Chapter D

Resource Assessment

Edited by J.R. Hatch *and* R.H. Affolter

Chapter D *of*

Resource Assessment of the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin

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Introduction

By J.R. Hatch[1] *and* R.H. Affolter[1]

A primary goal of the current coal assessment in the Illinois Basin is to provide an update of estimates of the quantity and recoverability of the remaining coal resources. To accomplish this goal, in this chapter we

(1) review the history of coal production in the basin,
(2) summarize the results of the previous Illinois Basin coal assessments efforts,
(3) detail the methodologies used to calculate the remaining resources,
(4) present the resource calculations for the Springfield, Herrin, Danville, and Baker Coals categorized by coal, state, mining area, county, coal depth, coal thickness, and geologic reliability category,
(5) apply a recently developed methodology for determining the uncertainty of the resource calculations for the assessed coals, and
(6) briefly discuss the results of the many coal availability and coal recoverability assessment studies completed for areas within the basin.

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Illinois Basin Coal Production

By J.R. Hatch[1] *and* R.H. Affolter[1]

Coal production began in Illinois in the early 1800's. In Indiana, coal was being advertised for sale by 1832, and the first coal company was officially incorporated in 1837. The first recorded coal production in western Kentucky was in 1820, in Henderson and Muhlenburg Counties. Since these early beginnings, coal production from the basin, in general, was related to the overall increasing demand for power generation. At the same time, specific events have had both short- and long-term effects on coal development, and these include socio-political, technological, and market factors.

The annual coal production from Illinois, Indiana, and western Kentucky between 1890 and 1998 is shown in figure 1. Between 1890 and the late 1920's, coal production in all three states rose significantly, spurred by industrial development and railroad expansion. Coal production reached 89 million short tons in Illinois in 1918, 31 million short tons in Indiana, also in 1918, and 20 million short tons in western Kentucky in 1927. Production then declined markedly during the Great Depression of the 1930's (fig. 1). Production increased to meet the demands of World War II, but later decreased due to competition from oil and gas and the conversion of railroad locomotives from coal to diesel-electric power. In the 1960's and early 1970's, increased production resulted from an increased demand to meet the needs of a growing number of coal-fired power plants. A maximum of about 148 million tons was produced from the Illinois Basin in 1984.

Since about 1990, coal production from the Illinois Basin has dropped, primarily a result of the enactment and implementation of Phase I restrictions of the 1990 Amendment to the Clean Air Act and increasing price competition from western low-sulfur coals (U.S. Energy Information Administration, 1998; Carey and Hiett, 2000). Average coal production from the Illinois Basin was about 138 million short tons between 1988 and 1992, about 116 million short tons between 1993 and 1997, and about 112 million short tons in 1998. From 1890 to 1998, about 5.6 billion short tons of coal were produced in Illinois, about 2.5 billion short tons in western Kentucky, and about 2.1 billion short tons in Indiana. (U.S. Energy Information Administration, 1998, 2000; Carey and Hiett, 2000).

Springfield, Herrin, Danville, and Baker Coals

The Springfield Coal has been the most extensively mined coal in the Illinois Basin. The Springfield was mined at the surface in western Illinois and is the only coal mined in west-central Illinois. It is the most important coal in southeastern Illinois and has been mined in southwestern Illinois (Damberger, 2000). The Springfield has been mined in both surface and underground mines in nine counties in Indiana and eight counties in western Kentucky (fig. 2).

The Herrin Coal Member has been the most extensively mined coal in Illinois and has been mined in western, west-central, southern, east-central, and northern Illinois (Damberger, 2000). The Herrin is neither well developed nor mined in Indiana. Mining activity in the Herrin coal in western Kentucky is centered along the southern edge of the field (fig. 3).

The Danville Coal Member has been mined in east-central Illinois and in the adjacent counties in Indiana. Most of the historical mining of the Baker coal has been by surface methods along the southern and eastern margins of the coal field (Weisenfluh and others, 1998) (fig. 4).

The annual coal production (million short tons) from the Springfield, Herrin, and Danville Coals in Illinois between 1890 and 1997 is shown in figure 5. The data shown in figure 5 were compiled by C.G. Treworgy and C.A. Chenoweth from coal production data from the Illinois Department of Mines and Minerals (written commun., 1998). Figure 5 shows that most of the historical Illinois coal production has been from the Herrin Coal and that most of the decrease in coal production in Illinois during the last five years has been primarily a result of decreased Herrin Coal production.

Coal Production from Surface and Underground Mines

Data comparing coal production from surface mines with production from underground mines in western Kentucky are shown in figure 6. Surface mining methods were introduced in this area in 1922, and production from surface mines exceeded underground production in 1957. From 1957 to 1985, production from surface mining was greater than that from underground mining, a maximum of about 33 million tons being produced by surface mining in 1972 (Weisenfluh and others, 1997; Carey and Hiett, 2000). Since 1972, coal production from surface mining has consistently diminished; in 1998, only about 8.0 million short tons (22 percent of total) was produced by this method. In 1998, 27.9 million short tons (78 percent of total) was produced from underground mines in western Kentucky (U.S. Energy Information Administration, 2000; Carey and Hiett, 2000).

The history of coal production from surface mines as compared to production from underground mines is similar in Illinois. Annual production from underground mines in Illinois reached a peak of 47 million short tons in 1992, and surface-mine production peaked at almost 35 million tons in 1969 (Illinois Department of Mines and Minerals, 1994). In 1998, nearly 89 percent (35.2 million tons) of Illinois coal production was from underground mines, whereas only about 11 percent (4.7 million tons) was produced from surface mines). Reasons for the significant decline in production from surface mines in Illinois and western Kentucky include stricter reclamation requirements and the depletion of low-cost reserves, as well as the 1990 Amendment to the Clean Air Act and increased price competition from western low-sulfur coals (Treworgy and others, 1997; Weisenfluh and others, 1997).

In Indiana, in contrast to decreases in production from surface mines in Illinois and western Kentucky, nearly 33.4 million short tons (91 percent of total) was produced from surface mines in 1998, compared to only 3.4 million short tons (9.3 percent of total) produced from underground mines (U.S. Energy Information Administration, 2000; Sanda, 2000a). Coal production in Indiana has actually increased since 1995, with production of 36.8 million tons being produced in 1998 (fig. 1) (U.S. Energy Information

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Administration, 2000).This increase in production has primarily been from coals that are relatively low in sulfur (Danville, Upper and Lower Block, Minshall and Buffaloville Coal Members (Blunck and Carpenter, 1997; Sanda, 2000b).

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Figure 1. Graph showing annual coal production (million short tons) in Illinois, Indiana, and western Kentucky between 1890 and 1998. Data are from Carey and Hiett (2000), U.S. Energy Information Administration (2000), and Illinois Department of Mines and Minerals (1994).

Figure 2. Map showing mined-out areas of the Springfield Coal in Illinois, Indiana, and Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

Figure 3. Map showing mined-out areas of the Herrin Coal in Illinois, Indiana, and Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

Figure 4. Map showing mined-out areas of the Danville Coal Member in Illinois and Indiana, and the Baker coal in Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

Figure 5. Graph showing annual coal production (million short tons) from the Springfield, Herrin, and Danville Coal Members in Illinois between 1890 and 1997. No data were available for 1902. These data were compiled by C.G. Treworgy and C.A. Chenoweth (written commun., 1998) from coal production data from the Illinois Department of Mines and Minerals .

Figure 6. Graph showing annual coal production (million short tons) from underground and surface mines in western Kentucky between 1922 and 1998. Data are from Carey and Hiett (2000). No data were available for 1929.

Previous Resource Assessments of Illinois Basin Coals

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Since 1899, a number of assessments of the original, remaining, and recoverable coal resources in the Illinois Basin have been completed. For Illinois, the assessments are those of DeWolf (1908), Bement, 1910, Cady (1952), Hopkins and Simon (1974), Treworgy and others (1978), Treworgy and Bargh (1982), and Treworgy and others (1997). For Indiana, they are those of Ashley (1899), Campbell and Leverett (1913), Spencer (1953), and Wier (1973). For western Kentucky they are those of Smith and Brant (1980) and Weisenfluh and others (1998). For the 1974 U.S. Geological Survey national coal resource assessment, Averitt (1975) reported the resource estimates of Hopkins and Simon (1974) for Illinois, Wier (1973) for Indiana, and Huddle and others (1963, p. 177) for western Kentucky.

Illinois

For Illinois, DeWolf (1908) estimated that there was about 137 billion short tons (both surface and deep mineable) in deposits greater than 24 in. thick. Bement (1910) estimated about 201 billion short tons by measuring the extent of the coal-bearing areas on a map at a scale of one inch equals two miles (1:63,360), then combining these measurements with the known or estimated thickness of the coals. Cady (1952) provided the first comprehensive assessment of the coal reserves in Illinois, estimating about 137.3 billion short tons of remaining coal in 20 different coals. Cady's (1952) estimate was categorized by county, coal bed, thickness (≥28 in.) and by reliability category (I–A: proved, 0–0.5 mi from a data point; I–B: probable, >0.5–2 mi; II–A: strongly indicated, >2–4 mi; and II–B: weakly indicated, >4 mi). About 74 percent of Cady's (1952) estimated 137.3 billion short tons was associated with two coals, the Herrin and Harrisburg-Springfield Coal Members; 98 percent was associated with seven coals (see table 1).

Hopkins and Simon (1974) updated the assessment of the coal resources of Illinois. They estimated about 148.2 billion short tons of remaining coal in eight identified coals and a miscellaneous coals category. Their estimate includes coal 28 in. thick or greater in all classes of reliability. About 73 percent of this total is associated with two coals, the Springfield–Harrisburg and the Herrin Coal Members; 96 percent of the resource is in six coals (table 2). Hopkins and Simon (1974) also estimated the percentage of each resource category that was strippable (> 28 in. thick and < 150 ft of overburden) for each county and the amounts of relatively low sulfur (<2.5 percent) coal for the Springfield-Harrisburg and Herrin. For the Springfield-Harrisburg Coal Member, low-sulfur reserves were estimated at about 2.7 billion short tons, and for the Herrin Coal Member, about 2.1 billion tons.

