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COVER ILLUSTRATION

Digital elevation model of the Booneville 7.5–minute quadrangle
(Source: U.S. Geological Survey)

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SUMMARY

The Booneville Quadrangle lies within the Southwestern Reserve District of the Eastern Kentucky Coal Field. Six coal beds in the quadrangle have been commercially developed, mainly by surface mining methods, and comprise the basis of this Coal Availability Study. These beds are, in descending stratigraphic order, Copland, Whitesburg, Amburgy, Upper Elkhorn No. 3, Jellico and Manchester. A computerized Geographic Information System (GRASS) was used to calculate estimates of original, mined–out and remaining resources, restrictions to mining and available resources.

Original Resources

The total original coal resources for the Booneville Quadrangle were **79.7** million short tons. The Jellico and Upper Elkhorn No. 3 beds comprise 66 percent of this amount. Approximately **70 percent** of the total original resources are in the 14 to 28 inch thickness category. Given a maximum overburden height of 100 feet for surface mining, **50 percent** of the resources lie in surface and deep categories. The reliability of these estimates based on the density of data points is **14 percent measured, 40 percent indicated and 45 percent inferred.**

Mined–Out and Remaining Resources

Total mined–out tonnages are **9.4** million tons. Surface mining accounts for **98 percent** of this amount. The remaining resources are **70.4** million tons or **88 percent** of the original. The proportional amounts of remaining resources are distributed similarly to the original resources with respect to overburden and thickness categories.

Restrictions and Available Resources

The total restricted coal for the area is **30.1** million tons or **43 percent** of the remaining resources. Coal too thin to mine by underground methods (technological restriction) accounts for **99 percent** of this amount. The available coal resources are estimated as **40.3** million tons which is **51 percent** of original and **57 percent** of remaining resources. About **76 percent** of available resources are in the surface mineable category. Jellico and Upper Elkhorn No. 3 comprise **64 percent** of available resources.

Summary of Total Tonnage Estimates for Original, Mined-Out, Remaining, Restricted, and Available Coal Resources (Millions of Short Tons).

	Original	*Mined-Out*	*Remaining*	*Restricted*	*Available*
Copland	4.7	0.1	4.6	*	4.6
Whitesburg	8.7	0.2	8.5	1.5	7.0
Amburgy	7.7	0.5	7.2	4.6	2.6
Upper Elkhorn No. 3	21.5	2.3	19.2	11.0	8.2
Jellico	31.6	6.3	25.3	7.9	17.4
Manchester	5.6	0	5.6	5.1	0.4
TOTAL	79.7	9.4	70.4	30.1	40.3

* Indicates measurements less than reported precision.

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INTRODUCTION

One of the primary functions of the Federal and State geological surveys is to estimate the amount and character of the Nation's mineral resources. Understanding these estimates and their inherent levels of uncertainess is crucial for policy makers who are involved with the task of long-term economic planning. In Kentucky, one of the most important energy resources is coal, which occurs in two regions of the State: the Eastern and Western Kentucky Coal Fields.

About 6.6 billion tons of coal have been mined in these two regions since the beginning of the nineteenth century. The amount of coal remaining in Kentucky is estimated to be about 90 billion tons (based on Brant and others, 1983, and annual production figures). Given present production levels of about 160 million tons per year, there is an apparently endless supply of coal in the State. There may, however, be significant portions of this resource that are not available for mining due to both regulatory statutes and adverse engineering or geological conditions (Eggleston and others, 1990). Quantification of the degree to which these factors restrict the resource is important in order to make realistic projections of future mining potential.

The objective of the Coal Availability Program is to measure, for selected areas, the magnitude of restrictions to mining. These restrictions fall under two categories: land use and technological. Land-use restrictions are those that generally apply to surface mining and are specified by state regulations. Examples are streams, roads, cemeteries, powerlines, municipalities, and their applicable buffer zones. Technological restrictions, such as deep-mine buffers and adverse geological conditions, generally apply to underground mining.

Each study area in this program is comprised of one 7.5-minute quadrangle, a map area of about 55 square miles or 38,000 acres. Estimates are presented for original, mined-out, remaining, restricted, and available resources. This report describes the results for the seventh project area, the Booneville Quadrangle in Owsley County, Kentucky.

LOCATION, GEOLOGY, AND MINING HISTORY

The Booneville Quadrangle is located about 6 miles south of the town of Beattyville, Kentucky, which lies at the confluence of the three forks of the Kentucky River. The quadrangle is bisected by the South Fork and its alluvial plain and occupies most of west–central Owsley County. State routes 11, 28, and 30 intersect at the town of Booneville in the northern part of the map area.

The Booneville Quadrangle lies near the northwestern margin of the Eastern Kentucky Coal Field within the Southwestern Coal District (**Fig. 1**). The area is dissected by tributaries of the South Fork of the Kentucky River and shows moderate topographic relief of about 500 to 700 feet. **Figure 2** shows the outcrop of one of the lower coal beds, highlighting the position of the major drainages. The geologic structure of the area dips to the southeast at an average rate of 25 feet per mile.

The principal coal seams of the area, as shown by Weir (1978), range from the Manchester bed upward to the Copland bed, a stratigraphic range of just over 600 feet (**Fig. 3**). The bed of greatest economic importance has been the Jellico, followed by the Upper Elkhorn No. 3, and Amburgy. The Jellico ranges from 24 to 44 inches in thickness where it has been mined, whereas the latter two seams are generally in the 18- to 32-inch range. The uppermost bed, the Copland, attains thicknesses of 50 inches, but is limited in areal distribution.

Most of the past mining in the Booneville Quadrangle has been by the contour strip method. Due to modest interburden thicknesses, these mines are commonly multiseam operations, with two to three beds being mined. In the northern part of the area, the Jellico was the main target, with the closely overlying Upper Elkhorn No. 3 included despite its high rate of thickness variation. In the south, the principal targets have been the Upper Elkhorn No. 3 and the Amburgy, which are separated by about 100 feet.

A number of small underground drift mines were developed in the Jellico bed near the town of Booneville in the late 1940's and early 1950's. At the present time there is little mining activity of any kind within the quadrangle.

METHODS

Approach

In order to estimate the amount (tons) of coal present within a given area, its volume must be known. The two factors necessary for calculating volume are area, which is defined by the outcrop of the coal bed, and thickness, which

