Text to accompany:

Open-File Report 78-045

1978

COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE ELMO QUADRANGLE, CARBON COUNTY, WYOMING

(Report includes 44 plates)

Prepared for:

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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INTRODUCTION

Purpose

This text is to be used along with the accompanying Coal Resource Occurrence (CRO) maps and the Coal Development Potential (CDP) maps of the Elmo quadrangle, Carbon County, Wyoming (44 plates; U.S. Geol. Survey Open-File Report 78-045), prepared by Texas Instruments Incorporated under contract to the U.S. Geological Survey. This report was prepared to support the land planning work of the U.S. Bureau of Land Management's Energy Minerals Activities Recommendation Systems (EMARS) program, and to contribute to a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRA) in the western United States. The Coal Resource Occurrence maps and the Coal Development Potential maps for this quadrangle cover part of the northeastern portion of the KRCRA of the Hanna coal field.

Acknowledgment

Texas Instruments Incorporated acknowledges the cooperation of the Rocky Mountain Energy Company, a wholly owned subsidiary of the Union Pacific Railroad Company, in supplying copies of survey sheets, drillers reports, electric logs, and coal analyses from the Union Pacific coal inventory program.

The Hanna and Carbon coal basins were studied as part of the inventory program and test drilling was conducted in 1970-1971. More than 650 Union Pacific coal drill holes have been evaluated as part of this contract study of 21 quadrangles in Carbon County, Wyoming, and the results and 230 coal analyses have been incorporated into these reports.

Location

The Elmo 7½-minute quadrangle is in the northeastern part of Carbon County, Wyoming. The center of the quadrangle is 19 miles (31 km) west of Medicine Bow and 5 miles (8 km) north of Hanna, Wyoming (Figure 1).

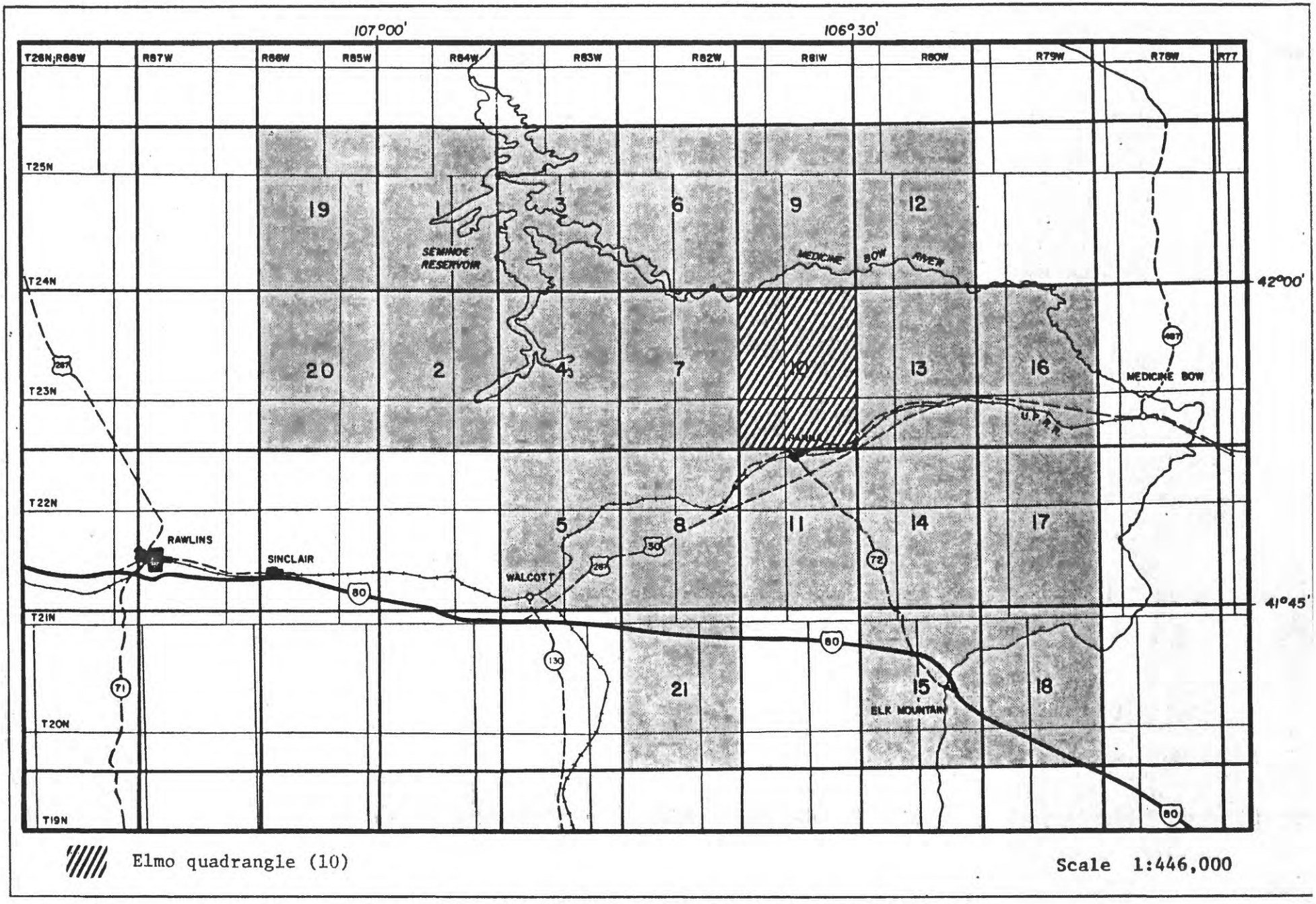

Figure 1. — Map of Hanna and Carbon Basins Study Area

Accessibility

The town of Hanna, U.S. Highway 30/287, and the Union Pacific Railroad are all located immediately south of the Elmo quadrangle, and access to the quadrangle is closely related to these facilities. A paved secondary highway at the southeast border of the quadrangle links the towns of Elmo and Hanna. An improved light-duty road crosses the eastern part of the quadrangle from south to north, connecting the town of Hanna to the Medicine Bow–Seminoe Dam site access road that is located immediately north of this quadrangle, on the north bank of the Medicine Bow River.

The other improved light-duty roads within the quadrangle are all mine service roads, as follows:

- The road from the Arch Mineral Corporation's offices, railroad yard, and coal tipple in the northwest part of sec. 9, T. 22 N., R. 81 W., to the company's Rosebud open pits in the east-central part of the quadrangle
- The road running east and northeast from Elmo to the Nugget No. 1 and No. 2 open pits in this quadrangle, and continuing to the two Hanna Basin open pits in the adjoining quadrangle to the east
- The road running north-northeast from Hanna to the Seminoe No. 2 open pits of Arch Mineral Corporation in this quadrangle
- The roads in the southwest corner of the quadrangle, providing access from Hanna to the Rimrock open pits of Energy Development Company.

