COOPERATIVE RESOURCES REPORT 4
ILLINOIS STATE WATER SURVEY
ILLINOIS STATE GEOLOGICAL SURVEY
Urbana, Illinois 61801

COAL AND WATER RESOURCES FOR COAL CONVERSION IN ILLINOIS

William H. Smith and John B. Stall

STATE OF ILLINOIS
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FOREWORD

The Illinois State Geological Survey and the Illinois State Water Survey have long collected and interpreted information on coal and water resources of Illinois. Many publications concerning these resources have provided authoritative data for a wide range of government agencies, industries, and private citizens.

In mid-1973, aware of the need for basic information about coal and water resources for use in siting coal conversion plants, the two Surveys embarked on a joint project to fill that need. In this publication all available information has been updated and put into a form convenient for assessing resources at sites that could be selected for coal conversion plants.

We believe that the data base on which this study was founded permits a comprehensive interpretation of coal and water resources in Illinois. Results indicate that Illinois has large resources of both coal and water. In addition, many other conditions relevant to the siting of coal conversion plants are so favorable that Illinois could provide excellent sites for a number of such plants.

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Coal and Water Resources for Coal Conversion in Illinois

William H. Smith and John B. Stall

ABSTRACT

Illinois has enormous reserves of coal and water. Nearly 100 billion tons of coal have been mapped in the two thickest and most extensive seams in the state, and numerous potential areas having sufficient water to supply one or more coal conversion plants have been evaluated and mapped. These resources of coal and water are sufficient to supply raw materials for many coal conversion plants that could provide synthetic fuels to help meet the rapidly expanding need for new energy sources in the Midwest and the eastern United States.

The report provides an up-to-date assessment of the state's most promising resources of coal and water. Three large maps included in the report show the geographic distribution of the coal and water. Supplementary maps and tables provide the fundamental information on coal and water resources that will be needed by the government agencies and private industries ultimately responsible for decisions regarding the siting of coal conversion facilities.

Remaining in-place reserves 42 or more inches thick total 59 billion tons for the Herrin (No. 6) Coal and 38 billion tons for the Harrisburg-Springfield (No. 5) Coal. In addition, reserves of the Harrisburg-Springfield and Herrin Coals that are less than 42 inches thick plus reserves in other Illinois coal seams total about 64 billion tons. The total reserves, therefore, constitute the largest reserves of bituminous coal in any state in the nation. The importance of these reserves is increased by the fact that 56 percent of the Herrin mapped for this report is 6 feet or more thick and 47 percent of the mapped Harrisburg-Springfield is 5 feet or more thick.

The report also locates sources of water capable of producing the 6 to 72 million gallons per day estimated to be required by coal conversion plants. The abundant reserves of coal and water documented in the report can support a synthetic fuels industry in Illinois large enough to contribute significantly to the energy needs not only of Illinois but of the surrounding regions.

INTRODUCTION

The state of Illinois, whose agricultural and mineral wealth and strategic location have made it a center of commerce and industry, contains enormous mapped resources of bituminous coal, only 5.2 percent of which has been depleted. The coal occurs in beds, or layers, varying from less than a foot to as much as 10 feet thick. A number of the beds are of minable thickness over many thousands of square miles. The two thickest and most widespread of these, the Herrin (No. 6) Coal and the Harrisburg-Springfield (No. 5) Coal, have supplied most of the coal needs of the state for the past 100 years, during which time 4.5 billion tons has been produced. In 1918, the year of highest coal production in Illinois history, 966 coal mines in Illinois produced a total of 88 million tons of coal. Illinois now ranks fourth among coal-producing states; in 1974 it had 55 mines that produced 58 million tons of coal, most of which was used for electric power generation. Because oil and gas are cleaner and more convenient to use and because of their low price after World War II, a large and efficient network of oil and gas pipelines and storage facilities was established. Consequently, coal lost many of its markets.

