281	0.14	382
0.07	293	0.17	497	226	0.16	358
0.08	251	0.18	457	183	0.17	318
0.09	217	0.20	430	150	0.19	291
0.10	190	0.21	405	131	0.21	274
0.11	168	0.23	382	116	0.22	259
0.12	149	0.24	362	103	0.24	245
0.13	133	0.26	343	92	0.25	232
0.14	119	0.27	325	83	0.27	220
0.15	107	0.29	309	75	0.28	209
0.16	97	0.30	295	67	0.29	200
0.17	88	0.32	281	61	0.31	191
0.18	81	0.33	268	56	0.33	182
0.19	74	0.35	256	51	0.34	173
0.20	68	0.36	244	47	0.35	165

Energy, 1979b). Like reserves, inventory is calculated using drill-hole data. If calculations made by the Grand Junction Office are correct, this table shows the importance of mining the lower grade material if all U_3O_8 is to be recovered. For example, 55 percent of the U308 is located in material containing 0.01- to 0.09-percent U_30_8

New Mexico resources

The DOE divides potential resources into three classes: probable, possible, and speculative. Probable resources are those estimated to occur in known productive uranium areas. Possible resources are those estimated to occur in undiscovered or partly defined deposits in formations or geologic settings productive elsewhere within the same geologic province or subprovince. Speculative resources are those estimated to occur in undiscovered or partly defined deposits. Table 39 shows New Mexico resource classifications for the $50-per-lb forward-cost resources as of January 1, 1979.

DOE assessments as of January 1, 1979, indicate 3,100 tons U_3O_8 probable and 1,500 tons U_30_8 possible for the Baca host rock south of the San Juan Basin. In the Burro Canyon Formation northeast of the San Juan Basin, approximately 1,200 tons U_30_8 are probable, 3,000 tons possible, and 3,000 tons speculative indicated (a small amount of this is in the Burro Canyon Formation in Colorado). The San Jose Formation, Point Lookout Sandstone, Ojo Alamo Sandstone, and Fruitland Formation located in northwestern New Mexico each contain probably less than 1,000 tons U_30_8 in the speculative classification. One hundred tons U_30_8 probable and 500 tons possible have been indicated for the Menefee Formation lying on the eastern side of the San Juan Basin. Probable resources of 8,400 tons U_3O_8 are indicated for the Todilto Limestone lying along the southern edge of the San Juan Basin. Probable resources of 1,000 tons U_3O_8 and possible resources of 1,000 tons U_3O_8 are indicated for the Dakota Sandstone. Probable resources of 500 tons U_3O_8 and possible resources of 500 tons U_3O_8 are indicated for the Espinaso Volcanics and Galisteo Formation in north-central New Mexico. The Popotosa Formation south of the San Juan Basin is believed to contain 100 tons probable and 500 tons possible U_30_8. In the speculative classification, less than 1,000 tons U_30_8 are believed to be contained in the Burro Mountain granite and other Precambrian granites and metamorphic rock of southwest New Mexico while less than 1,000 tons are believed

TABLE 39—NEW MEXICO $50/LB URANIUM RESOURCES IN TONS U_3O_8, JANUARY 1, 1979 (data from W. L. Chenoweth, U.S. Department of Energy, personal communication).

Location	$50/lb New Mexico resources in tons U_3O_8					
	Probable	% U.S.	Possible	% U.S.	Speculative	% U.S.
Grants mineral belt	538,000		275,000		0	
Other areas	12,000		166,000		8,000	
Totals	550,000	36.0	441,000	38.0	8,000	1.4

to be in the Thurman and Palm Park Formations and less than 1,000 tons in the Chinle Formation of southern New Mexico. The Sangre de Cristo Formation (north-central New Mexico) is thought to contain 6,000 tons U_3O_8 in the speculative classification. The Dockum Group on the eastern edge of New Mexico may also contain a small amount of U_3O_8 in the speculative category.

All the rest of the resources of New Mexico are located in the San Juan Basin area in the Morrison Formation. Thus, the Morrison is the dominant host rock not only for reserves in New Mexico but also for resources. Areas identified as favorable for uranium mineralization but with insufficient basis for estimation of potential uranium resources in New Mexico include the Sangre de Cristo Formation in the Las Vegas Basin; the Dakota Sandstone and Dockum Group in northeast New Mexico; the Ogallala Formation, Dockum Group, and Chinle Formation in eastern New Mexico; and the Yates Formation in southeastern New Mexico.

From July 19, 1978, to November 19, 1978, 15 holes with a total footage of 70,421 ft were drilled into the Westwater Canyon Member of the Morrison Formation near Chaco (Tps. 18 N. to 21 N., Rs. 6 W. to 10 W.) under the NURE (National Uranium Resource Evaluation) program. This drilling resulted in additions to the probable potential resources. Estimates of speculative potential resources in rocks of Cretaceous and Tertiary ages in the San Juan Basin decreased sharply from 1976 because of the unfavorable exploration experiences of several companies.