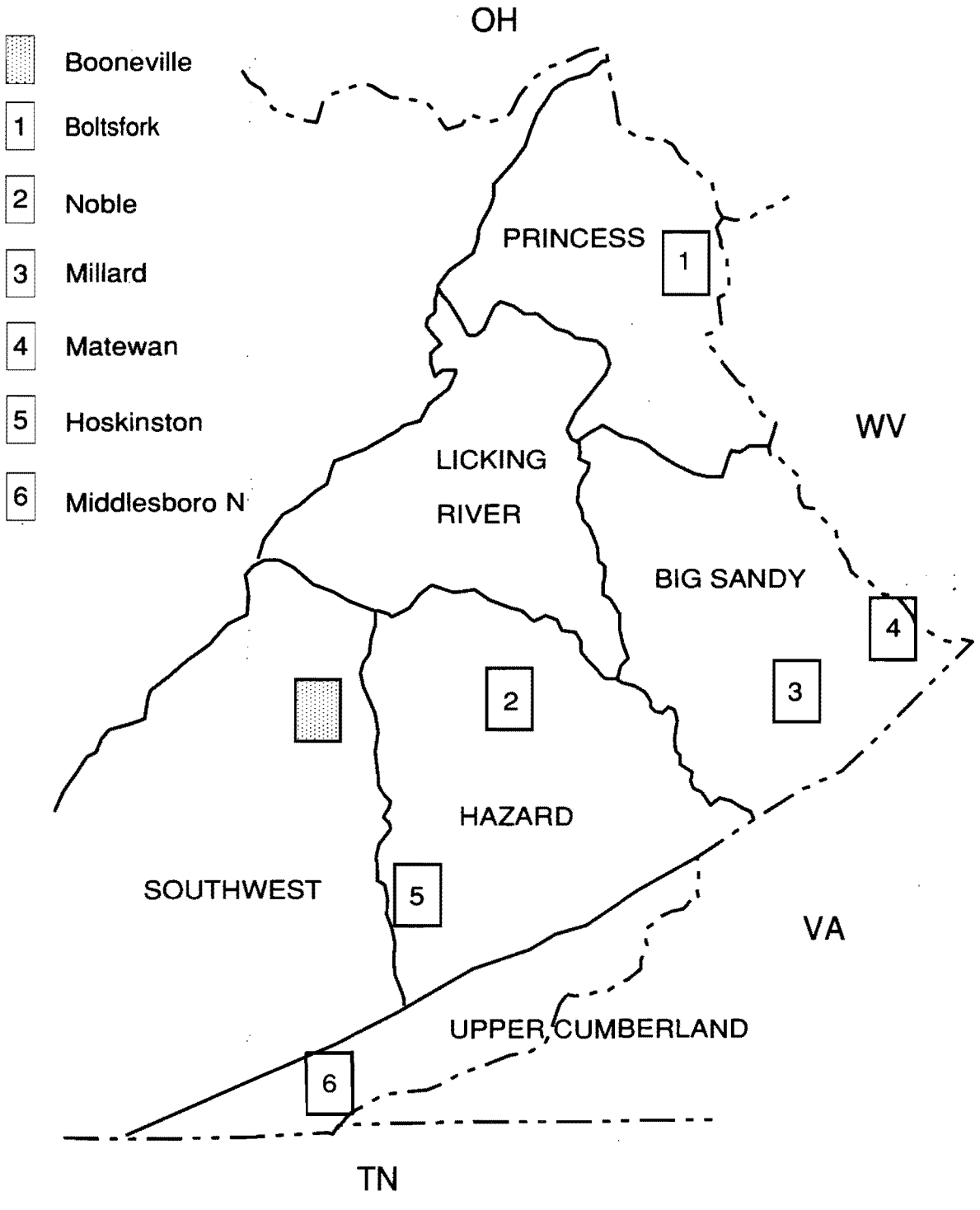

Figure 1. Location of the Booneville Quadrangle within the Eastern Kentucky Coal Field. Previous Coal Availability quadrangles shown relative to the six coal reserve districts.

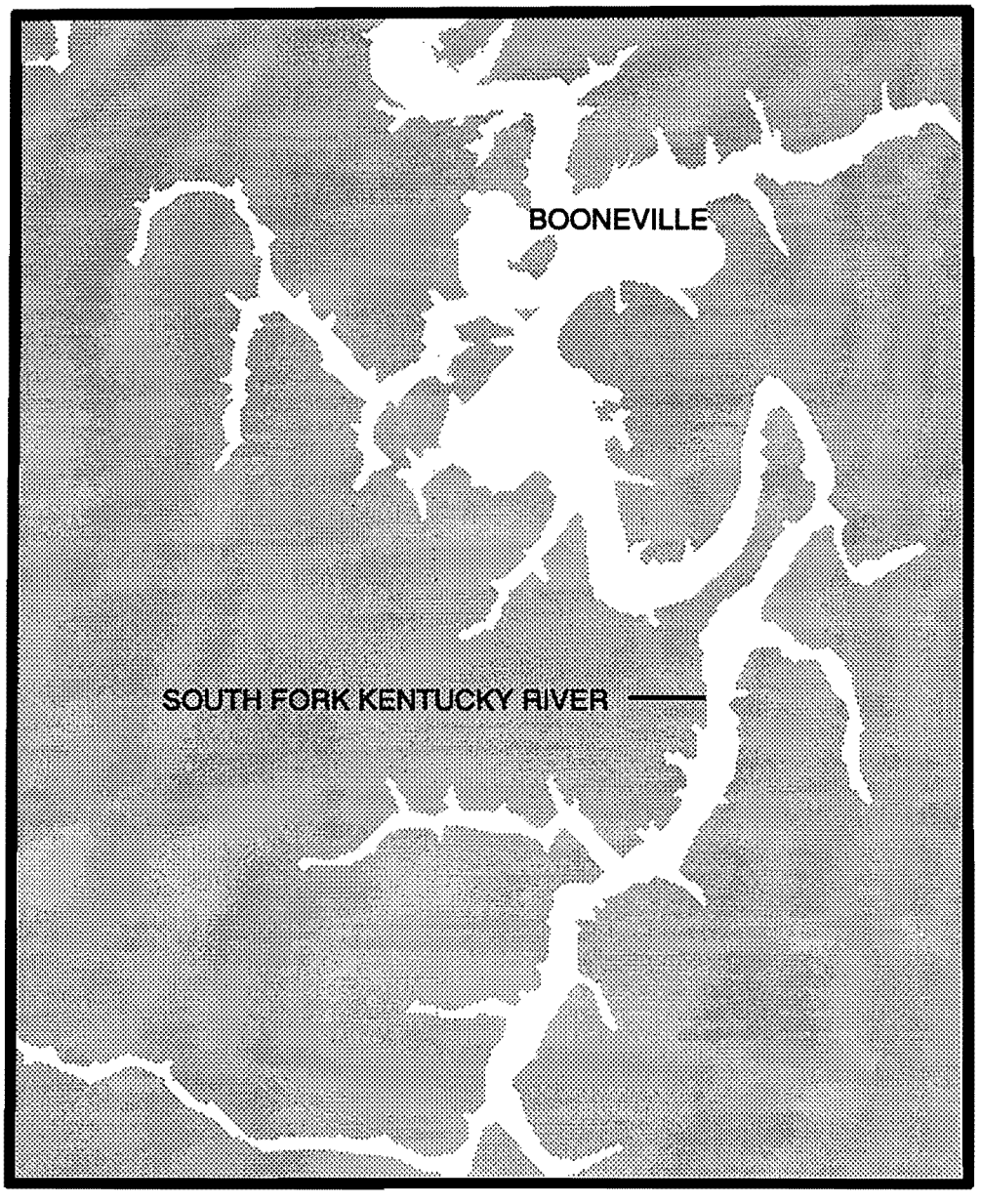

Figure 2. Outcrop area of the Manchester coal bed (stippled) within the Booneville Quadrangle.

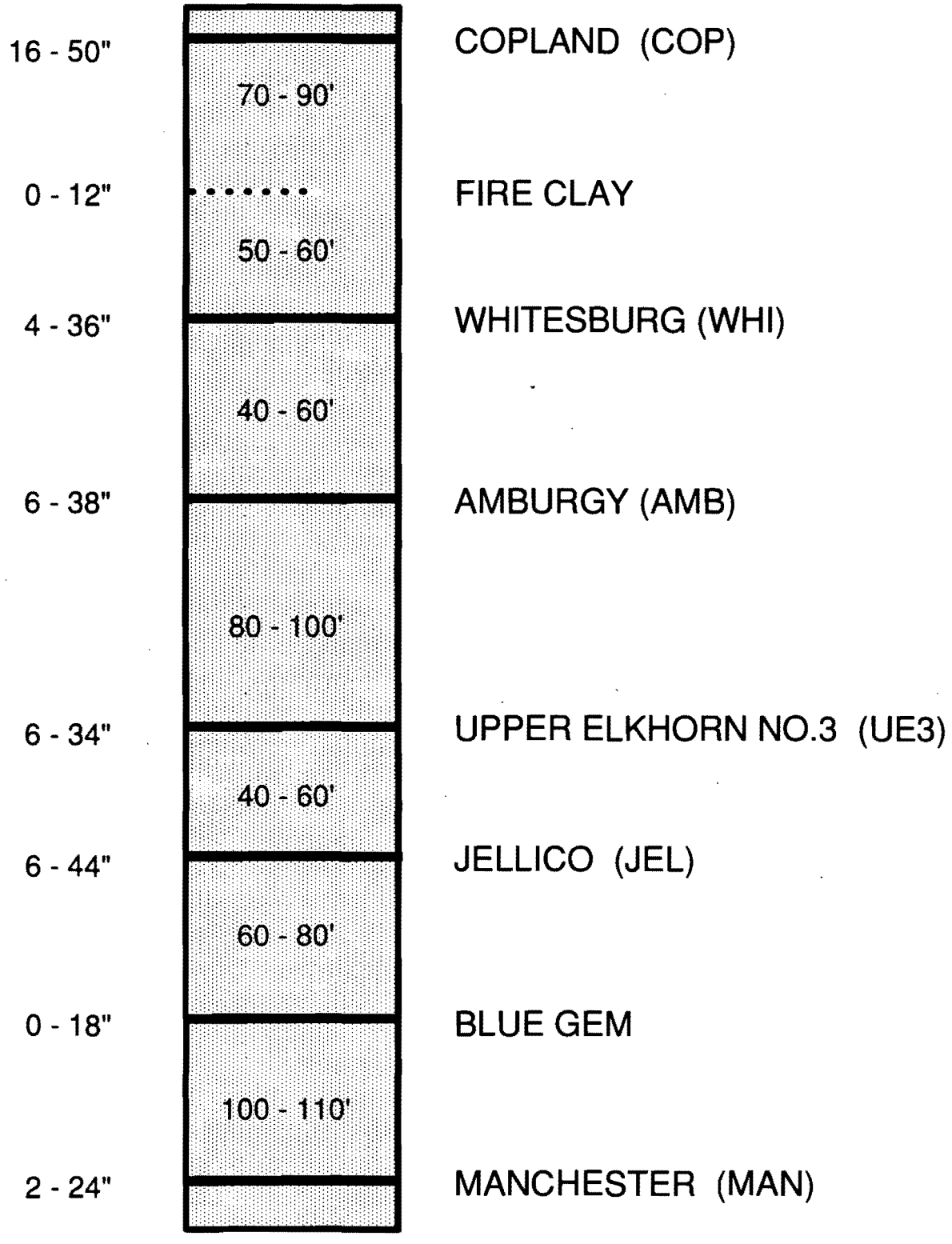

Figure 3. Stratigraphic section of the principal coal-producing portion of the Booneville Quadrangle. Coal and interburden thickness ranges are given for each seam. Coal-bed abbreviations in parentheses are used in subsequent parts of the report.

is estimated from point measurements along the outcrop and in subsurface boreholes. The various resource categories, mined-out areas, and restrictions described below make up some part of the whole area of each coal bed. Because the primary task, then, is one of determining and measuring map areas, a computerized Geographic Information System (GIS) approach was selected to perform the analysis. This type of system allows for the storage of digital map information and automated comparisons and calculations on one or more maps. The primary task, then, is preparing analog point-source and map information and rendering it in digital form.