Today, as the nation is well aware, reserves of oil and gas are declining and in the future cannot be relied upon to meet the ever-increasing energy demands. The undesirability of depending on foreign sources for much of our oil has aroused great interest in other domestic fuels. One alternative source of energy is the conversion of coal to gas or liquid fuels that are environmentally more acceptable than coal itself. Synthetic fuels from coal will be needed in increasingly large quantities to meet future energy needs.

Illinois offers outstanding advantages for the development of facilities for coal conversion by both liquefaction and gasification. Some of these have been presented in a recent report by Hogland and Asbury (1974),* prepared for the Illinois Institute for Environmental Quality. Among the factors favorable for locating coal conversion plants in Illinois are the huge reserves of relatively thick bituminous coal, mining conditions that are generally favorable for large-scale mining and high productivity, abundant and diverse sources of water, the location of the state in a large industrial and consuming area that has a well developed

* Reference cited in Bibliography at the end of Part 1, under the heading "Coal Conversion."

road and railroad network, easy access to many interstate oil and gas pipelines, and the availability of many existing and potential sites for underground storage of gas.

Purpose and Scope

The distribution, thickness, and quality of coal in Illinois has been studied for many decades by the Illinois State Geological Survey, and the Illinois State Water Survey for a corresponding period has investigated the availability and quality of water resources in the state. This report re-evaluates and summarizes the information available on the major coal resources (Part 1) and water resources (Part 2) in light of their availability for prospective coal conversion facilities in Illinois. Inasmuch as the Herrin (No. 6) and the Harrisburg-Springfield (No. 5) Coal Members constitute approximately 85 percent of the previously mapped coal reserves 42 or more inches thick, they alone were evaluated in this study.

The potential sources of water in the large quantities that will be needed by a single coal conversion plant were located by the Water Survey. They include (1) ground water from shallow and deep aquifers, (2) surface water from rivers, (3) existing and potential man-made reservoirs, and (4) treated wastewaters.

Water needs for coal conversion plants, based on estimates reported in the literature, range from a very low 6 million gallons per day (mgd) under extreme conservation measures, through a more normal low requirement of 14 mgd, to a high of 72 mgd. This range has been used as a basis for determining the availability of the water resources of the state for coal conversion.

No attempt is made in this study to evaluate various conversion processes or to assess many other factors that must be considered in locating coal conversion plants, many of which may be important determinants in site selection. Because availability of sufficient coal and water is so vital, however, we have attempted to assemble all data for the principal coal deposits and potential water sources and to present these data in the form most useful for site evaluation. The basic information on coal and water in the files of the Geological Survey and the Water Survey are accessible for further studies. Systems analysis can be used to interrelate these data with other types of information that can be used to determine the best sites for coal conversion facilities.

This report is the fourth in a series of cooperative reports by the two Surveys. The three previous reports concerned ground-water resources of the Chicago Region (Suter et al., 1959), Du Page County (Zeizel et al., 1962), and the Havana Region (Walker, Bergstrom, and Walton, 1965).*

* See references at end of Part 2.

Conversion of Coal

Gas has been commercially manufactured from coal since the early 19th century. Nearly every major city in the eastern United States once had its own gas plant where gas was manufactured from coal for domestic uses. After World War II, when natural gas pipelines were extended to most communities, the gas from coal plants was no longer needed. Liquid fuels also have been extracted from coal for many years, and gasoline made from coal was widely used in Germany in the later years of World War II. In South Africa gasoline has been produced from coal for several years.

