UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to Accompany:

COAL RESOURCE OCCURRENCE MAP COAL DEVELOPMENT POTENTIAL MAP OF THE DUNN CENTER NW QUADRANGLE, DUNN COUNTY, NORTH DAKOTA

[Report includes 33 plates]

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This report has not been edited for conformity with U.S. Geological Survey editorial standards or stratigraphic nomenclature.

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INTRODUCTION

The occurrence, extent, and preliminary geologic evaluation of coal beds in the Dunn Center NW quadrangle in west-central North Dakota are described in this report. Subsurface data consisting of oil and gas well and exploration drill hole logs and surface data comprised of measured sections are presented on the Coal Data Map and Coal Data Sheet, Plates 1 and 3, respectively. Federal ownership of coal, total Reserve Base, and Hypothetical Resources of coal by section are presented on the Boundary and Coal Data Map, Plate 2. Derivative maps, which consist of coal isopachs, structure contours, overburden/interburden isopachs, mining ratios, reserve categories, and Reserves and Reserve Base, have been compiled for each coal seam of reserve base thickness underlying the quadrangle and are presented on Plates 4 through 32, respectively. A Coal Development Potential Map for surface mining is presented on Plate 33.

This work has been performed under contract with the Conservation Division of the U.S. Geological Survey (Contract No. 14-08-0001-17118).

The resource information gathered in this program is in response to the Federal Coal Leasing Amendments Act of 1975 and is a part of the U.S. Geological Survey's (USGS) coal program.

This information is intended to provide basic data on coal resources for land-use planning purposes by the Bureau of Land Management, state and local governments, and the public.

LOCATION

The Dunn Center NW 7 1/2 minute quadrangle is located in northern Dunn County, North Dakota about 36 miles (57.9 km) north of Dickinson and 35 miles (56.3 km) southeast of Wetford City.

ACCESSIBILITY

The area is accessible by county road to State Highway 22, one and a half miles (2.4 km) to the west. State Highway 22 connects with Interstate 94 at Dickinson, 32 miles (51.5 km) to the south.

The Burlington Northern Railroad operates and maintains an east-west route which extends through Halliday, Dunn Center, and Killdeer, in the southern-most portion of the quadrangle.

PHYSIOGRAPHY

The quadrangle lies in the central portion of a large topographic high known as the Missouri Plateau which is being dissected by the Knife, Heart, Cannonball, and Cedar Creek Rivers. In the eastern portion of the plateau the topography is generally hilly, and along the Missouri River there are bluffs 500-600 feet (152-183 m) high. The western part of the

Missouri Plateau is characterized by more irregular topography than that which prevails throughout the remainder of the plateau. This area, known collectively as "The Badlands", comprises an intricate maze of narrow ravines, sharp crested ridges, and pinnacles.

The Dunn Center NW quadrangle may be characterized as gently rolling to hilly in the southern half of the quadrangle, but it is heavily dissected by stream drainage in the north half of the quadrangle. Jim and Corral Creeks, the major drainages of the area, are intermittent streams flowing west to east in the northern portion of the quadrangle. The maximum relief across the quadrangle of Dunn Center NW is 450 feet (137.2 m).

The vegetation is mixed prairie grasses, and some of the land is cultivated.

CLIMATE

North Dakota's climate may be characterized as semi-arid; the average annual precipitation is 17 inches (43.2 cm) at Dunn Center, which is located 2 miles (3.2 km) south of the quadrangle.

Maximum precipitation occurs during late spring and early summer with slightly over half the total annual precipitation occurring during May, June, and July. Although the mean annual temperature is about 40°F (4.4°C), temperatures as recorded at

the Dunn Center weather station by the U.S. Department of Commerce can range from 102°F (38.9°C) in summer months to -25°F (-31.7°C) in winter months. The prevailing northerly winds increase in velocity during the colder months of November through March.

LAND STATUS

The quadrangle lies in the western one-half of the Knife River Known Recoverable Coal Resource Area (KRCRA). The Federal Government owns the coal rights to approximately 40 percent of the quadrangle.

PREVIOUS WORK

This report has drawn on a number of basic data reports on the coal occurrences in the Knife River KRCRA, including: Law (1977), Benson (1953), and United States Geological Survey (USGS) and North Dakota Geological Survey (NDGS) (1976, 1977). Ground water basic data reports in the Knife River area were also used, including: Croft (1970) and Klausing (1971, 1974, 1976).