Data Preparation

Point Data

Most of the data relevant to the thickness of coal seams within the Booneville Quadrangle are from measurements made by geologists along the outcrop. These measurements include a coal bed's thickness, rock partings if present, elevation (estimated by altimeter or from topographic map), and the stratigraphic position of the seam. These data are stored in digital form in the Kentucky Geological Survey Relational Data Base System. Additional information about the thickness and elevation of coal beds was obtained from information included with surface-mine permits from the Kentucky Natural Resources and Environmental Protection Cabinet. All data were re-examined in order to verify correlations and accuracy in measurement, and modifications were made when necessary. The locations and measurements were then extracted into data files, with coordinates in the Universal Transverse Mercator system, thicknesses in whole inches, and elevations in feet above sea level.

Map Data

The various types of map information were digitized from stable map media (mylar tracings or photo reproductions) using the program GSMAP version 7.2. Coal-bed outcrops were determined from the Booneville 7.5-minute geologic quadrangle map (Weir, 1978) and from surface and underground mine maps that were obtained from the Kentucky Division of Permits and the Kentucky Department of Mines and Minerals. Land-use restrictions were digitized from USGS 7.5-minute topographic base maps. The locations of oil and gas wells were obtained from the Kentucky Geological Survey Oil and Gas Division. The digital elevation model (DEM) was obtained from the U.S. Geological Survey and consists of a rectilinear grid of surface elevations at 30-meter intervals within the map area. Restrictions and mined-out areas were field checked for accuracy.

Restrictions to Mining

Most land-use restrictions are outlined under the Kentucky Natural Resources and Environmental Protection Cabinet Document 405 KAR (Kentucky Administrative Register) 24:040, entitled "Permit Application Review." This document relates to KRS (Kentucky Revised Statutes) 350.465 and 350.610, which define the regulatory program for surface mining in Kentucky. These potential restrictions and their applicable buffers (within which mining is not permitted) are given in **Table 1**, which indicates that seven of the categories apply to the Booneville Quadrangle. It should be noted that, with the exception of Federally funded highways, Nationally protected lands, and cemeteries, variances are commonly granted for many of the listed restrictions. In the case of the Booneville Quadrangle, powerlines have been routinely undermined.

Technological restrictions, also listed in **Table 1**, include barriers around existing underground mines and oil and gas wells and coal too thin (less than 28 inches) for underground mining methods.

Data Analysis

The Geographic Information System software utilized for this phase of the project was GRASS, a U.S. Government publication produced primarily by the U.S. Army Corps of Engineers, the U.S. Soil Conservation Service, and the U.S. Geological Survey. GRASS is a raster–based GIS software package, which implies that map data are rendered as matrices of equal-sized grid cells. Maps stored in a GRASS data base must be oriented to a particular coordinate system. The Universal Transverse Mercator, based on the Clark 1866 spheroid, was chosen for this study. The size of grid cells for each map must be specified, but can vary between maps (*see* **Table 2**). In order to utilize map information for calculations, the original vector data (points, lines, or areas) must be converted to raster data files.

Table 1.—Potential Restrictions with Applicable Buffer Zones and Categories to Which They Apply. Restrictions Found in Booneville Quadrangle Indicated by Asterisk.

Restrictions	*Buffer*	*Land-Use*	*Technological*	*Surface*	*Deep*
Airports	area + 100'	X		X	X
Bridges	area + 100'	X		X	
Cemeteries*	area + 100'	X		X	
Faults*	area + 100'	X	X	X	X
Public Lands	area	X		X	X
Pipelines	area + 100'	X		X	
Powerlines*	area + 100'	X		X	
Railroads	area + 100'	X		X	
Roads*	area + 100'	X		X	
Streams*	area + 100'	X		X	X
Parks, National	area	X		X	
Parks, State	area	X		X	
Towns*	area + 300'	X		X	X
Oil & Gas Wells*	200'	X	X	X	X
Coal Too Deep	area		X		X
Mine Buffers*	50'		X		X
Interburden < 40'	area		X		X
Mining Within 40'	area		X		X
Coal Too Thin*	area		X		X

In the case of thickness and elevation point data, a gridding algorithm was used to interpolate cell nodes between data points. Two GRASS computer algorithms were utilized. The first, s.surf.pln, accepts unequally spaced data and applies a first-order trend surface fit to the nearest neighbors found by the specified search. This program works best on structural data, which have a large first-order component. It also works adequately on thickness data that are relatively closely spaced; however, interpolation problems occur in areas of sparse data and in the vicinity of closely spaced points that differ substantially in thickness. The second algorithm, s.surf.idw, uses a simple inverse-distance weighted function. This program is efficient at honoring data points, but is inaccurate farther away from the points. It was implemented for the uppermost seams where few data were available, but the area of outcrop was limited. A summary of data associated with each coal bed is given in **Table 3.**

Once all maps were prepared, the USGS program "resources" used GRASS commands to calculate areas (in square meters) for all categories of resources and for those portions of the original resource that are mined out or restricted. These data were then converted to acres, and short tons were calculated by the following equations, which use an average specific gravity figure for bituminous coal.

1 acre = 4,047 square meters

1 acre/foot of coal = 1,800 short tons

Table 2.—List of Map Types Used for Data Analysis. Data Source, Method of Generation, GRASS Cell Resolution, and Other Pertinent Information Given.

Map Type	*Data Source*	*Method*	*Resolution*	*Comments*
Map Boundary	corner points		5 meters	used as data mask
Outcrops	1:24,000 USGS GQ	digitized	5 meters	used for original resource maps
Mines	Dept. of Mines & Minerals	digitized	5 meters	used for remaining resource calculations
Land-Use Restrictions	1:24,000 topographic map	digitized	5 meters	used for available resource calculations
Oil & Gas Wells	KGS data base	s. poly output	5 meters	restriction
Reliability Arcs	KGS coal data base	s. poly output	5 meters	reliability categories
DEM	1:24,000 USGS digital file		30 meters	used for creating overburden maps
Structure contour	KGS data base	s.surf.pln	30 meters	used for overburden maps
Overburden isopach	derived	r.mapcalc	30 meters	
Thickness isopach	KGS data base	s.surf.pln or s.surf.idw	30 meters	used for thickness maps

Table 3.—Summary of Data Associated with Each Coal Bed Used in Resource Calculations.

Coal Bed	*Total Outcrop Area (acres)*	*% of Outcrop Within Original Resources*	*No. of Thickness Data Points*	*Points Per 1,000 Acres*	*Surface-Mine Acreage*	*Deep-Mine Acreage*
Copland	928	100	8	1.0	24	0
Whitesburg	2,190	99	5	0.9	53	0
Ambrgy	2,900	93	21	3.8	170	1
Upper Elkhorn No. 3	8,300	78	51	4.2	687[1]	0
Jellico	14,000	65	70	3.4	1,551	44
Manchester	32,000	8	43	0.5	0[1]	0

[1] Does not include surface mines developed in coal less than 14 inches thick.

Resource Categories

Tonnage estimates for each bed are reported by categories of coal thickness, overburden thickness, and reliability of the estimate. Standard U.S. Geological Survey procedures (Wood and others, 1983) stipulate thickness categories in multiples of 14 inches up to 42 inches and multiples of 42 inches up to 168 inches, with categories above 168 inches aggregated. For the Coal Availability studies, only two categories are used: 14 to 28 inches and greater than 28 inches. This division is based on the general constraint that coal less than 28 inches in not mineable by underground methods.

Overburden categories are also based on the potential effect on mining method. Three categories are defined: surface mineable, deep mineable, and too deep to mine. The thickness values for these categories can vary depending on topographic relief and seam and interburden thicknesses, but are generally 100 or 200 feet for maximum surface mine highwalls and 1,000 feet for maximum underground overburden. For this study 100 feet is used for surface mining, and no overburden thicknesses were found that exceeded 1,000 feet.

