Text to Accompany

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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE SOUTHWEST QUARTER OF THE MT. PENNELL 15-MINUTE QUADRANGLE, GARFIELD COUNTY, UTAH

[Report includes 11 plates]

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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INTRODUCTION

Purpose

This text is to be used in conjunction with Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) Maps of the Southwest Quarter of the Mt. Pennell 15-minute quadrangle, Garfield County, Utah. These maps and report were compiled to support the land planning work of the Bureau of Land Management and to provide a systematic coal resource inventory of Federal coal lands in the Henry Mountains Known Recoverable Coal Resource Areas (KRCRA's), Utah. Consequently, only those geologic features relevant to coal occurrences are described herein.

This investigation was undertaken by Dames & Moore, Salt Lake City, Utah at the request of the U.S. Geological Survey under contract number 14-08-0001-17489. The resource information gathered for this report is in response to the Federal Coal Leasing Amendments Act of 1976 (P.L. 94-377). Published and unpublished public information available through June, 1979 was used as the data base for this study. Neither drilling nor field mapping was performed; nor were any confidential data used.

Location

The Southwest Quarter of the Mt. Pennell 15-minute quadrangle is located in eastern Garfield County, Utah. Highway 276 is 15 miles (24 km) east and Lake Powell is 35 miles (36 km) south of the quadrangle's eastern and southern borders, respectively. The area is unpopulated.

Accessibility

Principal access is provided by a road extending southeastward from the northwest corner of the map area along Hall Creek and parallel to the Waterpocket Fold. A jeep trail through Grand Gulch breaks off the main road at The Post. Most of the map area is accessible only by foot and horseback. Generally, travel is not hampered by winter weather.

Physiography

The Southwest Quarter of the Mt. Pennell 15-minute quadrangle is located at the southern end of the Henry Mountains structural basin. Although located in a basin, the area is topographically higher than most of the surrounding region. Elevations range from 4,640 ft (1,414 m) in the southern drainage of Hall Creek to 6,200 ft (1,890 m) atop reefs along the Waterpocket Fold.

Mesa and badland terrain characterize the map area in the north and east. The southern half of Swap Mesa and Cave Point Mesa in the north rise steeply above the incised badlands to the south.

The Waterpocket Fold, a series of reefs following a southeasterly course through the west half of the map area, is the prominent physical feature in the region. Hogback ridges of resistant, folded rock and the steep-walled canyons of Grand Gulch dominate the terrain just east of the fold.

Principal drainages in the quadrangle are Muley and Hall Creeks. Both streams discharge into Lake Powell at Bullfrog Basin. Water quality and stream flow reflect seasonal climatic changes. Surface water is often saline due to high summer evaporation rates. Muley and Hall Creeks are intermittent in nature. All streams dry up during the late summer months.

Climate and Vegetation

The map area's climate is semi-arid to arid. Average annual precipitation is about eight inches (20.3 cm), occurring principally as localized late summer thundershowers and light winter snow and rain. Annual precipitation varies due to the erratic nature of desert rainfall.

Temperatures in the map area range from over $100^{\circ}F$ ($38^{\circ}C$) in the summer to below $0^{\circ}F$ ($-18^{\circ}C$) in the winter. The yearly average for the region is $56^{\circ}F$ ($13^{\circ}C$) (U.S. Bureau of Land Management, 1978). Temperatures tend to decrease and precipitation increases with increasing elevation.

Winds generally blow from the west and southwest. The highest seasonal wind velocities occur in the spring and early summer.

Principal types of vegetation in the area include grass, sagebrush, pinon, juniper, salt brush and greasewood (U.S. Bureau of Land Management, 1978).

Land Status

The central portion of the main Henry Mountains Known Recoverable Coal Resource Area extends into the northwestern portion of the Southwest Quarter of the Mt. Pennell 15-minute quadrangle; an isolated 760 acre tract of the KRCRA is located in the north-central part of the map area. Thirty-six percent of the map area is considered to be coal bearing. The Federal government owns the coal rights for most lands, as shown on plate 2 of the Coal Resource Occurrence map.