METHOD OF STUDY

Lithologic and geophysical logs from 16 drill holes provided the basic data for this study. The most important sources of data were Electric Log Services (1977), Klausing (1976), Law (1977), United States Geological Survey and North

Dakota Geological Survey (1976). The quality of the available coal information is variable. Lithologic and geophysical logs from exploration holes drilled by the North Dakota Geological Survey, North Dakota State Water Commission, and private coal companies generally provide the most detailed and reliable subsurface data. Lithologic logs of private water wells are somewhat less detailed and less reliable, but they provide usable information in some cases. Where the data for a specific coal bed appear to be inaccurate or inconsistent with surrounding drill hole data, they were not included in the data base that was used for construction of derivative maps for that coal bed. For instance, in some drill holes, where coal intervals were not noted and the data appeared anomalous in relation to data from adjacent drill holes, rather than plot a zero coal thickness, the coal bed was assumed to be laterally extensive. Many coal splits were not mapped because of inconsistent data that did not allow projection of split thicknesses with reasonable reliability or accuracy. Where the data base was sufficient to justify the projection of coal parting thicknesses, and both of the coal seams are greater than reserve base thickness, interburden isopach maps were constructed.

Drill hole data and projected coal outcrop traces from previous investigations (Law, 1977) were plotted on the Coal

Data Map, Plate 1. These outcrop data were then modified in accordance with structural trends in the present mapping. It was assumed that all beds extended to the surface, although it is known that thick alluvial, colluvial, and glacial materials are sometimes locally present. Subsurface information was used to construct correlation diagrams of coal beds (Coal Data Sheet, Plate 3). Correlation diagrams for the Dunn Center NW quadrangle and the adjoining Lake Ilo, Mandaree SW , Oakdale, and Dunn Center NE quadrangles were then integrated and coal structure contours, coal thickness isopachs, overburden, interburden isopachs, and mining ratio maps were constructed for coal beds of reserve base thickness (5 feet minimum) (Plates 4 through 32).

GEOLOGY

STRATIGRAPHY

The oldest rocks present in the uppermost 1000 feet (305 m) the stratigraphic section in the Dunn Center NW quadrangle are the Ludlow-Cannonball, and the coal-bearing Tongue River, and Sentinel Butte members of the Paleocene age Fort Union Formation (Rehbein, 1977). Sandstones, siltstones and shales of this formation are locally mantled by erosional remnants of the Upper Paleocene-Lower Eocene Golden Valley Formation, and by Quaternary glacial, eolian, and alluvial deposits.

Fort Union Formation - Paleocene.

Ludlow-Cannonball member - these sediments underlie but do not crop out in the study area. The Cannonball is the youngest known marine strata in the northern Great Plains region. Where it has been measured in the vicinity, it is about 350 feet (107 m) thick and consists of shale and thin-bedded sandstone which thins and interfingers to the west with the time-equivalent continental deposited Ludlow.

Tongue River member - this member ranges in thickness from 350 to 900 feet (107 to 274 m) and consists of an alternating sequence of fluvially deposited sandstone, siltstone, shale, and lignite. It conformably overlies the marine Cannonball member and the time-equivalent, nonmarine Ludlow member. The Tongue River member is similar to the overlying Sentinel Butte member and in places cannot be distinguished from it. The contact between the Tongue River and Sentinel Butte members, which has been arbitrarily set at the top of the HT Butte lignite, is conformable.

Sentinel Butte member - this member averages 500 feet (152 m) in thickness and consists of alternating sequences of fluvially deposited sandstone, siltstone, shale, carbonaceous shale, and lignite. In general, the sandstones are fine grained and poorly cemented. Shales range from soft, plastic,

clay to moderately indurated claystone. Locally, there are thin, calcareous or silicious concretions. Shales and siltstones readily break down and form gentle slopes beneath the sandstone ledges.

Golden Valley Formation - Eocene.

This formation consists of about 200 feet (61 m) of alternating shales, siltstones, and crossbedded sandstones. These sediments, which comformably overlie the Sentinel Butte member, have been eroded away in much of the study area.

Channel Deposits - Pleistocene.

Sand and gravel channel deposits of indeterminate thickness lie beneath alluvial deposits. These deposits underlie early Wisconsinan glacial till and Quaternary alluvium in the area.

Glacial Till - Pleistocene.

The glacial till is a heterogeneous mixture of clay, silt, sand, gravel, cobbles, and boulders which was deposited during Wisconsinan episodes of continental glaciation.

Eolian Deposits - Pleistocene and Recent.

Unconsolidated dune and loess-like deposits, from several inches to more than five feet thick, mantle most of the study area. The loess-like deposits consist of silty clays, clayey silt, and silty to clayey sands and are probably of late Pleistocene to Recent age. Recent dunes, consisting of silts

and very fine-grained uniform sand, have been deposited on the lee side of knobs and ridges.

Alluvium - Recent.

Alluvium consisting of clay, silt, sand, and gravel mantles valley floors in the study area.

DEPOSITIONAL ENVIRONMENTS OF THE LIGNITES

Many of the Ludlow member lignites are of small areal extent, display lenticularity and are interbedded with distributary channels indicative of deposition in a delta plain.