Reliability categories are areas determined by measuring distances from coal thickness measurements. "Measured" resources lie within 1/4 mile (1,320 ft. or 402 m) of a data point, "indicated" resources lie between 1/4 and 3/4 miles (3,960 ft. or 1,207 m), "inferred" resources lie between 3/4 and 3 miles (15,840 ft. or 4,828 m), and "hypothetical" resources are beyond 3 miles. While it is generally accepted that the rate of thickness variation differs for many coal beds, the reliability categories do give a measure of data spacing. No hypothetical resources were found in this study.

RESULTS

Overview

Original, mined–out, remaining, restricted, and available coal resources were calculated for six coal beds in the Booneville Quadrangle. These beds are, in ascending stratigraphic order, Manchester, Jellico, Upper Elkhorn No. 3, Amburgy, Whitesburg, and Copland. All of the beds lie above drainage and are accessible to both surface and drift mining methods. Resource estimates and restrictions are reported for each bed by categories of coal thickness (14–28 inches and greater that 28 inches), overburden (surface mineable = 0–100 feet, deep minable = greater than 100 feet) and reliability (measured = 1/4 mile, indicated = 3/4 mile, inferred = 3 miles) and are detailed completely in **Appendix A.**

The aggregated results of the coal availability investigation for the Booneville Quadrangle are summarized in **Table 4** and presented graphically in **Figure 4. Table 4** gives the original, remaining, and available resources for each bed and totals for mined-out and restricted coal. Results of this study indicate that 40.3 million tons (51 percent) of the original resources (79.7 million tons) are available for future economic development. A total of 9.4 million tons (11.8 percent) of the original resources have been mined, largely by surface methods. A total of 30.1 million tons or 43 percent of the remaining resources are restricted from mining. Technological restrictions (mainly coal too thin to mine by underground methods) account for 99 percent of the total restrictions.

Table 4.—Summary of Total Tonnage Estimates for Original, Mined-Out, Remaining, Restricted, and Available Coal Resources (Millions of Short Tons).

	Original	*Mined-Out*	*Remaining*	*Restricted*	*Available*
Copland	4.7	0.1	4.6	*	4.6
Whitesburg	8.7	0.2	8.5	1.5	7.0
Amburgy	7.7	0.5	7.2	4.6	2.6
Upper Elkhorn No. 3	21.5	2.3	19.2	11.0	8.2
Jellico	31.6	6.3	25.3	7.9	17.4
Manchester	5.6	0	5.6	5.1	0.4
TOTAL	79.7	9.4	70.4	30.1	40.3

* Indicates measurements less than reported precision.

There are other restrictions to mining that are not included in this study. These restrictions are: surface and mineral ownership divisions not conducive to mineral development, economic considerations, recoverability, and concealed geologic problems such as channel cutouts or poor coal quality. Though these types of restrictions are beyond the scope of the present study, some are currently being investigated by the U.S. Bureau of Mines.

Original Resources

Original coal resources represent estimates of the total amount of coal greater than 14 inches in thickness prior to any mining. The total original resources for all beds in this study are estimated as 79.7 million tons. The previous estimate for the same beds (Brant and others, 1983) was 72.9 million tons, a difference of 9 percent. Brant and others estimated an additional 10 million tons for other beds in the quadrangle; however, these estimates were based on few data or data located outside the map area. Consequently, these beds were not included in this study.

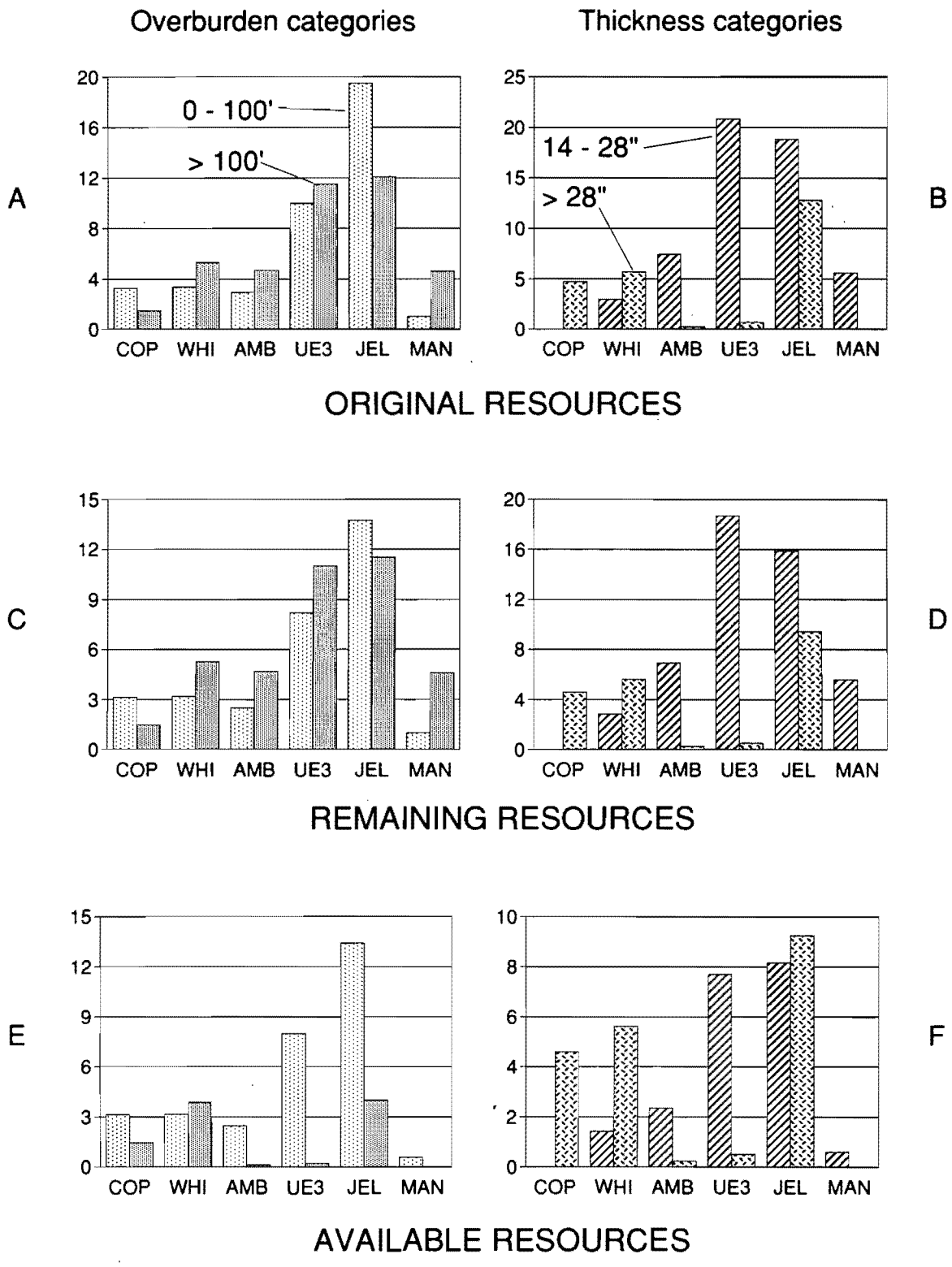

Figure 4. Summaries of original, remaining, and available coal resources by overburden and thickness categories. Coal-bed abbreviations explained in Figure 3.

Distribution of Original Resources

Stratigraphic

The distribution of original coal resources aggregated by thickness and overburden categories is illustrated in **Table 5** and **Figures 4** through **6**. Of the total 79.7 million tons, 66 percent is associated with the Jellico and Upper Elkhorn No. 3 beds. **Figure 5** shows that, with the exception of the Manchester bed, the total resources decrease upward stratigraphically. This is due, in part, to the decrease in outcrop area, as shown by **Figure 6**. This figure illustrates that the rate of decrease differs for the lower half of the geologic section (9,000 acres/100 vertical feet) compared to the upper half (500 acres/100 feet). This effect may be the result of differences in the composition of the interseam rock strata between the upper and lower seams. Also note that the proportion of the total outcrop area that contains resources greater than 14 inches increases stratigraphically upward. This trend may represent, in part, the effect of data spacing on thickness extrapolations.

Overburden

Approximately half of the original coal resources are located in the surface (0–100') overburden category and half in the underground (greater than 100') overburden category. **Figures 4a** and **5** show that some of the lower seams, like the Jellico, do not necessarily have a greater proportion of deep coal, as would be expected. This could be due to differences in topographic slope for the lower beds. In addition, most of the thickness data for the Booneville Quadrangle were measured in the surface category (along the outcrop). Hence, there may have been some preference toward extrapolated values less than 14 inches (excluded from original resources) within the deep overburden category for the beds with greater area. This is due to the lack of data control within these areas.

