COAL RESOURCES OF STATE-OWNED LANDS IN THE MULEY CANYON SANDSTONE MEMBER OF THE MANCOS SHALE, HENRY MOUNTAINS COALFIELD, WAYNE AND GARFIELD COUNTIES, UTAH

by

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EXECUTIVE SUMMARY

This report is an evaluation of the minable coal resources on 22 sections of state-owned land in the Henry Mountains coalfield. The study was done in Geographic Information System (GIS) format and was based on a compilation of existing geologic data from the Utah Geological Survey's (UGS) coal files and published geologic reports.

The 22, mostly non-contiguous sections encompass 14,235.42 acres of land. Twenty-one sections containing 13,595.42 acres are in Garfield County and one section containing 640 acres is in Wayne County. The Henry Mountains coalfield is in a remote part of Utah that has few paved roads and no railroads.

Coal mining activity in the Henry Mountains coalfield was sporadic and occurred, for the most part, between 1895 and the 1950s. A small surface mine near Factory Butte operated in 1978 with limited production. Most of the activity from the late 1960s through early 1980s was limited to exploration for surface-minable resources in the Muley Canyon Sandstone.

The coalfield lies in a structural basin that is bounded on the west by the Waterpocket Fold, and on the east by the Monument upwarp. This north-south elongated basin extends about 50 miles along its axis and is 2 to 18 miles wide. Coal occurs in the Upper Cretaceous Dakota Sandstone and in the overlying Ferron Sandstone and Muley Canyon Sandstone Members of the Cretaceous Mancos Shale. The coals in the Dakota Sandstone are thin, discontinuous, and not considered minable. Likewise, coals in the Ferron Sandstone, while thicker and somewhat more continuous than those in the Dakota, are also considered unminable. Previous studies have determined an in-place coal resource of 684 million tons for the Ferron coal zone. Limited coal-quality data indicate that the coal is high in ash and sulfur.

The Muley Canyon Sandstone contains thicker, more continuous coal measures and is located mostly in the southern half of the coalfield, east of Capitol Reef National Park. This study has determined the total, in-place coal resource of the Muley Canyon Sandstone to be 1.55 billion tons, of which 873 million tons is considered minable. The in-place resource underlying the 22 sections of state-owned land is 153 million tons, of which 94.0 million tons is considered minable. This minable resource consists of 36.0 million tons of surface-minable coal and 58.0 million tons of deep-minable coal.

The surface-minable resource is located primarily at the north and south ends of the Muley Canyon coal zone and the deep-minable resource is near the center of the coal zone. Most of the deep-minable resource lies under 1000 feet of cover and is readily developable. An area of deep-minable coal 6-plus feet thick was delineated that contains about 480 million tons, including 38.6 of the overall 58.0 million tons of deep-minable coal on state-owned lands. The five state-owned sections in this area are not contiguous and do not contain sufficient resources to mine independently. However, the state-owned sections are surrounded by U.S. Bureau of Land Management (BLM) land that, if combined, could contain a sufficiently large enough resource to develop. The deep-minable resource is less defined than the surface-minable resources because of a scarcity of drill hole and sampling data.

The Muley Canyon coal zone has an apparent rank of subbituminous A to high-volatile bituminous C. The minable coal horizon has a median heat content value of 10,200 Btu and a median sulfur content of 0.7%. The moisture and ash contents are highly variable across the coalfield and do not appear to show any distribution pattern.

The Mount Pennell Wilderness Study Area (WSA) encompasses federal lands in the south end of the Muley Canyon coal zone and the Mount Ellen-Blue Hills WSA encompasses federal lands in a large part of the north end of the coal zone. The WSAs are currently managed as wilderness, preventing mechanized access and surface mining. Passage of a Utah wilderness bill by the U.S. Congress could continue to prevent development of the surface-minable coal resource. A wilderness bill could also modify the WSA boundaries, increasing or decreasing the area of the WSAs and their effect on coal development.

INTRODUCTION

Location and Setting

The Henry Mountains coalfield is located in central Wayne and Garfield Counties in a remote area of Utah with few paved roads. State Highway 24 crosses the northern part of the coalfield and is the only paved road in the area. State Highways 24, 95, and 276 parallel the eastern margin of the coalfield and are about 15 miles to the east. The nearest rail line is the Union Pacific line at Green River, a distance of about 60 miles. Access to most of the coalfield is by a network of partly maintained dirt roads.

The Henry Mountains coalfield lies in a structural basin (Henry Mountains syncline) that is bounded on the west by the Waterpocket Fold, and on the east by the Monument upwarp. This north-south elongated basin extends about 50 miles along its axis and is 2 to 18 miles wide (plate 1). The coalfield consists primarily of two coal-bearing units, the Ferron Sandstone Member and the overlying Muley Canyon Sandstone Member of the Cretaceous Mancos Shale. The outcrop of the Ferron Sandstone defines the extent of the coalfield. The Muley Canyon Sandstone, which is about 1000 feet higher stratigraphically, is located mostly in the southern half of the coalfield. The southwestern margin of the coalfield lies within Capital Reef National Park, and the Mt. Ellen-Blue Hills and Mt. Pennell Wilderness Study Areas (WSA) overlie significant parts of the north and south ends of the coalfield.

Background

The evaluation of state-owned lands in the Henry Mountains coalfield is part of the UGS' ongoing, statewide geologic evaluation of the mineral potential of state-owned lands managed by the Utah School and Institutional Trust Lands Administration (SITLA). The UGS has long cooperated with SITLA on developing Utah's energy and mineral resources. During the past four years, the UGS has systematically evaluated mineral resources on state-owned land. The initial section-by-section evaluation phase of the project was completed in fall 2003. The current phase of the project consists of more detailed county, commodity, area specific, and large land

block evaluations. The Henry Mountains evaluation is the second of SITLA's coal holdings to be evaluated in detail.

Purpose and Scope

The purpose of this study is to compile all known information on the economic geology of the coals in the Muley Canyon Sandstone in the Henry Mountains coalfield into a report with attached maps and associated GIS data. The data have been interpreted and integrated into a discussion of resources, history of exploration and development, and economic potential.

Methodology

This study includes a compilation of mineral and geologic data from the UGS' Utah Mineral Occurrence System (UMOS) and coal files, and from other UGS published and unpublished sources. The coal resource evaluation for the Henry Mountains coalfield was completed in GIS format using the Spatial Analyst extension in ESRI, Inc.'s ArcView® and includes about 120 data points from the UGS' coal data bank.

Previous Work

Early reconnaissance surveys included the first descriptions of the geology and coal deposits of the Henry Mountains region (Gilbert, 1877). The first detailed study of the coal deposits of the Henry Mountains coalfield was conducted in the mid- to late 1930s by the U.S. Geological Survey (USGS) (Hunt and others, 1953). Doelling (1972) provided a detailed evaluation of the coalfield resources as part of his comprehensive study of the coal deposits of Utah. New information prompted Doelling (1975) and Doelling and Smith (1982) to revise earlier coal resource estimates and to provide more details on the surface-minable resources of the field. McKell and others (1978) summarized the baseline data on the coal deposits and rehabilitation potential of coal lands in the coalfield for the BLM. Law (1977, 1979a, 1979b, 1980) reported on the results of USGS drilling and fieldwork in the coal zone of the Emery Sandstone Member of the Mancos Shale (herein called the Muley Canyon Sandstone Member), and he concluded that tectonic and sedimentological controls caused the thickest coals in this unit to be deposited along the synclinal axis of the Henry Mountains basin. Hatch and others (1979) provided coal-quality data for the Ferron and Emery Sandstone (Muley Canyon Sandstone) Members. Tabet (1999, 2000) provided an updated coal resource assessment and a simplified geologic map of the Henry Mountains coalfield from parts of four regional maps by various authors. This study builds on the work of previous investigators and includes outcrop studies carried out by the UGS during the late-1980s and recently released coal company drilling and coal-quality data.