Surface ownership in the quadrangle is entirely public. The Federal government owns 96.5 percent and the state of Utah holds 3.5 percent of the property. Federal lands are supervised by the Bureau of Land Management and National Park Service. No Federal coal leases, prospecting permits or licenses are outstanding in the Southwest Quarter of the Mt. Pennell 15-minute quadrangle.

GENERAL GEOLOGY

Previous Work

John Wesley Powell, one of the first explorers of the region, named the Henry Mountains in 1869 and made some of the first geologic comments on the area (Gilbert, 1877). G. K. Gilbert conducted a study of the Henry Mountains in 1875 and 1876. His report (Gilbert, 1877) is considered one of the classics of geological literature. Gregory and Moore (1931) and later Smith and others (1963) and Davidson (1967) reported on parts of the Waterpocket Fold.

The first investigation of coal resources in the Henry Mountains was undertaken by C. B. Hunt and others who commenced work on the region in 1935, completed field studies in 1939 and published the results in 1953 as U.S. Geological Survey Professional Paper 228. More recently, Henry Mountains coals were studied in detail by Doelling (1972) of the Utah Geological and Mineralogical Survey and Law (1977) of the U.S. Geological Survey. The results of these later investigations provided most of the data used in this coal resource evaluation. Additional publications which describe geologic features in the region are included in the biblography.

Stratigraphy

A sequence of Triassic red beds overlain by Jurassic sandstones with minor shale occupy the southwest quarter of the map area along the Waterpocket Fold and Grand Gulch. The youngest Jurassic unit is the Morrison Formation, a variegated series of clays, shales and sandstones. The Morrison Formation crops out in both the south-center and southeast corner of the map area.

Overlying the Morrison Formation is the Cretaceous Dakota Sandstone, the oldest known coal bearing unit in the Henry Mountains coal field. Above the Dakota Sandstone are the Tununk Shale, Ferron Sandstone, Blue Gate Shale and Emery Sandstone members of the Mancos Shale, all of Cretaceous age. A composite columnar section accompanied by lithologic description on CRO plate 3 illustrates the stratigraphic relationships of the Cretaceous units.

The Dakota Sandstone is the oldest coal bearing unit in the region. It represents a westward trangressing littoral sequence and lies uncomformably atop the Brushy Basin member of the Morrison Formation. The Dakota Sandstone consists of conglomerate, sandstone, arenaceous shale and minor coal (Hunt, Averitt, and Miller, 1953). The formation is an average 100 ft (30 m) thick in the map area. Minor interbeds of gray and carbonaceous shale and coal in the formation reflect local marsh and lagoonal environments. In some places the Dakota Sandstone contains abundant fossil shells and along the Waterpocket Fold is generally known as Oyster Shell Reef (Doelling, 1972). The Dakota Sandstone weathers to form a thin series of ledges and slopes at the base of broad slopes developed upon the overlying Tununk Shale member of the Mancos Shale (Peterson and Ryder, 1975).

The Mancos Shale lies conformably over the Dakota Sandstone and fills the sedimentary basin in this part of the Henry Mountains. Only four of the five members of the Mancos Shale are present in the map area; the uppermost Masuk Shale member has been completely removed by erosion.

The lowermost, Tununk Shale member of the Mancos Shale is gradational and interfingering with the underlying Dakota Sandstone. It is about 955 ft (291 m) thick in the map area and represents a continuation of the first westward transgression of the Cretaceous sea in which the Dakota Sandstone was deposited (Peterson and Ryder, 1975).

The Tununk Shale member is a dark-bluish to greenish-drab, sandy shale with some bentonitic horizons and mostly thin-bedded, medium-grained sandstones. The member is generally poorly exposed and forms smooth broad valleys (Peterson and Ryder, 1975).