Unimproved dirt roads provide access to the remainder of the quadrangle from the light-duty roads.

The main east-west track of the Union Pacific Railroad is adjacent to the southern border of this quadrangle and passes immediately northwest of the southeastern corner. A single-track branch railroad spur of the Rosebud Coal Company leaves the main line tracks east of Hanna, passes east of Elmo, services the company's tipple in the west-central part of the sec. 9, T. 22 N., R. 81 W., and loops in secs. 3 and 4 immediately to the northeast. The spur line of Arch Mineral Corporation leaves the main line tracks 4 miles (6 km) east of Hanna, enters this quadrangle at its southeast corner, and continues northwesterly to the company's tipple and marshalling yard in the northwest part of the sec. 9, T. 22 N., R. 81 W.

Physiography

The quadrangle is located in the center of the Hanna structural basin. The rolling dissected topography is typical of the high plains grasslands of southern Wyoming. Elevations within the quadrangle range from 6,380 feet (1,945 m) in the Medicine Bow River valley at the northwest corner to 7,526 feet (2,294 m) at the headwaters of Willow Spring Draw in the center of the quadrangle. No prominent topographic features are found in the quadrangle; dissection of the landscape is more prominent in the northern one-third where intermittent streams drain to the Medicine Bow River, and man-made open coal pits are common features in the southern half.

Drainage of the quadrangle is part of the North Platte River basin. Streams in the northern one-third flow to the Medicine Bow River, a major tributary of the North Platte River; streams in the southern two-thirds flow to North Ditch, Middle Ditch, and Big Ditch, which in turn flow westward to the Seminoe Reservoir.

Climate

Climate data for the Elmo quadrangle were obtained by evaluating and averaging the data recorded at two nearby weather stations. The Seminoe Dam station is located 24 miles (39 km) northwest of the center of the quadrangle at an elevation of 6,838 feet (2,084 m); precipitation and temperature records are available for 33 years to 1970. The Medicine Bow station is located 20 miles (32 km) east-southeast of the center of the quadrangle at an elevation of 6,570 feet (2,003 m); precipitation and temperature records are available for 23 years to 1970.

The climate is semiarid with a mean annual temperature of 42°F (6°C) and extremes ranging from 98° to -38°F (37° to -39°C). July is the warmest month with a mean monthly temperature of 67°F (19°C) and January is the coldest month with 21°F (-6°C). For seven months of the year, April to October, the mean monthly temperature exceeds 32°F (0°C). Average annual precipitation is 12 inches (30 cm) with 57 percent of this total falling in the five months of March to July. Part of the precipitation in March, April, and May is in the form of snow. Average annual snowfall is 102 inches (259 cm) with 63 percent falling in the four months of January to April. Snow rarely falls in July and August but an inch or more of snow may

fall in any other month. March is the month of maximum snowfall (18 inches, or 46 cm). These snowfall data were obtained by averaging figures from Elk Mountain and Seminoe Dam stations; no data on snowfall were available from the Medicine Bow station. The Elk Mountain station is located 20 miles (32 km) southeast of the center of this quadrangle.

High winds are common throughout most of the year. The prevailing wind direction, as recorded at four weather stations around the perimeter of the Hanna and Carbon Basins, is westerly for all twelve months of the year. The growing season is restricted to less than 100 days between late May and early September which are the average times of the last killing spring frost and the first killing fall frost, respectively.

Land Status

The quadrangle is in the central part of the KRCRA of the Hanna and Carbon Basins. The Federal Government owns approximately 45 percent of the coal rights in the quadrangle; the remaining 55 percent is non-federally owned. Approximately 99 percent of the area of the quadrangle is included in the KRCRA. Within this region about 45 percent of the land is federally owned, with approximately 40 percent of the Federal land currently leased for coal. Plate 2 of the CRO maps illustrates the ownership status of land in the quadrangle and the boundary of the KRCRA.

Coal mining activity in the quadrangle has been consistently extensive. There are 12 abandoned mines, 5 inactive mines, and 5 active strip mines, as follows (Plate 1):

- Abandoned underground mines in T. 22 N., R. 81 W: the Elmo-Peacock mine, in sec. 16, was privately operated between 1932 and 1941, and mined coal bed 80A; the Hanna No. 3, No. 4, and No. 4A mines of the Union Pacific Coal Co., in sec. 16, 18, and 19, respectively, mined coal beds H1 (at No. 3) and H2 (at Nos. 4 and 4A) between 1905 and 1954; the Nugget mine of the Nugget Coal Company, in sec. 10, mined coal bed H1 from 1936 to 1943; the Red Mountain mine of the Colorado Coal Corporation, in sec. 8, mined coal bed H2 from 1929 to 1936.

- Abandoned strip mines in T. 22 N., R. 81 W: the Hanna No. 1 and No. 2 mines of the Monolith Portland Midwest Company, in secs. 8 and 4, respectively, mined coal bed H2 from 1937 to 1968; the Nugget No. 1, No. 2, and No. 5 mines of the Nugget Coal Company, in secs. 10, 16, and 3, respectively, mined coal beds H1 (at Nos. 1 and 2) and 80 (at No. 5) between 1942 and

1958; the Nugget Strip mine of the Nugget Coal Company (?), in sec. 10, mined coal bed 81 between 1942 and 1958.

- Inactive strip mines in T. 22 N., R. 82 W: the Rosebud No. 1 and No. 2 mines of the Rosebud Coal Sales Company, in sec. 13, mined coal bed H5 from 1961 to 1975 (?); the section 10 mine of Energy Development Company, in sec. 10, mined the Brooks coal bed from 1970 to 1975 (?); the Rimrock mine of Energy Development Company, in secs. 10 and 15, mined the Brooks coal bed from 1970 to 1975 (?).

- Inactive strip mine in T. 22 N., R. 81 W: the Rosebud No. 3 mine of the Rosebud Coal Sales Company, in sec. 8, mined coal bed H2 from 1961 to 1975 (?).