Mining History

Four groups of mines have operated in the Henry Mountains coalfield (plate 2). All are closed and abandoned. Total production from all mines is estimated to have been about 110,000 tons. Two groups of mines at opposite ends of the field were opened in Ferron coals. To the south the Stanton mines were opened to supply fuel for gold dredges on the Colorado River. At the north end of the field near Factory Butte, underground coal was mined intermittently from

1908 to the 1950s supplying local ranchers and residents of Wayne County. A second mine (surface) near Factory Butte operated in 1978. Two other mines were opened in Muley Canyon (referred to as the Emery by Doelling, 1972) coal west of Mt. Ellen and operated in the late 1940s. The coal also supplied residents of Wayne County. The mines and their locations are as follows:

Mine (Coal zone)	Location	Remarks
Factory Butte mines (Ferron)	section 11, T. 27 S., R. 9 E. section 2, T. 27 S., R. 9 E.	Intermittent 1908-1950s 1978 (estimated production- 100,000 tons)
Dugout Creek mines (Muley Canyon)	section 7, T. 31 S., R. 9 E.	Active in 1940s
Sweetwater Creek mine (Muley Canyon)	section 30, T. 31 S., R. 9 E.	Activity unknown
Stanton mines (Ferron)	section 36, T. 34 S., R. 10 E.	Active 1895-1900

Post-Mining Activity

A resurgence of coal exploration activity occurred during the late 1960s through early 1980s as a rush to develop new coal resources was fueled by an impending national "energy crisis." Several companies were active in the Henry Mountains coalfield and most of the data used in this evaluation was acquired during that time. Exploration on federal and state-owned lands in the Muley Canyon coal zone was carried out by AMAX Coal Company, Cayman Corporation, Consolidation Coal Company, Gulf Mineral Resources Company, and the USGS. Primary interest at the time was evaluating surface-minable coal deposits, but environmental and economic concerns and limitations eventually caused all prospecting areas to be dropped (Tabet, 2000).

The availability of the exploration data (over 100 drill holes), from the combined efforts of all the parties active in the 1960s, 1970s, and 1980s has allowed the delineation of a large amount of deep Muley Canyon coal resources. Deep resources could be mined with less surface disturbance than the originally anticipated surface mines, although mining costs would be higher.

Exploration and Development on State-Owned Lands

Approximately 9719 acres of state mineral leases in the Henry Mountains coalfield were held by Consolidation Coal Company in the late 1960s. Consolidation Coal drilled 28 wells in late 1968 to early 1969. Several of the wells were cored for coal samples and tested. Some of the state leases were relinquished in 1969, and the remainder in 1970. In 1977, Gulf Mineral Resources drilled six wells to test Muley Canyon coals on five sections of state-owned lands they had under lease. There has been no additional exploration activity on state-owned lands in

the Muley Canyon Sandstone since that time and there has been no development of Muley Canyon coal resources on state-owned lands in the Henry Mountains coalfield.

Description of State-Owned Lands in the Muley Canyon Coal Zone

Twenty-two sections of state-owned land containing 14,235.42 acres lie within the Muley Canyon coal zone. These sections are described as follows:

T. 30 S., R. 8 E., Salt Lake Base Line and Meridian
section 36, (640 acres)

T. 31 S., R. 8 E., Salt Lake Base Line and Meridian
sections 2 (887.40 acres), 16 (640 acres), and 36 (640 acres)

T. 31 S., R. 9 E., Salt Lake Base Line and Meridian
sections 16 (640 acres), and 32 (minerals only) (640 acres)

T. 32 S., R. 8 E., Salt Lake Base Line and Meridian
sections 2 (640.72 acres), 16 (640 acres), and 36 (640 acres)

T. 32 S., R. 9 E., Salt Lake Base Line and Meridian
sections 2 (640.40 acres), 16 (minerals only) (640 acres), 32 (640 acres), and 36 (640 acres)

T. 32 S., R. 10 E., Salt Lake Base Line and Meridian
section 32, (640 acres)

T. 33 S., R. 8 E., Salt Lake Base Line and Meridian
sections 2 (542.64 acres), and 36 (640 acres)

T. 33 S., R. 9 E., Salt Lake Base Line and Meridian
sections 2 (639.20 acres), 16 (640 acres), 32 (640 acres), and 36 (640 acres)

T. 34 S., R. 8 E., Salt Lake Base Line and Meridian
section 2 (640.40 acres)

T. 34 S., R. 9 E., Salt Lake Base Line and Meridian
section 16 (640 acres)

GEOLOGIC SETTING

Upper Cretaceous coal-bearing strata of the Henry Mountains coalfield are preserved in a structural basin, the Henry Mountains syncline. The syncline is bounded on the west by the Waterpocket Fold and on the east by the Monument upwarp. The Henry Mountains syncline forms a north-south elongated basin that extends about 50 miles along its axis and is 2 to 18

miles wide. The Henry Mountains lie along the eastern margin of the central and southern parts of the coalfield. An east to west cross section of the Henry Mountains basin is shown in figure 1, and the location is shown on plate 2.

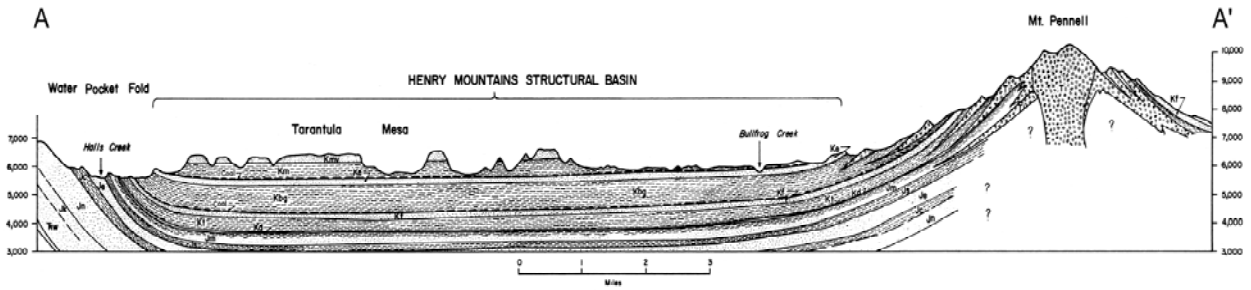

Figure 1. Idealized cross section of the Henry Mountains structural basin (modified from Doelling, 1972).

Coals are contained in the Dakota Sandstone and in the overlying Ferron Sandstone and Muley Canyon Sandstone Members of the Mancos Shale. The coals in the Dakota Sandstone are thin, discontinuous, and not considered minable. Coals in the Ferron Sandstone, while locally thicker are discontinuous and have limited mineability. Coals in the Muley Canyon Sandstone are thicker, more continuous, and have the greatest amount of potentially minable resources (Doelling, 1972).