The thinner Ludlow lignites are laterally more extensive than the lenticular beds; there is evidence of them having been deposited on the plains of abandoned delta lobes (Rehbein, 1977).

The Tongue River lignites differ from the Ludlow lignites of deltaic origin in that they are thicker and laterally more extensive. The HT Butte bed at the top of the Tongue River Formation can be traced over thousands of square miles. The lignite beds of the Tongue River member, in contrast to the Ludlow lignites, were formed in large swamps adjacent to fluvial channels (Rehbein, 1977).

The Sentinel Butte lignites, though fewer in number, are almost as continuous as the Tongue River lignites and had a similar depositional environment.

STRUCTURE

Regionally, the Knife River KRCRA is located on the southeastern flank of the Williston Basin, approximately 60 miles (97 km) from the basin center. Generally, the sedimentary units are flat lying or gently undulating, with a northward to northeastward regional dip ranging from less than 10 feet per mile (1.9 m per km) to 180 feet per mile (34 m per km). Upper strata have been warped into a gentle syncline with a northeast to southwest trending axis located approximately 10 miles (16 km) east of the town of Dodge. The dips on the flanks of the syncline are approximately 18 feet per mile (3.4 m per km). The coal beds, as mapped within this quadrangle, show minor structural variations from the regional structural framework. More definitive descriptions of the structural aspects of the coal seams may be found in the "Coal Geology" section which follows. Major faulting has not been observed in the area (Menge, 1977). Surficial materials generally mask most of the older stratigraphic units, making it difficult to assess the importance of minor faulting.

COAL GEOLOGY

Seven major coal beds and several local coal beds are either mapped at the surface or identified in the subsurface in this quadrangle. The H Lignite coal bed is stratigraphically

the lowest recognized coal bed. It is successively overlain by non-coal bearing rocks approximately 255 feet (77.7 m) thick; the Garner Creek coal bed; a sequence of rocks approximately 200 feet (61.0 m) thick which contain one local coal bed (Local 5, a local bed correlatable between several quadrangles); the Meyer coal bed; a sequence of rocks approximately 50 feet (15.2 m) thick which contains one local bed; the HT Butte coal bed; a sequence of rock approximately 180 feet (54.9 m) thick which contains two local coal beds (a local bed and Local 4, a local coal bed correlatable between several quadrangles); the Hazen coal bed; a sequence of rocks which average 60 feet (18.3 m) thick and include one local coal bed (Local 3, a local coal bed correlatable between several quadrangles); the Beulah-Zap coal bed; a sequence of rocks which average 70 feet (21.3 m) thick which contain one local coal bed; and the Schoolhouse coal bed, which is overlain by non-coal bearing rocks and a number of local coal beds and Local 1 coal bed (which is correlatable between adjacent quadrangles). Table 1 shows the coal bed names and their stratigraphic position.

The coal beds of the Fort Union Formation in the Knife River area are lignite in rank and contain 0.4 to 1.2 percent sulfur, less than 10 percent ash, and between 5910 and 7330 BTU/lb (Table A-1). Coal analyses indicate that these coals have less than or about the same amount of trace elements as

Table 1 -- Coal Bed Names and Stratigraphic Position

Bed Name	Stratigraphic Equivalent
Local 1	
↑ 45 ft ↓	
Schoolhouse	Otter Creek
↑ 35 ft ↓	
Local 2	
↑ 35 ft ↓	
Beulah-Zap	Dunn Center, Herman
↑ 25 ft ↓	
Local 3	
↑ 35 ft ↓	
Hazen	Spear, Hazen "B", Kruckenberg, Red Butte
↑ 110 ft ↓	
Local 4	
↑ 70 ft ↓	
HT Butte	Hazen "A", Garrison Creek, Yeager, Hagel, Berg, Keuther, Stanton
↑ 50 ft ↓	
Meyer	
↑ 75 ft ↓	
Local 5	
↑ 125 ft ↓	
Garner Creek	
↑ 255 ft ↓	
H-Lignite	

coal beds in other areas of the northern Great Plains coal province (Tables A-2 through A-5).

H LIGNITE COAL BED

The lowest mapped coal bed, the H Lignite, does not crop out in the Dunn Center NW quadrangle. Based upon data from one drill hole in the quadrangle and projections from adjacent quadrangles, it is assumed that the H Lignite dips north at 25 feet per mile (4.7 m per km) as shown on Plate 4.

The thickness of the bed ranges from 8 feet (2.4 m) to 14 feet (4.3 m), and the bed increases in thickness from north to south as shown on Plate 4. The overburden ranges in thickness from 700 feet (213.4 m) to 1,100 feet (335.3 m) as shown on Plate 4.