Treworgy and others (1978) estimated surface-mineable coal resources of 20.4 billion short tons for 14 different coals in Illinois. Treworgy and Bargh (1982) estimated deep-mineable resources of 161 billion short tons for 13 different coals. Surface-mineable coal is that which is less than 150 ft in depth and equal to or greater than 28 in. thick (Treworgy and others, 1978). Deep-mineable coal is that which is greater than 150 ft in depth and equal to or greater than 28 in. thick (Treworgy and Bargh, 1982). Estimated resources of surface-mineable and deep-mineable coal for the six principal coals in Illinois (from Treworgy and others, 1978; and Treworgy and Bargh, 1982) are listed in table 3.

Damberger (2000) listed remaining resources (as of January 1996) in Illinois by county and for nine different coals. He estimated the total remaining identified resource at about 199 billion short tons. About 71 percent of this total is associated with two coals, the Herrin and Springfield Coal Members, and 91 percent with six coals (table 4). Of the 199 billion short tons of coal estimated for Illinois, 22.4 billion short tons are identified as surface-mineable (Damberger, 2000). The resource numbers for the Springfield, Herrin, and Danville Coal Members listed by Damberger (2000) are the same numbers used for the current assessment.

In addition to the above listed state-wide coal resource assessments for Illinois, many additional reports provide coal occurrence maps and summaries of coal resources on a quad- rangle, county, mining district, or regional scale. Information in these reports was

Table 1. Estimated remaining resources of the principal coals in Illinois (Cady, 1952).

[Columns may not sum exactly due to independent rounding.]

Coal	Billion short tons	Percent of total
Danville (Sparland) Coal	7.8	5.7
Herrin Coal	62.6	45.6
Harrisburg (Springfield) Coal	38.5	28.0
LaSalle (Colchester) Coal	17.5	12.7
Dekoven Coal	2.5	1.8
Indiana III Coal	1.8	1.3
Davis-Wiley Coal	3.4	2.5
Other coals	3.2	2.3
Total	137.3	100.0

Table 2. Estimated remaining resources of the principal coals in Illinois (Hopkins and Simon, 1974).

[Columns may not sum exactly due to independent rounding.]

Coal	Billion short tons	Percent of total
Danville Coal	7.6	5.1
Herrin Coal	65.8	44.4
Springfield-Harrisburg Coal	42.6	28.7
Colchester Coal	20.8	14.0
Dekoven Coal	2.5	1.7
Davis Coal	3.4	2.3
Other coals	5.5	3.7
Total	148.2	100.0

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Table 3. Estimated resources of surface-mineable and deep-mineable coal for the principal coals in Illinois (Treworgy and others, 1978; Treworgy and Bargh, 1982).

[Columns may not sum exactly due to independent rounding.]

Coal	Surface mineable		Deep mineable	
	Billion short tons	Percent of total	Billion short tons	Percent of total
Danville Coal	1.4	6.9	10.2	6.3
Herrin Coal	6.9	33.8	67.0	41.6
Springfield Coal	4.0	19.6	54.8	34.0
Colchester Coal	7.2	35.3	9.0	5.6
Dekoven Coal	<0.1	<0.5	2.3	1.4
Davis Coal	<0.1	<0.5	2.6	1.6
Other coals	0.8	3.9	15.0	9.3
Total	20.4	100.0	160.9	99.8

used to compile the above-listed statewide assessments and summaries. The following is a partial listing of these reports (in chronological order):

Cady, 1915, District 1 (Longwall District), northern Illinois
Kay, 1915, District VII, southwestern Illinois
Kay and White, 1915, District VIII, Vermilion and Edgar Counties
Cady, 1916, District VI, Jefferson, Franklin, and Williamson Counties
Cady, 1917, District II, Jackson County
Cady, 1919a, District V, Saline and Gallatin Counties
Cady, 1919b, Hennepin and LaSalle quadrangles, LaSalle and Bureau Counties
Cady, 1921, District IV, west-central Illinois
Culver, 1925, District III, western Illinois
Willman and Payne, 1942, Marseilles, Ottawa, and Streator quadrangles, LaSalle, Livingston, and Grundy Counties
Cady and others, 1951, Clay, Edwards, Gallatin, Hamilton, and Richland Counties
DuBois, 1951, Shelby and Moultrie Counties and parts of Effingham and Fayette Counties
Harrison, 1951, White County
Cady and others, 1955, Wabash County
Williams and Rolley, 1955, Jasper County
Potter, 1956, Crawford and Lawrence Counties
Smith, 1957, Part 1—Gallatin, Hardin, Johnson, Pope, Saline, and Williamson Counties
Wanless, 1957, Beardstown, Glasford, Havanna, and Vermont quadrangles, Brown, Cass, Fulton, and Peoria Counties
Smith, 1958, Part 2—Jackson, Monroe, Perry, Randolph and St. Clair Counties
Clegg, 1959, Douglas, Coles, and Cumberland Counties
Clegg, 1961, Sangamon, Macon, and Menard Counties and parts of Christian and Logan Counties
Smith, 1961, Part 3—Madison, Macoupin, Jersey, Greene, Scott, Morgan, and Cass Counties
Smith and Berggren, 1963, Part 5A—Fulton, Henry, Knox, Peoria, Stark, and Tazewell Counties and parts of Bureau, Marshall, Mercer, and Warren Counties
Reinertsen, 1964, Part 4—Adams, Brown, Calhoun, Hancock, McDonough, Pike, and Schuyler Counties and southern parts of Henderson and Warren Counties
Clegg, 1965, Clark and Edgar Counties
Smith, 1968, Part 6—LaSalle, Livingston, Kankakee, Will, and Putnam Counties and parts of Bureau and Marshall Counties
Searight and Smith, 1969, Part 5B—Mercer, Rock Island, and Warren Counties and parts of Henderson and Henry Counties
Clegg, 1972, DeWitt, McLean, and Piatt Counties
Allgaier and Hopkins, 1975, Fairfield basin in southeastern Illinois
Jacobson and Bengal, 1981, Part 7—Vermilion and Edgar Counties
Nance and Treworgy, 1981, Part 8—Central and southern counties
Jacobson, 1983, Jackson and Perry Counties
Treworgy and Bargh, 1984, statewide coal maps
Jacobson, 1985, Grundy, LaSalle, and Livingston Counties
Nelson, 1987, Christian, Macoupin, Montgomery, and Sangamon Counties
Jacobson, 1993, Gallatin and Saline Counties

Indiana

Ashley (1899) estimated coal resources of Indiana to be about 47 billion short tons. Campbell and Leverett (1913), assuming a larger tonnage per acre-foot of coal, revised that

Table 4. Estimated remaining resources of the principal coals in Illinois (Damberger, 2000).

[Columns may not sum exactly due to independent rounding.]

Coal	Billion short tons	Percent of total
Danville Coal	17.8	8.9
Herrin Coal	78.9	39.6
Springfield Coal	61.7	31.0
Colchester Coal	16.6	8.3
Dekoven Coal	2.7	1.4
Davis Coal	3.5	1.8
Other coals	17.8	8.9
Total	199.0	100.0

Table 5. Estimated remaining resources of the principal coals in Indiana as of January 1, 1951 (Spencer, 1953).

[Columns may not sum exactly due to independent rounding.]

Coal	Billion short tons	Percent of total
Danville Coal	3.7	10.4
Hymera Coal	3.7	10.3
Springfield Coal	13.8	38.5
Survant Coal	3.9	10.9
Seelyville Coal	5.9	16.4
Other coals	4.8	13.4
Total	35.8	100.0

estimate to about 53 billion short tons. The first comprehensive coal resource assessment for Indiana is that of Spencer (1953), who estimated remaining resources (as of January 1, 1951) at 35.8 billion short tons for 17 different coals. About 31 billion short tons (86 percent) of this total was associated with five beds (table 5). Wier (1973), updating Spencer (1953), estimated remaining resources as of January 1, 1965, at 33.2 billion tons.

In addition to the above-listed state-wide coal resource assessments for Indiana, other reports summarize coal resources on a quadrangle, county, mining district, or regional scale. Information in many of these reports was used to compile later, state-wide summaries. The following is a partial listing of these reports in chronological order:

Indiana Geological Survey, 1950, Jasonville quadrangle, Greene and Sullivan Counties
Indiana Geological Survey, 1951, Linton quadrangle, Greene and Sullivan Counties
Wier, 1952, Vigo County
Wier and Stanley, 1953, Pike County
Friedman, 1954a, Gibson County
Friedman, 1954b, Vanderburgh County
Indiana Geological Survey, 1954a, Dugger quadrangle, Sullivan County
Indiana Geological Survey, 1954b, Hymera quadrangle, Sullivan County
Indiana Geological Survey, 1954c, Coal City quadrangle, Greene, Clay, and Owen Counties
Hutchison and Hamilton, 1956, Clay County
Indiana Geological Survey, 1958, Seelyville quadrangle, Vigo County
Hutchison, 1958, Warrick County
Indiana Geological Survey, 1959, Coal City quadrangle, Greene, Clay, and Owen Counties
Indiana Geological Survey, 1960, Switz City quadrangle, Greene County
Indiana Geological Survey, 1961, Terre Haute and Dennison quadrangles, Vigo County
Hutchison, 1961, Fountain and Warren Counties and the northernmost part of Vermillion County
Hutchison, 1964, Dubois County
Hutchison, 1967, Martin County
Powell and Wier, 1967, Knox County
Powell. 1968, Parke County and southern Vermillion County
Hutchison, 1971a, Perry County
Hutchison, 1971b, Daviess County
Hutchison, 1976, Parke and Putnam Counties
Hill, 1980, Putnam County
Tanner, and others, 1981a, southwestern Gibson County
Tanner and others, 1981b, northern Posey County
Tanner and others, 1981c, southern Posey County
Hutchison and Hasenmueller, 1988, Greene County
Friedman, 1989, Clinton area, west-central Indiana
Hasenmueller, 1993, Owen County
Callis, 1994, Spencer County
Callis and Rupp, 1994, Daviess County
Eggert, 1994, Gibson County
Harper and Eggert, 1995, Knox County
Ault, 1997, Posey County
Conolly and Buciak, 1997, Pike County

Western Kentucky

For western Kentucky, a comprehensive coal resource estimate was provided by Smith and Brant (1980), who estimated remaining coal resource at about 38.6 billion short tons for 33 different coals. About 36.4 billion short tons (94 percent) of the total was associated with seven coals (table 6).