Dakota Sandstone

The Dakota Sandstone is the basal Upper Cretaceous unit, and lies unconformably on older rocks (Peterson and others, 1980). It consists of a lower continental part of conglomeratic sandstone interbedded with carbonaceous mudstone and local thin beds of coal, and an upper marine part of fossiliferous, thin-bedded sandstone. The Dakota attains a maximum thickness of 92 feet (Hunt and others, 1953) with an average thickness of 35 feet (Peterson and others, 1980). The formation is thickest in the southwestern part of the Henry Mountains coalfield and is thin and locally missing in the northern part of the coalfield. Coal beds in the Dakota are discontinuous and rarely exceed 2 feet in thickness (Tabet, 2000).

Geology of the Mancos Shale

The nomenclature of the Upper Cretaceous Mancos Shale in the Henry Mountains coalfield is problematic, and numerous revisions have been suggested. The presently available maps of the area depict the Mancos Shale as composed of five members. In ascending order, they are the Tununk, Ferron Sandstone, Blue Gate, Muley Canyon Sandstone, and Masuk Members (Smith, 1983). Descriptions of these units are taken primarily from regional work of Peterson and others (1980), who consider each of these units a "distinct, mappable entity that probably should be considered a separate formation." A typical stratigraphic section of the Dakota through Tarantula Mesa Sandstone sequence is shown in figure 2.

Tununk Member

The Tununk conformably overlies the Dakota Sandstone and has a measured thickness from outcrop and drill holes ranging from 532 to 717 feet. The Tununk generally thickens toward the north. Lithologically, the unit is composed primarily of gray, bentonitic, calcareous shale, but near the base and top it is yellowish-gray to greenish-gray mudstone, siltstone, and very fine-grained sandstone (Tabet, 2000).

Ferron Sandstone Member

The Ferron Sandstone conformably overlies the Tununk and consists of 205 to 395 feet of interbedded sandstone, shale, mudstone, and coal. According to Peterson and others (1980), the lower part of the Ferron consists of thin-bedded sandstone and shale at the base that grade upward to thick, cliff-forming sandstone at the top. This part of the Ferron averages 197 feet thick and ranges from 130 to 305 feet thick. The lower part of the Ferron interfingers with the Tununk and the contact rises stratigraphically to the northeast.

The upper part of the Ferron is described by Peterson and others (1980) as a 15 to 205-foot-thick (average 110 feet) unit of interbedded lenticular sandstone, carbonaceous mudstone, and coal. The sandstones are lenticular, channel-shaped bodies that are generally less than 40 feet thick. As many as five coal beds, some of minable thickness, are present in the upper part of the Ferron. The depositional environment of the upper part was a system of meandering distributary channels and associated overbank flood-plain deposits (Peterson and others, 1980).

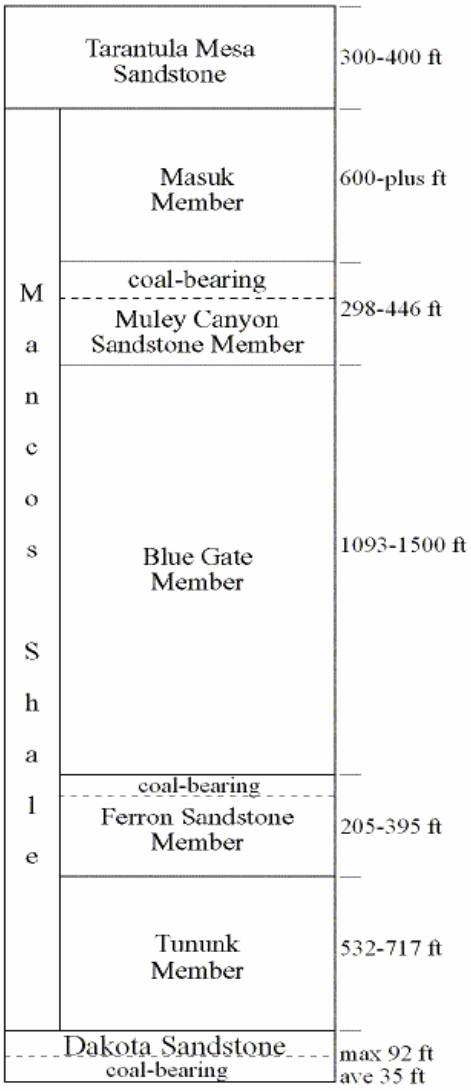

Figure 2. Composite stratigraphic section of the Upper Cretaceous Dakota – Tarantula Mesa Sandstone sequence in the Henry Mountains coalfield (modified from Smith, 1983).

Blue Gate Member

The Blue Gate unconformably overlies the Ferron. Although lithologically similar to the Tununk, the Blue Gate is much thicker, averaging 1280 feet (Peterson and others, 1980). The Blue Gate ranges in thickness from 1093 to 1500 feet and the member thickens northward. The upper 250-foot transition zone with the overlying Muley Canyon Member consists of interbedded yellowish- or greenish-gray mudstone, siltstone, and very fine-grained sandstone (Tabet, 2000).

Muley Canyon Sandstone Member

The Muley Canyon Sandstone Member ranges in thickness from 298 to 446 feet thick (Peterson and others, 1980). The lower part of the Muley Canyon Sandstone is a massive sandstone ranging in thickness from 131 to 307 feet and consists of very fine- to medium-grained sandstone that is laminated to thin bedded or cross-stratified. The top of this lower part is commonly a clean, white, low-angle, cross-laminated sandstone (a "white cap"). Locally, in the vicinity of Wildcat Mesa, tidal channel sandstones have been identified that are scoured into the top of the lower part of the Muley Canyon Sandstone (Law, 1980). This unit was deposited in a regressive nearshore and shoreline marine environment.

The upper part of the Muley Canyon Sandstone is more heterogeneous lithologically than the lower part and consists of lenticular sandstones and interbedded carbonaceous mudstone and coal. This part ranges in thickness from 92 to 209 feet and contains three to ten coal beds. This coal zone contains the thickest and most persistent coal beds in the Henry Mountains coalfield. The upper part of the Muley Canyon Sandstone was deposited in fluvial and tidal coastal-plain environments (Law, 1980).

Masuk Member

The Masuk Member conformably overlies the Muley Canyon Sandstone Member. Peterson and others (1980) reported that the gradational transition between the two members has made it difficult to pick a consistent marker horizon for the contact. The 600-plus feet of Masuk strata (Peterson and others, 1980) consists of two-thirds light-green mudstone with thin discontinuous lenses of carbonaceous mudstone or gray limestone, and one-third thin-bedded, ripple- or cross-laminated sandstone. The sandstones in the Masuk tend to have scoured bases and consist of fining-upward cycles. The mudstones and sandstones are typical of well-drained flood-plain and meandering-stream deposits. Fossils recovered from the Masuk support the interpretation of a freshwater, continental environment (Peterson and others, 1980).

Tarantula Mesa Sandstone

The Tarantula Mesa Sandstone has a gradational contact with the underlying Masuk Member of the Mancos Shale. It is a gray or brown cliff-forming sandstone that is preserved only in the central portions of the Henry Mountains basin on the top of Tarantula Mesa and on a few isolated surrounding mesas. Only a few sections of these strata have been measured, and thicknesses range from 300 to 400 feet (Peterson and others, 1980). The Tarantula Mesa Sandstone is composed of seemingly continuous sandstones formed from laterally migrated, discrete, stacked channel sands. According to Peterson and others (1980), these continuous-appearing sandstones contain very light gray or brown, fine-grained sandstone with local pebbles of chert, quartzite, and petrified wood.