A joint DOE-USGS study of part of the Grants mineral belt is underway to determine the interrelationships of such uranium-deposit parameters as grade, tonnage, thickness, and areal extent. Environments of uranium deposits in sandstones in the Grants mineral belt are undergoing study under the NURE program. Included in the NURE intermediate-grade-deposit study areas are the fluvial sandstone in the Baca Formation at Red Basin, New Mexico, and the calcrete deposits in the Deming area.

Demand for New Mexico uranium

Short-term projections 1979-1990

Short-term demands for uranium produced in the United States can be analyzed in several ways, including future sales commitments and uranium necessary to supply United States reactor needs on a short-term basis. The demand (which may not equal sales) for uranium produced in New Mexico can be estimated by assuming that New Mexico continues to supply 47 percent of the total United States U_3O_8 production, which is the average from 1966 through 1978 (excluding 1973, which was a year of a prolonged strike in New Mexico). Because the percentage of ore reserves is greater than 47 percent of the total, this assumption does not appear to be unreasonable. Tables 40 and 41 indicate demands on New Mexico uranium based on future sales and on short-term need projections developed by the Energy Information Agency of DOE. Future sales commitments are larger than projected need. This fact indicates stockpiling on the short-term basis. The Energy Information Agency projections are much less than DOE need projections made last year partly because of reduced projections for on-line reactor units and demand projections that are no longer made on the basis of enrichment.

On the short-term basis, the effects of the accident at Three Mile Island may not make much difference in demand because reactors on line and under construction may continue as planned, except perhaps for construction stretch-outs and extra down time for inspections, modifications, and repairs of operating reactors.

A comparison of average ore grade of New Mexico's $50-per-lb forward-cost reserves with grade sampled by mills in 1978, shows that ore grade must drop rapidly as the New Mexico reserves are mined. Therefore, ore production must increase in order to produce even the same amount of U_3O_8. For example, to produce the same amount of U_3O_8 from a 0.09-percent grade ore requires twice as much ore as a 0.18-percent ore if mill efficiency remains constant.

Many factors influence U_3O_8 demand. These include fuel-use efficiency, U-235 residue in tails, uranium in stockpiles, reactor lifetime, generating capacity and on-line generating time, and foreign imports and exports of uranium. Whether New Mexico uranium producers will be able to bring uranium production facilities on line to meet demands even on the short-term basis is dependent on many factors, including the availability of financing, the selling price of U_3O_8 vs. production costs, leasing

TABLE 40—FUTURE COMMERCIAL SALES COMMITMENTS FOR UNITED STATES U_3O_8, 1979-1981; New Mexico figure represents 47 percent of demand on United States production (U.S. Department of Energy, 1979b).

Year of delivery	U_3O_8 (tons)			
	Domestic sales	Foreign sales	Total	New Mexico
1979	17,600	1,400	19,000	8,930
1980	19,200	1,000	20,200	9,494
1981	19,000	400	19,400	9,118

TABLE 41—FORECAST OF DOMESTIC URANIUM REQUIREMENTS, 1979-1990; (data from U.S. Department of Energy, 1978b).

Year	U_3O_8 (tons)	
	U.S. DOE domestic total enrichment feed contracts	New Mexico (47% of U.S. total)
1979	12,800	6,016
1980	14,800	6,956
1981	18,400	8,648
1982	21,000	9,870
1983	22,300	10,481
1984	25,900	12,173
1985	28,300	13,301
1986	30,800	14,476
1987	33,500	15,745
1988	36,100	16,967
1989	38,800	18,236
1990	40,400	18,988
Total	323,100	151,857

policies adopted by the Indians, state and federal regulations and taxation, manpower supply, necessary development lead times, and electric- and liquid-fuel availability.

Long-term projections: 1991-2000

Projection of demands from 1991-2000 is more difficult because orders for reactors coming on line during that time probably have not yet been made. The Energy Information Agency of the DOE, however, has made growth projections. Their midcase demand forecast and corresponding possible demand for New Mexico's U_3O_8 reserves is given in table 42. Adding demand from 1979 through 1990 to demand from 1991 through 2000 shows that if New Mexico's production meets demand, almost all the reserves (or their equivalent transferred from the potential resource base) in the $50-per-lb forward-cost classification will possibly have to be mined by 2000.

TABLE 42—Forecast of domestic uranium requirements, 1991-2000; New Mexico's $50-per-lb forward-cost reserves are 473,900 tons (U.S. Department of Energy, 1978b).