As part of a discussion of the availability of coal resources in western Kentucky, Weisenfluh and others (1998) estimated the remaining resources for the Springfield, Herrin, and Baker coals (table 7). They did not estimate resources for the Man-

Table 6. Estimated remaining resources of the principal coals in western Kentucky as of January 1, 1976 (Smith and Brant, 1980).

[Smith and Brant (1980) reported results for the Herrin and Paradise coals together; the Mannington, Mining City, and Lewisport coals are thought to be continuous and are reported as one coal. Columns may not sum exactly due to independent rounding.]

Coal	Billion short tons	Percent of total
Coiltown coal	1.2	3.2
Baker coal	3.1	8.1
Herrin and Paradise coals	8.4	21.7
Springfield coal	9.4	24.3
Davis coal	7.5	19.3
Mannington, Mining City, and Lewisport coals	6.5	16.9
Other coals	2.5	6.5
Total	38.6	100.0

Table 7. Estimated remaining resources of the Springfield, Herrin, and Baker coals in western Kentucky as of August 15, 1998 (Weisenfluh and others, 1998).

Coal	Billion short tons
Baker coal	3.6
Herrin coal	2.6
Springfield coal	8.0

nington—Mining City—Lewisport, Davis, Paradise, or Coiltown coals in western Kentucky.

In addition to the coal resource assessments of Smith and Brant (1980) and Weisenfluh and others (1998), there are additional reports providing coal occurrence maps and summaries of coal resources on a quadrangle, county, or regional scale. The following is a partial listing of these reports in chronological order:

Walker and others, 1951, Henderson quadrangle, Henderson County
Cathey, 1955, Newburgh quadrangle, Henderson County
Mullins and others, 1963, parts of Butler, Edmonson, Grayson, Muhlenberg and Warren Counties
Hodgson, 1963, upper Tradewater River area, western Kentucky
Mullins and others, 1965, northwestern Kentucky (primarily Union, Henderson, and Webster Counties)

As part of a cooperative program between the U.S. Geological Survey and the Kentucky Geological Survey, geologic quadrangle maps were produced for all of western Kentucky. This quadrangle mapping program, completed in 1978, served as a basis for producing coal distribution maps and for calculating coal resources. The following 34 geologic quadrangle maps show the outcrops for the Springfield, Herrin and (or) Baker coals in western Kentucky:

Amos, 1970, Blackford quadrangle, Crittenden, Webster, and Union Counties
Fairer and Norris, 1972, Curdsville quadrangle, Henderson, Daviess, and McLean Counties
Franklin, 1967, Coiltown quadrangle, Hopkins County
Franklin, 1969, Nebo quadrangle, Webster and Hopkins Counties
Franklin, 1973, Millport quadrangle, Muhlenberg and Hopkins Counties
Gildersleeve, 1975, Cromwell quadrangle, Butler and Ohio Counties
Goudarzi, 1968, Hartford quadrangle, Ohio County
Goudarzi, 1969, Equality quadrangle, Ohio, McLean, and Muhlenberg Counties
Goudarzi, 1971, Panther quadrangle, Daviess County
Goudarzi and Smith, 1971, part of the Owensboro West quadrangle, Daviess County
Hansen, 1972, Drakesboro quadrangle, Muhlenberg County
Hansen, 1974, Rochester quadrangle, Muhlenberg, Ohio, and Butler Counties
Hansen and Smith, 1978, Livermore quadrangle, McLean, and Muhlenberg Counties
Johnson, 1971, Horton quadrangle, Ohio County
Johnson, 1972, Reed quadrangle, Henderson and Daviess Counties
Johnson, 1973a, Evansville South quadrangle, Henderson County
Johnson, 1973b, Spottsville quadrangle, Henderson County
Johnson and Smith, 1972a, Utica quadrangle, Daviess, McLean, and Ohio Counties
Johnson and Smith, 1972b, Glenville quadrangle, McLean and Daviess Counties
Johnson and Smith, 1975, Calhoun quadrangle, Daviess, McLean, and Webster Counties
Kehn, 1963, Madisonville East quadrangle, Hopkins and Muhlenberg Counties
Kehn, 1964, Madisonville West quadrangle, Hopkins County
Kehn, 1966a, Providence quadrangle, Webster, Crittenden, and Hopkins Counties
Kehn, 1966b, Dawson Springs quadrangle, Hopkins, Caldwel,l and Christian Counties
Kehn, 1968, Graham quadrangle, Muhlenberg, Hopkins, and Christian Counties
Kehn, 1971, Greenville quadrangle, Muhlenberg County
Kehn, 1974a, Dekoven and Saline Mines quadrangles, Crittenden, and Union Counties
Kehn, 1974b, Paradise quadrangle, Muhlenberg and Ohio Counties
Kehn, 1975, Sturgis quadrangle, Union and Crittenden Counties
Palmer, 1966, Dalton quadrangle, Caldwell, Hopkins, Crittenden and Webster Counties
Palmer, 1967, Saint Charles quadrangle, Hopkins and Christian Counties
Palmer, 1968, Nortonville quadrangle, Hopkins and Christian Counties
Palmer, 1969, Central City West quadrangle, Muhlenberg and Ohio Counties
Palmer, 1972, Central City East quadrangle, Muhlenberg and Ohio Counties

Summary

These earlier coal resource estimates all show that the Springfield, Herrin, Danville, and Baker Coals contain most of the remaining coal resources in the Illinois Basin. The combined remaining resources estimated by Cady (1952) for the Springfield, Herrin, and Danville Coal Members were about 79 percent of the total estimated for all of Illinois. The combined remaining resources estimated by Hopkins and Simon (1974) were about 78 percent of the total coal resource; the estimates by Treworgy and others (1978) and Treworgy and Bargh (1982) were 82 percent of the total coal resource; and the estimates by Damberger (2000) were 80 percent of the total coal resources of Illinois. For Indiana, the combined resource estimate for the Springfield and Danville Coal Members by Spencer (1953) represents 49 percent of the total resource estimate, and for western Kentucky the combined resource estimate for the Springfield, Herrin, and Baker coals by Smith and Brant (1980) represents 54 percent of the total coal resources estimated.

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Illinois

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Remaining Resources of the Springfield, Herrin, Danville, and Baker Coals

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Methodology

A Geographic Information System (GIS) was used to estimate volumes of coal resources from information on coal distribution and coal thickness. This approach allows for the digital storage of information obtained from drill hole cores and logs, coal outcrop maps, and maps showing areas where coal has been mined out, and it permits comparisons of calculations made from one map with those made from others (Weisenfluh and others, 1998). Data from descriptions of exploration drill holes, geophysical logs, outcrop measurements, and mine maps included stratigraphic position, coal bed thickness, thickness of rock partings if present, and elevation. Outcrop data were digitized from 1:24,000-scale geologic quadrangle maps. Maps showing mined-out areas in Illinois were preserved through a cooperative effort between the U.S. Bureau of Mines, the Illinois Office of Mines and Minerals, and the Illinois State Geological Survey. These include maps from more than 2,100 underground and 400 surface mines. Maps showing mined-out areas for western Kentucky were obtained from the Kentucky Department of Mines and Minerals; for Indiana, maps were provided by the Indiana Bureau of Mines and Mining Safety.

Resource Categories

Thickness

Wood and others (1983) defined the standard USGS procedures for estimating coal resources as including coal thickness greater than 14 in.; and categorized thickness in multiples of 14 in. between 14 and 42 in., and in multiples of 42 in. between 42 and 168 in. For this assessment of coal resources in Illinois, Indiana, and western Kentucky, only three categories were used: >14 to 28 in., >28 to 42 in., and >42 in. This categorization is based on historical mining practices in the Illinois Basin and on the assumptions that coal less than 28 in. thick is generally not mineable by underground methods and that coal less than 42 in. thick is not economically mineable by underground methods at this time.

Overburden

Resources and reserves are divided into categories based on the coal mining method (surface or underground) most likely to be used. Given current mining practices, an overburden of less than150 ft was used to estimate resources amenable to surface mining, and overburden between 150 and 1,500 ft was used to estimate resources amenable to underground mining. It should be noted that, in practice, maximum overburden thickness for surface mining is generally determined by a ratio of overburden to coal thickness. The footage limits stated above were used to provide estimates of surface-mineable and deep-mineable areas for purposes of the present study.

Reliability

The USGS standard reliability categories are "measured," "indicated," "inferred," and "hypothetical." Measured resources are within 0.25 mi of a data point; indicated resources, between 0.25 and 0.75 mi; inferred resources, between 0.75 and 3.0 mi; and hypothetical resources, greater than 3 mi (Wood and others, 1983). These categories were used for the coal resources from western Kentucky. Because of the considerable lateral continuity of the Springfield, Herrin, and Danville Coals, coal resources in Illinois and Indiana were categorized according to the I–A, I–B, II–A and II–B class system originally defined by Cady (1952) and modified by Treworgy and Bargh (1982) to include oil test geophysical logs as accepted data points for class II–A. In this system, I–A (proved) resources are within 0.5 mi of a data point, I–B (probable) resources between 0.5 and 2 mi, II–A (strongly indicated) resources between 2 and 4 mi, and II–B (weakly indicated) resources beyond 4 mi from a data point. The I–A category is approximately equivalent to the USGS "measured" category, I–B to the USGS "indicated" category, and II–A to the USGS "inferred" category (Treworgy and others, 1997).