Chemical Analyses of the H Lignite Coal Bed - No proximate or elemental analyses of the H Lignite coal bed have been found in the literature. It is assumed, however, that the quality of the coal is comparable to that of the other coal beds of the Fort Union Formation and is lignite in rank.

GARNER CREEK COAL BED

The Garner Creek coal bed overlies the H Lignite coal bed and is separated from the H Lignite coal bed by approximately 270 feet (82.3 m) of rock. Records of two drill holes penetrating the Garner Creek coal bed in this quadrangle were

found. Based upon these records and projections from adjacent quadrangles, it is assumed that the Garner Creek coal bed dips west at approximately 15 feet per mile (2.8 m per km) as shown on Plate 6.

The thickness of the bed ranges from 4 feet (1.2 m) to 21 feet (6.4 m), with the thickness increasing from east to west as shown on Plate 7. The overburden ranges from 400 feet (121.9 m) to 900 feet (274.3 m) thick, as shown on Plate 6.

Chemical Analyses of the Garner Creek Coal - No known proximate and elemental analyses of the Garner Creek coal have been found in the literature; however, it is assumed that the coal is comparable to that of other coal beds in the Fort Union Formation and is lignite in rank.

LOCAL 5 COAL BED

The Local 5 coal bed overlies the Garner Creek Coal bed. It is separated from the Garner Creek coal bed by approximately 120 feet (36.6 m) of rock. Due to local thinning of the bed, Local 5 does not occur under all the quadrangle. Records of three drill holes penetrating the Local 5 coal bed in this quadrangle were found. The Local 5 coal bed dips northeast at approximately 40 feet per mile (7.5 m per km) as shown on Plate 9.

The thickness of the bed ranges from 3 feet (0.9 m) to 10 feet (3.0 m), with the thickness increasing from west to east

as shown on Plate 9. The overburden ranges from 250 feet (76.2 m) to 700 feet (213.4 m) thick, as shown on Plate 9.

Chemical Analyses of the Local 5 Coal

No known proximate and elemental analyses of the Local 5 coal have been found in the literature; however, it is assumed, that the coal is similar to other coal beds in the Fort Union Formation and is lignite in rank.

MEYER COAL BED

The Meyer coal bed overlies the Local 5 coal bed and the Garner Creek coal bed. It is separated from the Local 5 coal bed by approximately 70 feet (21.3 m) of rock and is separated from the Garner Creek coal bed by approximately 200 feet (61.0 m) of rock and coal. Records of three drill holes penetrating the Meyer coal bed in this quadrangle were found. The Meyer coal bed dips to the west-center of the quadrangle at approximately 10 feet per mile (1.9 m per km) as shown on Plate 11.

The thickness of the bed ranges from 0 feet (0.0 m) to 8 feet (2.4 m), with the thickness increasing from south to north as shown on Plate 12. The overburden ranges from 150 feet (45.7 m) to 600 feet (182.9 m) thick, as shown on Plate 11.

Chemical Analyses of the Meyer Coal

No proximate and elemental analyses of the Meyer coal have

been found in the literature. It is assumed, however, that the quality of the coal is similar to other coal beds in the Fort Union Formation and is lignite in rank.

HT BUTTE COAL BED

The HT Butte coal bed overlies the Meyer coal bed. It is separated from the Meyer coal bed by approximately 50 feet (15.2 m) of rock. Records of seven drill holes penetrating the HT Butte coal bed in this quadrangle were found. The coal bed dips toward the northeast corner at approximately 7 feet per mile (1.3 m per km) to 60 feet per mile (11.3 m per km) as shown on Plate 14.

The thickness of the bed bed ranges from 5 feet (1.5 m) to 17 feet (5.2 m) with the thickness generally increasing from southwest to northwest as shown on Plate 15. The overburden ranges from 100 feet (30.5 m) to 550 feet (167.6 m) thick, as shown on Plate 14. The interburden ranges from 11 feet (3.4 m) to 21 feet (6.4 m) thick, as shown on Plate 14.

Chemical Analyses of the HT Butte Coal - Several proximate and elemental analyses of the HT Butte coal bed are presented in Tables A-1 and A-2, respectively. Analysis of coal samples from the Center quadrangle indicate the following: ash content varies between 4.9 and 5.9 percent; sulfur content varies between 0.5 and 0.7 percent; and BTU/lb varies between 6970 and 7150. These data show that the HT Butte coal is lignite in rank.

LOCAL 4 COAL BED

The Local 4 coal bed overlies the HT Butte coal bed. It is separated from the HT Butte coal bed by approximately 70 feet (21.3 m) of rock. Records of three drill holes penetrating the Local 4 coal bed in this quadrangle were found. The Local 4 coal bed dips northwest at approximately 20 feet per mile (3.8 m per km) as shown on Plate 18.