	U_3O_8 (tons)		
Year	U.S. domestic uranium requirements		New Mexico (47% of U.S. demand)
1991	43,000		20,210
1992	47,000		22,090
1993	49,000		23,030
1994	53,000		24,910
1995	55,000		25,850
1996	57,000		26,790
1997	60,000		28,200
1998	63,000		29,610
1999	66,000		31,020
2000	69,000		32,430
Total	562,000		264,140
		1979-1990	151,857
			415,997

TABLE 43—Uranium recovery costs, ranges by geographic area; costs based on 30-year estimate of "could" production capability, January 1977 dollars. Ore haulage costs and royalty costs exclude solution mining. In Colorado and Utah, where both uranium and vanadium were assumed to be recovered, only the costs allocated to uranium are shown. Maximum haulage costs for Colorado, Utah, South Dakota, and Wyoming are second highest costs; showing highest costs might reveal the company involved. Capital figures refer to forward cost as of January 1, 1977 (U.S. Department of Energy, 1979b).

Area	Aquisition and exploration costs - $/lb U_3O_8 in concentrate	Ore haulage costs - $/ton of ore	Royalty costs $/lb U_3O_8 in concentrate
Arizona, New Mexico	1.30-7.30	0.50-2.70	0.40-2.10
California, Nevada, Oregon, Texas, Washington	1.70-5.10	0.80-2.40	0.20-2.80
Colorado, Utah	0.30-3.40	0.05-5.10	0.90-5.70
South Dakota, Wyoming	1.00-6.40	0.10-2.80	0-1.70
Total U.S.	0.30-7.30	0.05-5.10	0-5.70
	Underground mining costs, $/ton of ore		
	Capital	Operating	Total
Arizona, Nevada	29-33	28-33	61-62
Colorado, Utah	1-19	22-25	23-44
New Mexico	4-19	28-45	32-64
South Dakota, Wyoming	1-11	22-34	31-39
Total U.S.	1-33	22-45	23-64
	Open-pit mining costs, $/ton of ore		
	Capital	Operating	Total
Arizona, California, Oregon	9-23	9-12	18-34
Colorado, Washington	7-26	8-14	20-34
New Mexico, Texas	7-14	5-14	16-21
South Dakota, Wyoming	6-21	5-15	14-33
Total U.S.	6-26	5-15	14-34
	Conventional milling costs, $/ton of ore		
	Capital	Operating	Total
Arizona, New Mexico, Texas	1-4	5-11	6-15
California, Nevada, Oregon, Washington	2-5	7-12	9-17
Colorado, Utah	1-7	6-16	8-22
South Dakota, Wyoming	1-3	4-12	5-14
Total U.S.	1-7	4-16	5-22

TABLE 44—URANIUM SEVERANCE-TAX COLLECTIONS IN NEW MEXICO, 1973–1978. Years are calendar years, based on month of production activity. Deductions are total federal or state rents or royalties payable. Section 72-18-2.2 NMSA 1953 defines uranium price for severance-tax purposes as one half of the taxpayer's average unit sales price of U_3O_8 during the preceding calendar year, "old law" (data from New Mexico Taxation and Revenue Department).

Time period	Total production lbs of U_3O_8	Price weighted average ($)	Gross value ($)	Adjusted gross value/ 50% of gross ($)	Deductions ($)	Taxable value ($)	Tax due ($)
1978	15,383,860	26.62	409,519,828	N/A	N/A	N/A	17,617,133
1977	12,317,108	14.89	183,377,081	34,501,877	862,994	36,559,798	4,414,590
1976	12,434,876	5.09	63,322,529	31,661,265	5,687,548	25,973,717	259,737
1975	10,852,685	3.68	39,962,322	19,981,161	1,825,578	18,155,583	181,556
1974	10,797,712	3.35	36,123,739	18,061,870	1,843,997	16,178,872	162,179
1973	9,922,639	3.10	30,728,244	15,364,122	2,170,599	13,193,523	131,935

Because most of the reserves are located in the Morrison Formation in the San Juan structural basin, the impact of mining will be felt chiefly in this region.

Recovery costs and revenues

Recovery costs

Costs for exploration, ore haulage, mining, milling, and royalty are shown in table 43 for New Mexico and other areas. Costs (not including land acquisition) for Phillips' Nose Rock property development from 1973 through May 1979 have been released by Phillips and are indicated below:

Year	Exploration & development	Mine	Mill
1973	$ 252,461	—	—
1974	786,687	—	—
1975	4,261,123	—	—
1976	10,444,990	96,468	239,237
1977	8,868,171	10,614,639	70,697
1978	10,252,391	24,581,647	1,140,913
1979– (January–May)	3,161,835	9,920,057	229,421

Progress to May 1979 on the Phillips' Nose Rock property consisted of the development of drill-hole information that appeared to indicate the feasibility of six mining units, the beginning of plans for a 2,500-ton-per-day mill to be enlarged to 5,000 tons per day, and the beginning of the sinking of three shafts.

Revenues to the state

Information from the New Mexico Taxation and Revenue Department indicates a severance tax of $17,617,133 on 15,383,860 lbs of U308 at an average price of $26.62 for calendar year 1978. This figure represents a substantial increase from $4,414,589 in 1977 and $259,737 in 1976. Table 44 gives detailed comparisons of severance tax collections over the past six years and table 45 gives resources-excise-tax data for the uranium industry from 1973 through 1978.