- Active strip mines: from 1961, the Rosebud Coal Sales Company has mined coal bed 78 at the Rosebud No. 4 mine in sec. 34, T. 23 N., R. 81 W., the Rosebud No. 4S mine in sec. 3, T. 22 N., R. 81 W., and the Rosebud No. 8 mine in secs. 21 and 28, T. 23 N., R. 81 W.; also from 1961, the same company has mined coal bed 80 at the Rosebud No. 5 mine in secs. 27 and 34, T. 23 N., R. 81 W.; from 1975, Arch Mineral Corporation has mined coal beds H2 and 76 at the Seminoe No. 2 mine in sec. 32, T. 23 N., R. 81 W. and secs. 5, 8, and 17, T. 22 N., R. 81 W.

GENERAL GEOLOGY

Previous Work

Dobbin, Bowen, and Hoots (1929) mapped the Elmo quadrangle as part of their study of the geology and coal and oil resources of the Hanna and Carbon Basins. Weitz and Love (1952) compiled a geologic map of Carbon County which incorporates available data, published and unpublished, to that date. Gill, Merewether, and Cobban (1970) provide a detailed description and discussion of the more important sedimentary rock formations of the area.

Stratigraphy

Rocks exposed in the Elmo quadrangle are of Late Cretaceous and Tertiary age. The oldest formation exposed is the Ferris, represented by a limited outcrop in secs. 10 and 15, T. 22 N., R. 82 W. Approximately 150 feet (46 m) at the top of the formation are exposed in the extreme southwest corner of the quadrangle.

The Ferris Formation consists of a thick sequence of continental rocks divided into two parts: a lower unit of Late Cretaceous age which is about

1,100 feet (335 m) thick, and an upper unit of Paleocene age which is about 5,400 feet (1,646 m) thick. The upper unit consists of gray, brown and yellow sandstones and numerous thick beds of coal (Gill and others, 1970, p. 46).

Uncomformably overlying the Ferris Formation, the Hanna Formation is exposed over the remainder of the quadrangle, with a thickness of approximately 6,600 feet (2,011 m). The Hanna Formation, of continental origin, consists of light tan to dark orangish-brown very fine to coarse-grained thin- to massive-bedded sandstones, gray mudstones, dark-brown carbonaceous shales, and coal. The sandstones are conglomeratic near the base of the formation and fine upward in many of the sand bodies. The Hanna Formation may be as much as 13,500 feet (4,115 m) thick according to Gill, Merewether, and Cobban (1970, p. 47). The age of the Hanna Formation is in doubt; here, in the center of the Hanna Basin the formation may be as old as late-early Paleocene or middle Paleocene.

Structure

The Elmo quadrangle is in the central part of the intermontane Hanna Basin. This structural basin is comparatively small in areal extent, 40 miles (64 km) east-west and 25 miles (40 km) north-south, but very deep. Here, in its central portion, there may be as much as 30,000 to 35,000 feet (9,140 to 10,670 m) of sediments overlying crystalline basement (Glass, 1972). The confines of the present basin were defined during the Laramide Orogeny when the bordering highlands of the basin were raised and deformed while sedimentary fill accumulated rapidly in the basin. Today, the borderlands are characterized by complex folding and faulting, while within the basin only mild deformation is expressed by a few broad folds and normal faults.

Direction of dip of the sediments within the quadrangle is to the northeast and north, except in the south-central and southeastern areas. In these latter areas, the dips reflect the form of the Hanna syncline; the south-southwest trending axial trace of this structure passes by the northeast corner of sec. 16, T. 22 N., R. 81 W., and the plunge of the structure is to the south-southwest. Other structures in the quadrangle are a series of normal faults in the southern half that trend northwesterly and a small reverse fault in the southwest corner with a similar trend.

COAL GEOLOGY

Previous Work

The coal deposits of the Hanna and Carbon Basins have been studied by Veatch (1907), Dobbin, Bowen, and Hoots (1929), Berryhill and others (1950), and Glass (1972 and 1975).

Twenty-six coal analyses have been published since 1913 for coal beds of the Mesaverde Group and the Medicine Bow, Ferris, and Hanna Formations within the Hanna and Carbon Basins (Appendices 1 and 2). Samples collected and analyzed prior to 1913 have not been considered in this report (American Society for Testing and Materials, 1977, p. 218). An average analysis and apparent rank of coal beds in each of these four stratigraphic units have also been calculated for the 230 analyses from the Union Pacific coal inventory program (Appendices 1 and 2). A standard rank determination (ASTM, 1977, p. 216, sec. 6.2.2) cannot be made because: (a) some of the published analyses are from weathered coal samples; and (b) the procedure and quality of sampling for the Union Pacific coal evaluation program are not known.

Glass (1975) and U.S. Department of Interior (1975) published not only proximate coal analyses for 17 samples collected in the Hanna Basin, but also assays for 10 major and minor oxides, 12 major and minor elements, and up to 32 trace elements. Glass (1975, p. 1) stresses that his assay data are insufficient to characterize the chemical and physical properties of any individual coal bed, but that this will be possible at a later date as the study continues. Assay results of the 17 Hanna Basin samples show that these coals contain no significantly greater amounts of trace elements of environmental concern than are found in the 42 samples collected in six other Wyoming coal fields.

General Features

In the Elmo quadrangle, 47 coal beds and 119 local coal lenses have either been mapped by Dobbin, Bowen, and Hoots (1929) or have been identified in the subsurface (Plates 1 and 3). One coal bed and 3 local coal lenses occur in the Ferris Formation; the remainder, 46 coal beds and 116 local coal lenses, occur in the Hanna Formation.

Direction of dip of the coal beds is generally northeast and north, except in the south-central and southeastern areas where the dips reflect the structure of the Hanna syncline. Dip angles vary from 3° to 19°.

Coal bed thicknesses within the quadrangle range from 0.5 to 23.1 feet (0.2 to 7.0 m) at measured sections and in drill holes. Several of the coal beds are thick enough and persistent enough to be mined and there has been continuous, extensive mining in the southern half of the quadrangle (see preceding section, Land Status).

Of the coal beds identified in the quadrangle, ten were selected by the U.S. Geological Survey for resource evaluation. These coal beds are the Brooks bed, coal bed 75, the Hanna 2 bed, and the coal beds 77, 78, 80, 81, 85, and 88. All these coal beds are in the Hanna Formation. The five oldest coal beds are each affected by the series of northwest-trending faults. Displacements on the faults decrease eastwards; for example, coal bed 75 shows displacements of 150 to 400 feet (46 to 122 m), while coal bed 78 further east shows displacements of about 50 feet (15 m).