The upper part of the Tarantula Mesa Sandstone is more conglomeratic and exhibits less planar bedding surfaces and more scouring between beds. The lithology and sedimentary structures of the Tarantula Mesa Sandstone point to a highly meandering or braided fluvial environment of deposition (Peterson and others, 1980).

Younger Beds on Tarantula Mesa

Erosional remnants of younger Cretaceous strata are locally preserved on the top of Tarantula Mesa. Fossils reported by Eaton (1990) indicate a Campanian age. Only 36 to 100 feet of these beds is preserved, with the thickest deposits located on the western part of the mesa (Peterson and others, 1980). These strata are not well exposed because they are commonly capped by a veneer of Quaternary gravel and wind-blown sand. Where exposed, they consist of 75% yellowish- to greenish-gray mudstone with several carbonaceous lenses containing fossil plant fragments and 25% light- to dark-brown, very fine- to fine-grained sandstone. This unit is interpreted to have been deposited in a flood-plain environment (Peterson and others, 1980).

COAL GEOLOGY

A thorough discussion of the coal resources of the Ferron Sandstone and Muley Canyon Sandstone coals in the Henry Mountains coalfield is presented in UGS Open-File Report 362, "Coal Resources of the Henry Mountains Coalfield" (Tabet, 1999) and U.S. Geological Survey Professional Paper 1625-B, Chapter R, "Coal Resources of the Henry Mountains Coal Field, Utah" (Tabet, 2000). The geologic description of the Ferron Sandstone and Muley Canyon Sandstone and the coal data pertaining to the Muley Canyon Sandstone in Professional Paper 1625-B are the basis for the Muley Canyon Sandstone coal resource evaluation in this report. A discussion of the Ferron Sandstone is included to present an overall geologic description of the Henry Mountains coalfield.

Thickness and Geometry of Ferron Sandstone Coal

The coals in the Ferron Sandstone Member of the Mancos Shale occur in the upper 110 feet of the nonmarine part of the unit. The coal beds are generally in a 50-foot-thick zone immediately above the lower marine part of the Ferron. The coal interval contains one to five beds that have an aggregate thickness of as much as 16.5 feet. Individual beds seldom exceed 4 feet in thickness and commonly average 1 to 3 feet.

The areal distribution is patchy, with isolated east-west-elongated pods present at scattered locations across the Henry Mountains basin. The pods are approximately 1 to 5 miles wide and from 3 to 10 miles long (figure 3). Although the coal-thickness data come primarily from the margins of the coalfield, it appears that the coal is best developed in three widely separated areas in the northern, central, and southern parts of the coalfield. The coal in the central area is more speculative than the other two areas because it relies heavily on data from only one deep oil and gas well.

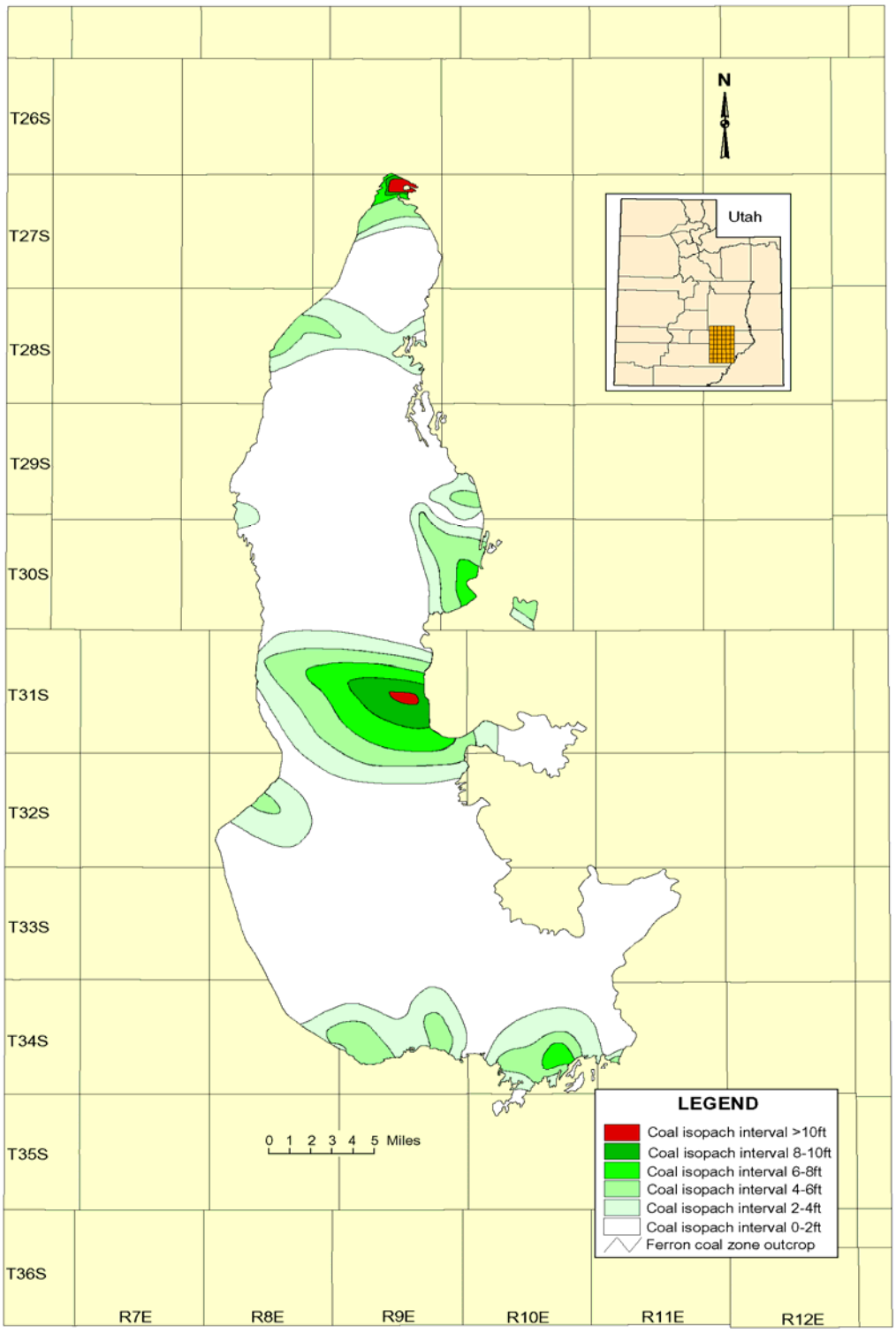

Figure 3. Isopach map of the Ferron Sandstone coal zone (from Tabet, 2000).

Depth to Ferron Coal Zone

The coal in the Ferron Sandstone Member generally occurs in the upper part, but in many places throughout the field there is no coal. The top of the Ferron is exposed around the margins of the Henry Mountains basin, and it reaches a maximum depth of slightly more than 2000 feet in an area of several square miles that lies beneath the highest portions of Tarantula Mesa in the central part of the basin. Thus, all the Ferron coal deposits of the Henry Mountains coalfield that are thick enough to mine occur at potentially minable depths.