Much research is being devoted to development of large-scale coal gasification and coal liquefaction processes. Older technologies are being modified for greater production, while numerous entirely new concepts of coal conversion are being developed, none of them yet operative on a commercial scale. Different processes for gasification of coal produce different types of gas: (1) gas with a low heating value (100 to 200 British thermal units per standard cubic foot [Btu/scf]); (2) gas with intermediate values of 300 to 500 Btu/scf; and (3) gas of pipeline quality, similar in heating value to natural gas (950 to 1,000 Btu/scf). The various gasification processes now under development have been described by Mudge et al. (1974), Hogland and Asbury (1974), National Academy of Engineering (1972, 1973), and Seay et al. (1972).*

The amount of coal needed for coal conversion at any one plant site will vary, of course, with the plant's capacity, the nature of the coal, and the efficiency of the process. Most discussions in the literature relating to high-Btu gasification consider as a standard a plant with a capability of producing 250 million standard cubic feet per day (scfd). To produce gas of 950 Btu/scf from Illinois coal containing 11,260 Btu/lb (as-received basis) in a plant with 70 percent thermal efficiency, 15,066 tons of coal per day would be required to generate the 250 million scf. On that basis, operation of a conversion plant for 335 days per year would require 5,047,101 tons of coal. If the mines supplying the coal were to operate 250 days per year, a mine production of 20,188 tons would be required daily. For a plant life of 30 years, 151.4 million tons of coal would be needed, a requirement that would necessitate a coal reserve of about 300 million tons in the ground if the recovery rate were 50 percent.

It is likely that such a large amount of coal would require the output of two, or probably three, mines. It would be convenient to have these mines near the plant site, but even then some transportation of the coal would be necessary.

To increase the heating value of the coal, coal preparation may be desirable to remove as much as practical of the

• These references are given in the Bibliography of Part 1, under the heading "Coal Conversion."

mineral matter, including sulfur, in the coal. Most of the coal now used in Illinois has had some preparation. The disposal of wastes resulting from coal preparation and of the ash and other wastes remaining after coal conversion must be considered in planning a coal conversion plant, and the method of disposal must be environmentally acceptable.

Although no data based on practical experience are available regarding water requirements for commercial coal conversion operations, estimates of the requirements for the various processes indicate that conversion industries will be major users of water. Large quantities of water will be used for cooling and processing, and the water discharged will be altered in physical state, mineral quality, and temperature. Up to about 10 percent of the water will actually be consumed and must be replaced by make-up water. Most of the consumed water is returned to the atmosphere by evaporation from cooling towers and surfaces such as ponds. A significant portion is consumed to supply hydrogen for the production of hydrocarbons. The total water demands and the make-up water requirements are comparable to the water supplies required by large cities. The total water requirements of a coal conversion plant will depend largely upon the measures taken to conserve or recycle the water. The maximum amount of water would be required by a plant that used once-through circulation of water for cooling.

At the proposed WESCO plant of the Western Gasification Company (1973)* in New Mexico, where water resources are limited, stringent efforts will be made to reduce use and to maximize reuse of water. The plans for this plant probably involve a minimum of water consumption. Estimated disposition of the water is given in table 1.

In our report, the availability of water resources for coal conversion is evaluated on the basis of requirements for water consumption or make-up water instead of on the total water need. It is assumed that coal conversion plants with a capacity of 250 million scfd of high-Btu synthetic natural gas (SNG) will consume from 14 to 72 mgd of water, but that, with extreme conservation measures, water consumption may be reduced to as low as 6 mgd. The levels of water consumption considered in this report are given in table 2. Much the same amounts of water will be required for liquefaction of coal.

The quality of water required for coal conversion processes has not yet been determined. Water treatment is now so highly developed that raw water of almost any quality can, by a combination of processes, be changed to a finished water that will meet almost any specifications. Naturally, if the water is highly mineralized or highly polluted, the treatment costs will be much higher than they would be if the water is relatively clean.

* Reference appears in Reference list at end of Part 2.