Thickness

The original resources are not distributed uniformly by thickness categories. Seventy percent of the total resources are in the 14 to 28 inch range. **Figure 4b** shows that the proportion of 14 to 28 inch versus greater than 28 inch coal varies widely from bed to bed. The Manchester, Amburgy, and Upper Elkhorn No. 3 beds contain less than 3 percent greater than 28 inch coal, while the Copland, Whitesburg, and Jellico lie in the 40 to 60 percent range.

Geographic

Of the beds with significant resources, only the Jellico is represented mainly in the northern half of the quadrangle. Both the Amburgy and Upper Elkhorn No. 3 are best developed in the southern half. The outcrop area for the Whitesburg and Copland are limited to the south and east, while the Manchester bed is only greater than 14 inches in a small area in the northwestern corner of the quadrangle.

Reliability of the Estimates

The reliability of resource estimates is expressed by the categories of measured, indicated, and inferred, which are given for each bed in **Appendix A** and are illustrated in **Figure 7**. As stated above, these designations are based on the density of thickness data points and this characteristic is also quantified in **Table 3**, where the total acreage and number of points per 1,000 acres are given.

For all beds, approximately 14 percent of the resource is estimated as measured, 40 percent as indicated, and 45 percent as inferred. Only three individual beds, Jellico, Upper Elkhorn No. 3, and Amburgy, contain measured resources in excess of 10 percent. As shown by **Table 3**, these same beds are those that contain the highest number of points per area and have significant mined-out tonnages.

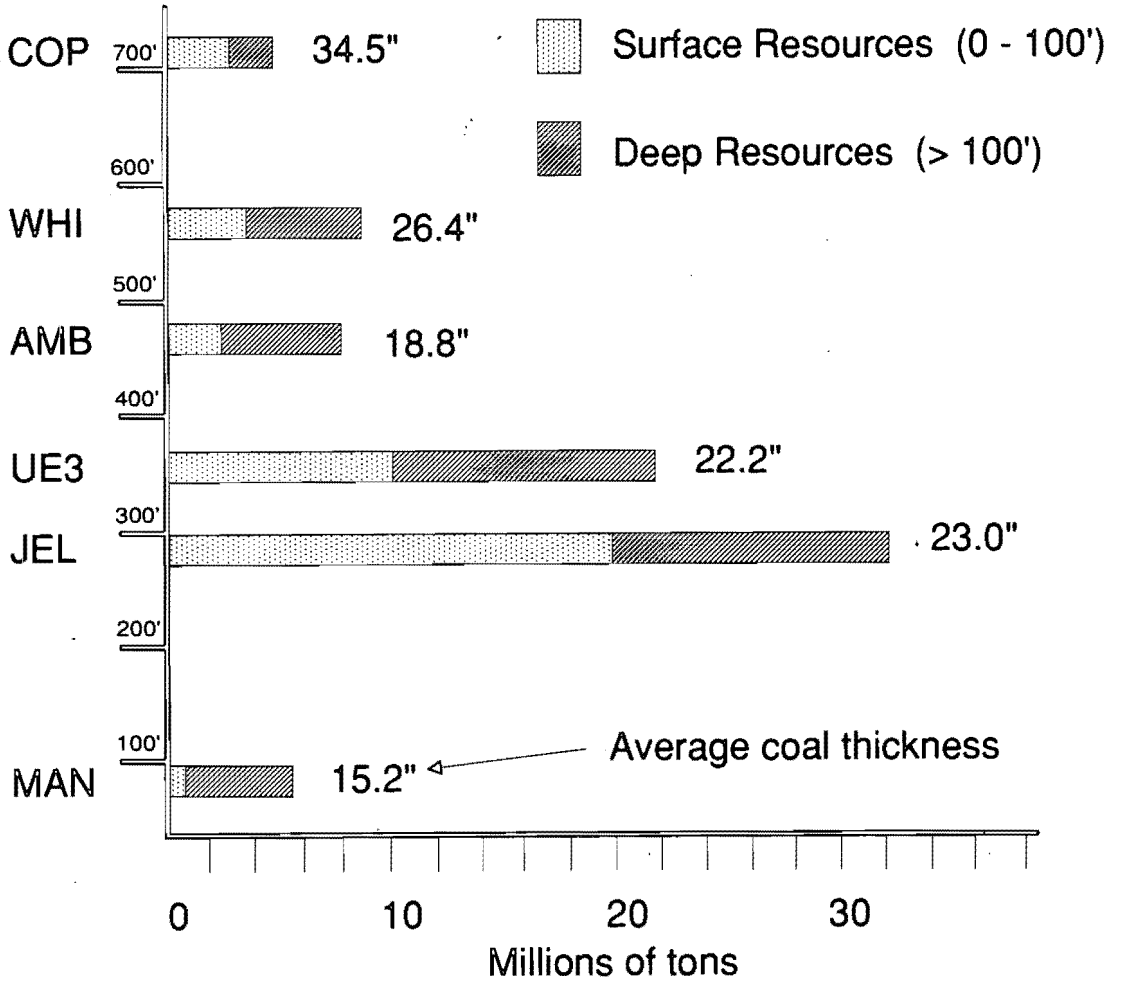

Figure 5. Stratigraphic distribution (relative feet) of original resources by overburden category. Average coal thickness is for greater-than-14-inch coal only. Coal-bed abbreviations explained in Figure 3.

Table 5.—Original Coal Resources Reported by Overburden and Thickness Categories (Thousands of Short Tons).[1]

Coal Bed	*Surface (0–100')*			*Deep (> 100')*			*Thickness Totals*		*TOTALS*
	14–28"	*>28"*	*Total*	*14–28"*	*>28"*	*Total*	*14–28"*	*>28"*	
Copland	0	3,275	3,275	0	1,463	1,463	0	4,738	4,738
Whitesburg	1,487	1,867	3,353	1,466	3,835	5,301	2,952	5,701	8,654
Amburgy	2,826	119	2,945	4,595	118	4,713	7,421	238	7,659
Upper Elkhorn No. 3	9,555	431	9,986	11,261	251	11,512	20,817	681	21,498
Jellico	11,006	8,488	19,494	7,816	4,281	12,096	18,822	12,769	31,591
Manchester	857	0	857	4,743	0	4,743	5,599	0	5,599
TOTAL	25,731	14,180	39,910	29,881	9,948	39,828	55,611	24,127	79,739

[1] Totals may not equal sum of components because of independent rounding.

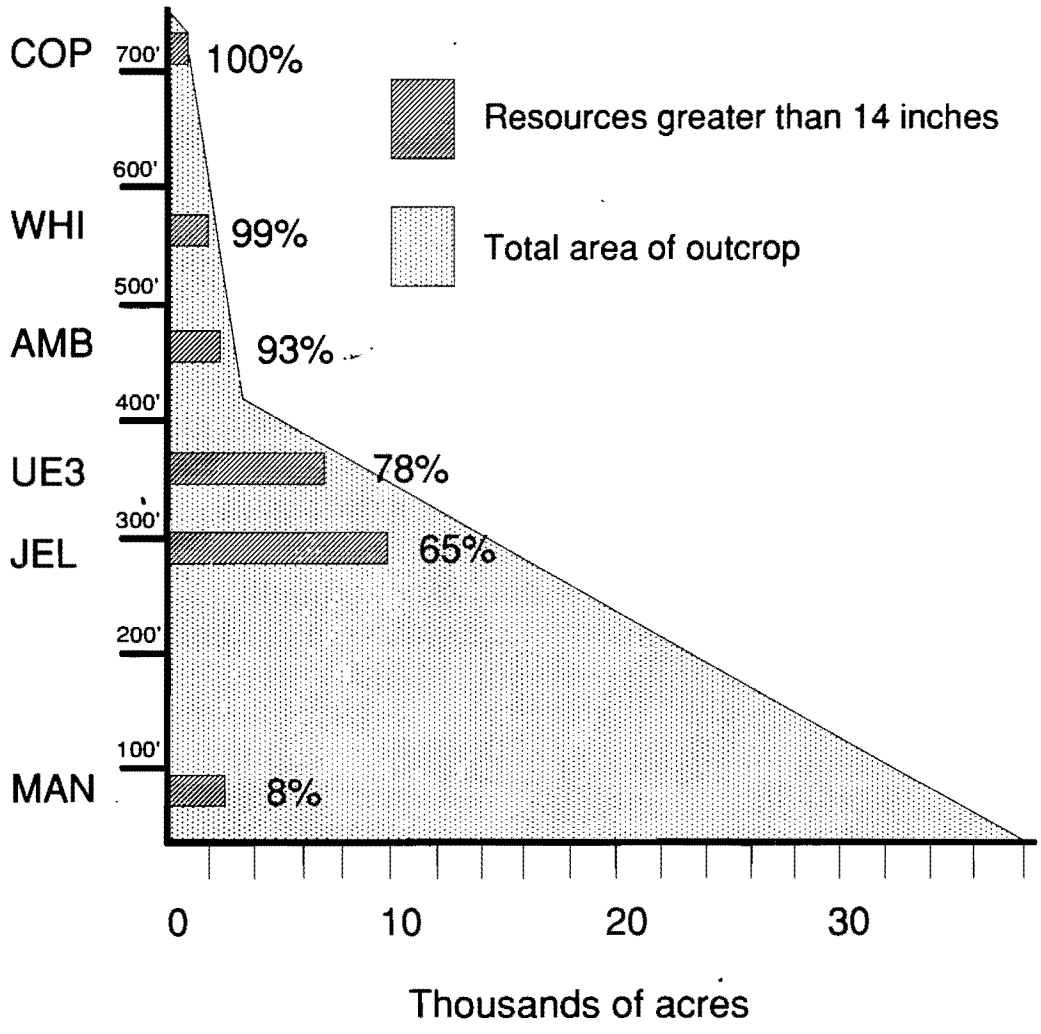

Figure 6. Outcrop area of each coal bed (relative stratigraphic position) and the proportional amount of area that contains measurable resources. Coal-bed abbreviations explained in Figure 3.