Ferron Coal Quality

Only four coal-sample analyses from the Ferron coals have been published for the Henry Mountains coalfield (Doelling, 1972; Hatch and others, 1979). These coals have an apparent rank of high-volatile C bituminous. The four samples come from the northern (three samples) and southern (one sample) edges of the field. The mean analytical values indicate high ash (14.5%) and sulfur (2.5%) contents.

Coal Resources of the Ferron Sandstone

Tabet (2000) in his analysis of the Ferron coal zone calculated an in-place resource of 684 million tons, of which about three-quarters lies in Garfield County. Because of limited exploration data, only 27%, or 187 million tons of the total resource falls in the demonstrated resource category (occurring within 0.75 mile of a thickness-measurement point). The bulk of the coal resource (67%) falls in the inferred resource category (occurring at least 0.75 mile to 3 miles from a thickness-measurement point). Only a few percent of the resource lies more than 3 miles from a thickness-measurement point, or in the hypothetical category. Because of the lenticular nature of the coals and the lack of adequate drill-hole data, no minable coal resource was determined for the Ferron Sandstone. The in-place resource is field wide and no attempt was made to segregate the Ferron coal resource on state-owned lands.

Thickness and Geometry of the Muley Canyon Coal Zone

The Muley Canyon coal zone covers an area of approximately 82,943 acres mostly in the southern half of the Henry Mountains coalfield (plate 1). The coal zone lies in an area approximately 20 miles long and 10 miles wide and coal measures are well exposed along outcrops in most parts of the coal zone. Large areas of shallow, flat-lying coal are present in the northern and southern parts of the coal zone. Field measurements by Doelling (1972) show the Emery Sandstone (Muley Canyon Sandstone of this report) to be nearly flat lying along its western perimeter, with dips averaging less than 5°. Along the eastern margin of the coalfield in the vicinity of Mount Ellen the beds dip westward at an average of 30°.

The upper part of the Muley Canyon Sandstone Member is a nonmarine, coal-bearing interval with thicknesses ranging from 92 to 209 feet and averaging about 120 feet. This stratigraphic interval, referred to as the Muley Canyon coal zone in this report, commonly contains 3 to 4 coal beds, but locally has as many as 10 beds. Individual coal beds range in thickness from 0 to 15.0 feet and are commonly 2 to 5 feet thick. The aggregate thickness of

coal is as much as 27.5 feet. Most of the coal zone has at least 5 feet of total coal, and about half of the area has 10 feet or more of total coal.

The coal zone is thickest in elongate pods oriented in an east-west direction that tend to be thicker on the west side of the Henry Mountains basin and thin gradually to the east**.** The largest thick pod of coal lies in the center of the basin, as is the case with the Ferron coals.

Muley Canyon Minable Coal Quality

The Muley Canyon coal zone has an apparent rank of subbituminous A to high-volatile bituminous C (Hatch and others, 1979; Law, 1980), a slightly lower rank than the Ferron coals that translates to a lower heat content and higher moisture content. The heat content of the minable coal horizon ranges from a low of 7710 Btu to a high of 11,468 Btu, and has a median value of 10,200 Btu. The sulfur content of the minable coal horizon ranges from a low of 0.4% to a high of 2.8%, and has a median value of 0.7%. Sulfur values do not appear to show any pattern of distribution. For example, the sample locations with the highest and lowest sulfur values are within a half mile of each other. Similarly, moisture and ash values vary widely and do not show any continuity.

The coal beds in the Muley Canyon coal zone have been sampled more extensively than those in the Ferron. The coal samples come primarily from the northern and southern ends of the Muley Canyon coal zone where there is shallow cover and not from the deeper, central area. Coal analyses for the entire Muley Canyon coal zone include data from 7 outcrop samples and 30 drill cores. Coal analyses for the minable portion of the coal zone include data from 19 of the 30 drill holes and 1 outcrop sample. Plate 3 shows the location of sample points and coal-quality values for the Muley Canyon minable coal zone and table 1 contains the coal-quality analyses for each sample location. Figure 4 contains histograms of coal-quality parameters that show the variability and distribution of moisture, ash, sulfur, and Btu contents of the minable coal zone.

The distribution of sample points is very irregular across the Muley Canyon coal zone because the exploration emphasis was to determine the surface-minable resource. As a result, almost all of the coal-quality sampling was done in areas of shallow cover, leaving the majority of the deep resource untested.

Depth to Muley Canyon Minable Coal Horizon

Broad areas of the minable coal horizon in the Muley Canyon coal zone at the northern and southern ends of the unit's exposure are less than 100 feet deep (plate 4). Thus, some of the thicker coal beds under parts of Stephens Mesa, Wildcat Mesa, Cave Flat, and Swap Mesa are potentially surface minable (plate 2). The thickest, more extensive, deep-minable coal lies under Tarantula Mesa and reaches a maximum depth of slightly more than 1000 feet.

Table 1. Coal-quality analyses for the Muley Canyon minable coal zone.

DH-No.	Sample thickness (ft)	Moisture (%)	*VM (%)	*FC (%)	Ash (%)	Sulfur (%)	Btu/lb
EMRIA-1	2.7	13.0	35.0	37.7	14.3	0.70	9670
EMRIA-15	6.8	11.6	36.6	42.7	9.1	0.60	10620
EMRIA-15	6.1	10.3	36.0	36.3	17.4	0.70	9400
EMRIA-2	3.3	12.1	37.1	41.4	9.4	0.40	10660
EMRIA-3	5.8	12.5	33.6	35.7	18.2	0.70	9300
EMRIA-4	5.4	12.5	34.6	39.3	13.6	0.50	9990
EMRIA-5	2.0	11.6	35.4	36.3	16.7	2.80	9610
EMRIA-9	6.0	11.5	35.3	40.3	12.9	0.80	10110
H-101	2.5	13.6	32.6	39.3	14.5	0.80	9597
H-307	0.8	13.5	34.5	43.6	8.5	0.83	10660
H-308	2.1	13.3	36.2	39.3	11.1	1.05	*
H-312	4.2	13.3	36.4	43.4	6.0	0.67	11010
H-332	4.6	14.4	35.6	45.5	4.5	1.09	10759
HM-19	7.0	13.5	32.0	35.7	18.8	0.66	9015
HM-20	4.9	13.9	34.4	41.3	10.4	0.53	10204
HM-22	6.8	10.5	38.3	45.3	6.0	0.78	11468
HM-25	9.1	11.3	36.1	43.9	8.7	0.46	10856
HM-26	7.8	12.3	36.7	45.5	5.6	0.55	11147
HM-28	8.2	13.7	37.2	44.2	4.9	0.47	11121
MP-3	0.8	14.7	27.4	30.6	27.3	0.40	7710
O 31-9-30	10.6	11.5	38.5	40.8	7.7	1.50	*

Note: VM=volatile matter, FC=fixed carbon
* reported values were outside the computed Btu value range based on a combination of moisture and ash content.

COAL RESOURCES AND DEVELOPMENT POTENTIAL

Resource Calculation Methods

Values for the areal extent and thickness of each coal bed in the Muley Canyon coal zone were entered into a spreadsheet where the coal tonnage was calculated using a density value of 1800 tons per acre-foot of coal (Wood and others, 1983). The minable coal horizon was selected from the thicker, more continuous part of the coal zone and consists of, for the most part, a single-seam thickness without partings. Both total in-place coal resources and minable coal resources were determined field wide and by section for state-owned lands. The data for state-owned lands are shown in the appendix.