The New Mexico Legislature imposed a graduated scale of taxation in 1977 based on selling price, with a maximum of a 6.48-percent tax on uranium selling for $50 per lb. A surtax on uranium selling for greater than $50 per lb was also included; it amounted to one quarter of the percentage increase in the national consumer price index. The 1979 Legislature passed a bill that increased the surtax to 100 percent of the percentage increase in the consumer price index.

TABLE 45—URANIUM RESOURCES EXCISE-TAX COLLECTIONS IN NEW MEXICO, 1973–1978. Taxes are processors tax. Sales of metalliferous ores such as uranium to the United States and New Mexico are not deductible. Royalties paid in 1976 and 1978 include an amount of service charge that cannot be disclosed because of confidentiality (data from New Mexico Taxation and Revenue Department).

Calendar year	Total quantity reported (lbs.)	Price: weighted average	Gross value	Deductions: Sales	Deductions: Federal or State Royalties paid	Deductions: Federal or State Service charge	Taxable value	Tax due
1978	15,715,097.00	25.75	404,656,439.00	-	1,043,691.00			3,027,425.
1977	13,827,394.00	25.00	345,675,642.48	-	1,504,748.16	1,008,928.92	343,161,965.40	2,573,714.
1976	13,043,390.84	12.54	163,627,799.19	-	5,898,891.86	-	157,728,907.33	1,182,966.
1975	9,671,941.12	7.98	77,135,834.95	-	1,935,526.13	-	75,200,308.82	564,002.
1974	10,392,288.18	6.83	70,971,417.56	-	1,931,718.94	-	69,039,698.62	517,797.
1973	9,897,508.40	6.35	62,946,412.96	-	2,200,036.71	-	60,746,376.25	455,597.

Geothermal energy

by Kay S. Hatton, *Bureau of Geology*

Geothermal potential

Occurrences

A major heat-flow anomaly bisects New Mexico from north to south on the western side of the Rio Grande rift. Other principal geothermal areas are in the west-central and southwestern portions of the state. Major areas associated with the Rio Grande rift are the Baca Location No. 1 KGRA (Known Geothermal Resource Area), also known as the Valles caldera, Jemez Hot Springs, and the San Ysidro KGRA in Sandoval County; Ojo Caliente in Taos County; the Socorro Peak KGRA in Socorro County; the Truth or Consequences thermal area in Sierra County; the Radium Springs KGRA, the Kilbourne Hole KGRA, and the Las Alturas geothermal field in Doña Ana County; and the southern Tularosa Basin in Otero County.

The portion of the west-central geothermal area with the greatest terrestrial heat-flow value lies in the southwest corner of McKinley County. The southwestern geothermal area contains the Lower Frisco KGRA in Catron County; the Gila Hot Springs KGRA, Turkey Creek, Mimbres, and Faywood Hot Springs, and the Cliff area in Grant County; and the Lightning Dock KGRA (Animas Hot Spot) in Hidalgo County.

Most of New Mexico's geothermal areas are associated with one of two geologic occurrences: 1) Quaternary faulting along deep sedimentary basins, especially along the Rio Grande rift, with hot water traveling along the faults to the surface; and 2) Quaternary volcanic activity (Swanberg, 1979).

Information on New Mexico's geothermal areas is growing each year with continued research, exploration, and drilling. An evaluation of the hydrologic characteristics of New Mexico's low-temperature geothermal sites was initiated in August 1978 under the auspices of the DOE (U.S. Department of Energy) Western States Cooperative Direct Heat Geothermal Program. As part of this project, L. Chaturvedi designated over 40 areas in New Mexico for possible low-temperature geothermal application (unpublished memorandum, December 1978). Estimated reservoir base temperatures were made by Chaturvedi using bottom-hole temperatures from oil and gas wells and by C. A. Swanberg using chemical geothermometry (unpublished memorandum, December 1978).

Areas with estimated temperatures between 100° and 150 °C are Ojo Caliente (Joseph's Hot Springs), Mamby's (American) Hot Spring, and Ponce de Leon Hot Spring in Taos County; Montezuma Hot Springs in San Miguel County; San Ysidro in Sandoval County; Truth or Consequences and Derry Springs in Sierra County; and Las Alturas and Mesquite-Berino in Dona Ana County.

Areas with estimated temperatures equal to or above 150°C are Valles caldera in Sandoval County, Lower Frisco Hot Springs in Catron County, and Lightning Dock in Hidalgo County.

Subsurface chemistry data indicate that the following areas are prospective high-temperature geothermal resource areas; no confirmation is available to date from drilling: Guadalupe and Jemez Reservoir in Sandoval County; Prewitt in McKinley County; North of Socorro in Socorro County; an area called Lordsburg in Grant County (as distinguished from the town in Hidalgo County); Columbus in Luna County; Kilbourne Hole in Dona Ana County; and Southern Tularosa Basin in Otero County (C. A. Swanberg, personal communication, October 1979).