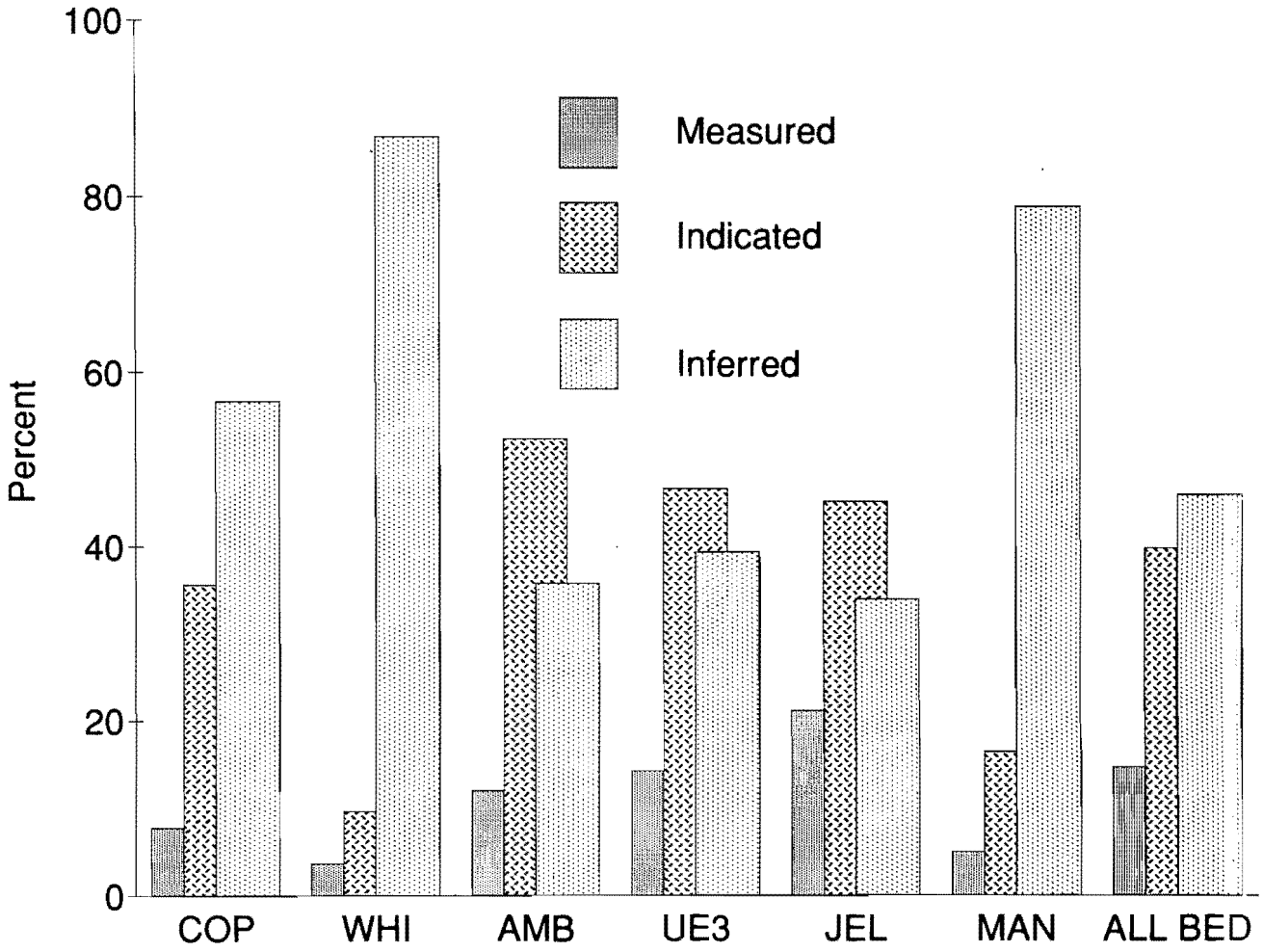

Figure 7. Distribution of original resources by reliability category. Coal-bed abbreviations explained in Figure 3.

Mined-Out and Remaining Resources

Estimates of mined-out tonnages and remaining resources are aggregated by thickness and overburden categories in **Tables 6** through **8** and by all categories in **Appendix A**. Mined-out tonnages are calculated from mine acreages and thicknesses interpolated from data points. Production data are not used because it is difficult to associate these data with specific map areas.

Most mining in the Booneville Quadrangle has been by surface methods. Of the 9.4 million tons that have been mined out, 9.2 (98 percent) have been by surface methods. Approximately 60 percent of this amount was developed from beds 14 to 28 inches in thickness and 40 percent in beds greater than 28 inches. The Jellico and Upper Elkhorn No. 3 beds account for 8.4 million tons (91 percent) of the total surface tonnage. A number of small underground drift mines were developed in the Jellico bed in the late 1940's and early 1950's, but these account for only 185,000 tons of depleted coal resources.

Total remaining resources are estimated as 70.4 million tons, or 88 percent of the original. These resources are distributed similarly to the original estimates (**Figs. 4b–c**). About half are allocated to each overburden category and 70 percent to beds 14 to 28 inches in thickness. The Jellico, Upper Elkhorn No. 3, and Amburgy beds account for 74 percent of the remaining resources.

Table 6.—Coal Resources Mined-Out by Surface Methods, Reported by Overburden and Thickness Categories (Thousands of Short Tons).[1]

Coal Bed	*Surface (0–100')*			*Deep (> 100')*			*Thickness Totals*		*TOTALS*
	14–28"	*>28"*	*Total*	*14–28"*	*>28"*	*Total*	*14–28"*	*>28"*	
Copland	0	134	134	0	*	*	0	134	134
Whitesburg	96	77	173	14	0	14	111	77	188
Amburgy	461	0	461	16	0	16	477	0	477
Upper Elkhorn No. 3	1,651	147	1,798	474	17	491	2,124	164	2,289
Jellico	2,619	2,985	5,604	275	225	500	2,894	3,209	6,104
Manchester	0	0	0	0	0	0	0	0	0
TOTAL	4,827	3,343	8,170	779	242	1,021	5,606	3,584	9,192

[1] Totals may not equal sum of components because of independent rounding.
* Indicates measurements less than reported precision.

Table 7.—Coal Resources Mined-Out by Underground Methods, Reported by Overburden and Thickness Categories (Thousands of Short Tons).[1]

Coal Bed	*Surface (0–100')*			*Deep (> 100')*			*Thickness Totals*		*TOTALS*
	14–28"	*>28"*	*Total*	*14–28"*	*>28"*	*Total*	*14–28"*	*>28"*	
Copland	0	0	0	0	0	0	0	0	0
Whitesburg	0	0	0	0	0	0	0	0	0
Amburgy	3	0	3	0	0	0	3	0	3
Upper Elkhorn No. 3	0	0	0	0	0	0	0	0	0
Jellico	45	84	129	16	40	56	61	124	185
Manchester	0	0	0	0	0	0	0	0	0
TOTAL	48	84	132	16	40	56	64	124	185

[1] Totals may not equal sum of components because of independent rounding.

Table 8.—Remaining Coal Resources, Reported by Overburden and Thickness Categories (Thousands of Short Tons).[1]

Coal Bed	*Surface (0–100')*			*Deep (> 100')*			*Thickness Totals*		*TOTALS*
	14–28"	*>28"*	*Total*	*14–28"*	*>28"*	*Total*	*14–28"*	*>28"*	
Copland	0	3,141	3,141	0	1,463	1,463	0	4,604	4,604
Whitesburg	1,390	1,790	3,180	1,451	3,835	5,286	2,842	5,625	8,466
Amburgy	2,363	119	2,482	4,579	118	4,697	6,941	238	7,179
Upper Elkhorn No. 3	7,905	284	8,188	10,788	233	11,021	18,692	517	19,209
Jellico	8,342	5,420	13,761	7,525	4,016	11,541	15,866	9,436	25,302
Manchester	857	0	857	4,743	0	4,743	5,599	0	5,599
TOTAL	20,857	10,754	31,609	29,086	9,665	38,751	49,940	20,420	70,359

[1] Totals may not equal sum of components because of independent rounding.