Data Analysis

Illinois

The following steps were taken to calculate coal resources in Illinois (Treworgy and others, 1997):

1. Thickness, depth, and elevation contours for each bed were created from the selected data points by using Earthvision, version 3 (Dynamic Graphics Inc., Alameda, CA).
2. These computer-generated contour maps were converted from the grid format of the contouring software to a format used by GIS software (ArcInfo version 7.04 by Environmental Systems Research Institute, Redlands, CA).
3. The GIS software was used to create reliability zones, which were then merged with maps of bed thickness, depth, and mined areas.
4. Tonnages were calculated from the merged layers by assuming 1 acre-foot of bituminous coal = 1,800 short tons of coal.

Indiana

The following steps were taken to calculate coal resources in Indiana (C. L. Connolly, written commun., 2000):

1. ArcInfo was used to create a 200-m resolution floating-point grid of coal thickness in inches.

[1]U.S. Geological Survey, Mail Stop 939, Box 25046, Denver, CO 80225–0046
[2]Indiana Geological Survey, Indiana University, 611 N. Walnut Grove, Bloomington, IN 47405–2208
[3]Illinois State Geological Survey, Natural Resources Building, 615 E. Peabody Drive, Champaign, IL 61820
[4]Kentucky Geological Survey, 228 Mining and Minerals Bldg., University of Kentucky, Lexington, KY 40506–0107

2. The floating-point grid was reclassified to create a grid in which the coal thickness values correspond to 7-in. contour intervals.
3. The reclassified grid was converted to a polygon coverage.
4. The 7-in. contour interval coal thickness coverage was combined with coverages for surface mines, underground mines, reliability circles (I–A, II–A, and I–B), and coal depth (0–150 ft and >150 ft).
5. The tonnage in each polygon was calculated by using the conversion constants of 1,800 short tons of coal/(acre–feet of coal), and 4,046.9 m^2/acre.

Western Kentucky

The GIS software utilized for resource calculations was GRASS (Geographic Resources Analysis Support System), a U.S. Government software package developed primarily by the U.S. Army Corps of Engineers, the U.S. Soil Conservation Service, and the USGS. GRASS is a raster-based GIS, which means that map data are rendered as matrices of equal-sized cells. Maps stored in a GRASS database must be oriented to a particular coordinate system. In order to utilize map information for calculations, the original vector data (points, lines, areas) must be converted to raster (gridded) data files. Following map and file preparation, the USGS program "resources" used GRASS commands to calculate areas (in square meters) for all resource categories (original, mined-out, and remaining). These data were then converted to acres, and coal tonnages were calculated by using the conversions constants of 1,800 short tons of coal /(acre-feet of coal), and 4,047 m^2/acre (Weisenfluh and others, 1998).

Coal Resource Assessment Results

Estimated remaining coal resources (million short tons) for the Springfield, Herrin, Danville, and Baker Coals are listed in appendixes 1–3 (at the end of chapter D). Resources are categorized on the basis of coal bed, state, mining area (in Illinois), county, overburden thickness (0–150 ft and >150 ft), coal thickness (>14–28 in., >28-42 in., and >42 in.), and reliability of estimate (Illinois and Indiana: I–A, 0–0.5 mi from a data point; I–B, >0.5–2 mi; II–A, >2–4 mi. Western Kentucky: measured, 0–0.25 mi; indicated, >0.25–0.75 mi; inferred, >0.75–3.0 mi; and hypothetical, >3 mi). Figure 7 shows the mining areas of the Illinois Basin. The mining areas in Illinois are from Damberger (2000, fig. 1) and, in general, are based on historic mining districts. Each of these areas in Illinois is comparable in size to the coal-producing areas of Indiana and western Kentucky.

Identified coal resources are those resources in categories I–A + I–B + II–A, or measured + indicated + inferred. Summaries of the remaining identified coal resources estimates (million short tons) for the Springfield, Herrin, Danville, and Baker Coals as listed in appendixes 1–3 are listed in tables 8–10 by mining area, coal thickness interval (>14–28 in., >28–42 in., and >42 in.), and overburden thickness (0–150 ft and >150 ft). Histograms in figure 8 show the distribution of remaining identified coal resources by coal and by thickness interval. Histograms in figures 9–11 show the remaining identified coal resources in beds greater than 42 in. thick, summarized by mining area and by coal depth (0–150 ft and >150 ft).

Figure 8 shows that the large majority (81 and 84 percent, respectively) of the identified coal resources for the Springfield and Herrin Coals are in relatively thick (>42 in.) coal, whereas, for the Danville and Baker Coals, only 39 percent of the identified resources are in coals >42 in. thick. For the Springfield Coal (fig. 9), the mining areas having the largest amount of remaining identified resources include west-central Illinois (19 billion short tons), southeastern Illinois (29 billion short tons), and Indiana (12 billion short tons). In these areas, the Springfield Coal is generally greater than 42 in. thick (fig. 10). For the Herrin Coal (fig. 11), the mining areas having the greatest amount of remaining identified resources include west-central Illinois (27 billion short tons), southwestern Illinois (14 billion short tons), and southeastern Illinois (26 billion short tons). In these areas, the Herrin Coal is also generally greater than 42 in. thick (fig. 12). For the Danville and Baker Coals (fig. 13), the mining areas having the largest remaining identified resources are on the east side of the Illinois basin in east-central Illinois (7.3 billion short tons), southeastern Illinois (4.4 short billion tons), and Indiana (6.3 billion short tons). As shown in figure 14, these mining areas are where Danville and Baker Coals reach their greatest thickness.

For the Springfield Coal, the mining areas having the largest remaining identified resources in coals >42 in. thick and at depths 0—150 ft (table 8 and fig. 9) include western Illinois (1.2 billion short tons), west-central Illinois (1.1 billion short tons), and Indiana (1.8 billion short tons). For the Herrin Coal (table 9 and fig. 10), areas having such resources are western Illinois (1.9 billion short tons) and southwestern Illinois (2.4 billion short tons), and for the Danville and Baker Coals (table 10 and fig. 11), such areas are in east-central Illinois (450 million short tons) and Indiana (500 million short tons).

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Figure 7. Map showing mining areas of the Illinois Basin and the extent of coal-bearing rocks in Illinois, Indiana, and western Kentucky. The six mining areas in Illinois are from Damberger (2000, fig. 1). This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

Figure 8. Histogram showing remaining, identified coal resources (million short tons) of the Springfield, Herrin, and Danville-Baker Coals in Illinois, Indiana, and western Kentucky, summarized by thickness. Identified resources include categories I–A, I–B, and II–A in Illinois and Indiana, and measured, indicated, and inferred in western Kentucky.

Figure 9. Histogram showing remaining, identified coal resources (>42 in. thick, million short tons) of the Springfield Coal in Illinois, Indiana, and western Kentucky, summarized by mining area and by overburden thickness (coal depth). Data are from table 8. Identified resources include categories I–A, I–B, and II–A in Illinois and Indiana, and measured, indicated, and inferred in western Kentucky.

Figure 10. Map showing thickness of the Springfield Coal in Illinois, Indiana, and western Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

Figure 11. Histogram showing remaining, identified coal resources (>42 in. thick, million short tons) of the Herrin Coal in Illinois and western Kentucky, summarized by mining area and by overburden thickness (coal depth). Data are from table 9. Identified resources include categories I–A, I–B, and II–A in Illinois and Indiana, and measured, indicated, and inferred in western Kentucky.

Figure 12. Map showing thickness of the Herrin Coal in Illinois, Indiana, and western Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

Figure 13. Histogram showing remaining, identified coal resources (>42 in. thick, million short tons) of the Danville Coal Member in Illinois and Indiana, and the Baker coal in western Kentucky, summarized by mining area and by overburden thickness (coal depth). Data are from table 10. Identified resources include categories I–A, I–B, and II–A in Illinois and Indiana, and measured, indicated, and inferred in western Kentucky.

Figure 14. Map showing thickness of the Danville Coal Member in Illinois and Indiana, and the Baker coal in western Kentucky. This illustration was modified from regional shapefiles contained in the Illinois Basin ArcView project (Gunther and others, this publication).

Table 8. Summary of estimated remaining, identified resources of the Springfield Coal in Illinois, Indiana, and western Kentucky.

[Data are from appendix 1. Identified resources include geologic reliability categories I–A, I–B, and II–A for Illinois and Indiana, and measured, indicated, and inferred for Kentucky. Resources are listed by mining area and are categorized by overburden thickness (coal depth) and coal thickness. Resource numbers are rounded to two significant figures, or to the nearest one hundred million short tons for resources greater than ten billion short tons. Columns may not sum exactly due to rounding.]

Mining area	Coal depth (feet)	Remaining, identified resources (million short tons)			
		Coal thickness (inches)			
		>14-28	>28-42	>42	All
Northern Illinois	0 – 150	0	0	37	37
	> 150	0	2,200	2,500	4,700
	Subtotal	0	2,200	2,500	4,700
Western Illinois	0 – 150	380	450	1,200	2,000
	> 150	0	68	480	550
	Subtotal	380	520	1,700	2,600
West-central Illinois	0 – 150	0	0	1,100	1,100
	> 150	0	2,400	15,600	18,000
	Subtotal	0	2,400	16,700	19,100
East-central Illinois	0 – 150	17	9	13	39
	> 150	0	1,700	3,700	5,400
	Subtotal	17	1,700	3,700	5,500
Southwestern Illinois	0 – 150	12	98	250	370
	> 150	0	89	300	380
	Subtotal	12	190	550	740
Southeastern Illinois	0 – 150	0	4	370	370
	> 150	0	5,400	23,200	28,600
	Subtotal	0	5,400	23,600	29,000
Illinois	0 – 150	410	560	3,000	4,000
	> 150	0	11,900	45,800	57,700
	Subtotal	410	12,400	48,800	61,700
Indiana	0 – 150	25	280	1,800	2,100
	> 150	150	1,500	8,400	10,100
	Subtotal	180	1,700	10,200	12,100
Western Kentucky	0 – 150	1	17	960	990
	> 150	9	180	5,800	6,000
	Subtotal	10	200	6,800	7,000
Illinois Basin	0 – 150	430	860	5,700	7,000
	> 150	160	13,500	60,000	73,700
	Total	590	14,400	65,700	80,700

Table 9. Summary of estimated remaining, identified resources of the Herrin Coal in Illinois and western Kentucky.