Ferris Coal Beds

Coal Bed 66, the only Ferris coal bed mapped in the quadrangle by Dobbin, Bowen, and Hoots (1929), crops out in the southwest corner. There are no measured sections within the quadrangle and the coal bed was not intersected by any drill hole down dip from the outcrop. In the quadrangle adjoining to the west, coal bed 66 is about 2.3 feet (0.7 m) thick; in the quadrangle to the south, 1.8 feet (0.5 m) thick.

Hanna Coal Beds

The Brooks coal bed occurs 200 feet (61 m) above the base of the Hanna Formation, as mapped by Dobbin, Bowen, and Hoots (1929) in this quadrangle. The coal dips to the east at 4° to 9° and bed thickness ranges from 4.7 to 7.5 feet (1.4 to 2.3 m). A reverse fault with small displacement has offset this coal by 10 to 15 feet (3 to 4.6 m). The Brooks coal bed in this quadrangle has been mined along its entire outcrop. Analyses of three samples from this coal bed are shown in Appendix 3.

Coal bed 75 is 3,250 feet (991 m) above the Brooks coal bed in the Hanna stratigraphic section. The interval between the two coal beds contains 11 coal beds and 47 local coal lenses. Coal bed 75 dips to the northeast, to the east, and to the southeast, as its outcrop is traced southwards; amount of dip is about 18°. Measured thicknesses of the coal bed range from 1.8 to 13 feet (0.5 to 4.0 m). No sample analyses are available for this coal bed.

The Hanna 2 coal bed is 130 feet (40 m) above coal bed 75 and the intervening section contains two coal beds and 5 local coal lenses. The Hanna 2 coal bed crops out in the central and south-central areas of the quadrangle; the bed dips east and southeast at about 11° and its thickness ranges from 9 to 30 feet (2.7 to 9.1 m). This coal bed has been extensively mined in this quadrangle. Analyses of five samples from the Hanna 2 coal bed are shown in Appendix 3.

Coal bed 77 is 490 feet (149 m) above the Hanna 2 coal bed and the intervening section contains no coal beds or local coal lenses. Coal bed 77 crops out in the northwest part of the quadrangle, with a dip to the northeast of 15° and a thickness of less than 4 feet (1.2 m). As the coal bed is traced southeasterly the direction and degree of dip remains constant but the thickness increases rapidly to a maximum of 23.1 feet (7 m) in the east-central part of the quadrangle. The coal bed outcrop then changes direction as the bed crops out on the northwestern limb of the Hanna syncline. Strike of the coal bed changes to southerly, then southwesterly, and the angle of dip decreases to about 10°. Coal bed thicknesses in the south-central part of the quadrangle decrease to between 2 and 9 feet (0.6 and 2.7 m). Analyses of three samples from coal bed 77 are shown in Appendix 3.

Coal bed 78 is 180 feet (55 m) above coal bed 77 and the intervening section contains three coal beds and one local coal lens. The outcrops of coal beds 77 and 78 are essentially similar and parallel, and therefore the dips are similar. The thickness of coal bed 78 varies from 7.7 to 22.2 feet (2.3 to 6.8 m) with the maximum thickness in the east-central part of the quadrangle. Analyses of two samples of coal bed 78 are shown in Appendix 3 (Glass, 1975, samples 74-24 and 74-25). The coal bed designations of Dobbin, Bowen, and Hoots (1929) are used in this report; the equivalent coal bed numbering by Glass (1975) is shown on Plate 1.

Coal bed 80 is 350 feet (107 m) above coal bed 78 and the intervening section contains three coal beds and five local coal lenses. Coal bed 80 crops out in the north-central, northeast, and east-central parts of the quadrangle; the strike of the bed is southeasterly and the dip is northeast 15°, decreasing to 8° in the east-central part of the quadrangle. Measured thicknesses range from 3.1 to 10.8 feet (0.9 to 3.3 m). This coal bed is being mined for one-third of its outcrop in the Rosebud No. 5 open pit. Dobbin, Bowen, and Hoots (1929, p. 74 and 82) state that coal bed 80 in this quadrangle is probably equivalent to coal beds 81A and 82A in T. 22 N., R. 81 W.; however, they fail to map any outcrops of these latter beds or to show any measured sections on Plate 20 of their report. Analyses of two samples of this coal bed 80 from an intersection in drill hole 17, are included in Appendix 3.

The stratigraphic interval between coal bed 81 and the next designated coal bed, 85, is about 1,000 feet (305 m) and contains 6 coal beds and 9 local coal lenses. Coal bed 85 crops out in the northeastern corner of the quadrangle, with a southeasterly strike and a dip to the northeast of 12° to 14°. Measured thicknesses of this coal bed range from 1.2 to 11.9 feet (0.4 to 3.6 m). Analyses of three samples from the intersection of coal bed 85 in drill hole 9 are shown in Appendix 3.

Coal bed 88, the youngest designated coal bed in the Hanna Formation in the Elmo quadrangle, is certain to be of Eocene age as a result of detailed mapping in the area by Knight (1951, Plate 2). For this project study, however, the complete geologic map of Knight (1951) and a mapping of the Eocene coal beds are not available; therefore, the mapping of Dobbin, Bowen, and Hoots (1929) is used in the coal evaluation of the TE Ranch, Difficulty, Elmo, and Como West quadrangles.

Coal bed 88 crops out in the northeast corner of the quadrangle and, both here and in the adjoining quadrangle to the north, the bed is described by Dobbin, Bowen, and Hoots (1929) as a thick bed of carbonaceous shale containing numerous intercalated beds of coal. Their mapping includes coal bed EL7, and probably coal bed EL8 also, in their measured sections of coal bed 88. Immediately to the north of this quadrangle, coal bed 88 is a zone of carbonaceous shale, bony coal, and coal that is more than 104 feet (31.7 m) thick; only 31 percent of the zone is coal and bony coal, in 36 individual

beds; 4 distinct sections of coal are separated by shale sections that are 30, 8, and 14 feet (9.1, 2.4, and 4.3 m) thick. In the Elmo quadrangle, in the northwest part of sec. 3, T. 23 N., R. 81 W., coal bed 88 is over 85.5 feet (26.1 m) thick; 21 percent of the zone is coal and bony coal, in 15 individual beds, of which only two are more than 2 feet (0.6 m) thick; and again, 4 distinct sections of coal are separated by shale sections that are 34.2, 15 and 10 feet (10.4, 4.6, and 3.0 m) thick. Tracing the outcrop of coal bed 88 southeasterly, in the southeast of sec. 3 the coal bed is a zone that is 39.7 feet (12.1 m) thick; 52 percent of the zone is coal and bony coal, in 16 individual beds, of which only one is more than 2 feet (0.6 m) thick; there are no distinct shale sections in the zone. Further to the southeast, in the southwest part of the adjoining sec. 2, coal bed 88 was measured by Dobbin, Bowen, and Hoots (1929) as 5.5 feet (1.7 m) of coal and bony coal with 1 foot (0.3 m) of interbedded shale.