The thickness of the bed ranges from 2 feet (0.6 m) to 10 feet (3.0 m), with the thickness increasing from northeast to southwest, as shown on Plate 19. The overburden ranges from 50 feet (15.2 m) to 500 feet (152.4 m) thick, as shown on Plate 18.

Chemical Analyses of the Local 4 Coal - No proximate and elemental analyses of the Local 4 coal have been found in the literature. It is assumed, however, that the coal is similar to other coal beds in the Fort Union Formation and is lignite in rank.

HAZEN COAL BED

The Hazen coal bed overlies the Local 4 coal bed and the HT Butte coal bed. It is separated from the Local 4 coal bed by approximately 100 feet (30.5 m) of rock and is separated from the HT Butte coal bed by approximately 180 feet (54.9 m)

of rock and coal. The Hazen coal bed underlies approximately 90 percent of the quadrangle. In the remainder of the quadrangle the Hazen coal bed has been removed by erosion. Records of four drill holes penetrating the Hazen coal bed in this quadrangle were found. The Hazen coal bed dips north at approximately 28 feet per mile (5.3 m per km) as shown on Plate 21.

The coal thickness ranges from 3 feet (.91 m) to 15 feet (4.6 m), with the thickness increasing from south to north, as shown on Plate 22, and has one parting which is 9 feet (2.7 m) thick. The overburden ranges from 0 feet (0 m) to 400 feet (121.9 m) thick, as shown on Plate 21.

Chemical Analyses of the Hazen Coal

Only one chemical analysis of the Hazen coal bed from within the KRCRA is available (Table A-1). Analysis of the coal sample indicates the following: ash content is approximately 4.2 percent; sulfur content is approximately 0.5 percent; and the BTU/lb is approximately 6290. Two elemental analyses are given in Table A-3. All are from the same locality near Center in Oliver County. The Hazen coal bed is lignite in rank.

LOCAL 3 COAL BED

The Local 3 coal bed overlies the Hazen coal bed and is separated from the Hazen coal bed by approximately 35 feet

(10.7 m) of rock. The Local 3 coal bed underlies approximately 60 percent of the quadrangle. In the remainder of the quadrangle the Local 3 coal bed has been removed by erosion or has thinned out. Records of three drill holes penetrating the Local 3 coal bed in this quadrangle were found. The Local 3 coal bed dips north at approximately 26 feet per mile (4.9 m per km) as shown on Plate 24.

The coal thickness ranges from 5 feet (1.5 m) to 10 feet (3.0 m), with the thickness increasing from north to south, as shown on Plate 25. The overburden ranges from 100 feet (30.5 m) to 300 feet (91.4 m) thick, as shown on Plate 24.

Chemical Analyses of the Local 3 Coal - No proximate and elemental analyses of the Local 3 coal are available; it is assumed, however, that the coal is similar to other coal beds in the Fort Union Formation and is lignite in rank.

BEULAH-ZAP COAL BED

The Beulah-Zap coal bed overlies the Local 3 coal bed and the Hazen coal bed. It is separated from the Local 3 coal bed by approximtely 20 feet (6.1 m) of rock and is separated from the Hazen coal bed by approximately 60 feet (18.3 m) of rock and coal. The Beulah-Zap coal bed underlies approximately 85 percent of the quadrangle. In the remainder of the quadrangle the Beulah-Zap coal bed has been removed by erosion. Records of eight drill holes penetrating the Beulah-Zap coal bed in

this quadrangle were found. The Beulah-Zap coal bed dips toward the center of the quadrangle at approximately 55 feet per mile (10.3 m per km) as shown on Plate 27.

The bed ranges in thickness from 3 feet (0.9 m) to 16 feet (4.9 m), with the thickness increasing from the south-center outward, as shown on Plate 28. The overburden ranges from 0 feet (0 m) to 300 feet (91.4 m) thick, as shown on Plate 27. The interburden ranges from 5 feet (1.5 m) to 17 feet (5.2 m) thick, as shown on Plate 27.

Chemical Analyses of the Beulah-Zap Coal - Several proximate and elemental analyses of the Beulah-Zap coal bed are presented in Tables A-1 and A-4, respectively. Analyses of coal samples from the Dunn Center area, Dunn County, indicate the following: ash content varies between 4.9 and 8.0 percent; sulfur content varies between 0.4 and 1.11 percent; and BTU/lb varies between 5910 and 7330. They show the Beulah-Zap coal to be lignite in rank.

SCHOOLHOUSE COAL BED

The Schoolhouse coal bed is the uppermost mapped coal bed in the quadrangle. It is present in 75 percent of the quadrangle, the remainder having been removed by erosion over some of the quadrangle. Where present the bed overlies the Beulah-Zap coal bed and is separated from it by 80 feet (24.4 m) of rock and a thin local coal bed. The bed dips toward the

center of the quadrangle at approximately 35 feet per mile (6.6 m per km), as shown on Plate 30.