[Data are from appendix 2. Identified resources include geologic reliability categories I–A, I–B, and II–A for Illinois and measured, indicated, and inferred for western Kentucky. Resources are listed by mining area and are categorized by overburden thickness (coal depth) and coal thickness. Resource numbers are rounded to two significant figures, or to the nearest one hundred million short tons for resources greater than ten billion short tons. Columns may not sum exactly due to rounding.]

Mining area	Coal depth (feet)	Remaining, identified resources (million short tons)			
		Coal thickness (inches)			
		>14-28	>28-42	>42	All
Northern Illinois	0 – 150	77	140	170	390
	> 150	0	330	62	390
	Subtotal	77	470	230	780
Western Illinois	0 – 150	15	470	2,000	2,500
	> 150	0	130	320	450
	Subtotal	15	600	2,300	2,900
West-central Illinois	0 – 150	98	600	300	990
	> 150	0	2,800	23,400	26,100
	Subtotal	98	3,400	23,700	27,100
East-central Illinois	0 – 150	81	56	470	610
	> 150	0	2,200	5,200	7,400
	Subtotal	81	2,300	5,700	8,000
Southwestern Illinois	0 – 150	2	17	2,400	2,400
	> 150	0	150	11,200	11,300
	Subtotal	2	170	13,600	13,800
Southeastern Illinois	0 – 150	3	47	580	630
	> 150	0	4,900	20,800	25,700
	Subtotal	3	4,900	21,400	26,300
Illinois	0 – 150	280	1,300	5,900	7,600
	> 150	0	10,500	60,900	71,400
	Subtotal	280	11,800	66,800	78,900
Western Kentucky	0 – 150	47	74	430	550
	> 150	140	460	1,500	2,100
	Subtotal	180	530	1,900	2,600
Illinois Basin	0 – 150	320	1,400	6,300	8,100
	> 150	140	11,000	62,400	73,500
	Total	460	12,400	68,700	81,600

Table 10. Summary of estimated remaining, identified resources of the Danville Coal in Illinois and Indiana, and the Baker coal in western Kentucky.

[Data are from appendix 3. Identified resources include geologic reliability categories I–A, I–B, and II–A for Illinois and Indiana, and measured, indicated, and inferred for Kentucky. Resources are listed by mining area and are categorized by overburden thickness (coal depth) and coal thickness. Resource numbers are rounded to two significant figures, or to the nearest one hundred million short tons for resources greater than ten billion short tons. Columns may not sum exactly due to rounding.]

Mining area	Coal depth (feet)	Remaining, identified resources (million short tons)			
		Coal thickness (inches)			
		>14-28	>28-42	>42	All
Northern Illinois	0 – 150	290	340	190	810
	> 150	570	950	1,300	2,800
	Subtotal	850	1,300	1,500	3,600
Western Illinois	0 – 150	430	200	0	630
	> 150	0	150	37	190
	Subtotal	430	350	37	820
West-central Illinois	0 – 150	0	0	0	0
	> 150	18	1,300	450	1,800
	Subtotal	18	1,300	450	1,800
East-central Illinois	0 – 150	57	350	450	850
	> 150	0	2,500	3,900	6,400
	Subtotal	57	2,800	4,400	7,300
Southeastern Illinois	0 – 150	120	4	0	120
	> 150	0	2,700	1,500	4,200
	Subtotal	120	2,700	1,500	4,300
Illinois	0 – 150	900	880	630	2,400
	> 150	590	7,600	7,300	15,500
	Subtotal	1,500	8,500	8,000	17,900
Indiana	0 – 150	210	840	500	1,600
	> 150	1,200	2,900	670	4,700
	Subtotal	1,400	3,700	1,200	6,300
Western Kentucky	0 – 150	310	360	260	930
	> 150	580	500	1,300	2,400
	Subtotal	890	870	1,600	3,400
Illinois Basin	0 – 150	1,400	2,100	1,400	4,900
	> 150	2,300	11,000	9,200	22,500
	Total	3,700	13,100	10,600	27,400

Confidence Limits for Resource Estimates of Illinois Basin Coals

By J.H. Schuenemeyer,[1] H.C. Power,[2] *and* J.R. Hatch[1]

Methodology

As part of the current USGS coal resource assessment, a geostatistical procedure has been developed (Schuenemeyer and Power, 2000) to estimate the uncertainty of coal resource calculations for the geological reliability categories used in the Illinois Basin The procedure of Schuenemeyer and Power (2000) involves trend removal, an examination of spatial correlation, computation of a sample variogram, and fitting a semi-variogram model. In the Illinois Basin, the data consist of spatially clustered coal-thickness measurements from coal beds that cover areas from 853 to 14,050 mi^2. The number of drill holes is generally proportional to areal extent. This model provides standard deviations for the uncertainty estimates. The minimum number of sample points for each reliability category was estimated (called a pseudo n) by dividing the area measured by the area determined by the maximum distance for a category (as examples, 0.5 mi for I–A, 0.25 mi for indicated). Measurement errors in coal bed thickness were then obtained from the fitted model. From this information, approximate estimates of uncertainty (confidence interval) for each reliability category were computed. A complete explanation of this procedure (with examples) is in Schuenemeyer and Powers (2000).

Results

Based on the above outlined procedure, volumes of the Springfield, Herrin, Danville, and Baker Coals were calculated at a 90-percent confidence interval on the volume (total resource in million short tons) of coal with measurement error for each geological reliability category used in the Illinois Basin. For Illinois and Indiana, resources are reported by categories of I–A (0–0.5 mi from a data point), I–B (>0.5–2 mi), and II–A (>2–4 mi). Resources in western Kentucky are reported by categories of measured (0–0.25 mi from a data point), indicated (0.25–0.75 mi), inferred (0.75–3.0 mi), and hypothetical (>3.0 mi). Although the state resource estimates listed in appendixes 1–3 and summarized in tables 8–10 were computed by using both the available public and proprietary data, only the publicly available data from each state were used to make the uncertainty calculations. The number of publicly available data points ranged from 16,325 for the Herrin Coal Member in Illinois to 653 for the Herrin coal in western Kentucky. If both the public and proprietary data points were to be used for the calculations, the estimates of uncertainty would most likely be less.

Summaries of the calculations of confidence intervals for geological reliability categories for the Springfield, Herrin, and Danville Coal Members in Illinois are shown in tables 11—13; for the Springfield and Danville Coal Members in Indiana, tables 14 and 15; and for the Springfield, Herrin, and Baker coals in western Kentucky, tables 16—18. Because of the generally low variability in coal thickness for the Springfield, Herrin, Danville, and Baker Coals in the Illinois Basin, estimates of uncertainty are also low. Ranges of the estimated percent errors for the various reliability categories from tables 11—18 are shown in figure 15.

Discussion

For the Springfield, Herrin, and Danville Coal Members in Illinois and the Springfield and Danville Coal Members in Indiana, estimated percent error for reliability category I–A ranges from <1 to 2 percent; for reliability category I–B it ranges from 2 to 6 percent (fig. 15). For category II–A in Illinois, estimated percent error ranges from 4 to 9 percent, whereas for category II–A in Indiana, percent error is much higher, 37 percent for the Springfield and 40 percent for the Danville. For the Springfield, Herrin, and Baker coals in western Kentucky, estimated percent error for the measured resources ranges from <1 to 2 percent; for indicated resources, 2 to 5 percent; for inferred resources, 5 to 16 percent; and for hypothetical resources, 34 to 77 percent. For the combined categories I–A, I–B, and II–A for Illinois and Indiana, estimated percent error ranges from 3 to 6 percent. For the combined measured, indicated, inferred, and hypothetical resources in western Kentucky, estimated percent error ranges from 5 to 15 percent.

As shown in figure 15, the uncertainty (<1 to 2 percent) for category I–A resources as used in Illinois and Indiana is comparable to the uncertainty (<1 to 2 percent) for measured resources as used in western Kentucky. Similarly, the uncertainty (2 to 6 percent) for I–B resources in Illinois and Indiana is comparable to the uncertainty (2 to 5 percent) for indicated resources in western Kentucky, and the uncertainty (4 to 9 percent) for II–A resources in Illinois is similar to, although not as high as, the uncertainty (5 to 16 percent) for inferred resources in western Kentucky. In contrast, the uncertainty (37 to 40 percent) for II–A resources in Indiana is similar to the range of uncertainty (34 to 77 percent) for hypothetical resources in western Kentucky.

These studies show that in addition to "distance from a data point," other geologic characteristics (for example, variability in coal thickness) of the coal have to be understood if resource reliability categories for a coal are to be comparable to those assigned to other coals in the basin or in other basins.

Reference Cited—Confidence Limits

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Table 11. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Springfield Coal Member in Illinois.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. I–A resources are within 0.5 mi of a data point; I–B resources, >0.5–2 mi; and II–A resources, >2–4 mi. Number of publicly available data points = 10,630. NA, not applicable.]

Parameter	Reliability Category			
	I-A	I-B	II-A	Entire area
Area (acres)	705,000	2,501,000	5,255,000	8,462,000
Percent of area	8	30	62	100
Pseudo n^* = minimum number of points in area	1403	311	163	NA
Half interval width (90% confidence interval)	48	419	1,337	1,805
Percent error (half interval width / volume) x 100	<1	2	4	3
Lower 90% confidence bound (million short tons)	5,960	19,100	34,500	59,600
Volume (million short tons)	6,000	19,600	35,800	61,400
Upper 90% confidence bound (million short tons)	6,050	20,000	37,200	63,200

Table 12. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Herrin Coal Member in Illinois.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. I–A resources are within 0.5 mi of a data point; I–B resources, >0.5–2 mi; and II–A resources, >2–4 mi. Number of publicly available data points = 16,325. NA, not applicable.]