The data set for the Muley Canyon coal zone consists of 106 drill holes and 12 measured sections. Seam correlation was not possible over the entire resource area because of the scarcity of data over much of the deeper part of the resource and the apparent lenticular nature of the coal beds.

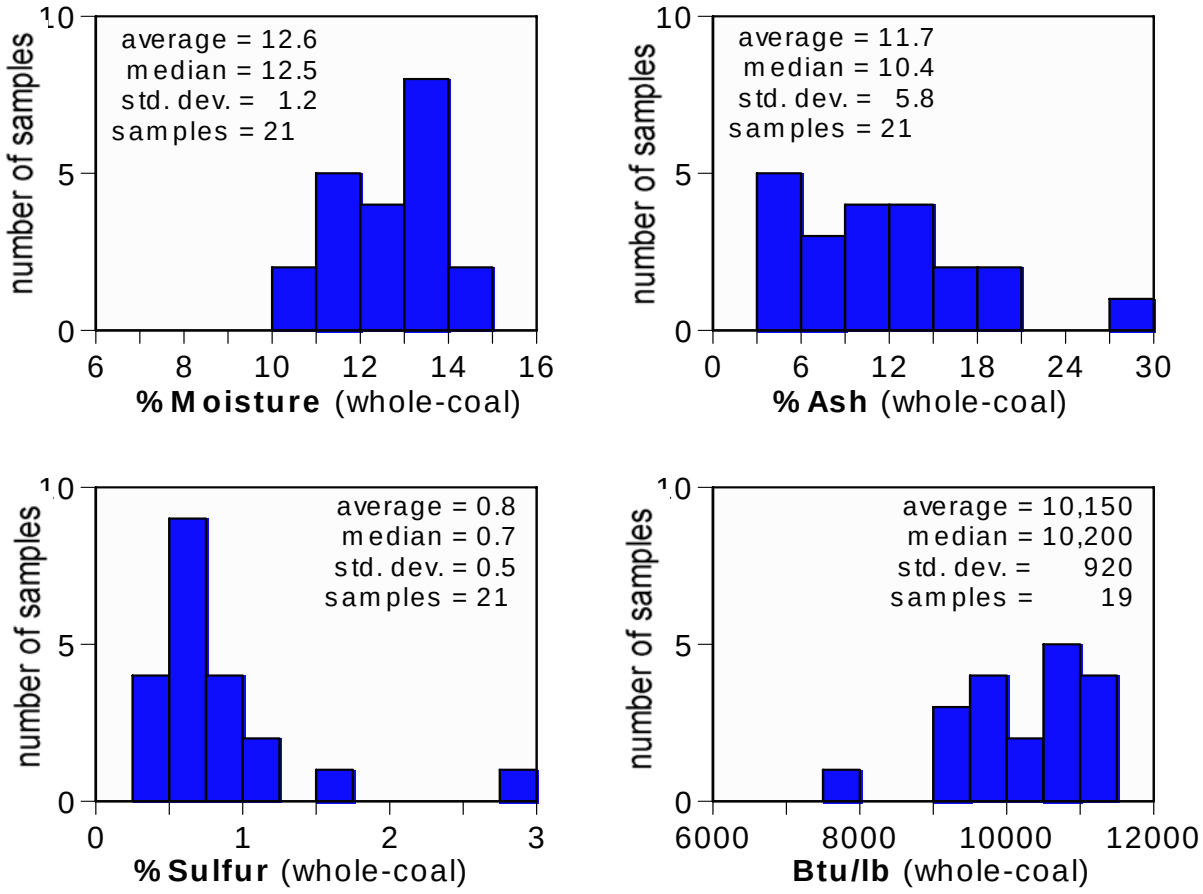

Figure 4. Frequency histograms and summary statistics showing ash, sulfur, moisture, and Btu values for the Muley Canyon minable coal zone. The histograms show the absolute frequency distribution of data records (one data record equals one count). Data are modified from Tabet (2000).

Creating Maps Using ArcView

Maps showing coal-bed depth (plate 4) and thickness (plate 5) were created from drill hole and measured section data using the Spatial Analyst (v.1.1) extension for ESRI's ArcView® (v.3.2) software. The intersection of the coal bed elevation and surface elevation defines the coal bed outcrop.

Resource Classification

The U.S. Geological Survey (USGS) (Wood and others, 1983) narrowly defines a coal reserve as coal that can be economically produced at the time of determination, whereas a coal resource is broadly defined to include coal for which economic extraction is potentially feasible. In this study, we did not rigorously consider coal-production costs, the percent of the in-ground coal that can be recovered, or other factors required to estimate the coal reserve. Instead, we identified a subset of the in-place coal resource, which we call the minable coal resource.

Coal Resources of the Muley Canyon Sandstone

The in-place coal resources were determined based on a minimum coal thickness of 1 foot and minable coal resources were determined based on a minimum coal thickness of 2 feet. In-place resources were determined for each state-owned section by overburden interval, but were not subdivided by thickness interval. Minable coal resources on state-owned sections were aggregated by coal-thickness intervals of 2 to 4, 4 to 6, 6 to 8, 8 to 10, and 10-plus feet (appendix). Minable coal resources were also aggregated by depth-of-overburden intervals of 0 to 100, 100 to 1000, and 1000-plus feet, field wide and for each state-owned section. Plate 4 maps the overburden thickness for the minable coal resource and plate 5 maps the thickness intervals of minable coal resources. No comparable maps were made for the in-place coal resource.

The Muley Canyon Sandstone contains an in-place coal resource of 1.55 billion tons and a minable coal resource of 868 million tons. Approximately 224 million tons are surface minable and 644 million tons are deep-minable resources. The amount of in-place coal on state-owned lands is about 153 million tons, of which 94 million tons is classified as minable. The remainder of the minable resource (774 million tons) is distributed between federal and private ownership with the majority being federal.

Approximately 38% of the minable resource on state-owned lands has an overburden interval of 0 to 100 feet, and is presumably surface minable. About 49% of the minable resource has 100 to 1000 feet of overburden, and 13% of the minable resource has 1000-plus feet of overburden. The maximum overburden depth of 1036 feet is at Tarantula Mesa. The relatively shallow overburden allows access to all of the deep-minable resources. The distribution of in-place and minable coal resources by depth of overburden field wide and on state-owned lands is as follows:

Muley Canyon coal zone (resource in millions of short tons)

Overburden interval	In-place resource	Minable resource
0 to 100 feet	460.3	224.1
100 to 1000 feet	1,040.8	612.2
1000-plus feet	50.6	32.0
Total	1,551.7	868.3

State-owned lands (resource in millions of short tons)

Overburden interval	In-place resource	Minable resource
0 to 100 feet	63.0	36.0
100 to 1000 feet	71.3	46.2
1000-plus feet	18.7	11.8
Total	153.0	94.0

Coal Development Potential

Overview

The Muley Canyon coal zone covers approximately 82,943 acres including all or parts of the 22 sections of state-owned land totaling 14,235.42 acres. Minable coal resources by section range from a low of 356,000 tons in section 2, T. 32 S., R. 9 E. to a high of 14.3 million tons in section 36, T. 32 S., R. 8 E. (appendix). Surface-minable resources are on 18 of the 22 sections. Seven of the 18 sections are at the north end of the Muley Canyon coal zone, six sections are at the southern end, and five sections are on either the east or west side of the coal zone near its center. Four sections that contain only deep-minable resources are located near the center of the coal zone.