Coal bed 88 is about 500 feet (152 m) above coal bed 85, according to the mapping of Dobbin, Bowen, and Hoots (1929), and the intervening section contains coal beds 86, 86a, and 87 and eight local coal lenses. Coal bed 88 dips northeasterly at 8°. There are no coal analyses for this coal bed.

COAL RESOURCES AND RESERVES

Previous Work

Coal reserves of the Hanna and Carbon Basins have been estimated or calculated by Dobbin, Bowen, and Hoots (1929), Berryhill and others (1950), and Glass (1972).

Method of Calculating Resources and Reserves

Data from Dobbin, Bowen, and Hoots (1929), an oil well log, and coal drill holes (written communications, Rocky Mountain Energy Company, 1977 and U.S. Geological Survey, 1978) were used to construct a coal data map (Plate 1) and coal data sheets (Plates 3 and 3A). U.S. Geological Survey reviewed these three plates and on the basis of Reserve Base criteria, selected nine coal beds for the calculation of coal resources in the Elmo quadrangle. In addition, calculation of coal resources was requested for isolated or non-correlatable data points.

The coal data map and coal data sheets were used to construct structure contour, coal isopach, and overburden isopach maps of the correlatable coal beds (Plates 4-9, 12-14, 16-18, 21-23, 26-34, and 37-39). For single coal beds, the maps were drawn using, as control points, thicknesses measured at outcrop and subsurface data from drill hole information. Where coal beds are split, cumulative coal thicknesses were used, excluding non-coal partings.

Plates 4-9, 12-14, 16-18, 21-23, 26-34, 37-39 provide the data for calculating the coal resources and reserves within the KRCRA boundary of the quadrangle in accordance with the classification system given in U.S. Geological Survey Bulletin 1450-B and the instructions provided by U.S. Geological Survey on approval of these 27 plates. Calculation of the resources and reserves is in accordance with the following criteria:

- Identified coal resources of the quadrangle, as selected by U.S. Geological Survey, are contained within coal beds BB, 75, H2, 77, 78, 80, 81, 85, and 88, and the resources defined by isolated or noncorrelatable data points.

- Coal bed thicknesses from surface mapping are true thicknesses; thicknesses from subsurface data are apparent thicknesses. An apparent thickness is corrected to true thickness if the dip of the selected coal bed exceeds 25^{o}. In the Elmo quadrangle the selected coal beds dip at less than 25^{o}.

- Strippable coal resources (the resources capable of being extracted by strip-mining methods) are composed of single coal beds at least 5 feet (1.5 m) thick and having 200 feet (61 m) or less of overburden.

- Nonstrippable coal resources (subsurface resources capable of being mined by underground methods) are single coal beds with a minimum thickness of 5 feet (1.5 m); a maximum dip of 15^{o}; an overburden thickness of 0 to 3,000 feet (914 m). To avoid duplicating strippable coal Reserve Base and reserve values, no nonstrippable coal Reserve Base and reserve values are calculated where a coal bed occurs above the stripping limit. When calculating nonstrippable coal Reserve Base values, an average thickness for each coal bed is determined from the coal bed thicknesses at control points within a measured area. When calculating nonstrippable coal reserve values, the average thickness for each coal bed is determined in a like manner after coal bed thicknesses greater than 12 feet (3.7 m) have been reduced to 12 feet (3.7 m).

- All coal deeper than 3,000 feet (914 m) is excluded.

- Reliability or geologic assurance categories (measured, indicated, and inferred resources) are defined according to proximity of the coal to a data point. Measured resources occur within 0.25 mile (402 m) of a data point; indicated resources occur within an area that is 0.25 to 0.75 mile (0.4 to 1.2 km) from a data point; inferred resources occur within an area that is 0.75 to 3 miles (1.2 to 4.8 km) from a data point. A data point is either a measured coal thickness in a drill hole or a measured coal thickness location on a mapped outcrop.

- Coal resources from isolated or noncorrelatable data points are calculated for a single coal bed at least 5 feet (1.5 m) thick or for an aggregate thickness of multiple coal beds each at least 5 feet (1.5 m) thick. The single coal bed, or the stratigraphically highest bed in an aggregate of coal beds, is locally projected up dip to the surface to establish an inferred outcrop. Strippable coal resources for the projected bed or beds are considered to occur from surface to a depth of 200 feet (61 m); nonstrippable coal resources are considered to occur from surface to a depth of 3,000 feet (914 m). Only the coal resources underlying an area within 0.5 mile (804 m) of a drill hole or a measured surface outcrop are considered, and they are assigned to the inferred category of reliability.

- Coal resources are calculated for unleased Federal land within the KRCRA boundary (Plate 2). Information pertaining to leased or fee acreage and to non-Federal land is considered proprietary and not for publication.

In preparing a map of the areal distribution of identified resources for the isolated or noncorrelatable coal beds, some data require a unique solution. For example:

- Where short segments of coal bed outcrop have data points that indicate a coal thickness of 5 feet (1.5 m) or more, an arc with a radius equal to half the outcrop length is drawn down dip from the outcrop, connecting to the ends of the outcrop. The resulting contained area defines the total coal resource, segmented into strippable and nonstrippable resource sections.

- Where a coal bed outcrop has data points with coal thicknesses less than 5 feet (1.5 m), a 5-foot (1.5-m) cut-off point is interpolated, and the resulting segments with values greater than 5 feet (1.5 m) are used to generate arcs (radii equal to half the outcrop length) for defining the extent of the coal resources. When several data points occur on the outcrop of a resource area, an average of their coal thickness values is used to calculate a tonnage of coal.

- Where areas within outcrop segment arcs and areas within 0.5 mile (804 m) of a drill hole coincide, the areas are combined, and drill hole coal thickness values are averaged with outcrop coal thickness values.

- When evaluating multiple coal beds of an isolated or noncorrelatable data point, the interburden between subsurface coal beds may be too great to allow the aggregate thickness of coal to be considered as one planar unit. In such instances, a conservative judgment is made, and the resources for each coal bed are calculated separately and then totaled.

Results

The areal distribution of leasable Federal coal resources within the KRCRA boundary is shown on Plates 10, 15, 19, 24, 35, and 40 for six of the nine selected coal beds. Evaluation of coal beds BB, 80, and 81 showed that no mappable coal resources are present beneath unleased Federal land; therefore, the coal beds are excluded from Reserve Base and reserve calculations.