Under this DOE-sponsored program, the researchers are compiling this statewide geothermal evaluation work in a composite geothermal map to be published by the New Mexico Energy Institute at New Mexico State University. Two sets of maps, one for the lay public and the other with detailed technical information, are expected to be available for distribution by December 1979. This work is being coordinated by C. A. Swanberg, New Mexico State University.

Some of the federal- and state-funded geothermal evaluation projects now taking place include the following:

G. Jiracek and coworkers, University of New Mexico, have selected a geothermal target area in the Albuquerque vicinity on the West Mesa. The area covers approximately 225 sq km and includes the site of Albuquerque's proposed new airport. Eight shallow-gradient holes were drilled during summer 1979 based on electrical-resistivity reconnaissance and gravity/magnetic anomalies. One of these holes yielded an 80 °C per km geothermal gradient. The researchers plan to drill additional evaluation holes and to continue the detailed resistivity studies of this promising geothermal area near New Mexico's largest city. Also, Jiracek will initiate reconnaissance studies in target areas near Albuquerque, including the vicinity of the Jemez Reservoir and Santa Ana Mesa, the Puerco fault zone, and the Cat Hills volcanoes.

Researchers are also conducting studies at Truth or Consequences, Las Alturas, Socorro, and San Diego Mountain. M. A. Reiter, New Mexico Bureau of Mines and Mineral Resources, is continuing his statewide heat-flow studies. W. J. Stone, New Mexico Bureau of Mines and Mineral Resources, is preparing final reports on a five-year study, in cooperation with the USGS and the New Mexico State Engineer's Office, called *Hydrogeology and water resources—northwest New Mexico.* In addition to the studies mentioned here, many other geothermal projects are being conducted in New Mexico with both government and private funds.

Geothermal systems

Geothermal energy is heat from the earth. Many investigators believe the principal source of this heat to be geologically recent magma bodies at shallow depths.

When a magma pocket lies close to the surface of the earth, the heat it emits to overlying rocks and water may, if sufficiently intense, be discovered and developed to produce electricity. Low-temperature geothermal energy can be used directly to heat homes, public buildings, and greenhouses, and for commercial food processing, agricultural heating, fish farming, and industrial applications.

The petroleum crisis of 1973 caused a worldwide expansion of geothermal exploration and development. The yearly growth rate for worldwide geothermal electrical generating capacity was 7 percent between 1945 and 1977. Figures for installations constructed in 1977 and 1978, however, and for those expected to go on line by 1983, indicate a worldwide yearly growth rate of approximately 19 percent (Muffler, 1979). Worldwide installed geothermal electrical capacity through 1977 was about 1,400 megawatts electric and about 1,800 megawatts electric through 1978 (M. Guffanti, personal communication, September 1979).

Geothermal energy is expected to play an ever-greater role in the United States economy as the price of conventional fuels continues to rise; and New Mexico, which has an outstanding geothermal potential, may become one of the states in which this resource is most extensively developed.

Leasing activity

As of September 12, 1979, the BLM (U.S. Bureau of Land Management) had issued 121 geothermal leases that are currently active. These leases cover 219,995 acres of national-resource land in New Mexico. Seventy of these leases, comprising 133,156 acres, were issued after noncompetitive bidding; 51 leases, comprising 86,840 acres, were issued after competitive bidding.

On September 19, 1978, the BLM called for competitive bids on 24,093 acres consisting of three parcels in the Lightning Dock KGRA, four parcels in the Radium Springs KGRA, and 11 parcels in the Socorro Peak KGRA. Bids were received and granted for seven of these parcels covering 8,768 acres; high bids totaled $72,640. The total of all bids received was $114,830. The highest bid paid per acre, $56, was made by Norma K. Hunt for Leasing Units Nos. 5 and 6 in the Radium Springs KGRA. Acreage in these two parcels totals 360 acres. The highest total bonus bid, $32,688, was paid by Amax Exploration, Inc., for Leasing Unit No. 2, a 2,501-acre parcel in the Lightning Dock KGRA. All parcels offered in the Lightning Dock and Radium Springs KGRA's were leased. No bids were received on the parcels in the Socorro Peak KGRA.

The next BLM lease sale was held September 18, 1979. Twelve parcels of land comprising 17,401 acres in the Radium Springs and Socorro Peak KGRA's were offered. Bids were received and granted for four of these parcels covering 7,063 acres. High bids totaled $240,632. The total of all bids received was $368,274. The highest bid per acre, $111, was made by Norma K. Hunt for Leasing Unit No. 22 in the Radium Springs KGRA, with 636 acres. The highest total bonus bid, $75,358, was paid by Thermal Power Company for Leasing Unit No. 27, a 2,426-acre parcel in the Socorro Peak KGRA. No bids were received on Leasing Units Nos. 23 through 26 in the Radium Springs KGRA or on Leasing Units Nos. 30 through 33 in the Socorro Peak KGRA.

Hunt Petroleum Corporation recently applied to the BLM for further geothermal acreage in the Kilbourne Hole Area.