Restrictions and Available Resources

Tonnages for restricted coal are reported in two formats. In order to calculate the available resources, the unique area of each restriction type is subtracted from remaining resources. This is due to overlapping buffers for some restrictions. In the Booneville Quadrangle, for example, roads, streams, and municipal areas occupy the same general space in valley bottoms. These results (total restriction tonnages by overburden and thickness categories) are shown in **Table 9. Table 10** and **Appendix A** give the total tonnages associated with each restriction. In most cases the sum of these later tonnages will exceed the totals used for calculating available resources.

The total amount of restrictions for the Booneville Quadrangle is 30.1 million tons, or 43 percent of the remaining resource. Technological restrictions (largely coal too thin to mine by underground methods) account for 99 percent of this total. Only about 1 million tons are associated with land-use restrictions (**Fig. 8**), and most of this tonnage is for powerlines and municipal areas. It should be noted that, in practice, powerlines have been routinely undermined in the Booneville area.

The amount of coal available for mining in the Booneville Quadrangle is 40.3 million tons (**Table 11**). This represents 51 percent of original and 57 percent of remaining resources. An estimated 30.6 million tons (76 percent) of available coal resources are in the surface (0–100') category. The available resources are divided equally between thickness categories. The Jellico and Upper Elkhorn No. 3 beds account for 63 percent of the available resources.

Figure 9 summarizes the tonnages and proportional amounts of original, mined-out, restricted, and available coal resources for the Booneville Quadrangle.

Table 9.—Total Restrictions, Reported by Overburden and Thickness Categories (Thousands of Short Tons).[1]

Coal Bed	*Surface (0–100')*			*Deep (> 100')*			*Thickness Totals*		*TOTALS*
	14–28"	*>28"*	*Total*	*14–28"*	*>28"*	*Total*	*14–28"*	*>28"*	
Copland	0	2	2	0	0	0	0	2	2
Whitesburg	18	0	18	1,451	0	1,451	1,469	0	1,469
Amburgy	20	0	20	4,579	0	4,579	4,599	0	4,599
Upper Elkhorn No. 3	198	11	209	10,788	0	10,788	10,986	11	10,997
Jellico	174	167	341	7,525	19	7,544	7,699	186	7,885
Manchester	413	0	413	4,743	0	4,743	5,155	0	5,155
TOTAL	823	180	1,003	29,086	19	29,105	29,908	199	30,107

[1] Totals may not equal sum of components because of independent rounding.

Table 10.—Total Tonnages Associated with Individual Restriction Categories (Thousands of Short Tons). Does Not Account for Overlapping Areas.

Coal Bed	*Land Use*							*Technological*		
	Cemeteries	*Faults*	*Oil & Gas*	*Power-lines*	*Roads*	*Streams*	*Towns*	*Barriers*	*Oil & Gas*	*Coal Too Thin*
Copland	0	0	0	2	0	0	0	0	0	0
Whitesburg	0	3	0	14	0	0	0	0	0	1,451
Amburgy	0	0	2	18	0	0	0	*	0	4,579
Upper Elkhorn No. 3	0	0	10	151	0	6	43	0	*	10,788
Jellico	0	63	4	154	1	*	126	29	0	7,525
Manchester	5	0	11	0	141	38	375	0	23	4,743
TOTAL	5	66	27	339	142	44	544	29	23	29,086

* Indicates measurements less than reported precision.

Table 11.—Available Coal Resources, Reported by Overburden and Thickness Categories (Thousands of Short Tons).[1]

Coal Bed	*Surface (0–100')*			*Deep (> 100')*			*Thickness Totals*		*TOTALS*
	14–28"	*>28"*	*Total*	*14–28"*	*>28"*	*Total*	*14–28"*	*>28"*	
Copland	0	3,139	3,139	0	1,463	1,463	0	4,602	4,602
Whitesburg	1,373	1,790	3,162	0	3,835	3,835	1,373	5,625	6,997
Amburgy	2,343	119	2,462	0	118	118	2,343	238	2,580
Upper Elkhorn No. 3	7,706	273	7,979	0	233	233	7,706	506	8,212
Jellico	8,168	5,252	13,420	0	3,997	3,997	8,168	9,249	17,417
Manchester	444	0	444	0	0	0	444	0	444
TOTAL	20,034	10,573	30,606	0	9,646	9,646	20,034	20,220	40,252

[1] Totals may not equal sum of components because of independent rounding.

Figure 8. Total area of land-use restrictions for the Booneville Quadrangle.

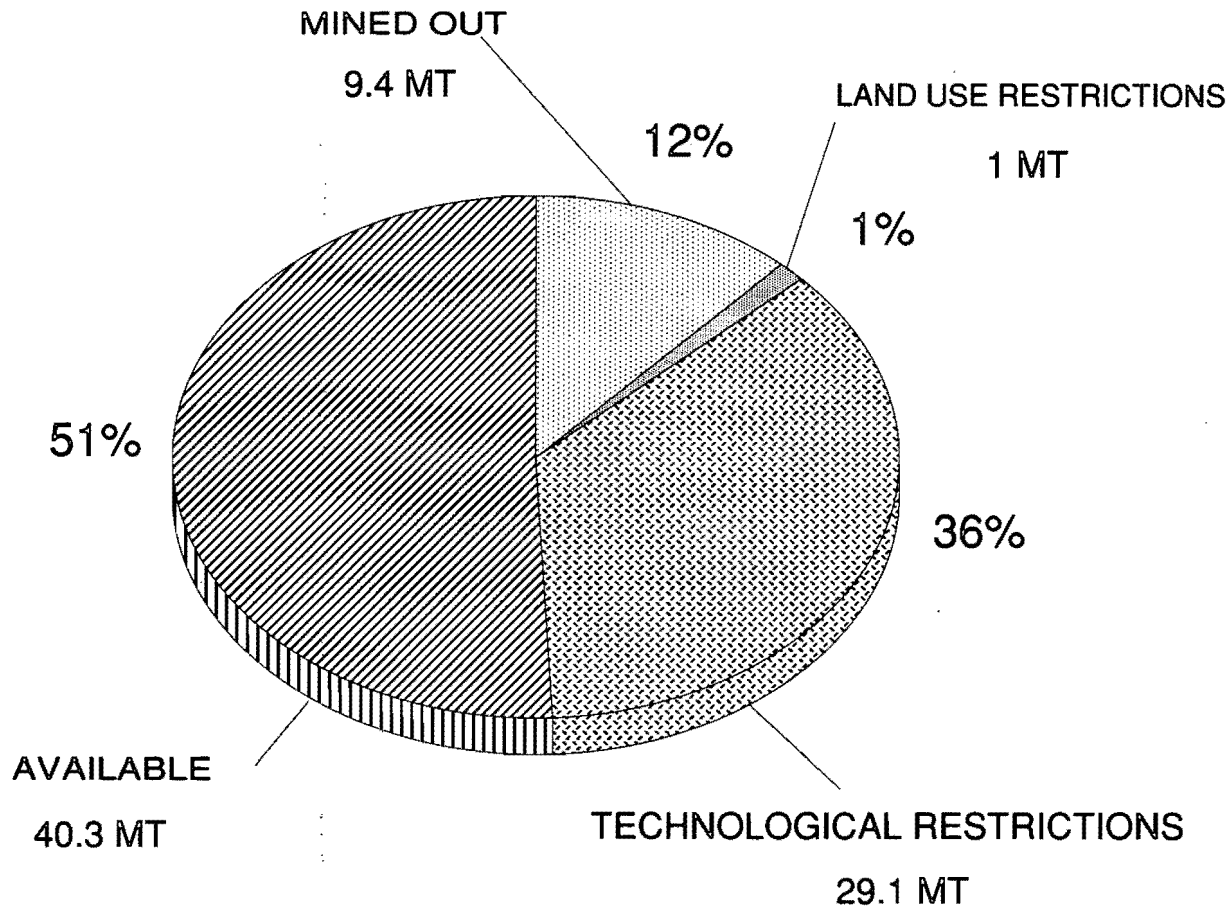

Figure 9. Summary of results for the Coal Availability Study of the Booneville Quadrrangle. MT=millions of tons.