Parameter	Reliability Category			
	I-A	I-B	II-A	Entire area
Area (acres)	1,749,000	3,637,000	3,604,000	8,989,000
Percent of area	19	41	40	100
Pseudo n^* = minimum number of points in area	3,479	452	112	NA
Half interval width (90% confidence interval)	100	610	1,290	2,000
Percent error (half interval width / volume) x 100	<1	2	5	3
Lower 90% confidence bound (million short tons)	19,100	33,800	24,100	76,900
Volume (million short tons)	19,200	34,400	25,400	78,900
Upper 90% confidence bound (million short tons)	19,300	35,000	26,700	80,900

Table 13. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Danville Coal Member in Illinois.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. I–A resources are within 0.5 mi of a data point; I–B resources, >0.5–2 mi; and II–A resources, >2–4 mi. Number of publicly available data points = 6,465. NA, not applicable.]

Parameter	Reliability Category			
	I-A	I-B	II-A	Entire area
Area (acres)	254,000	1,247,000	1,520,000	3,021,000
Percent of area	8	41	50	100
Pseudo n^* = minimum number of points in area	505	155	47	NA
Half interval width (90% confidence interval)	37	332	732	1,100
Percent error (half interval width / volume) x 100	2	4	9	6
Lower 90% confidence bound (million short tons)	1,810	7,180	7,720	16,700
Volume (million short tons)	1,850	7,510	8,450	17,800
Upper 90% confidence bound (million short tons)	1,890	7,840	9,180	18,900

Table 14. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Springfield Coal Member in Indiana.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. I–A resources are within 0.5 mi of a data point; I–B resources, >0.5–2 mi; and II–A resources, >2–4 mi. Number of publicly available data points = 4,842. NA, not applicable.]

Parameter	Reliability Category			
	I-A	I-B	II-A	Entire area
Area (acres)	1,031,000	705,000	68,600	1,805,000
Percent of area	57	39	4	100
Pseudo n^* = minimum number of points in area	2051	88	2	NA
Half interval width (90% confidence interval)	74	280	177	531
Percent error (half interval width / volume) x 100	1	6	37	5
Lower 90% confidence bound (million short tons)	6,610	4,460	296	11,400
Volume (million short tons)	6,680	4,740	473	11,900
Upper 90% confidence bound (million short tons)	6,750	5,020	649	12,400

Table 15. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Danville Coal Member in Indiana.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. I–A resources are within 0.5 mi of a data point; I–B resources, >0.5–2 mi; and II–A resources, >2–4 mi. Number of publicly available data points = 3,088. NA, not applicable.]

Parameter	Reliability Category			
	I-A	I-B	II-A	Entire area
Area (acres)	707,000	571,000	55,900	1,334,000
Percent of area	53	43	4	100
Pseudo n^* = minimum number of points in area	1407	71	2	NA
Half interval width (90% confidence interval)	35	142	96	273
Percent error (half interval width / volume) x 100	1	5	40	4
Lower 90% confidence bound (million short tons)	3,280	2,550	145	5,980
Volume (million short tons)	3,320	2,690	241	6,250
Upper 90% confidence bound (million short tons)	3,350	2,830	337	6,520

Table 16. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Springfield coal in western Kentucky.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. Measured resources are within 0.25 mi of a data point; indicated resources, >0.25–0.75 mi; inferred resources, >0.75–3 mi; and hypothetical resources, >3 mi. Number of publicly available data points = 984. NA = not applicable.]

Parameter	Reliability Category				
	Measured	Indicated	Inferred	Hypothetical	Entire area
Area (acres)	198,000	379,000	566,000	73,800	1,218,000
Percent of area	16	31	47	6	100
Pseudo n^* = minimum number of points in area	1576	335	31	1	NA
Half interval width (90% confidence interval)	8	33	181	176	399
Percent error (half interval width / volume) x 100	<1	2	5	34	5
Lower 90% confidence bound (million short tons)	1,050	2,200	3,520	347	7,110
Volume (million short tons)	1,060	2,230	3,700	524	7,510
Upper 90% confidence bound (million short tons)	1,070	2,270	3,880	700	7,910

Table 17. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Herrin coal in western Kentucky.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. Measured resources are within 0.25 mi of a data point; indicated resources, >0.25–0.75 mi; inferred resources, >0.75–3 mi; and hypothetical resources, >3 mi. Number of publicly available data points = 650. NA, not applicable.]

Parameter	Reliability Category				
	Measured	Indicated	Inferred	Hypothetical	Entire area
Area (acres)	104,000	167,000	231,000	43,900	546,000
Percent of area	19	31	42	8	100
Pseudo n^* = minimum number of points in area	829	148	13	1	NA
Half interval width (90% confidence interval)	8	37	193	132	371
Percent error (half interval width / volume) x 100	2	4	15	45	13
Lower 90% confidence bound (million short tons)	463	799	1,110	160	2,540
Volume (million short tons)	471	836	1,310	293	2,910
Upper 90% confidence bound (million short tons)	480	873	1,500	425	3,280

Table 18. Estimates of uncertainty (calculated with measurement error) of coal resource estimates for the Baker coal in western Kentucky.

[To show detail, resources are reported in million short tons to three significant figures. Resources will not sum due to independent rounding. Measured resources are within 0.25 mi of a data point; indicated resources, >0.25–0.75 mi; inferred resources, >0.75–3 mi; and hypothetical resources, >3 mi. Number of publicly available data points = 2,343. NA, not applicable.]

Parameter	Reliability Category				
	Measured	Indicated	Inferred	Hypothetical	Entire area
Area (acres)	120,000	212,000	334,000	66,100	733,000
Percent of area	16	29	46	9	100
Pseudo n^* = minimum number of points in area	956	188	18	1	NA
Half interval width (90% confidence interval)	10	49.0	256	218	533
Percent error (half interval width / volume) x 100	2	5	16	77	15
Lower 90% confidence bound (million short tons)	621	1,060	1,360	64	3,100
Volume (million short tons)	631	1,110	1,610	282	3,640
Upper 90% confidence bound (million short tons)	642	1,160	1,870	500	4,170

Figure 15. Graph showing range in percent uncertainty (at the 90 percent confidence level) for coal resource reliability categories from Illinois (range for three coals), Indiana (range for two coals), and western Kentucky (range for three coals). I–A resources are within 0.5 mi of a data point; I–B resources, >0.5–2 mi; and II–A resources, >2–4 mi. Measured resources are within 0.25 mi of a data point; indicated resources, >0.25–0.75 mi; inferred resources, >0.75–3 mi; and hypothetical resources, >3 mi.

Availability and Recoverability of Illinois Basin Coals

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Introduction

Coal Availability, a cooperative program between the USGS and various State geological surveys, has been assessing coal resources within various coal regions to determine how much is potentially available for mining (Carter and Gardner, 1989; Eggleston and others, 1990; Carter and others, 1995). The coal resource available for mining is significantly less than estimates of coal in the ground because resources are unavailable due to land-use and technological restrictions. The Coal Recoverability Program of the USGS and the former U.S. Bureau of Mines addresses the technological, economic, and environmental restrictions that may affect the extractability of coal. Coal recoverability considerations modify the available coal resource estimates to reflect the current state of mining technology, present and near-future market conditions, and the impact of 1990 Amendment to the Clean Air Act (Plis and others, 1993; Rohrbacher and others, 1993; Suffredini and others, 1994; Staff, U.S. Bureau of Mines, Intermountain Field Operations Center, 1995).

Coal Availability

Availability of coal resources for an area is determined by calculating the original, in-place resource and then subtracting (a) the coal resources that have already been mined, (b) coal resources that are restricted by land-use considerations, and (c) coal resources that are restricted by technological considerations. Land-use restrictions apply to areas through which, or under which, mining is prohibited, either by law, or because of potential legal liabilities. Such restrictions to coal mining include

(1) Cities, towns, rural dwellings and buildings, cemeteries
(2) Rivers, lakes, reservoirs, major streams
(3) Major highways and rail lines, airports
(4) Power lines, pipelines, oil and gas wells
(5) National or State forests, parks, protected wildlife areas, recreation sites

An example of how land-use restrictions can limit coal mining on a quadrangle scale is shown in figure 16 for the Seelyville 7.5-minute quadrangle, Indiana (modified from Connolly and Krueger, 1997a).

Technological restrictions are mainly due to a geologic setting of the coal that affects the ability to physically extract the coal. Some of the restrictions affect only surface mining operations, some affect only underground mining operations, and some apply to both. Technological restrictions to coal mining include

(1) Coal depth and thickness (too deep or too thin)
(2) Mine barriers (needed between separate mines)
(3) Adjacent coal beds (overlie or underlie too closely)
(4) Structural problems (faulting or areas of weak rock)
(5) Overburden (unstable or too thin)
(6) Oil and gas wells (nonmineable buffers required around active wells)

A diagram illustrating some of the technological restrictions to coal mining is shown in figure 17 (modified from Axon, 1996).

In the Illinois Basin, coal availability studies have been completed for forty-one 7.5-minute quadrangles (nineteen in Illinois, ten in Indiana, and twelve in western Kentucky; fig. 18). Coal recoverability studies have been completed for 16 of the 41 quadrangles (eight in Illinois, three in Indiana, and five in western Kentucky). The quadrangles studied were selected on the basis of likely differences in both land use and technological restrictions and the availability of data, which permitted a variety of coal resource scenarios to be analyzed. For example, each quadrangle has its own unique combination of in-place coal resource size, current and (or) previous mining activity, geologic structure, cultural development, and land-management regulations. These 41 quadrangles also represent an average sampling of the potential coal resource development within each state, as well as throughout the Illinois Basin.