TABLE 1-WATER BUDGET FOR A LURGI COAL GASIFICATION PLANT

(Production 250 million standard cubic feet per day synthetic natural gas; after WESCO, 1973)

Disposition of water	gpm	Percentage of water used
PROCESS CONSUMPTION		
To supply hydrogen	1,120	
Produced as methanation by-product	-600	
Net consumption	520	10.2
RETURN TO ATMOSPHERE		
Evaporation:		
From raw water ponds	420	
From cooling tower	1,760	
From quenching hot ash	150	
From pelletizing sulfur	250	
From wetting of mine roads	730	
	3,310	
Stack gases: *		
From steam blowing of boiler tubes	200	
From stack gas SO_2 scrubbers	40	
	240	
Total return to atmosphere	3,550	69.6
DISPOSAL IN MINE		
In water treating sludges	100	
In wetted boiler ash	30	
In wetted gasifier ash	300	
Total disposal in mine	430	8.4
OTHER MEANS		
Retained in slurry pond	20	
Miscellaneous mine uses	580	
Total others	600	11.8
TOTAL	5,100	100.0

** Does not include water derived from burning of boiler fuel.*

TABLE 2-RANGE IN WATER CONSUMED BY ONE COAL CONVERSION PLANT

(Production 250 million standard cubic feet per day of synthetic natural gas)

Level of use	gpm	cfs	mgd
Very low (extreme conservation measures)	4,000	9	6
Low	10,000	22	14
Medium	20,000	45	29
High (would use if readily available)	50,000	111	72

Part 1. Coal Resources

William H. Smith

INTRODUCTION

The coal-bearing sequence of rocks in Illinois, formally termed the Pennsylvanian System, underlies about 65 percent of the state—36,806 out of a total of 56,400 square miles. The Herrin (No. 6) Coal Member, the thickest and most widespread coal in Illinois, as mapped in this study is 42 or more inches thick throughout an area of 9,269 square miles and has been mined out in an additional area of about 927 square miles. The Harrisburg-Springfield (No. 5) Coal Member, which is second in abundance, is 42 or more inches thick throughout 7,299 square miles and has been mined out in about 331 square miles.

The distribution, by thickness and tonnage, of an estimated total of approximately 97 billion tons of coal 42 or more inches thick in the Herrin and Harrisburg-Springfield seams is shown in the maps and tables of this report. Of this total, an estimated 59 billion tons are Herrin Coal and 38 billion tons are Harrisburg-Springfield Coal. The distribution of these reserves is shown on plates 1 and 2, in which the color used for each township symbolizes the estimated average tons of coal in place per square mile. Other maps and tables in the report and tables in Appendix 1 provide additional basic information on coal resources and geological factors relating to their minability and use, all of which should prove helpful in the siting of coal conversion facilities.

The inventory of Illinois coal reserves made in 1952 by the Illinois Geological Survey included coal in seams more than 28 inches thick and revealed an estimated 137 billion tons of coal in some 20 different seams. Subsequent studies by the Geological Survey, including a series of seven reports on strippable coal reserves in seams 18 or more inches thick and no more than 150 feet deep, increased the estimate of remaining reserves of coal to 147 billion tons, 71 percent of which was Herrin and Harrisburg-Springfield Coals. In this report additional reserves of approximately 14.7 billion tons have been mapped that were not included in previous studies. Estimated total coal reserves for Illinois mapped by the Geological Survey, therefore, have increased from 147 billion to 161.6 billion tons (fig. 1).

The data on reserves compiled in this report do not represent a complete re-evaluation of total coal resources in Illinois. Several areas in the state have other coal seams 42 or more inches thick, some of which may have large enough reserves to support several mines. Seams less than 42 inches have been strip mined in some places, particularly the Colchester (No. 2) Coal Member, which averages about 30 inches thick in several areas. Other seams containing coal 42 or more inches thick may be locally significant. It is possible that some Illinois coals thinner than 42 inches can be used to supply part of the coal needed for conversion plants but it is unlikely that sites primarily dependent on coals thinner than 42 inches will be selected.

The computer techniques developed for this study will facilitate any future re-evaluation of Illinois coal resources. Details of methods used in assembling and plotting data and in calculating reserves are given in Appendix 2.