The lowest few feet of the Tununk Shale member everywhere contain abundant oysters. A diagnostic bed of fossils containing Gryphaea, Exogyra and Inoceramus occurs roughly 100 feet (30 m) above the base of the member (Hunt, Averitt, and Miller, 1953).

Sandstone becomes more abundant toward the top of the Tununk Shale member where it is transitional with the overlying Ferron Sandstone member. The top of the Tununk Shale member is placed beneath the first thick-bedded or massive sandstone ledge in the transition zone. A regressive sequence, partially the result of deltaic progradation, occurs in the upper part of the Tununk Shale member (Hunt, Averitt, and Miller, 1953).

The first significant coal bearing horizon in the quadrangle, the Ferron Sandstone member of the Mancos Shale, is a regressive unit composed of littoral and coastal plain facies (Doelling, 1972). A lower, littoral unit is characterized by massive, gray to tan, medium-grained sandstone. The upper portion of the member is a coastal plain deposit of lensoidal sandstone, thin shale which is locally carbonaceous, white to brown, medium-grained, massive sandstone, siltstone, shale and coal (Hunt, Averitt, and Miller, 1953). A section of Ferron Sandstone measured by Doelling (1972) in the quadrangle is described as follows:

Section of Ferron Sandstone member measured near The Post, sec. 19, T. 34 S., R. 9 E.

Blue Gate shale member
Ferron Sandstone member

Coal Zone

		Feet
1.	Sandstone, white to light gray medium-grained, massive cliff former........................	8.5
2.	Coal..	0.3
3.	Siltstone, gray with rustry colored bands, sandy, massive slope former........................	7.5
4.	Sandstone, white to light brown, silty with thin seamlets of coal, slope former................	1.8
5.	Coal..	2.8
6.	Shale, dark brown, coaly..	0.7
7.	Coal..	0.8
8.	Shale, gray to black, nonresistant.................	4.5

Middle Unit

9.	Sandstone, tan, medium-grained, massive cliff former.......................................	28.5
10.	Shale, brown, coaly, fissile.......................	0.5
11.	Sandstone, brown, medium-grained, massive cliff former.......................................	31.4
12.	Shale, gray interbedded with thin-bedded, sandstone, light brown, fine-grained...............	3.4
13.	Sandstone, gray to tan, medium-grained, massive cliff former..............................	31.7

Total Ferron Sandstone member.......................... 122.4
Tununk Shale member

The thin white sandstone bed which locally caps the Ferron Sandstone member probably represents a transgressing beach deposit (Hunt, Averitt, and Miller, 1953). In this map area, the Ferron Sandstone member averages 130 ft (40 m) thick.

The Ferron Sandstone member is unconformably overlain by the Blue Gate Shale member. The contact between the Ferron Sandstone and the Blue Gate Shale members is a sharp erosional hiatus. Detailed correlation of sandstone beds in the Ferron Sandstone member sugget 50 to 100 ft (15 to 30 m) or more of the top of the Ferron Sandstone member have been removed at the unconformity in the region (Peterson and Ryder, 1975).

Overlying the erosional unconformity, the Blue Gate Shale member of the Mancos Shale, like the Tununk Shale member, represents a transgressive sequence of marine depositions. It is composed of blue-gray, finely laminated shale with thin beds of shaly sandstone and shaly limestone in the upper one third of the unit (Hunt, Averitt, and Miller, 1953). The member weathers easily to form smooth valleys or broad benches. The lower part is concealed by alluvium in many places, but the upper part is generally well exposed in cliffs that are capped by Emery Sandstone (Peterson and Ryder, 1975).

The average thickness of the Blue Gate Shale member in the Southwest Quarter of the Mt. Pennell quadrangle is 1,100 ft (335 m). The upper contact between the Blue Gate Shale member and the overlying Emery Sandstone member is interfingering and gradational.