As of July 18, 1979, the New Mexico State Land Office had issued a total of 137 geothermal leases that are currently active covering 56,991 acres. On July 19, 1979, the Land Office called for competitive bids on 18,198 acres consisting of 17 parcels in Hidalgo County, three parcels in Doña Ana County, and 25 parcels in Socorro County. One parcel in Doña Ana County was offered at oral bid. Bids were received and granted for 22 of these parcels, which cover 8,788 acres. Bonus bids totaled $4,843.

Recent exploration

From January 1978 through June 1979, the NMOCD (New Mexico Oil Conservation Division) approved 30 temperature-gradient wells and six geothermal producer wells. Chevron USA, Inc., Gulf Oil Corporation, New Mexico State University, Sunoco Energy Development Company, and Union Geothermal Company of New Mexico will drill these wells on state and private land in New Mexico. Drilling is to be concentrated in the Lightning Dock and Radium Springs KGRA vicinities (Chevron), west of Socorro (Gulf), east of Las Cruces (New Mexico State University), east of the Jemez River from Jemez Springs to Jemez Pueblo (Sunoco), and in the Redondo Creek Geothermal Field of the Baca Location No. 1 KGRA (Union).

In 1978, the USGS issued permits to Anadarko, Chevron, Phillips, and Sunoco to drill 26 shallow temperature-gradient holes (500-ft maximum) and one deep temperature-gradient hole (1,500-ft maximum) in the Baca Location No. 1, Kilbourne Hole, Radium Springs, and Socorro Peak KGRA's. Anadarko led in number of shallow temperature-gradient holes drilled with 16 in the Kilbourne Hole KGRA. Chevron obtained a permit for a gravity survey in the Radium Springs KGRA, and Phillips a permit for a magnetotelluric survey in the Baca Location No. 1 KGRA. The USGS issued 25 leases in 1978.

Recent legislation

The National Energy Act of October 1978 granted major incentives to the geothermal industry. These included: 1) an authorization to drillers of a tax deduction for intangible drilling costs and a 22-percent depletion allowance for wells drilled after December 31, 1977; 2) eligibility to utilities installing geothermal equipment for a 10-percent investment tax credit above the normal 10 percent (this additional credit is available for utility equipment up to the transmission stage and can be applied to new as well as to existing structures and processes); 3) eligibility to homeowners installing geothermal equipment in residences for a residential energy tax credit of 30 percent of the first $2,000 and 20 percent of the next $8,000 of investment; 4) deregulation of the price of geopressured methane; 5) authorization of a 10-percent depletion allowance for geopressured methane wells drilled during the next five years; 6) authority given the Federal Energy Regulatory Commission to order interconnection and wheeling for utilities and co-generators installing geothermal plants; and 7) provisions for the exemption of small geothermal facilities from public-utility regulation.

Several bills now constituting the geothermal section of the Energy Omnibus Bill were introduced during the First Session of the 96th Congress in order to expedite geothermal development. Included in these bills are amendments and additions to existing laws. These revisions would, among other incentives, provide for: 1) an increase from 20,480 to 51,200 acres in the per-state limitation on geothermal leaseholds held by a single company or individual; 2) an adjustment of the primary lease term from 10 to 20 years; 3) time limitations on review periods; 4) direct, 90-percent forgivable loans for feasibility studies and exploratory drilling; 5) preclusion of noncompetitive applications from KGRA designation; and 6) declassification of KGRA lands that remained unbid after a lease sale or unleased 12 months after designation. Final drafting of the proposed compromise bill will take place after Congress reconvenes in September 1979, and this legislation is expected to give geothermal exploration and development a major boost.

In the 1979 session, the New Mexico State Legislature approved the following geothermal-related legislative actions:

1) House Bill 366—provides $2 million to the Energy and Minerals Department for energy research and development projects. Seventy-five percent of this amount must be spent on projects having practical application in New Mexico
2) House Bill 446—raises the state geothermal acreage limitation for companies or individuals from 25,600 to 51,200 acres. Adds a five-year secondary lease term to the five-year primary term, with provision for a possible three-year extension
3) House Bill 447—clarifies the regulatory powers of the NMOCD regarding geothermal resources
4) Senate Joint Memorial 9—requests that the Legislative Council include a geothermal policy study in the work of at least one interim study committee. The committee is directed to cooperate closely with the National Conference of State Legislatures' Geothermal Policy Project, the Energy Institute at New Mexico State University, and the Energy and Minerals Department
5) Senate Joint Memorial 10—directs the Commissioner of Public Lands to examine the existing policy of leasing state lands on a competitive basis and to consider alternatives. These alternatives would include a system combining exploration permits for resource assessment, noncompetitive leases for land with low or unknown potential, and competitive leases for lands with demonstrated geothermal value. The commissioner is to consult with the Energy Institute at New Mexico State University and the Energy and Minerals Department.

These state actions, like those of the federal government, constitute important incentives to exploitation of geothermal energy in New Mexico.