Results

Illinois

Coal availability studies for 19 representative 7.5-minute quadrangles in Illinois have been completed (Treworgy, Chenoweth, and Bargh, 1995; Jacobson and others, 1996; Treworgy, Chenoweth, and Jacobson, 1996; Treworgy, Chenoweth, and Justice, 1996; Treworgy and others, 1994, 1995, 1997, and 1998). Results of these studies are summarized in figures 19 and 20. Figure 19 shows that the original coal resources for all coals studied in the 19 quadrangles was about 10 billion short tons and that the remaining available coal is about 4.6 billion short tons (46 percent of the original coal resource). Figure 20 illustrates the amount of original resource, how much of the resource has been mined-out, or is not available because of land-use and technological restrictions, and the amounts of available coal for the Danville, Davis, Herrin, Seelyville, and Springfield Coal Members, the coals that have the largest estimated original resources in these 19 quadrangles. Figure 20 shows that

(1) Mining has been mainly from the Springfield and Herrin; production from the other three coals has been minimal.
(2) For all five coals, technological restrictions are the primary factors affecting the amounts of available coal.
(3) Technological and land-use restrictions leave little of the Danville available for future mining.

Indiana

Coal availability studies for 10 representative 7.5-minute quadrangles in Indiana have been completed (Cetin and others,

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1994, 1995; Conolly and Cetin, 1995, 1996; Cetin and Conolly, 1996a,b; Conolly and others, 1996; and Conolly and Krueger, 1997a,b, 1998). Results of these studies are summarized in figures 21 and 22. Figure 21 shows that the original coal resource for all coals studied in the 10 quadrangles was about 5.8 billion short tons and that the remaining available coal is about 3.3 billion short tons (57 percent of the original coal resource). Figure 22 illustrates the amount of original resource, how much of the resource has been mined out or is not available because of land-use and technological restrictions, and the amounts of available coal for the Danville, Hymera, Seelyville, Springfield, and Survant Coal Members, the coals that have the largest estimated original resources in these 10 quadrangles. Figure 22 shows that

(1) Mining has been primarily from the Springfield and Hymera, with lesser production from the Danville, Seelyville, and Survant Coal Members.
(2) For the Springfield, previous mining is the primary factor affecting coal availability; for the other four coals, technological restrictions are the primary factors.

Western Kentucky

Coal availability studies for 12 representative 7.5-minute quadrangles have been completed in western Kentucky (Weisenfluh and others, 1998). Results of this study are summarized in figures 23 and 24. Figure 23 shows that the original coal resource for all coals studied was about 5.1 billion short tons and that the remaining available coal is about 2.7 billion short tons (53 percent of the original coal resource). Figure 24 illustrates the amounts of original resource, how much of the resource has been mined-out, or is not available because of land-use and technological restrictions, and the amounts of available coal for the Baker, Davis, Herrin, Paradise, and Springfield coals, the coals that have the largest estimated original resources in these 12 quadrangles. Figure 24 shows that

(1) Mining has been primarily from the Springfield coal, with lesser production from the Baker, Herrin and Paradise coals, and minimal production from the Davis coal.
(2) For the Springfield coal, mined-out coal is the largest factor affecting coal availability, but for the other four coals, technological restrictions are the primary factors.

Coal Recoverability

Recoverability of coal resources for an area is determined by subtracting from the available coal resource the resources that cannot be removed during mining because of mine barriers, areas having an unstable mine roof or floor, areas where the mining slope would be too steep, and the resources that are lost during the cleaning process. The definition of available coal resources in calculating coal recoverability is a bit different than the definition as discussed in the above paragraphs. For coal recoverability, available coal includes partings within the coal because the partings cannot be removed during the mining process. The economically recoverable coal is the recoverable coal resource minus the recoverable resource that cannot be mined at a profit. The economics of coal mining vary and depend upon the mine location, characteristics of the coal, mined coal quality, mining method, shipping costs, and taxes.

In the Illinois Basin, coal recoverability studies have been completed for sixteen of the forty-one 7.5-minute quadrangles where coal availability studies have been completed. Eight of these are in Illinois, three are in Indiana, and five are in western Kentucky; quadrangle locations are shown in figure 18. These coal recoverability studies demonstrate that only a small percentage (from less than 1 percent to about 13 percent) of the original coal resource is economically mineable in today's coal market.

Results

Illinois

Coal recoverability studies for eight quadrangles in Illinois have been completed (Sullivan, 1995; DST and Associates unpublished contract studies, 1998a–c, 1999a–d). Results of these studies (illustrated in fig. 25) show that of the 7.1 billion short tons of original coal resource in place, only about 900 million short tons of coal can potentially be mined at a profit. This 900 million short tons is about 13 percent of the original coal resource.

Indiana

Coal recoverability studies for three quadrangles in Indiana have been completed (DST and Associates, 1998d,e, and 1999e). Results of these studies (illustrated in fig. 26) show that of the 2.4 billion short tons of original coal resource in place, only about 170 million short tons of coal can potentially be mined at a profit. This 170 million short tons is about 7 percent of the original coal resource.

Western Kentucky

Coal recoverability studies for five quadrangles in western Kentucky have been completed (Scott, 1997). Results of these studies (illustrated in figure 27) show that of the 2.8 billion short tons of original coal resource in place, only about 7 million short tons of coal can potentially be mined at a profit. This 7 million short tons is less than 1 percent of the original coal resource.

Summary

In summary, coal availability and coal recoverability studies in the Illinois Basin show that only a part of the original coal resources within the 7.5-minute quadrangles studied is available for development (46 percent of the resources for 19 quadrangles in Illinois, 57 percent for 10 quadrangles in Indiana, and 53 percent for 12 quadrangles in western Kentucky). Even less of the original resource is actually recoverable, and only a small percentage of the original coal resource is economically recoverable (13 percent of the resource for eight Illinois quadrangles, 7 percent for three Indiana quadrangles, and less than 1 percent for five quadrangles in western Kentucky).

Figure 16. Map showing land use that can limit coal mining in the Seelyville 7.5-minute quadrangle, Indiana (modified from Conolly and Krueger, 1997a).

Figure 17. Diagram illustrating some of the technological restrictions on mining (modified from Axon, 1996).

Figure 18. Map of the Illinois Basin showing county boundaries and locations of the 7.5-minute quadrangles studied for coal availability and coal recoverability.

Figure 19. Chart showing results from coal availability studies for 19 representative 7.5-minute quadrangles in Illinois.

Figure 20. Chart comparing effects of restrictions on available coal resources for the Danville, Davis, Herrin, Seelyville, and Springfield Coal Members in 19 representative 7.5-minute quadrangles in Illinois.

Figure 21. Chart showing results from coal availability studies for 10 representative 7.5-minute quadrangles in Indiana.

Figure 22. Chart comparing effects of restrictions on available coal resources for the Danville, Hymera, Seelyville, Springfield, and Survant Coal Members in 10 representative 7.5-minute quadrangles in Indiana.

Figure 23. Chart showing results from coal availability studies for 12 representative 7.5-minute quadrangles in western Kentucky.

Figure 24. Chart comparing effects of restrictions on available coal resources for the Baker, Davis, Herrin, Paradise, and Springfield coals in 12 representative 7.5-minute quadrangles in western Kentucky.

Figure 25. Chart showing results from coal availability and coal recoverability studies for eight 7.5-minute quadrangles in Illinois.

Figure 26. Chart showing results from coal availability and coal recoverability studies for three 7.5-minute quadrangles in Indiana.

Figure 27. Chart showing results from coal availability and coal recoverability studies for five 7.5-minute quadrangles in western Kentucky.

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Appendixes 1–3

Appendix 1. Estimated remaining resources of the Springfield Coal in Illinois, Indiana, and western Kentucky.

[Resources are listed by mining area and county and are categorized by geologic reliability (I–A, 0–0.5 mi from a data point; I–B, >0.5–2 mi; II–A, >2–4 mi; measured, 0–0.25 mi; indicated, >0.25–0.75 mi; inferred, >0.75–3.0 mi; and hypothetical, >3 mi), coal thickness, and overburden thickness (coal depth). Resource numbers are rounded to two significant figures, or to the nearest one hundred million short tons for numbers greater than ten billion short tons. Columns may not sum exactly due to rounding.]

County	Coal depth (feet)	Remaining resources (million short tons)																Coal depth (feet)
		I-A				I-B				II-A				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Northern Illinois																		
McLean	>150	0	6	13	19	0	75	90	170	0	1,800	1,900	3,700	0	1,900	2,000	4,000	>150
Tazewell	0–150	0	0	0	0	0	0	30	30	0	0	8	8	0	0	37	37	0–150
	>150	0	1	50	51	0	0	150	150	0	0	220	220	0	1	420	420	>150
	Subtotal	0	1	50	51	0	0	180	180	0	0	230	230	0	1	460	460	Subtotal
Woodford	>150	0	0	0	0	0	46	0	46	0	210	0	210	0	260	0	260	>150
Northern	0–150	0	0	63	0	0	0	30	30	0	0	8	8	0	0	37	37	0–150
Illinois	>150	0	7	0	70	0	120	240	360	0	2,000	2,200	4,200	0	2,200	2,500	4,700	>150
	Total	0	7	63	70	0	120	270	390	0	2,000	2,200	4,200	0	2,200	2,500	4,700	Total
Western Illinois																		
Fulton	0–150	0	0	0	0	0	0	580	580	0	0	0	0	0	0	580	580	0–150
	>150	0	0	0	0	0	0	80	80	0	0	0	0	0	0	80	80	>150
	Subtotal	0	0	0	0	0	0	660	660	0	0	0	0	0	0	660	660	Subtotal
Knox	0-150	0	0	0	0	190	170	99	460	150	12	0	160	340	180	99	620	0-150
Peoria	0–150	0	0	0	0	0	140	440	590	31	120	0	150	31	260	440	740	0-150
	>150	0	0	0	0	0	0	400	400	0	68	0	68	0	68	400	460	>150
	Subtotal	0	0	0	0	0	140	840	980	31	190	0	220	31	330	840	1,200	Subtotal
Schuyler	0-150	0	0	0	0	1	10	86	96	9	0	0	9	9	10	86	100	0-150
Warren	0-150	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0-150
Western	0–150	0	0	0	0	190	330	1,200	1,700	190	130	0	320	380	450	1,200	2,000	0–150
Illinois	>150	0	0	0	0	0	0	480	480	0	68	0	68	0	68	480	550	>150
	Total	0	0	0	0	190	330	1,700	2,200	190	200	0	390	380	520	1,700	2,600	Total

Appendix 1. Estimated remaining resources of the Springfield Coal in Illinois, Indiana, and western Kentucky—Continued.