The coal resource acreage within each area of unleased Federal land was determined by planimeter. Coal Reserve Base values are obtained by multiplying the coal resource acreage for the planimetric portion of each area of unleased Federal land by the average isopach value of the selected coal bed, times the conversion factor for subbituminous coal, 1,770 short tons (1,606 t) of coal per acre-foot. The coal Reserve Base tonnages are recorded as follows:

- From coal beds 75, H2, 77, 78, 85, and 88: 15.04 million short tons (13.64 million t); assigned to measured, indicated, or inferred categories; shown on Plates 10, 15, 19, 24, 35, and 40; included in the coal Reserve Base totals shown on Plate 2.

- From isolated or noncorrelatable data points: 13.82 million short tons (12.54 million t) of strippable resources and 27.0 million short tons (24.49 million t) of nonstrippable resources, assigned to the inferred resource category, included in the coal Reserve Base totals shown on Plate 2.

In summary, the total Reserve Base for all coal beds thicker than 5 feet (1.5 m) that lie less than 3,000 feet (914 m) below the ground surface of unleased Federal land within the KRCRA in the Elmo quadrangle is 55.86 million short tons (50.68 million t).

Coal reserves for the quadrangle are calculated by applying recovery factors to the measured, indicated, and inferred resources of coal beds 75, H2, 77, 78, 85, and 88. The inferred resources determined from isolated or noncorrelatable data points are excluded from coal reserve calculations.

For strippable resources, a recovery factor of 0.85 is used; for nonstrippable resources, the recovery factor is 0.50. Reserve tonnages, to the nearest 10,000 short tons, are shown on Plates 10, 15, 19, 24, 35, and 40. Total coal reserves for unleased Federal land within the KRCRA in the Elmo quadrangle are 9.24 million short tons (8.38 million t), consisting of 5.19 million short tons (4.71 million t) recoverable by strip mining or by underground mining and 4.05 million short tons (3.67 million t) recoverable by underground mining only.

COAL DEVELOPMENT POTENTIAL

Method of Calculating Development Potential

Following the calculation of Reserve Base values and coal reserves, the coal resources of the KRCRA of the Elmo quadrangle, except those coal resources determined from isolated or noncorrelatable data points, are evaluated for their development potential in each of two mining-method categories, surface and subsurface.

Strippable and nonstrippable resources are assigned to one of four development potential categories (high, moderate, low, and unknown) according to the following criteria:

Strippable Resources

- Assignment is based on calculated mining ratio values for subsurface data points (wells and drill holes) and for points of intersection of coal isopachs (Plates 5, 8, 13, 17, 22, 27, 30, 33, 38) and overburden isopachs (Plates 6, 9, 14, 18, 23, 28, 31, 34, 39).

- The formula used to calculate mining ratios was provided by U.S. Geological Survey as follows:

$$MR = \frac{t_o\ (0.911)}{t_c\ (rf)}$$

where

MR = mining ratio

t_o = thickness of overburden, in feet

t_c = thickness of coal, in feet

rf = recovery factor (0.85 for strip mining)

0.911 = a constant

- If mining ratio is 0-10, resources have high development potential.

  If mining ratio is 10-15, resources have moderate development potential.

  If mining ratio is greater than 15, resources have low development potential.

- If insufficient data prevent the construction of mining ratio contours, the resources are assigned to unknown development potential category, provided that there is reasonable assurance the coal bed is present in that area.

Nonstrippable Resources

- Coal beds must be more than 5 feet (1.5 m) thick. Coal beds less than 5 feet (1.5 m) thick are excluded from the Reserve Base coal resources. Where coal beds are more than 12 feet (3.7 m) thick, only 12 feet (3.7 m) of the total thickness is used for Reserve Base calculations.

- If the overburden is between 0 and 1,000 feet (0 and 305 m), resources have high development potential; if the overburden is between 1,000 and 2,000 feet (305 and 610 m), resources have moderate development potential; if the overburden is between 2,000 and 3,000 feet (610 and 914 m), resources have low development potential.

- If insufficient data prevent the construction of coal isopachs or overburden isopachs, or if the correlatable coal bed in the area is located completely above the stripping limit, the resources are assigned to the unknown development potential category, provided that there is reasonable assurance the correlatable coal bed is present in the area.

By applying the above criteria, mining-ratio maps (Plates 11, 20, 25, 36, and 41) were prepared for the selected coal beds 75, 77, 78, 85, and 88. Mining-ratio maps for the selected coal beds H2, 80, and 81 are omitted because of insufficient data within the unleased Federal land of the KRCRA in this quadrangle. A mining-ratio map for the coal bed BB is omitted because the bed crops out entirely on leased or non-Federal land.

Development potential acreages were then blocked out, as shown on CDP Plates 42 and 43. Acreage for strippable and nonstrippable resources of selected coal beds is shown in Table 1 for each of the four development potential categories. In accordance with a constraint imposed by the U.S. Bureau of Land Management, the highest development potential affecting any portion of a 40-acre (16 ha) parcel is applied to the entire parcel.

Table 1. — Development potential for identified resources of the selected coal beds within the KRCRA of the Elmo quadrangle

Coal bed	Development potential (acres)							
	Strippable resources			Nonstrippable resources			Unknown category	
	High	Moderate	Low	High	Moderate	Low	Strippable	Nonstrippable
BB	0	0	0	0	0	0	0	640
75	240	80	40	40	0	0	80	1,480
H2	0	0	0	360	40	0	0	120
77	560	0	0	360	0	0	0	240
78	200	40	0	160	0	0	0	240
80	0	0	0	0	0	0	0	1,360
81	0	0	0	0	0	0	0	600
85	80	80	0	0	0	0	640	1,440
88	80	0	40	120	0	0	0	40
Totals	1,160	200	80	1,040	40	0	720	6,160

To convert acres to hectares, multiply by 0.4046.

For example, if 5 acres (2 ha) within a parcel are assigned a high development potential, 25 acres (10 ha) a moderate development potential, and 10 acres (4 ha) a low development potential, then the entire 40 acres (16 ha) are assigned a high development potential.

Additionally, at the direction of the U.S. Geological Survey, an unknown development potential is assigned to coal resources calculated for any coal bed that, although not selected for coal resource evaluation, is (a) wholly, or partly, of Reserve Base thickness, or (b) of unknown thickness.