The bed, if present, ranges from 2 feet (0.6 m) to 7 feet (2.1 m) in thickness and increases in thickness toward the center of the quadrangle, as shown on Plate 31. The overburden ranges from 0 feet (0 m) to 200 feet (61.0 m) thick, as shown on Plate 30. The interburden ranges from 5 feet (1.5 m) to 13 feet (4.0 m) thick, as shown on Plate 30.

Chemical Analyses of the Schoolhouse Coal - Proximate and elemental analyses of the Schoolhouse coal bed are presented in Tables A-1 and A-5, respectively. Analyses of coal samples from the Schoolhouse coal bed near Center in Oliver County indicate the following: ash content varies between 5.7 and 6.6 percent; sulfur varies between 1.0 and 1.2 percent; and BTU/lb varies between 6720 and 6910. They show the Schoolhouse coal to be lignite in rank.

LOCAL COAL BEDS

In the Dunn Center NW quadrangle, ten local coal beds, ranging in thickness from 1 to 10 feet (0.3 to 3.0 m), occur in the Ludlow-Cannonball and the Sentinel Butte and Tongue River members of the Fort Union Formation. Three local coal beds, Local 3, 4, and 5, are of reserve base thickness; derivative maps were constructed and coal resources and reserves were calculated. Generally, the other local coal beds are thin, usually less than 5 feet thick, and of limited extent.

Derivative maps were not constructed and coal resources and reserves were not calculated for seven local coal beds due to their lenticular nature, insufficient data, and thickness.

COAL RESOURCES

Coal resource classification, as used in this report, is based on the degree of geological assurance of the existence and economic minability of the coal bed. The criteria for resource classification are based on the distance from the data point. The resource categories are:

Identified

measured - within 1/4 mile radius of data point

indicated - between 1/4 and 3/4 mile radius of data point

inferred - between 3/4 and 3 mile radius of data point

Hypothetical - beyond 3 mile radius of data point

Coal resource/reserve calculations are made using data presented on isopach and overburden contour maps for all Federal Government coal land in the quadrangle.

In areas suitable for surface mining, Reserve Base and Reserve tonnages were calculated for identified coal resources. Reserves are not calculated for hypothetical coal resources.

In areas suitable for underground mining (coal bed thickness of 5 feet or greater and overburden from 200 to 1000 feet), Reserve Base and Hypothetical coal resource tonnages were calculated.

The resource tonnages are estimated by a computer algorithm which is interactive with an automated planimeter-digitizer. Each area was traced with a magnifying cursor and, when a section is completed, a check was made to see that partial areas stored on diskettes sum to the area of the whole section.

The areas measured were converted by the algorithm using given parameters (lignite = 1750 tons per acre foot (1750 tons per acre foot = 12871 metric tons per hectare meter); recovery factor for strippable coal is 85 percent to yield Reserve Base and Reserves in millions of short tons per section for each class. Coal resource values for the H Lignite, Garner Creek, Local 5 and Meyer beds are shown on Plates 5, 8, 10 and 13, respectively. Reserve base and reserve values for the HT Butte, Local 4, Hazen, Local 3, Beulah-Zap and Schoolhouse beds are shown on Plates 17, 20, 23, 26, 29 and 32, respectively. Reserve base and reserve values are rounded off to the hundredth of one million short tons.

Total Reserve Base and Hypothetical resource data for the ten coal beds mapped in this quadrangle are shown on Plate 2.

COAL DEVELOPMENT POTENTIAL

Areas considered to have strip mining potential are assigned a high, moderate, or low development potential based on the mining ratio (cubic yards of overburden per ton of recoverable coal).

Coal outcrop traces were projected from structure contour maps and checked against previously projected outcrops (Law, 1977). An overlay of the structure contour and topographic maps provides data for computation of overburden thickness. The coal isopach map was overlain by the overburden isopach map and a mining ratio was calculated using the following the formula:

$$MR = \frac{To\ (.922)}{Tc\ (.85)}$$

where:

MR = cubic yards of overburden per ton of recoverable coal

To = thickness of overburden

Tc = thickness of coal

0.922 = factor to convert thickness of overburden and thickness of coal to cubic yards per ton

0.85 = coal recovery factor (85%)

The Coal Development Potential (CDP) map is compiled by

overlaying each mining ratio map for the quadrangle on the property base and noting, for all Federal coal land, whether each 40-acre tract contains Reserve Base coal in any of the mining ratio categories (Plate 33). 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. The highest rating for each tract is plotted on the CDP map. Areas beyond the outcrop are designated "not applicable" and areas of less than 5 feet coal thickness are designated "0" development potential. Mining ratios are not calculated where the coal thickness is less than 5 feet or overburden thickness exceeds 200 feet.