This study has been the first to produce statewide maps from the ILLIMAP program developed in 1970 by D. H. Swann and others at the Illinois Geological Survey for computer mapping of geological information. The computer-graphics techniques used to calculate the coal resources inventory and to compute and plot the information displayed on the maps employ some new methods that are briefly described in Appendix 2.

The bibliography immediately following Part 1 is divided into six subject categories. Within each category the references appear in alphabetical order, but throughout the

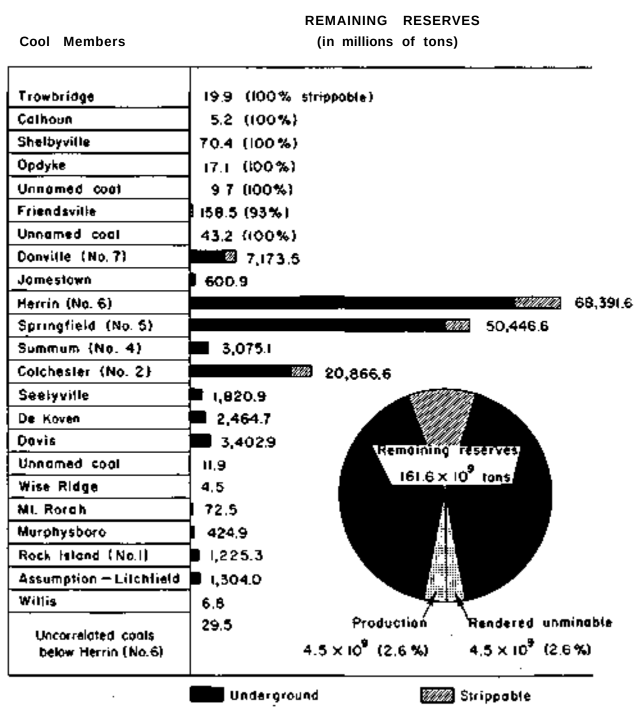


Figure 1. Remaining reserves of coal in place in Illinois, January 1,1975.

TABLE 3-SUMMARY OF CLASSIFICATIONS FOR COAL RESERVES INVENTORY (Cady and others, 1952[28])

Class	Maximum distance from datum points*	Accepted datum points	Remarks
I-A Proved	½ mile	Mined-out areas Diamond drill holes Outcrops	Approximately equivalent to "measured" category of the U. S. Geological Survey
I-B Probable	2 miles	All points of Class I-A plus coal test churn drill holes	Approximately equivalent to "indicated" category of the U. S. Geological Survey
II-A Strongly indicated	4 miles	All points of Classes I-A and I-B plus churn drill holes drilled for oil or water with unusually good records and control rotary drill holes	Approximately equivalent to "inferred" category of the
II-B Weakly indicated	Indefinite	All points used in higher categories plus knowledge of geologic probability based on all available information	U. S. Geological Survey

** Distances modified in practice by geological considerations.*

bibliography as a whole they are numbered consecutively, regardless of category. The text citations, therefore, consist of the author's name, the date of publication, and a superscript referring to the reference number in the bibliography—for example (Damberger, 1971[5]).

PREVIOUS INVESTIGATIONS

The comprehensive report on the minable coal reserves of Illinois published by the Geological Survey (Cady and others, 1952[28]) reviewed the estimates of coal reserves that had previously been made and established definitions and premises for the classification of coal reserves on the basis of the distribution and reliability of data. The definitions (table 3) have been followed, with some modifications, in subsequent reports of the Survey. When the present report was compiled, the work maps for the 1952 study provided the principal source of data for the two coal seams studied, and the classification of the reserves followed the basic premises and parameters that Cady had used, although information from more recent reports was incorporated. In addition, we used conventional electric logs of oil and gas wells to estimate coal thickness in certain areas where the data from coal test holes are scarce.