COMPARISON TO PREVIOUS STUDIES

The Booneville Quadrangle has the lowest amount of original resources of the seven quadrangles completed to date (**Table 12**). This is characteristic of quadrangles near the northwestern margin of the coal field. Booneville ranks with the Noble and Matewan Quadrangles for having the smallest percentage of remaining resources among the seven areas (88 percent). The range of the proportional amount of land-use versus technological restrictions is large for all quadrangles. Booneville has the fewest land-use restrictions, primarily because all of the coal resources lie above the valley bottoms and therefore do not coincide with the primary areas of such restrictions. It has among the largest proportion of technological restrictions and, like the other quadrangles, this arises from coal too thin to be mined by underground methods. The proportion of available coal for the Booneville Quadrangle is near the average of 59 percent for all quadrangles.

Table 12.—Summary of All Seven Eastern Kentucky Coal Availability Quadrangles.

Quadrangle	*Original Resources*		*Remaining Resources*[1]		*Land-Use Restrictions*[2]		*Technological Restrictions*[2]		*Available Resources*[2]	
Matewan	986	100%	858	87%	17	2%	228	27%	613	71%
Noble	460	100%	399	86%	77	19%	51	13%	270	68%
Middlesboro N.	339	100%	328	97%	35	11%	138	42%	154	47%
Millard	843	100%	777	92%	30	4%	400	51%	347	45%
Hoskinston	498	100%	488	98%	21	4%	213	44%	254	52%
Boltsfork	243	100%	231	95%	15	7%	62	47%	169	73%
Booneville	80	100%	70	88%	1	1%	29	41%	40	58%

[1] Remaining—percent of original.
[2] Restrictions and Available—percent of remaining.

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Appendix A:
All Resources and Restrictions, Reported by Overburden, Thickness, and Reliability

COPLAND COAL BED

Coal Availability Results
(Thousands of Short Tons)[1]

	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	0	0	0	263	1,083	1,928	0	0	0	107	603	753
Mined-Out Surface	0	0	0	44	14	76	0	0	0	0	0	*
Mined-Out Deep	0	0	0	0	0	0	0	0	0	0	0	0
Remaining	0	0	0	220	1,069	1,852	0	0	0	107	603	753
Total Restrictions	0	0	0	0	0	2	0	0	0	0	0	0
Total Available	0	0	0	220	1,069	1,850	0	0	0	107	603	753
Land-Use Restrictions[2]												
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0
Faults	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	0	0	0	0	0	2	0	0	0	0	0	0
Roads	0	0	0	0	0	0	0	0	0	0	0	0
Streams	0	0	0	0	0	0	0	0	0	0	0	0
Towns	0	0	0	0	0	0	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	0	0	0	0	0	0
Coal Too Thin	0	0	0	0	0	0	0	0	0	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

* Indicates measurements less than reported precision.

[1] Totals may not equal sum of components because of independent rounding.

[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.

WHITESBURG COAL BED

Coal Availability Results

(Thousands of Short Tons)[1]

	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	114	246	1,126	104	312	1,451	58	144	1,264	43	132	3,60
Mined-Out Surface	66	30	0	71	6	0	14	0	0	0	0	0
Mined-Out Deep	0	0	0	0	0	0	0	0	0	0	0	0
Remaining	48	216	1,126	33	306	1,451	43	144	1,264	43	132	3,60
Total Restrictions	0	0	17	0	0	0	43	144	1,264	0	0	0
Total Available	48	216	1,109	33	306	1,451	0	0	0	43	132	3,60
Land-Use Restrictions[2]												
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0
Faults	0	0	3	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	0	0	14	0	0	0	0	0	0	0	0	0
Roads	0	0	0	0	0	0	0	0	0	0	0	0
Streams	0	0	0	0	0	0	0	0	0	0	0	0
Towns	0	0	0	0	0	0	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	0	0	0	0	0	0
Coal Too Thin	0	0	0	0	0	0	43	144	1,264	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

[1] Totals may not equal sum of components because of independent rounding.

[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.

AMBURGY COAL BED

Coal Availability Results

(Thousands of Short Tons)[1]

	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	318	1,308	1,200	105	14	0	395	2,664	1,536	102	17	0
Mined-Out Surface	126	309	26	0	0	0	2	15	0	0	0	0
Mined-Out Deep	0	0	3	0	0	0	0	0	0	0	0	0
Remaining	193	998	1,172	105	14	0	393	2,649	1,536	102	17	0
Total Restrictions	3	0	17	0	0	0	393	2,649	1,536	0	0	0
Total Available	190	998	1,155	105	14	0	0	0	0	102	17	0
Land-Use Restrictions[2]												
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0
Faults	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	2	0	0	0	0	0	0	0	0	0
Powerlines	3	0	16	0	0	0	0	0	0	0	0	0
Roads	0	0	0	0	0	0	0	0	0	0	0	0
Streams	0	0	0	0	0	0	0	0	0	0	0	0
Towns	0	0	0	0	0	0	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	*	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	0	0	0	0	0	0
Coal Too Thin	0	0	0	0	0	0	393	2,649	1,536	0	0	0

MEAS = measured. IND = indicated. INF = inferred.

* Indicates measurements less than reported precision.

[1] Totals may not equal sum of components because of independent rounding.

[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.

UPPER ELKHORN NO. 3 COAL BED

Coal Availability Results

(Thousands of Short Tons)[1]

	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	1,502	3,935	4,118	279	104	48	1,138	5,894	4,230	148	60	43
Mined-Out Surface	685	609	357	145	2	0	275	178	20	17	0	0
Mined-Out Deep	0	0	0	0	0	0	0	0	0	0	0	0
Remaining	817	3,326	3,761	133	102	48	863	5,715	4,210	131	60	43
Total Restrictions	11	66	121	5	6	0	863	5,715	4,210	0	0	0
Total Available	806	3,260	3,641	128	96	48	0	0	0	131	60	43
Land-Use Restrictions[2]												
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0
Faults	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	6	4	0	0	0	0	0	0	0	0	0
Powerlines	11	61	68	5	6	0	0	0	0	0	0	0
Roads	0	0	0	0	0	0	0	0	0	0	0	0
Streams	0	0	6	0	0	0	0	0	0	0	0	0
Towns	0	0	43	0	0	0	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	0	*	0	0	0	0
Coal Too Thin	0	0	0	0	0	0	863	5,715	4,210	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

* Indicates measurements less than reported precision.

[1] Totals may not equal sum of components because of independent rounding.

[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.

JELLICO COAL BED

Coal Availability Results
(Thousands of Short Tons)[1]

	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	1,619	5,011	4,377	2,718	4,384	1,386	1,026	2,253	4,537	1,310	2,576	394
Mined-Out Surface	754	1,531	335	1,635	1,152	198	50	179	47	156	68	*
Mined-Out Deep	18	27	0	42	41	0	3	13	0	25	15	0
Remaining	846	3,453	4,042	1,041	3,191	1,188	974	2,061	4,490	1,129	2,493	394
Total Restrictions	34	87	54	31	136	*	974	2,061	4,490	9	10	0
Total Available	813	3,366	3,989	1,010	3,055	1,188	0	0	0	1,120	2,483	394
Land-Use Restrictions[2]												
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0
Faults	0	4	0	14	45	0	0	0	0	0	0	0
Oil & Gas Wells	0	*	0	*	3	0	0	0	0	0	0	0
Powerlines	23	75	28	3	24	0	0	0	0	0	0	0
Roads	0	0	0	1	0	0	0	0	0	0	0	0
Streams	0	0	*	0	0	0	0	0	0	0	0	0
Towns	10	7	25	20	64	*	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	5	5	0	9	10	0
Oil & Gas Wells	0	0	0	0	0	0	0	0	0	0	0	0
Coal Too Thin	0	0	0	0	0	0	974	2,061	4,490	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

* Indicates measurements less than reported precision.

[1] Totals may not equal sum of components because of independent rounding.

[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.

MANCHESTER COAL BED

Coal Availability Results
(Thousands of Short Tons)[1]

	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	133	260	464	0	0	0	145	659	3,938	0	0	0
Mined-Out Surface	0	0	0	0	0	0	0	0	0	0	0	0
Mined-Out Deep	0	0	0	0	0	0	0	0	0	0	0	0
Remaining	133	260	464	0	0	0	145	659	3,938	0	0	0
Total Restrictions	75	143	195	0	0	0	145	659	3,938	0	0	0
Total Available	58	116	270	0	0	0	0	0	0	0	0	0
Land-Use Restrictions[2]												
Cemeteries	3	0	2	0	0	0	0	0	0	0	0	0
Faults	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	11	0	0	0	0	0	0	0	0	0
Powerlines	0	0	0	0	0	0	0	0	0	0	0	0
Roads	35	56	50	0	0	0	0	0	0	0	0	0
Streams	8	21	7	0	0	0	0	0	0	0	0	0
Towns	61	138	177	0	0	0	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	0	9	14	0	0	0
Coal Too Thin	0	0	0	0	0	0	145	659	3,938	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

[1] Totals may not equal sum of components because of independent rounding.

[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.