The Emery Sandstone member of the Mancos Shale, like the Ferron Sandstone member, represents a period of marine regression (Peterson and Ryder, 1975). The member can be divided into two units. The lowermost unit is a coastal plain facies consisting of thin interbeds of light brown sandstone and gray shale near the base, grading upward into thick-bedded, yellow to brown sandstone with shale partings. Above this is a second coastal plain sequence of gray shale, coal and lenticular sandstone (Doelling, 1972). The average thickness of the Emery Sandstone member in the Southwest Quarter of the Mt. Pennell 15-minute quadrangle is 225 ft (69 m). The member caps Swap Mesa and Cove Point Mesa in the northern portion of the quadrangle and is the youngest consolidated sedimentary unit in the map area.

Structure

The Southwest Quarter of the Mt. Pennell 15-minute quadrangle lies across the axis of the Henry Mountains syncline. Dips immediately west of the syncline axis, ranging around 2 or 3 degrees, are slightly greater than those east of the axis.

The Henry Mountains syncline is paralleled by the Muley Creek anticline in the east-central map area. The effect of the anticline is to accentuate westward dips on its west flank and produce generally horizontal strata to the east.

The most prominent structural feature in the Southwest Quarter of the Mt. Pennell 15-minute quadrangle is the Waterpocket Fold in the southwest map area. The fold is essentially an east dipping monocline separating the Henry Mountains structural basin on the east from the Circle Cliffs uplift to the west. Eastward dips up to 40 degrees or more are not uncommon in strata along the fold. Inclinations decrease gradually eastward into the Henry Mountains Basin.

No faults of any consequence have been mapped in the quadrangle.

Geologic History

Most pre-Cretaceous Mesozoic rocks in this part of the Colorado Plateau are continental in origin. Permian through Jurassic continental deposition was along coastal plains adjacent to principal seaways. The major types of depositional environments that existed during this period were eolian, intertidal mudflats, lacustrine, fluvial and flood plains (Hunt, Averitt, and Miller, 1953).

The Cretaceous history of the Henry Mountains coal field is similar to that of coal fields in central Utah and throughout the Colorado Plateau in general. The region is one in which classic transgressive and regressive sedimentation provided an environment for coal deposition.

During the early Cretaceous, the Henry Mountains region lay on a lowland plain over which neither subsidence nor uplift were occurring. However, sufficient erosion took place to remove lower Cretaceous strata and plane off the top of the Jurassic Morrison Formation.

Subsidence then resumed in the region and fluvial sand and clay were deposited to form the Dakota Sandstone. Broad flood plains with swamps and lakes provided an environment in which vegetation flourished. Resulting accumulations of carbonaceous material formed local, thin coal seams.

In the meantime, as subsidence increased, a sea in which the Mancos Shale was to be deposited began its encroachment from the east. The sea eventually covered all the Henry Mountains region and extended westward to the present-day Wasatch Plateau area. The shoreline remained there throughout Mancos Shale deposition except for two dramatic regressions which deposited the Ferron Sandstone and Emery Sandstone members. Orogenic pulses to the west supplied clastics for these sandstone members faster than the area could subside (Doelling, 1972). Shale deposition changed to nearshore sand and finally to lagoonal and fluvial sand and shale. Forests flourished, dead vegetation accumulated and, in places, coal was produced. All of the thick coal seams in the Henry Mountains Basin were deposited during these two events.

After deposition of the Mancos Shale the Cretaceous sea retreated permanently eastward. Although sedimentation undoubtedly continued in the Henry Mountains region, continental rather than marine beds were deposited and these were later removed by erosion.

According to Hunt and others (1953) the Waterpocket Fold and presumably the Henry Mountains structural basin were formed between the close of Cretaceous time and the Eocene epoch. Undisturbed eocene deposits are found in the basin.

Emplacement of the Henry Mountains intrusives may have occurred anytime after early to mid-Tertiary. Thereafter, the Colorado Plateau began its uplift and erosion instead of deposition dominated. This activity has continued to the present day.