Strippable coal reserves were included in the 1952 report but were not differentiated from other coal reserves. In a series of reports published by the Geological Survey, beginning in 1957, strippable coal reserves were mapped at the scale of half an inch to the mile for most of the coal seams in Illinois that are strippable (fig. 2). In those reports, strippable coal, divided on the basis of quality of data into two categories of reliability of mapped reserves, was mapped by township and by 1-foot increments of coal thickness, beginning at 18 inches. Within each of these categories

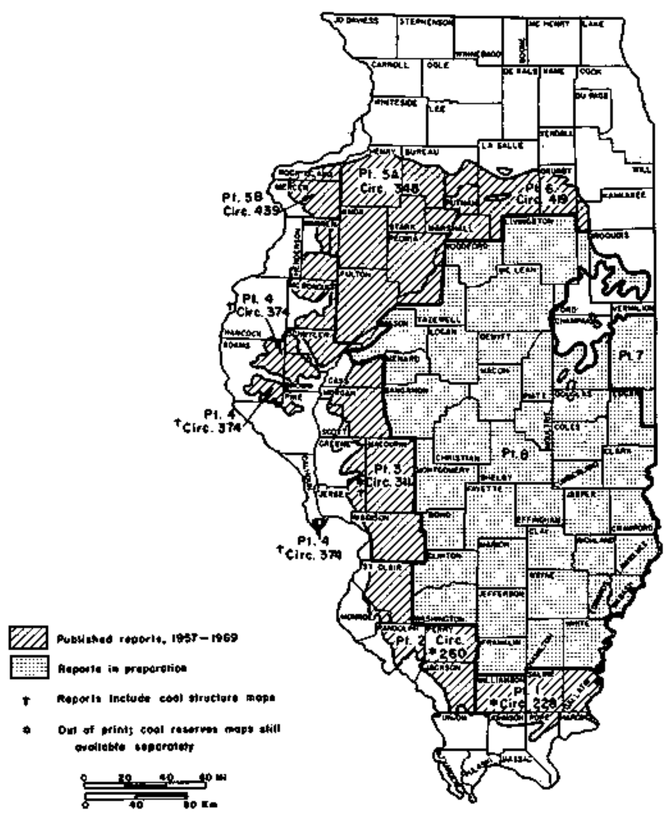


Figure 2. Index to reports on strippable coal reserves of Illinois.

the coal was divided into three classes on the basis of depth of overburden-0 to 50 feet, 50 to 100 feet, and 100 to 150 feet (Reinertsen, 1964[42]; Searight and Smith, 1969[43]; Smith, 1957[45], 1958[46], 1961[47], 1968[48]; Smith and Berggren, 1963[49]).

In a series of Geological Survey reports dealing with subsurface geology and coal resources of the Pennsylvanian System in certain Illinois counties, the reserves mapped in the 1952 study were modified to include additional information and more detailed maps of the geology and structure of the coal seams. These reports are listed under "Coal Resources" in the bibliography to Part 1.

Coal reserves in several counties in southeastern Illinois (fig. 3) have been mapped in recent years. Hopkins (1968[37]) investigated the reserves of the Harrisburg Coal in southeastern Illinois, and his study was the first report published by the Survey to use data from electric logs of oil and gas test holes for mapping coal reserves. Since publication of that report, much of the area for which reserves were mapped has been leased and extensively drilled for coal. Results generally have confirmed the coal thickness interpreted from the electric logs. In a similar report, Allgaier and Hopkins (1975[24]) mapped reserves for the Herrin Coal in several southeastern Illinois counties (fig. 3).