Thicker, deep-minable resources are located near the center of the field. An area designated the primary area of deep-minable coal has been outlined that contains coal that is 6-plus feet in thickness. This area encompasses 26,790 acres and includes all or parts of five state-owned sections that contain 38.6 million tons of deep-minable coal.

The economic viability of mining any of the coal resources in the Henry Mountains coalfield south of State Highway 24, including all of the Muley Canyon Sandstone coal, is diminished by the location and size of WSAs and the proximity of Capitol Reef National Park (plate 2).

Surface-Minable Resources

The Muley Canyon coal zone contains a surface-minable resource (a resource with up to 100 feet of overburden) of about 224 million tons including 36.0 million tons (16%) on 18 sections of state-owned lands (plate 4). The surface-minable coal is located primarily at the north and south ends of the coal zone. In general, the coals are thinner and more lenticular than in the center of the coal zone. The north end of the coal zone can be accessed by an existing network of dirt roads extending south of State Highway 24 east of Capitol Reef National Park. The surface-minable coal in the south end of the coal zone can be accessed by a network of dirt roads that extend west of State Highway 276.

The development potential of the surface-minable resource appears to be limited. The two major constraints are the location of WSAs that overlie most of the surface-minable resources in the north and south parts of the Muley Canyon coal zone, and the BLM's designation of federal lands in the same areas as unsuitable for surface mining. State-owned lands are not included in the WSAs and thus are eligible for surface mining.

The Mount Ellen-Blue Hills WSA overlies most of the northern surface-minable resource and the Mount Pennell WSA overlies all of the southern surface-minable resource (plates 1 and 2). Although it may take years to make a final Wilderness designation for either WSA, the lands must be maintained in their current undisturbed state. As part of the re-evaluation of the WSAs, the Richfield Field Office has proposed revisions to both WSAs. According to SITLA, the

proposed revisions do not appear to make any significant changes within the Muley Canyon coal zone (John Blake, written communication, December 2004).

The determination of areas unsuitable for surface mining was done in conjunction with revision of the BLM's Management Framework Plan for the Henry Mountains Planning Area. The unsuitability study was done in October 1981 and the Management Framework Plan was completed in 1982. The BLM's Richfield Field Office is preparing a new Resource Management Plan (RMP) that includes the former Henry Mountains Planning Area. According to announcements posted on the Richfield Resource Management Plan website, <www.richfieldrmp.com>, the complete, final EIS and the proposed RMP are scheduled to be released in spring 2005, and the complete Record of Decision and the RMP will be released in summer 2005.

Deep-Minable Resources

The total, deep-minable coal resource, with more than 100 feet of overburden, for the Muley Canyon coal zone is 646 million tons, of which 58.0 million tons (9%) is on state-owned lands. The thicker coal (6-plus feet) lies in the center of the Muley Canyon coal zone. This area is referred to as the primary area of deep-minable coal (plate 5). The minable coal zone in the primary area ranges in thickness from 6 to 15 feet. The minable resource for the primary area is 480 million tons including 38.6 million tons (8%) on five sections of state-owned lands. Three of the five state-owned sections contain coal that is 8-plus feet thick (plate 5). The three state-owned sections are surrounded by BLM land that, if combined, could contain a sufficiently large enough resource to develop. Two other state-owned sections are located along the eastern margin of the primary area and contain only a small amount of deep-minable coal that is 6-plus feet thick. However, the two sections are useful as each one provides outcrop access and the potential for mine development facilities.

The development potential for deep coal is less constrained than the surface-minable resource, but will be subject to limitations on access and site development imposed by the proximity of the WSAs and Capitol Reef National Park. Access to the west side of the primary area of deep-minable coal may not be possible because of the proximity of Capitol Reef National Park (plate 1). Access to the east side of the primary area is through an east-west corridor extending west of State Highway 24 between the Bull Mountain WSA to the north and the Mount Pennell WSA to the south (plate 1).

RECOMMENDATIONS FOR FURTHER EVALUATION

The Muley Canyon Sandstone contains a large resource of surface-minable and deep-minable coal. Exploration drilling for surface-minable coal has outlined significant, potentially economic resources in the north and south ends of the coal zone. Substantially larger resources of deep-minable coal are located near the center of the coal zone in an area referred to as the primary area of deep-minable coal. Drill hole and other data in the primary area of deep-minable coal is scarce, and coal-quality data are limited to one location in the primary area and several additional locations near the south perimeter of the primary area. State-owned lands within the

primary area are, for the most part, not contiguous and do not contain sufficient resources to mine independently.

To fill in data gaps, I recommend that additional drilling and sampling be done on the five state-owned sections in the primary area of deep-minable coal. Following that, the data should be integrated with the current GIS data and a new coal resource study should be undertaken for the primary area. Additional drill-hole and coal-quality data should allow for a more detailed analysis of the minable coal zone including mapping of thickness and quality. Strata above and below the minable coal zone should be sampled to evaluate roof and floor stability. The new resource study should also include the possible locations of mine entries and facilities, access routes, and electrical infrastructure. The new study should also include the selection of federal lands within the primary area that might be acquired to "block out" a minable coal reserve.

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APPENDIX

In-place and minable coal resources of state-owned lands in the Muley Canyon coal zone in the Henry Mountains coalfield. Tons are reported in thousands.

			MINABLE TONS			
TRACT	**TOTAL ACRES**	**COAL ACRES**	**0-100 FT**	**100-1000 FT**	**1000+ FT**	**TOTAL**
T. 30 S., R. 8 E.						
SECTION 36	640.00	47.01				
2-4 FT			0	0	0	0
4-6 FT			0	0	0	0
6-8 FT			0	0	0	0
8-10 FT			778	0	0	778
10 FT+			0	0	0	0
TOTAL MINABLE COAL			778	0	0	**778**
TOTAL IN-PLACE COAL			1124	0	0	**1124**
T. 31 S., R. 8 E.						
SECTION 2	887.40	592.43				
2-4 FT			0	0	0	0
4-6 FT			791	0	0	791
6-8 FT			3845	0	0	3845
8-10 FT			2778	0	0	2778
10 FT +			520	0	0	520
TOTAL MINABLE COAL			7934	0	0	**7934**
TOTAL IN-PLACE COAL			13424	0	0	**13424**
SECTION 16	640.00	50.93				
2-4 FT			0	0	0	0
4-6 FT			140	32	0	172
6-8 FT			460	14	0	474
8-10 FT			0	0	0	0
10 FT +			0	0	0	0
TOTAL MINABLE COAL			600	46	0	**646**
TOTAL IN-PLACE COAL			1086	75	0	**1161**
SECTION 36	640.00	640.00				
2-4 FT			537	918	0	1455
4-6 FT			763	1509	0	2272
6-8 FT			572	1068	0	1640
8-10 FT			0	162	0	162
10 FT +			0	0	0	0
TOTAL MINABLE COAL			1872	3657	0	**5529**
TOTAL IN-PLACE COAL			2664	5915	0	**8579**
T. 31 S., R. 9 E.						
SECTION 16	645.06	610.39				
2-4 FT			3089	222	0	3311
4-6 FT			0	0	0	0
6-8 FT			0	0	0	0
8-10 FT			0	0	0	0
10 FT +			0	0	0	0
TOTAL MINABLE COAL			3089	222	0	**3311**
TOTAL IN-PLACE COAL			5708	576	0	**6284**
SECTION 32	640.00	640.00				
2-4 FT			207	3252	0	
4-6 FT			0	0	0	
6-8 FT			0	0	0	
8-10 FT			0	0	0	
10 FT +			0	0	0	
TOTAL MINABLE COAL			207	3252	0	**3459**
TOTAL IN-PLACE COAL			207	4190	0	**4397**
T. 32 S., R. 8 E.						
SECTION 2	640.72	595.95				
2-4 FT			148	2222	0	2370
4-6 FT			1039	334	0	1373