COAL GEOLOGY

The Dakota Sandstone and the Ferron Sandstone, and Emery Sandstone members of the Mancos Shale are coal bearing in the quadrangle. However, Dakota coal has been only spot checked, resulting in a single published measured section containing 5.2 ft (1.6 m) of coal (Dak-1) in section 24, T. 34 S., R. 8 E. Dakota coals are cited as lenticular and containing shale partings where observed (Doelling, 1972).

A single, relatively persistent coal bed occupies most of the Ferron coal zone in the map area. The bed (Fe-1) is exposed along a bench at the south foot of Swap Mesa in the south central map area. It maintains an average thickness of 3.6 ft (1.1 m) with a few rock partings, reaching a maximum of 5.5 ft (1.7 m) in section 29, T. 34 S., R. 9 E. Elsewhere the Ferron coal zone contains one to four coal beds which individually seldom exceed a few feet in thickness.

The Emery Sandstone member bears the thickest coals in the map area, but their occurrence is sporadic, suggesting highly lensoidal seams, and their areal distribution is limited. Most notable are two measured sections containing 8.4 ft (2.6 m) (Em-2) and 9.8 ft (3.0 m) (Em-3) of coal in sections 11 and 14, repectively, T. 34 S., R. 8 E. near the rim on the west side of Swap Mesa. Near the rim on the east side of the mesa three measured sections along a 1,300 ft (394 m) strike length of the Emery coal zone contain an average of 11.6 ft (3.5 m) of coal in seams separated by one foot (30 cm) of shale. Elsewhere in the map area, seams in the Emery Sandstone member are generally less than 3 ft (90 cm) thick and average only 1.5 ft (50 cm).

Chemical Analyses of Coal

No analyses of coal from the map area are available. However, analytical results for four Emery coal samples from the adjacent Northwest Quarter of the Mt. Pennell 15-minute quadrangle were reported by Doelling (1972) (table 1). Analytical results are shown in table 1. These values indicate the coal to be subbituminus A in rank (ASTM, 1966).

Table 1 -- Average proximate analyses of coal samples in percent

	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Btu/lb
1. Outcrop Emery coal bed Sec 2 T.33S., R.9E.	10.48	42.30	49.99	6.3	0.83	11,468
2. Outcrop Emery coal bed Sec. 11, T.33S., R.9E.	11.34	40.65	49.40	9.27	0.49	10,856
3. Outcrop Emery coal bed Sec. 14, T.33S., R.9E.	12.29	41.02	50.91	5.96	0.59	11,147
4. Outcrop Emery coal bed Sec. 11, T.33S., R.9E.	13.70	42.01	49.89	5.30	0.51	11,121
Average	11.95	41.50	50.05	6.72	0.61	11,148

Doelling (1972)

COAL RESOURCES

Data from 41 measured surface sections and surface mapping by Doelling (1972) and Law (1979) were used to construct outcrop, isopach and structure contour maps of coal zones and beds in the map area, (CRO plates 1 through 8).

Coal resources were calculated using data obtained from the coal isopach maps (CRO plates 4 and 7). The coal-bed acreage (measured by planimeter) multiplied by the average isopached thickness of the coal bed times a conversion factor of 1,770 short tons of coal per acre-foot for subbituminous coal yielded the coal resources in short tons of coal for each isopached coal bed. Reserve Base for the Fe-1 and Em-1 through Em-3 coal beds are shown on CRO plates 6 and 9, and are rounded to the nearest 10,000 short tons (9,072 metric tons). Only that coal equal to or thicker than the 5.0 ft (1.5 m) minimum advocated in U.S. Geological Survey Bulletin 1450-B is included in the Reserve Base. Thinner beds presently being mined or for which there is evidence that they could be mined commercially at this time are not included in the Reserve Base calculation. Reserve Base tonnage for all coal beds thicker than 5.0 ft (1.5 m), as shown on CRO plate 2, totals about 14.46 million short tons (13.12 million metric tons). Reserve Base (in short tons) in the various development-potential categories for surface and underground mining methods are shown in tables 2 and 3.