Development Potential for Strippable Resources

Development potential for strippable coal resources within unleased Federal land in the KRCRA of this quadrangle is shown in Table 1 for each selected coal bed. Plate 42 and Table 2 show the highest surface development potentials for the selected coal beds. The totals are obtained after assigning the highest assessed development potential for any coal bed within the smallest legal subdivision to that subdivision.

Table 2. Highest development potential for identified resources of the selected beds within the KRCRA of the Elmo quadrangle

Development potential (acres)							
Strippable resources			Nonstrippable resources			Unknown category	
High	Moderate	Low	High	Moderate	Low	Strippable	Nonstrippable
910	200	50	725	0	0	2,920	3,600

To convert acres to hectares, multiply by 0.4046.

There are approximately 9,160 acres (3,706 ha) of unleased Federal land within the KRCRA of this quadrangle. Of this area, 4,160 acres (1,683 ha), or 45.4 percent of the total, are estimated to be underlain by coal resources, from the selected coal beds, with development potential for surface mining. Of the 4,160 acres (1,683 ha), a high development potential is assigned to 910 acres (368 ha), a moderate development potential to 200 acres (81 ha), a low development potential to 50 acres (20 ha), and an unknown development potential to 2,920 acres (1,181 ha).

Of the 9.160 acres (3,706 ha) of unleased Federal land, there are 3,435 acres (1,390 ha) or 38 percent of the total, which are classifiable as of unknown surface mining potential on the basis of both (a) the presence of outcrops of noncorrelatable coal beds of unknown thickness and (b) data gaps on beds selected for coal resource evaluation.

Development Potential for Nonstrippable Resources

Development potential for nonstrippable coal resources within unleased Federal land in the KRCRA of this quadrangle is shown in Table 1 for each selected coal bed. Plate 43 and Table 2 show the highest subsurface development potentials for the selected coal beds. The totals are obtained after assigning the highest assessed development potential for any coal bed within the smallest legal subdivision to that subdivision.

Of the 9,160 acres (3,706 ha) of unleased Federal land within the KRCRA of this quadrangle, 4,400 acres (1,780 ha), or 48.0 percent of the total, are estimated to be underlain by coal resources, from the selected coal beds, with development potential for underground mining. Of the 4,400 acres (1,780 ha), a high development potential is assigned to 725 acres (293 ha), and an unknown development potential to 3,600 acres (1,457 ha).

Of the 9,160 acres (3,706 ha) of unleased Federal land, there are 5,880 acres (2,379 ha) or 64 percent of the total, which are classifiable as of unknown subsurface mining potential on the basis of both (a) the presence of outcrops of noncorrelatable coal beds of unknown thickness and (b) data gaps on beds selected for coal resource evaluation.

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Appendix 1. — Average analyses of coal samples from the Hanna and Carbon Basins

Source of Data	Number of samples (1)	Total footage Ft	in	Average analyses — as received basis: Percent: Moisture	Ash	Volatile matter	Fixed carbon	Sulfur	Btu/lb	Calorific Value, Btu/lb Moist, mineral-matter-free basis (2)	Apparent rank of coal (3)
Published analyses	26	318	6	12.5	7.1	36.2	44.2	0.6	10,553	11,438	sub A or hvCb
Union Pacific coal inventory program	230	1,605	10	12.48	8.74	35.12	43.68	0.82	10,398	11,494	sub A or hvCb

Notes:

(1) Published data from USBM (1931, p. 40-45, sample nos. 2623, 2624, 22800, 22972, 93486, 93488, 93541, A14123, A14124); Glass (1975, p. 16-19, sample nos. 74-23 to 74-34, inclusive); Dept. of Interior (1975, p. 38, sample nos. D169597-99, D169607-08). Union Pacific coal inventory program data from company files, Rocky Mountain Energy Company (1977).

(2) Moist, mineral-matter-free Btu/lb calculated from average analyses, as received basis, using Parr formula (ASTM, 1977, p. 216, sec. 8.2).

(3) Sub A — subbituminous A; hvCb — high volatile C bituminous (ASTM, 1977, p. 215, sec 4.2, and p. 217).

[To convert feet and inches to meters, multiply feet by 0.3048 and inches by 0.0254. To convert Btu/lb to kilojoule/kilogram, multiply by 2.326].

Appendix 2. — Average analyses of coal grouped by coal-bearing formations in the Hanna and Carbon Basins

Source of data	Formation or Group	Number of samples (1)	Total footage Ft	Total footage in	Average analyses — as received basis: Percent: Moisture	Ash	Volatile matter	Fixed carbon	Sulfur	Btu/lb	Calorific Value, Btu/lb: Moist, mineral-matter-free basis (2)	Apparent rank of coal (3)
Published analyses	Mesaverde	1	4	0	14.1	7.8	36.5	41.6	1.1	10,290	11,251	sub A or hvCb
	Medicine Bow	2	10	1	12.8	3.8	33.3	50.2	0.8	11,050	11,534	hvCb
	Ferris	10	93	1	13.0	8.3	34.3	44.3	0.4	9,970	10,956	sub A or hvCb
	Hanna	13	211	4	12.0	6.6	38.1	43.3	0.7	11,946	11,797	hvCb
Union Pacific coal inventory program	Mesaverde	13	70	5	9.45	8.41	35.42	46.72	0.77	11,112	12,237	hvCb
	Medicine Bow	16	93	4	13.09	4.03	35.46	47.42	0.80	10,927	11,446	sub A or hvCb
	Ferris	114	863	1	12.69	7.96	34.39	44.97	0.44	10,331	11,309	sub A or hvCb
	Hanna	87	579	0	12.51	10.67	35.96	40.85	1.33	10,280	11,640	hvCb

Notes:

(1) Published data from USBM (1931, p. 40-45, sample nos. 2623, 2624, 22800, 22972, 93486, 93488, 93541, A14123, A14124); Glass (1975, p. 16-19, sample nos. 74-23 to 74-34, inclusive); Dept. of Interior (1975, p. 38, sample nos. D169597-99, D169607-08). Union Pacific coal inventory program data from company files, Rocky Mountain Energy Company (1977).

(2) Moist, mineral-matter-free Btu/lb calculated from average analyses, as received basis, using Parr formula (ASTM, 1977, p. 216, sec. 8.2).

(3) Sub A — subbituminous A; hvCb — high volatile C bituminous (ASTM, 1977, p. 215, sec. 4.2, and p. 217).

[To convert feet and inches to meters, multiply feet by 0.3048 and inches by 0.0254. To convert Btu/lb to kilojoule/kilogram, multiply by 2.326].