Research and development

Sandia Laboratories has successfully tested a prototype geothermal borehole temperature- logging instrument at 275 °C (527°F). This is the highest operational temperature ever accomplished using an instrument containing active electronics that are neither cooled nor thermally insulated. The test was conducted in a Union Oil Company geothermal well at depths of 7,500 to 8,045 ft and with pressures ranging up to 3,500 lbs per square inch. Sandia is in the process of transferring this technology to the commercial sector, and several companies are now manufacturing the instruments. Since conventional well-logging tools are not reliable at temperatures much higher than 150 °C (302 °F), and since some geothermal resources are in the 200-350°C (392-662 °F) range, these high-temperature electronic instruments are extremely important in reservoir evaluations. The information gathered by these instruments may be crucial to geothermal developers and investors who are reluctant to build power plants if there is risk in evaluating geothermal production potential.

Research is progressing on Sandia's continuous chain bit. This bit has proven efficient for well drilling and is the basis for new designs now being considered by the drilling industry. Other industrial applications, such as use in coal-mining machines, are also being considered (A. F. Veneruso, personal communication, August 1979).

The DOE-sponsored Sandia Magma Energy Research Project is continuing. The general purpose of this project is to investigate the technological feasibility of extracting energy directly from the earth's magma. The project is specifically studying problems related to: 1) locating and defining buried magma bodies, 2) tapping and maintaining access to the magma source, 3) estimating the physical and chemical properties of the high-temperature high-pressure magma bodies, 4) determining if energy-extraction materials can survive in a magmatic environment, and 5) evaluating methods of extracting energy. Magma-energy utilization may someday provide an environmentally acceptable, significant part of United States energy requirements.

Kilauea Iki lava lake in Hawaii was the site of a recent series of seismic and electromagnetic experiments by the USGS, Massachusetts Institute of Technology, University of Texas, and Sandia Laboratories. These experiments yielded a good description of the hydrothermal and hot dry regions; drilling was then undertaken to define the thickness and state of the molten lens. The molten region with temperatures higher than 1,000°C (1,832 °F) was penetrated. The slightly cooler portion of the upper crust contained veins of molten material, and the liquid lens was composed of a high-viscosity mixture of 40-60 percent crystals in melt. Drilling data will aid in future interpretation of geophysical data.

Laboratory experiments under way at Texas A&M's Center of Tectonophysics in cooperation with Sandia Laboratories suggest that boreholes through deep hot rocks will be stable to depths of 10 km under certain formation stress conditions.

In situ magmatic compositions are being duplicated at Sandia in test vessels for measurement of chemical and physical properties. These experiments will be used to evaluate material compatibilities and to identify engineering materials for drilling and energy-extraction equipment. Certain high-chromium steels and superalloys have shown a compatibility with simulated magmas for 100 hours at 1,150°C (2,102 °F) (J. L. Colp, personal communication, August 1979).

Researchers at New Mexico Institute of Mining and Technology are using seismic waves from local microearthquakes, mining explosions, and distant earthquakes to locate and map magma bodies in the crust of the Rio Grande rift near Socorro. The magma occurs as a large, deep body and as several postulated shallow bodies. As presently mapped, the large body is a thin, flat sill at depths of 19-20 km (about 12 mi) beneath 1,700 sq km of the central part of the Rio Grande rift near Socorro. The shallow pockets may occur at depths of 5-10 km (3-6 mi).

Direct geophysical detection, one of the methods of exploration for magma bodies now being employed by New Mexico Institute of Mining and Technology, may prove effective for predicting the occurrence of hydrothermal systems in areas where their existence might otherwise go undetected, owing, for example, to the flow of ground water masking the heat flow. If the presence of shallow magma pockets is confirmed by further studies, the overlying crust may prove to be a favorable area for exploratory geothermal drilling (A. R. Sanford, personal communication, September 1979).

In the United States, almost all geothermal energy is in the form of hot dry rock. It is estimated that the total energy content of the formations underlying the 50 states to a depth of about 6 mi and at temperatures above 150 °C (302 °F) is about 13.2 million quads (a quad is 1 quadrillion Btu) or about 170,000 times the present total annual energy consumption in the United States. More than 99 percent of this energy exists in hot dry rock. If only 2 percent of this energy were recoverable, it would provide the United States with over 2,000 years of nontransportation energy at the present rate of consumption (Nunz, 1979).

The Hot Dry Rock Geothermal Energy Project undertaken by LASL (Los Alamos Scientific Laboratory) at the Fenton Hill site west of the Valles caldera has yielded promising technical results. The project has established that hot dry rock can be fractured and utilized for superheated water production by the circulation of water introduced into a fracture system. Technical results indicate that thermal or electrical energy produced by this method may be a feasible alternate energy source. In the second phase of the project, LASL plans to use a hole now being drilled into deeper (14,000 ft) and hotter zones to create a commercial-sized reservoir with the capacity to produce 20-50 megawatts thermal for not less than 10 years. Rock temperatures in the new downhole system will be in the 250-275 °C (482-527 °F) range.