DEVELOPMENT POTENTIAL FOR SURFACE MINING METHODS

The coal development potential for surface mining methods (less than 200 feet (61 m) of overburden) is shown on Plate 33 and coal tonnages are summarized in Table 2.

High coal development potential is rated for many areas throughout the Dunn Center NW quadrangle. The Schoolhouse coal bed reaches thicknesses of only 7 feet (2.1 m) but is widely distributed beneath thin overburden. It accounts for approximately 4 square miles rated high development potential in the south central and south eastern part of the map. The rest of the high development potential ratings in the

Table 2 - Strippable Coal Reserve Base Data for Federal Coal Lands (in millions of short tons) in the Dunn Center, NW Quadrangle, Dunn County, North Dakota.

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)	Total
Schoolhouse	25.16	24.23	17.65	67.04
Beulah-Zap	45.75	38.42	63.03	147.20
Local 3	0.00	0.00	23.60	23.60
Hazen	16.79	16.30	40.41	73.50
Local 4	0.50	0.21	1.51	2.22
HT Butte	0.00	0.18	7.58	7.76
Local 5	0.00	0.00	15.72	15.72
Meyer	0.00	0.00	2.08	2.08
Garner Creek	0.00	0.00	0.00	0.00
H Lignite	0.00	0.00	0.00	0.00
Total	88.20	79.34	171.58	339.12

southeastern corner and in the northwest half of the quadrangle are due to thick Beulah-Zap coal under thin overburden cover.

Ratings of moderate and low development potential are scattered over the entire quadrangle. In the southwest, the lower ratings are attributed to the Schoolhouse and Beulah-Zap coal beds which are covered by thick overburden. Another area of low development potential extends over approximately 3 square miles in the east central area of the map. Either Local 3 or Beulah-Zap coal beds account for low ratings where Schoolhouse coal bed is not mappable. A few 40-acre tracts either do not contain coal of reserve base thickness or are deeper than the defined overburden limit, and therefore have no development potential rating.

A small area of moderate and low rated land on the north-central western border of the quadrangle is attributable to Beulah-Zap coal which is neither thick enough nor near enough to the surface to merit a high rating.

A very few small tracts along the north boundary of the Dunn Center NW quadrangle are rated low because in that area the Meyer coal reaches thicknesses of up to 8 feet (2.0 m) and is less than 200 feet deep.

DEVELOPMENT POTENTIAL FOR UNDERGROUND MINING METHODS AND IN SITU GASIFICATION

The H Lignite coal bed, which is the lowest identified coal bed in the quadrangle, and the Garner Creek, Local 5,

Meyer, HT Butte, Local 4, Hazen, Local 3, and HT Butte coal beds all have substantial quantities of non-strippable (greater than 200 feet of overburden) coal resources as shown in Table 3. The areal distribution of the coal resources is shown on Plates 5, 8, 10,13, 17, 20, 23, and 26, respectively.

The development potential for underground mining methods is considered low in this quadrangle because there are no active or planned underground mines in the quadrangle and no criteria for underground mining have been established.

No criteria have been established for rating the development potential by in situ gasification of coal methods in this area.

Table 3 - Nonstrippable Coal Reserve Base Data for Federal Coal Lands (in millions of short tons) in the Dunn Center, NW Quadrangle, Dunn County, North Dakota.

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

Coal Bed	High development potential	Moderate development potential	Low development potential	Total
Schoolhouse	0.0	0.0	0.0	0.0
Beulah-Zap	0.0	0.0	16.17	16.17
Local 3	0.0	0.0	61.27	61.27
Hazen	0.0	0.0	100.60	100.60
Local 4	0.0	0.0	96.06	96.06
HT Butte	0.0	0.0	143.05	143.05
Local 5	0.0	0.0	0.0	0.0
Meyer	0.0	0.0	0.0	0.0
Garner Creek	0.0	0.0	120.88	120.88
H Lignite	0.0	0.0	38.85	38.85
Total	0.0	0.0	576.88	576.88

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APPENDIX A

PROXIMATE AND ELEMENTAL ANALYSES

Table A-1 Proximate Analyses (as received)