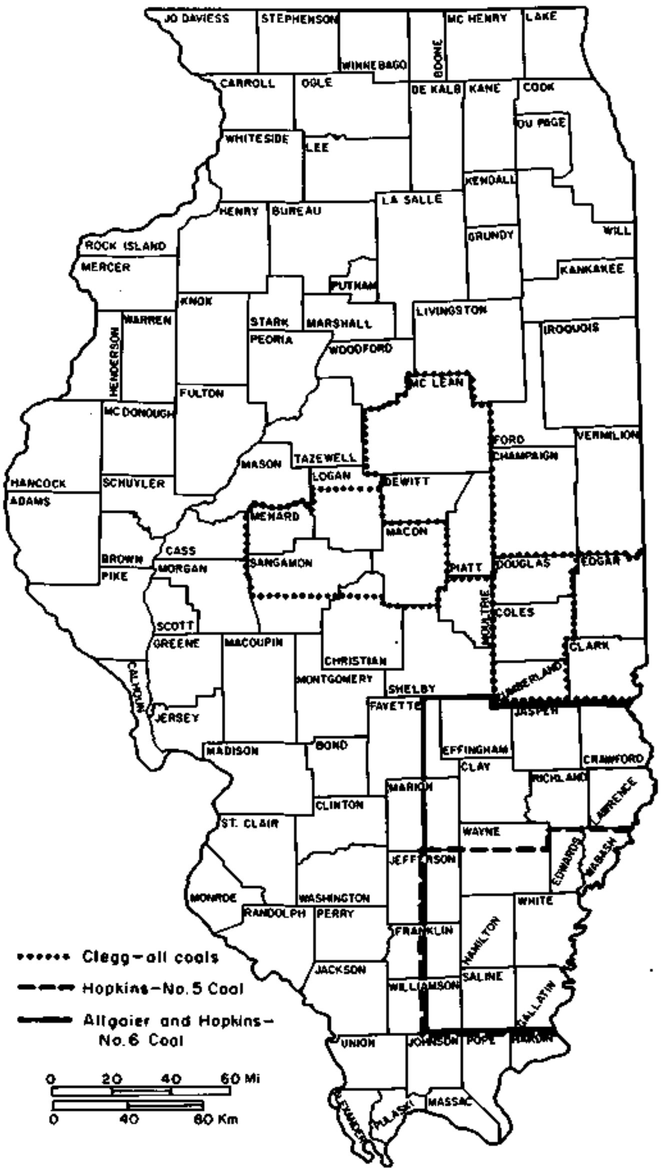


Figure 3. Index to area reports on coal reserves.

DEFINITIONS AND METHODS

The quantities of coal estimated in this study are referred to collectively as reserves and have not been further subdivided, as they were in most previous studies. The term "reserves" as used here refers broadly to coal deposits that, based on interpretation of geologic information, are presumed with a reasonable degree of certainty to exist within a coal seam. We have mapped and calculated only coal that is 42 or more inches thick and could best meet the anticipated demands for large quantities of coal by coal conversion plants. All new information relating to coal thickness and distribution that has been acquired since the inventory conducted by Cady and others (1952[28]) was added to the data base used in the earlier study. Certain areas of coal, described later, have been excluded in making these estimates.

In this report the estimates of coal reserves include coal lying within a maximum distance of 4 miles from the nearest datum point (table 4). This definition encompasses all coal in the categories designated in the 1952 study as Class I-A *(proved),* Class I-B *(probable),* and Class II-A *(strongly indicated)* (table 3).

Classification of Reserves

The classification of reserves set up in the 1952 study was modified for this report (table 4) to place all coal reserves 42 or more inches thick in a single class. The single classification enabled us to handle the data more quickly and easily by the computer methods employed.

Figures 4 and 5 show areas with Class I reserves and Class II reserves. However, on plates 1 and 2 and in the reserves tabulation, only one class, combining Classes I and II, was used. For the Herrin Coal, approximately 73 percent of the areal extent of the estimated reserves is in Class I (Classes I-A and I-B of the 1952 study) and approximately 27 percent is in Class II (Class II-A of the 1952 study) (table 3). For the Harrisburg-Springfield Coal, approximately 49 percent of the area is in Class I, and about 51 percent is in Class II.