Appendix 3. — Coal analyses, Elmo quadrangle

Drill hole	Location			Coal bed	Sample interval				Sample width		Analyses - as received basis					
					From		To				Percent					
	Sec.	Twp.	Rge.		Ft	in	Ft	in	Ft	in	Moisture	Ash	Volatile matter	Fixed carbon	Sulfur	Btu/lb
35	3	22N	82W	BB	417	0	423	0	6	0	11.92	5.16	33.28	49.64	0.26	10,941
36	11	22N	82W	BB	325	0	330	7	5	7	12.78	4.85	32.45	49.92	0.25	10,911
40	15	22N	82W	BB	21	0	27	4	6	4	13.09	4.29	33.41	49.21	0.26	11,118
9	9	23N	81W	85	59	9	62	3	2	6	9.52	8.97	38.09	43.42	1.73	10,982
9	9	23N	81W	85	62	3	67	3	5	0	8.01	23.49	33.14	35.36	2.64	9,079
9	9	23N	81W	85	67	3	74	0	6	9	8.32	20.62	34.32	36.74	1.64	9,460
17	17	23N	81W	L	347	0	355	6	8	6	8.72	8.88	37.63	44.77	0.97	11,352
17	17	23N	81W	81	665	6	674	0	8	6	8.65	4.30	38.81	48.24	0.55	12,169
17	17	23N	81W	81	674	3	676	0	1	9	8.57	4.24	40.72	46.47	0.62	12,086
16	17	23N	81W	79	367	0	382	3	15	3	8.83	5.18	38.79	47.20	0.69	11,857
16	17	23N	81W	79	382	3	391	0	8	9	9.09	6.35	37.81	46.75	0.70	11,706
24	19	23N	81W	74	54	3	56	8	2	5	8.14	21.33	34.29	36.24	2.29	9,677
27	21	23N	81W	L	56	0	64	1	8	1	10.06	6.62	37.75	45.57	0.94	11,413
27	21	23N	81W	80	382	10	391	4	8	6	11.36	4.67	36.91	47.04	0.76	11,583
26	21	23N	81W	77	227	0	236	6	9	6	10.23	5.60	39.09	45.08	0.92	11,393
26	21	23N	81W	77	236	6	241	6	5	0	9.41	11.38	39.04	40.17	0.88	10,711
26	21	23N	81W	77	241	6	245	7	4	1	8.39	22.80	34.38	34.43	1.06	9,213

Appendix 3 (Contd)

Drill hole	Location			Coal bed	Sample interval				Sample width		Analyses - as received basis					
					From		To				Percent					
	Sec.	Twp.	Rge.		Ft	in	Ft	in	Ft	in	Moisture	Ash	Volatile matter	Fixed carbon	Sulfur	Btu/lb
30	31	23N	81W	72	26	2	33	6	7	4	16.22	5.16	32.49	46.13	0.46	9,856
31	31	23N	81W	72a	169	0	174	11	5	11	9.27	10.80	35.91	44.02	1.26	11,084
32	31	23N	81W	L	27	8	33	6	5	10	9.34	11.83	36.92	41.91	1.32	10,918
34	33	23N	81W	L	570	0	574	3	4	3	8.63	6.43	39.71	45.23	0.51	11,641
34	33	23N	81W	L	576	1	589	3	13	2	9.03	7.24	40.95	42.78	0.30	11,369
34	33	23N	81W	L	593	3	598	0	4	9	9.75	7.52	39.55	43.18	0.69	11,205
29	25	23N	82W	L	168	4	172	5	4	1	11.02	8.59	34.86	45.53	0.68	11,174
Sample number																
74-23	34	23N	81W	82					11	3	11.2	7.3	40.9	40.6	1.0	10,830
74-24	3	22N	81W	80					13	11	12.4	8.8	39.2	39.6	1.2	10,450
74-25	28	23N	81W	80					18	1	10.6	4.4	37.4	47.6	0.7	11,510
74-26	4	22N	81W	H2					35	5	11.3	5.4	40.1	43.2	0.4	11,350
D169598	4	22N	81W	H2					33	0	10.7	10.3	38.5	40.5	0.7	10,650
D169599	9	22N	81W	82					25	0	12.1	9.8	36.2	41.9	0.9	10,330
				+80					+10	0						
93488	8	22N	81W	H2?					8	9	17.2	3.8	33.2	45.8	0.8	10,400
A2623	17-20	22N	81W	H2					18	4½	11.2	4.1	40.6	44.1	0.3	11,460
A2624	17-20	22N	81W	H2					6	7½	12.7	5.5	41.2	40.6	0.5	11,000

Drill hole data from Rocky Mountain Energy Company (1977). Data for samples 74-23 through 74-26 from Glass (1975); for samples D169598-599 from U.S. Dept. of Interior (1975); for sample 93488 from U.S. Bureau of Mines (1931); for samples A2623-24 from U.S. Bureau of Mines (1931).

[To convert feet and inches to meters, multiply feet by 0.3048 and inches by 0.0254. To convert Btu per pound to kilojoules per kilogram (kJ/kg), multiply by 2.326].

Appendix 4. — Coal Reserve Base Data for Federal coal lands (in short tons) in the Elmo quadrangle, Carbon County, Wyoming.

Strippable coal Reserve Base data for Federal coal lands (in short tons) in the Elmo quadrangle, Carbon County, Wyoming [Development potential are based on mining ratios (cubic yards of overburden/ton of underlying coal). To convert short tons to metric tons, multiply by 0.9072]

Coal Bed	High Development Potential (0-10 mining ratio)	Moderate Development Potential (10-15 mining ratio)	Low Development Potential (>15 mining ratio)	Total
75	300,000	30,000	230,000	560,000
77	3,430,000	670,000	240,000	4,340,000
78	50,000	50,000	0	100,000
85	30,000	60,000	40,000	130,000
88	10,000	40,000	130,000	180,000
Total	3,820,000	850,000	640,000	5,310,000

Non-strippable coal reserve Base data for Federal coal lands (in short tons) in the Elmo quadrangle, Carbon County, Wyoming. (To convert short tons to metric tons, multiply by 0.9072)

Coal Bed	High Development Potential (0-1000 ft of overburden)	Moderate Development Potential (1000-2000 ft of overburden)	Low Development Potential (2000-3000 ft of overburden)	Total
75	80,000	0	0	80,000
77	3,440,000	0	0	3,440,000
H2	2,660,000	0	0	2,660,000
78	840,000	0	0	840,000
88	280,000	0	0	280,000
Total	7,300,000	0	0	7,300,000