6-8 FT			146	0	0	146
8-10 FT			0	0	0	0
10 FT +			0	0	0	0
TOTAL MINABLE COAL			1333	2556	0	**3889**
TOTAL IN-PLACE COAL			2658	8439	0	**11097**
SECTION 16	640.00	91.00				
2-4 FT			0	0	0	0
4-6 FT			783	0	0	783
6-8 FT			0	0	0	0
8-10 FT			0	0	0	0
10 FT +			0	0	0	0
TOTAL MINABLE COAL			783	0	0	**783**
TOTAL IN-PLACE COAL			2348	0	0	**2348**
SECTION 36	640.00	640.00				
2-4 FT			0	0	0	0
4-6 FT			0	0	0	0
6-8 FT			0	0	0	0
8-10 FT			0	0	0	0
10 FT +			0	9144	5152	14296
TOTAL MINABLE COAL			0	9144	5152	**14296**
TOTAL IN-PLACE COAL			0	14234	8058	**22292**
T. 32 S., R. 9 E.						
SECTION 2	640.00	65.94				
2-4 FT			303	53	0	356
4-6 FT			0	0	0	0
6-8 FT			0	0	0	0
8-10 FT			0	0	0	0
10 FT +			0	0	0	0
TOTAL MINABLE COAL			303	53	0	**356**
TOTAL IN-PLACE COAL			303	53	0	**356**
SECTION 16	640.00	640.00				
2-4 FT			0	275	0	**275**
4-6 FT			0	5378	0	**5378**
6-8 FT			0	0	0	**0**
8-10 FT			0	0	0	**0**
10 FT +			0	0	0	**0**
TOTAL MINABLE COAL			0	5653	0	**5653**
TOTAL IN-PLACE COAL			0	5927	0	**5927**
SECTION 32	640.00	640.00				
2-4 FT			0	0	0	0
4-6 FT			0	0	0	0
6-8 FT			0	0	0	0
8-10 FT			0	3271	854	4125
10 FT +			0	7354	662	8016
TOTAL MINABLE COAL			0	10625	1516	**12141**
TOTAL IN-PLACE COAL			0	15415	2308	**17723**
SECTION 36	640.00	467.50				
2-4 FT			0	0	0	0
4-6 FT			3044	1155	0	4199
6-8 FT			0	70	0	70
8-10 FT			0	0	0	0
10 FT +			0	0	0	0
TOTAL MINABLE COAL			3044	1225	0	**4269**
TOTAL IN-PLACE COAL			5191	1990	0	**7181**
T 32 S., R. 10 E.						
SECTION 32	640.00	71.69				
2-4 FT			0	0	0	0
4-6 FT			628	0	0	628
6-8 FT			0	0	0	0
8-10 FT			0	0	0	0
10 FT +			0	0	0	0
TOTAL MINABLE COAL			628	0	0	**628**
TOTAL IN-PLACE COAL			1383	0	0	**1383**
T. 33 S., R. 8 E.						
SECTION 2	542.64	542.64				
2-4 FT			0	0	0	0
4-6 FT			0	0	0	0

6-8 FT			0	0	0	0
8-10 FT			0	2227	3931	6158
10 FT +			0	2018	1224	3242
TOTAL MINABLE COAL			0	4245	5155	**9400**
TOTAL IN-PLACE COAL			0	6741	8326	**15067**
SECTION 36	640.00	453.30				
2-4 FT			2168	0	0	2168
4-6 FT			362	0	0	362
6-8 FT			0	0	0	0
8-10 FT			0	0	0	0
10 FT +			0	0	0	0
TOTAL MINABLE COAL			2530	0	0	**2530**
TOTAL IN-PLACE COAL			6169	0	0	**6169**
T. 33 S., R. 9 E.						
SECTION 2	639.20	634.31				
2-4 FT			0	0	0	0
4-6 FT			1765	8	0	1773
6-8 FT			2923	2261	0	5184
8-10 FT			0	400	0	400
10 FT +			0	0	0	0
TOTAL MINABLE COAL			4688	2669	0	**7357**
TOTAL IN-PLACE COAL			5454	3372	0	**8826**
SECTION 16	640.00	623.31				
2-4 FT			1375	1878	0	3253
4-6 FT			0	142	0	142
6-8 FT			0	0	0	0
8-10 FT			0	0	0	0
10 FT +			0	0	0	0
TOTAL MINABLE COAL			1375	2020	0	**3395**
TOTAL IN-PLACE COAL			2292	3305	0	**5597**
SECTION 32	640.00	355.27				
2-4 FT			778	322	0	1100
4-6 FT			913	480	0	1393
6-8 FT			0	0	0	0
8-10 FT			0	0	0	0
10 FT +			0	0	0	0
TOTAL MINABLE COAL			1691	802	0	**2493**
TOTAL IN-PLACE COAL			2423	1113	0	**3536**
SECTION 36	640.00	105.27				
2-4 FT			533	0	0	533
4-6 FT			54	0	0	54
6-8 FT			0	0	0	0
8-10 FT			0	0	0	0
10 FT +			0	0	0	0
TOTAL MINABLE COAL			587	0	0	**587**
TOTAL IN-PLACE COAL			943	0	0	**943**
T. 34 S., R. 8 E.						
SECTION 2	640.40	395.52				
2-4 FT			0	0	0	0
4-6 FT			3541	0	0	3541
6-8 FT			0	0	0	0
8-10 FT			0	0	0	0
10 FT +			0	0	0	0
TOTAL MINABLE COAL			3541	0	0	**3541**
TOTAL IN-PLACE COAL			7835	0	0	**7835**
T. 34 S., R. 9 E.						
SECTION 16	640.00	183.65				
2-4 FT			892	0	0	892
4-6 FT			178	0	0	178
6-8 FT			0	0	0	0
8-10 FT			0	0	0	0
10 FT +			0	0	0	0
TOTAL MINABLE COAL			1070	0	0	**1070**
TOTAL IN-PLACE COAL			1792	0	0	**1792**
TOTAL MINABLE COAL BY INTERVAL						

2-4 FT			10030	9142	0	19172
4-6 FT			14001	9038	0	23039
6-8 FT			7946	3413	0	11359
8-10 FT			3556	6060	4785	14401
10+ FT			520	18516	7038	26074
GRAND TOTAL MINABLE COAL	14,235.42	9,086.11	36,053	46,169	11,823	**94,045**
GRAND TOTAL IN-PLACE COAL			63,004	71,345	18,692	**153,041**