Bed Name	No. of Samples	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulphur (Ultimate) %	Btu/lb*	Data Source
HT Butte	2	36.6	27.9	29.5	5.9	0.7	6970	Pollard et al., 1972
HT Butte	2	32.4	31.6	30.3	5.9	0.7	7024	Brant, 1953
HT Butte	3	35.5	28.6	31.1	4.9	0.5	7150	Johnson & Kunkel, 1959
Hazen	1	41.0	25.9	28.9	4.2	0.5	6290	Johnson & Kunkel 1959
Beulah-Zap	15	36.1	26.9	30.7	6.2	0.73	6890	Sondreal, Kube Elder, 1968
Beulah-Zap	3	34.0	29.0	29.0	8.0	0.8	6800	Pollard, et al., 1972
Beulah-Zap	1	39.5	28.3	25.3	6.9	0.4	5910	Johnson & Kunkel, 1959
Beulah-Zap	2	35.7	28.5	30.8	4.9	0.6	7018	Brant, 1953
Beulah-Zap	2	35.88	27.66	30.18	6.27	1.00	6566	Leonard, et al., 1925
Beulah-Zap	4	36.3	28.1	29.6	6.0	1.16	7028	USGS & Mont.Bur. of Mines & Geol. 1976
Beulah-Zap	10	29.6	29.6	34.2	6.7	0.5	7330	Swanson et al., 1976
Schoolhouse	1	35.8	26.9	31.7	6.6	1.0	6910	Pollard, et al., 1972
Schoolhouse	3	38.1	27.5	28.7	5.7	1.2	6720	Johnson & Kunkel 1959
Ave. Dunn Co.	-	40.6	-	-	7.0	0.6	6310	USDI, 1977
Ave. N.D.	-	36.0	28.0	29.0	6.0	0.7	6600	Leonard, et al., 1925

* To convert Btu/lb to Kilojoules/Kilogram, multiply by 2.326

Table A-2 -- Elemental Analysis of HT Butte Coal Bed

Element	Concentration in % Sample No.* D-80824	Sample No.* D-80825	Sample No.* D-80823
Sulphur	0.6	0.4	0.4
Hydrogen	6.8	6.9	6.9
Carbon	41.5	43.1	42.3
Nitrogen	0.7	0.6	0.7
Oxygen	44.0	45.0	45.5

*Johnson and Kunkel, 1959.

Table A-3 -- Elemental Analysis of Hazen Coal Bed

Element	Concentration-in % Sample No.* D-55178	Sample No.* 49875
Sulphur	0.5	
Hydrogen	7.0	
Carbon	38.0	
Nitrogen	0.6	
Oxygen	49.7	
U		0.0001
Ge**		ND
Ga**		0.002
V**		0.005
Cu**		0.004
Cr**		0.002
Zn**		0.01
Ni**		0.005
Co**		0.002
Be**		0.0003
Y**		0.01
La**		0.02
Mo**		ND

* Johnson and Kunkel, 1959
** Results in percent of ash

Table A-4 -- Elemental Analysis of Beulah-Zap Coal Bed

Element	Concentration in % Sample No.* 49879	Sample No.*** ND-KR-Bu	Sample No.**** ND-TT-DS	Sample No.***** D175930 to D17539
Sulphur				0.5
Hydrogen				6.2
Carbon				44.6
Nitrogen				0.7
Oxygen				41.3
U	0.0003			0.00005
Ge**	ND	0.001	ND	ND
Ga**	0.002	0.002	0.004	0.0015
V**	0.008	0.005	0.007	0.0035
Cu**	0.005	0.007	0.02	0.0055
Cr**	0.006	0.005	0.004	0.0025
Zn**	ND	ND	ND	0.0025
Ni**	0.005	0.003	0.006	0.0020
Co**	0.002	0.001	0.002	0.0010
Be**	0.0002	0.0008	0.0008	0.0003
Y**	0.01	0.004	ND	0.0025
La**	0.01	0.004	ND	0.01
Mo**	ND	0.002	0.004	0.0010
B**		0.24		0.110
Ti**		0.2		0.70******
Sn**		ND		---

* Johnson and Kunkel, 1959
** Results in percent of ash
*** Zubovic et al., 1961, average of 4 samples
**** Zubovic et al., 1961, average of 2 samples
***** Swanson et al., 1976
****** as TiO_2

Table A-5 - Elemental Analaysis of Schoolhouse Coal Bed

	Concentrations in %				
Element	Sample No.* D-55179	Sample No.* D-55176	Sample No.* D-55175	Sample No.* 49874	Sample No.* 49880
Sulphur	0.9	0.5	2.1		
Hydrogen	7.1	6.9	6.7		
Carbon	39.9	40.4	39.2		
Nitrogen	0.6	0.6	0.6		
Oxygen	46.4	47.4	43.6		
U				0.0001	0.0001
Ge**				ND	ND
Ga**				0.002	0.002
V**				0.01	0.006
Cu**				0.02	0.004
Cr**				0.007	0.005
Zn**				0.7	0.06
Ni**				0.002	0.003
Co**				0.001	0.001
Be**				0.001	0.0007
Y**				0.01	ND
La**				0.02	ND
Mo**				ND	ND

* Johnson and Kunkel, 1959
** Results in percent of ash