LASL is negotiating with Plains Electric Generation and Transmission Cooperative for the establishment of a commercial power plant at the site. The German government is participating in the Fenton Hill project, and the government of Japan may also participate. As a result of LASL's success with the Fenton Hill project, DOE has asked the laboratory to manage the national Hot Dry Rock Geothermal Energy Development Program. During the next nine months, two sites geologically dissimilar to the Fenton Hill area will be thoroughly studied to determine their suitability for hotdry-rock demonstrations: the Stumpy Point-Wallops Island area in eastern Maryland and a region near Mountain Home, Idaho, on the western Snake River Plain (R. A. Pettitt, personal communication, September 1979). LASL is also drilling a geothermal exploratory hole to 10,000 ft or more at the Sigma Mesa site near the laboratory's main technical area in an effort to develop underground heat as an energy source for the laboratory's own use.

Union Oil and Public Service Company of New Mexico are proceeding with plans for a 50-megawatt electrical generating facility in the Valles caldera. The demonstration plant is partially funded by DOE. All contractual arrangements have been completed between Union, Public Service Company of New Mexico, and DOE. The construction starts are pending environmental hearings. Final approval is expected to be given in December 1979, with construction starting in 1980. Electricity is projected to come on line in late 1982 or early 1983 (W. A. Tonning, personal communication, August 1979).

While New Mexico appears to have good potential for several electricity-producing geothermal sites, the state also holds a vast and largely untapped capacity for direct-heat geothermal applications. As the nation's economy continues to feel the impact of greater reliance on foreign oil for fuel, New Mexico's tremendous direct-heat geothermal potential is likely to be more extensively exploited.

Geothermal projects

State funds totaling $199,020 were allocated to six projects under the geothermal resource assessment program of the New Mexico Energy Institute at New Mexico State University. The demonstration project funds are contingent on several conditions, including a requirement that matching money be obtained from federal or private sources. Awards were based on recommendations of the New Mexico Energy Research and Development Review Committee. The projects are:

Project number and title	**Authorized funding**
67-51—Geothermal heating of Carrie Tingley Hospital, Truth or Consequences	$ 46,186
67-52—Geothermal heating of Senior Citizens Center, Truth or Consequences	$ 24,726
67-53—Geothermal heating of solar-assisted greenhouse, Taos County	$ 40,663
67-54—Geothermal heating of greenhouse, Silver City	$ 21,208
67-70—Geothermal resource evaluation and well drilling for industrial use, Las Cruces	$ 56,237
67-71—Geothermal well for spaceheating of University Center, New Mexico State University	$ 10,000

DOE's Appropriate Energy Technology Small Grants Program awarded $20,179 in September, 1979, to T. W. McCants of Animas for geothermal heating of a greenhouse.

Ongoing geothermal projects funded from the Energy Research and Development Fund by the Energy and Minerals Department as of August 30, 1979, were:

Project number and title	Authorized funding
76-262—Regional operations research for development of geothermal energy resources in the southwestern United States	$100,000
76-264—Evaluation of geothermal potential of the Basin and Range Province of New Mexico	$103,235
77-2203—Active and passive seismic studies of geothermal resources in New Mexico and investigations of earthquake hazards to geothermal development	$ 50,000
77-2211—United States DOE and New Mexico cooperative program low-temperature geothermal reservoir assessment	$ 15,000
77-2312—Seismic exploration for shallow magma bodies in the vicinity of Socorro, New Mexico	$ 36,510
77-2113—The stability of a large open hydraulic penny-shaped fracture near the earth's surface	$ 10,000
77-2314—Development and application of a computer model for simulating a geothermal system in New Mexico (Phase 1)	$ 31,600
77-2218—Las Alturas geothermal reservoir confirmation study	$ 20,000
78-2219—Feasibility study for establishing a centralized geothermal data base for New Mexico	$ 6,000
78-2120—Computer-based chemical and stable-isotope modeling of geothermal systems in New Mexico	$ 39,150
78-2321—Deep subsurface temperature studies in the basins of New Mexico and neighboring geologic areas	$ 35,500
78-2122—Engineering and economic feasibility study of hot water geothermal energy in the Albuquerque area	$ 57,681
78-2123—Assessment of the geothermal potential of southwestern New Mexico	$ 28,820
78-2333—Heating of the New Mexico Tech campus with geothermal energy (Part 2)	$ 13,944
78-2234—Utilization of geothermal energy for agribusiness development in southwestern New Mexico (Part 1)	$ 76,214
78-2135—Evaluation of the geothermal resource in the area of Albuquerque, New Mexico	$ 76,874
78-2236—Southwest geothermal regional operations research study	$100,000
78-2537—Conduct a geothermal test well drilling program for the Village of Jemez Springs, New Mexico	$ 31,163
78-2238—New Mexico cooperative direct heat geothermal program (Phase 2)	$ 30,000

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