Dames & Moore has not made any determination of economic recoverablity for any of the coal beds in this report.

Isolated Data Points

In instances where isolated measurements of coal beds of Reserve Base thickness (greater than 5 feet or 1.5 meters) are encountered, the standard criteria for construction of isopach, structure contour, mining ratio, and overburden isopach maps are not available. The lack of data concerning these beds limits the extent to which they can be reasonably projected in any direction and usually precludes correlations with other, better known, beds. For this reason, the isolated data point is mapped separately and is shown on figure 2. The isolated point mapped in this quadrangle is listed below.

Source	Location	Coal Bed	Millions Short Tons	Thickness
Doelling (1972)	Section 24 T.34S., R.8E.	Dak-1	1.38	5.2 ft (1.6 m)

▲ ⑲
C 5.2(Dak)[1]

POINT OF MEASUREMENT - Showing thickness of coal, in feet. Includes all points of measurement other than drill holes. Index number refers to hole on plate 1 of CRO map. Letters designate name of coal bed as listed below. Bracketed number identifies coal bed named on plates 1 or 3.

Dak - Dakota coal zone

COAL BED SYMBOL AND NAME - Coal bed identified by bracketed number is not formally named, but is numbered for identification purposes in this quadrangle only.

Dak

TRACE OF COAL ZONE OUTCROP - Showing symbol of name of coal zone as listed above. Arrow points toward coal-bearing area. Dashed where inferred.

SL

STRIPPING-LIMIT LINE - Boundary for surface mining (in this quadrangle, the 100-foot-overburden isopach). Arrow points toward area suitable for surface mining.

A

BOUNDARY OF IDENTIFIED RESERVE BASE COAL - Drawn along the coal bed outcrop, an arc (A) drawn 2,640 feet from the nearest point of Reserve Base coal bed measurement, the PRLA boundary (P), the quadrangle boundary (Q), and the non-Federal coal ownership boundary (N). Arrow points toward area of identified Reserve Base coal.

RB

— (Measured)
— (Indicated)
0.16 (Inferred)

IDENTIFIED COAL RESOURCES - Showing totals for Reserve Base (RB), in millions of short tons, for each section or part(s) of section of non-leased Federal coal land, either within or beyond the stripping-limit. Dash indicates no resources in that category.

To convert short tons to metric tons, multiply short tons by 0.9072.

To convert feet to meters, multiply feet by 0.3048.

SCALE - 1:24,000 (1 inch = 2,000 feet)

FIGURE 1. - Explanation for FIGURE 2.

COAL DEVELOPMENT POTENTIAL

Coal development potential areas are drawn so as to coincide with the boundaries of the smallest legal land subdivisions shown on plate 2. In sections or parts of sections where no land subdivisions have been surveyed by the BLM, approximate 40-acre (16-ha) parcels have been used to show the limits of the high, moderate, or low development potentials. A constraint imposed by the BLM specifies that the highest development potential affecting any part of a 40-acre (16-ha) lot, tract, or parcel be applied to that entire lot, tract, or parcel. For example, if 5 acres (2 ha) within a parcel meet criteria for 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.

Development Potential for Surface Mining Methods

Areas where the coal beds of Reserve Base thickness are overlain by 100 ft (30 m) or less of overburden are considered to have potential for surface mining and were assigned a high, moderate or low development potential based upon the mining ratio (cubic yards of overburden per ton of recoverable coal). The formula used to calculate mining ratios for surface mining of coal is as follows:

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

where MR = mining ratio

t_o = thickness of overburden in feet

t_c = thickness of coal in feet

rf = recovery factor (85 percent for this quadrangle)

cf = conversion factor to yield MR value in terms of cubic yards of overburden per short ~~tons~~ ton of recoverable coal:

0.911 for subbituminous coal

0.896 for bituminous coal

Note: To convert mining ratio to cubic meters of overburden per metric ton of recoverable coal, multiply MR by 0.8428.