Appendix 1. Estimated remaining resources of the Springfield Coal in Illinois, Indiana, and western Kentucky—Continued.

Appendix 1. Estimated remaining resources of the Springfield Coal in Illinois, Indiana, and western Kentucky—Continued.

Appendix 1. Estimated remaining resources of the Springfield Coal in Illinois, Indiana, and western Kentucky—Continued.

Appendix 2. Estimated remaining resources of the Herrin Coal in Illinois and western Kentucky.

[Resources are listed by mining area and county and are categorized by geologic reliability (I–A, 0–0.5 mi from a data point; I–B, >0.5–2 mi; II–A, >2–4 mi; measured, 0–0.25 mi; indicated, >0.25–0.75 mi; inferred, >0.75–3.0 mi; and hypothetical, >3 mi), coal thickness, and overburden thickness (coal depth). Resource numbers are rounded to two significant figures, or to the nearest one hundred million short tons for numbers greater than ten billion short tons. Columns may not sum exactly due to rounding.]

Appendix 2. Estimated remaining resources of the Herrin Coal in Illinois and western Kentucky—Continued.

Appendix 2. Estimated remaining resources of the Herrin Coal in Illinois and western Kentucky—Continued.

Appendix 2. Estimated remaining resources of the Herrin Coal in Illinois and western Kentucky—Continued.

Appendix 3. Estimated remaining resources of the Danville Coal in Illinois and Indiana, and the Baker coal in western Kentucky.

[Resources are listed by mining area and county and are categorized by geologic reliability (I–A, 0–0.5 mi from a data point; I–B, >0.5–2 mi; II–A, >2–4 mi; measured, 0–0.25 mi; indicated, >0.25–0.75 mi; inferred, >0.75–3.0 mi; and hypothetical, >3 mi), coal thickness, and overburden thickness (coal depth). Resource numbers are rounded to two significant figures, or to the nearest one hundred million short tons for numbers greater than ten billion short tons. Columns may not sum exactly due to rounding.]

Appendix 3. Estimated remaining resources of the Danville Coal in Illinois and Indiana, and the Baker coal in western Kentucky—Continued.

Appendix 3. Estimated remaining resources of the Danville Coal in Illinois and Indiana, and the Baker coal in western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons)																Coal depth (feet)
		I-A				I-B				II-A				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Indiana																		
Gibson	0–150	49	82	17	150	13	33	4	49	0	0	0	0	61	110	21	200	0–150
	>150	230	360	70	660	130	210	22	360	0	0	0	0	360	580	92	1,000	>150
	Subtotal	280	440	87	810	140	240	25	410	0	0	0	0	420	690	110	1,200	Subtotal
Knox	0–150	15	80	60	150	8	92	28	130	0	16	0	16	23	190	88	300	0–150
	>150	73	380	190	640	32	300	120	440	0	8	0	9	110	680	300	1,100	>150
	Subtotal	88	460	250	790	40	390	150	570	0	24	0	24	130	870	390	1,400	Subtotal
Pike	0–150	4	6	0	10	4	36	6	46	3	30	5	38	10	72	12	94	0–150
	>150	1	5	0	6	2	19	0	21	0	0	0	0	2	25	0	27	>150
	Subtotal	5	12	0	17	5	55	6	67	3	30	5	38	12	97	12	120	Subtotal
Posey	0–150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0–150
	>150	92	450	11	550	220	380	1	600	40	18	0	57	350	850	12	1,200	>150
	Subtotal	92	450	11	550	220	380	1	600	40	18	0	57	350	850	12	1,200	Subtotal
Sullivan	0–150	22	130	86	230	19	87	25	130	0	0	0	0	41	210	110	360	0–150
	>150	87	230	120	440	75	270	30	370	0	2	0	2	160	500	150	820	>150
	Subtotal	110	360	210	670	94	350	55	500	0	2	0	2	200	710	260	1,200	Subtotal
Vanderburgh	0–150	4	1	1	6	11	8	1	19	13	27	0	40	27	36	1	65	0–150
	>150	42	16	0	58	77	60	0	140	32	44	0	76	150	120	0	270	>150
	Subtotal	46	17	1	63	88	69	1	160	45	71	0	120	180	160	1	340	Subtotal
Vermillion	0–150	0	1	27	27	0	0	9	9	0	0	1	1	0	1	37	38	0–150
	>150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	>150
	Subtotal	0	1	27	27	0	0	9	9	0	0	1	1	0	1	37	38	Subtotal
Vigo	0–150	5	77	130	210	2	82	110	190	0	0	0	0	6	160	230	400	0–150
	>150	10	21	53	83	10	86	65	160	0	1	0	1	20	110	120	240	>150
	Subtotal	14	98	180	290	11	170	170	350	0	1	0	1	26	270	350	640	Subtotal
Warrick	0–150	24	49	4	77	13	10	1	24	1	0	0	1	38	60	4	100	0–150
	>150	2	4	0	6	0	1	0	1	0	0	0	0	2	4	0	6	>150
	Subtotal	26	53	4	83	13	11	1	25	1	0	0	1	40	64	4	110	Subtotal
Indiana	0–150	120	430	320	870	70	350	180	600	16	73	7	96	210	840	500	1,600	0–150
	>150	540	1,500	440	2,400	540	1,300	230	2,100	72	73	0	140	1,200	2,900	670	4,700	>150
	Total	660	1,900	760	3,300	610	1,700	410	2,700	88	150	7	240	1,400	3,700	1,200	6,300	Total

Appendix 3. Estimated remaining resources of the Danville Coal in Illinois and Indiana, and the Baker coal in western Kentucky—Continued.

County	Coal depth (feet)	Remaining resources (million short tons)																				Coal depth (feet)
		Measured				Indicated				Inferred				Hypothetical				Total				
		Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				Coal thickness (inches)				
		>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	>14-28	>28-42	>42	All	
Western Kentucky																						
Daviess	0–150	3	0	0	3	4	0	0	4	3	6	1	10	1	0	0	1	10	6	1	18	0–150
	>150	0	0	0	0	1	1	1	3	0	3	4	7	0	0	0	0	1	4	5	10	>150
	Subtotal	3	0	0	3	5	1	1	7	3	10	5	17	1	0	0	1	11	10	7	28	Subtotal
Henderson	0–150	14	19	29	62	44	47	71	160	67	82	80	230	27	8	8	43	150	160	190	500	0–150
	>150	1	4	17	22	3	15	70	89	19	82	210	310	35	41	28	110	58	140	320	520	>150
	Subtotal	15	22	46	84	47	62	140	250	86	160	290	540	63	49	36	150	210	300	510	1,000	Subtotal
Hopkins	0–150	18	5	15	38	21	7	9	37	11	1	1	12	0	0	0	0	50	13	24	88	0–150
	>150	22	25	50	97	43	35	120	190	110	55	77	240	22	21	0	43	190	140	240	570	>150
	Subtotal	40	30	65	130	64	43	130	230	120	55	78	250	22	21	0	43	240	150	270	660	Subtotal
McLean	0–150	5	5	2	12	9	11	2	22	15	20	1	36	1	0	0	1	30	37	4	71	0–150
	>150	27	25	17	60	44	38	19	100	71	39	21	130	0	0	0	0	140	92	57	290	>150
	Subtotal	32	21	19	72	53	49	21	120	86	59	22	170	1	0	0	1	170	130	61	360	Subtotal
Muhlenberg	0–150	7	3	3	13	15	6	0	22	33	26	0	59	2	13	0	15	57	49	3	110	0–150
	>150	15	5	1	21	30	6	3	39	27	6	0	33	0	0	0	0	72	17	4	94	>150
	Subtotal	22	8	4	34	44	12	3	60	60	32	0	93	2	13	0	15	130	66	8	200	Subtotal
Ohio	0–150	0	3	2	5	1	8	3	12	20	74	7	100	1	25	2	28	22	110	15	150	0–150
	>150	0	0	0	0	0	0	0	0	4	13	5	22	0	6	0	7	4	19	5	28	>150
	Subtotal	0	3	2	5	1	9	3	12	24	87	12	120	1	31	3	35	26	130	20	180	Subtotal
Union	0–150	1	2	1	4	3	2	0	5	4	2	0	6	0	0	0	0	9	5	1	15	0–150
	>150	25	22	5	52	54	22	5	80	45	10	1	56	19	0	0	19	140	54	11	210	>150
	Subtotal	27	24	6	56	57	24	5	86	49	12	1	61	19	0	0	19	150	59	12	220	Subtotal
Webster	0–150	1	2	14	16	1	3	23	26	6	26	3	36	2	1	0	2	9	32	39	80	0–150
	>150	10	25	190	230	18	36	260	310	20	51	260	330	3	7	6	17	52	120	720	890	>150
	Subtotal	10	27	200	240	18	39	280	340	26	77	260	370	5	8	6	19	60	150	760	970	Subtotal
Western Kentucky	0–150	50	40	65	150	97	85	110	290	160	240	92	490	34	47	10	91	340	410	270	1,000	0–150
	>150	100	96	280	480	190	150	470	820	290	260	580	1,100	80	77	35	190	660	580	1,400	2,600	>150
	Total	150	130	350	630	290	240	580	1,100	450	500	670	1,600	110	120	45	280	1,000	990	1,600	3,600	Total