Areas of high, moderate and low development potential for surface mining methods are here defined as areas underlain by coal beds having respective mining ratio values of 0 to 10, 10 to 15, and greater than 15. These mining ratio values for each development potential category are based on economic and technological criteria and were provided by the U.S. Geological Survey.

Areas where the coal data are absent or extremely limited between the 100-foot (30-m) overburden line and the outcrop are assigned unknown development potentials for surface mining methods. This applies to those areas where no known coal beds

5 feet (1.5 m) or more thick occur or where coal exceeds 5 feet (1.5 m) but data is insuffcient to properly evaluate coal development potential. Limited knowledge pertaining to the areal distribution, thickness, depth and attitude of the coal beds prevents accurate evaluation of the development potential in the high, moderate or low categories.

The coal development potential for surface mining methods is shown on plate 10. Of the Federal land areas assigned a development potential for surface mining methods, 97 percent are rated high and 3 percent are rated moderate.

Development Potential for Subsurface Mining Methods

Areas considered to have a development potential for conventional subsurface mining methods include those areas where the coal beds of Reserve Base thickness are between 100 and 3,000 ft (30 and 914 m) below the ground surface and have dips of 15° or less. Coal beds lying between 100 and 3,000 ft (30 and 914 m) below the ground surface, dipping greater than 15°, are considered to have a development potential for in-situ mining methods.

Areas of high, moderate and low development potential for subsurface mining methods are defined as areas underlain by coal beds at depths ranging from 100 to 1,000 ft (30 to 305 m), 1,000 to 2,000 ft (305 to 610 m), and 2,000 to 3,000 ft (610 to 914 m), respectively.

Areas where the coal data are absent or extremely limited between 100 and 3,000 feet (30 and 914 m) below the ground surface are assigned unknown development potentials. Even though these areas may contain coal thicker than 5 feet (1.5 m), limited knowledge pertaining to the areal distribution, thickness, depth and attitude of the coal beds prevents accurate evaluation of the development potential in the high, moderate or low categories.

The coal development potential for subsurface mining methods is shown on plate 11. All of the Federal land areas assigned a development potential for conventional subsurface mining methods are assigned a high development potential.

Table 2 -- Coal Reserve Base data for surface mining methods for Federal coal lands (in short tons) in the Southwest Quarter of the Mt. Pennell 15-minute quadrangle, Garfield County, Utah

[Development potentials are based on mining ratios (cubic yards of overburden/ton of underlying coal). To convert short tons to metric tons, multiply by 0.9072; to convert mining ratios in yd^3/ton coal to m^3/t, multiply by 0.842]

Coal bed	High development potential (0-10 mining ratio)	Moderate development potential (10 - 15 mining ratio)	Low development potential (>15 mining ratio)	Unknown development potential	Total
Em-3	2,920,000	1,080,000	190,000		4,190,000
Em-2	500,000	160,000	320,000		980,000
Em-1	2,190,000	310,000	160,000		2,660,000
Fe-1	400,000	130,000	60,000		590,000
Dak-1 isolated data point	---	---	---	720,000	720,000
Total	6,010,000	1,680,000	730,000	720,000	9,140,000

Table 3 -- Coal Reserve Base data for subsurface mining methods for Federal coal lands (in short tons) in the Southwest Quarter of the Mt. Pennell 15-minute quadrangle, Garfield County, Utah.

[To convert short tons to metric tons, multiply by 0.9072]

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Em-3	1,470,000	---	---	---	1,470,000
Em-2	520,000	---	---	---	520,000
Em-1	2,670,000	---	---	---	2,670,000
Fe-1	---	---	---	---	---
Dak-1 isolated data point	---	---	---	660,000	660,000
Total	4,660,000	---	---	660,000	5,320,000

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