TABLE 4-CLASSIFICATION OF RESERVES MAPPED IN THIS REPORT

Class	Maximum distance from datum points	Accepted datum points	Remarks†
All coals included in a single class that incorporates Classes I-A, I-B, and II-A of Cady and others (1952[28]) and subsequent studies*	4 miles	All classes of data used in 1952 report plus interpretations of conventional electric logs of oil and gas drill holes in some areas	Only coal 42 or more inches thick included

* *Includes strippable coal 42 or more inches thick (total coal in ground with less than 150 feet of overburden).*

† *All volume calculations were based on coal having a specific gravity of 1.32, which is equivalent to 82.64 lb/cu ft. This is equivalent to 1,800 tons/acre-ft, or 1.152 million tons/sq mi-ft.*

Areas Excluded from Estimates of Reserves

Areas where the coal has been mined out or is missing because geologic features such as sandstone-filled channels are known to have disrupted its lateral extent have been excluded from the estimates of reserves. Plates 1 and 2 show mined-out areas for the Herrin and Harrisburg-Springfield Coals as they were on July 1, 1973. Areas overlying oil pools (closely drilled areas), shown on plates 1 and 2, also have been excluded. Not excluded, however, are areas of coal that may be unminable by virtue of their location under municipalities, highways, water impoundments, and other cultural features.

Areas of coal that overlie oil and gas pools and are closely drilled have been excluded from the estimates because current mining practices make it impractical to mine coal within such areas. The current Federal mining law prohibits the mining of coal within a radius of 150 feet around oil wells unless adequate well plugging ensures safe conditions with smaller coal pillars. Well spacing within the excluded areas shown on plates 1 and 2 generally is 660 feet (one well per 10 acres), but mining under such conditions is generally uneconomic.

Only the oil and gas wells within pool areas, shown in gray on plates 1 and 2, have been excluded. In the many single wells scattered throughout the coal fields, a pillar of coal 300 feet in diameter (in some cases smaller pillars) must be left around the well, but the unrecoverable coal around these wells could not accurately be deleted from our calculation of reserves.

Areas in which coal is thin and areas for which insufficient information is available for mapping classified reserves also were excluded from the reserves (pls. 1 and 2), as were the areas adjacent to some of the sandstone channels where the coal is known to be split by partings of shale or sandstone that generally make the coal unminable by underground mining methods. All of the sandstone-channel and split-coal areas that are known within the two coal seams are indicated on plates 1 and 2 and are described later in more detail.

Acknowledgments

The author is indebted to M. E. Hopkins, Head of the Geological Survey Coal Section, for assistance in the administration of the project and for his help in editing the manuscript and maps. Lawrence E. Bengal was responsible for much of the planning and execution of the mapping, and Russell J. Jacobson assisted in compilation of the reserves estimates, which were drawn from the work of many past and present members of the staff of the Geological Survey Coal Section.

J. P. Hoeflinger of the Computer Services Section of the Geological Survey coordinated computer programming and processing of the data in cooperation with other members of this unit. Assistance in computer mathematics and programming were provided by William G. Miller. L. Michael Kaas and Paul M. Juneman of International Business Machines Corporation supplied information about the STAMPEDE computer program and its application to the mapping techniques used in this study. Illustrations for Part 1 were prepared by Marie L. Martin, Sue-Ann Meyer, and Patricia A. Whelan. The manuscript was edited by Betty Lynch.

ESTIMATED COAL RESERVES

Estimated coal reserves 42 or more inches thick totaling 97 billion tons have been mapped for the Herrin (No. 6) Coal and the Harrisburg-Springfield (No. 5) Coal. Their thickness ranges from the 42-inch minimum established for this study to more than 10 feet. The total coal in the ground in that thickness range is shown in table 5. Average thickness of the Herrin Coal is 5.52 feet, and 56 percent of the mapped reserves of this coal is 6 feet or more thick. The Harrisburg-Springfield Coal averages 4.55 feet thick, and 47 percent of its mapped reserves is 5 feet or more thick (table 5).

The distribution of these reserves for each county is given in table A (Appendix 1) by 1-foot increments of thickness, beginning at 4 feet. Table A also shows for each of

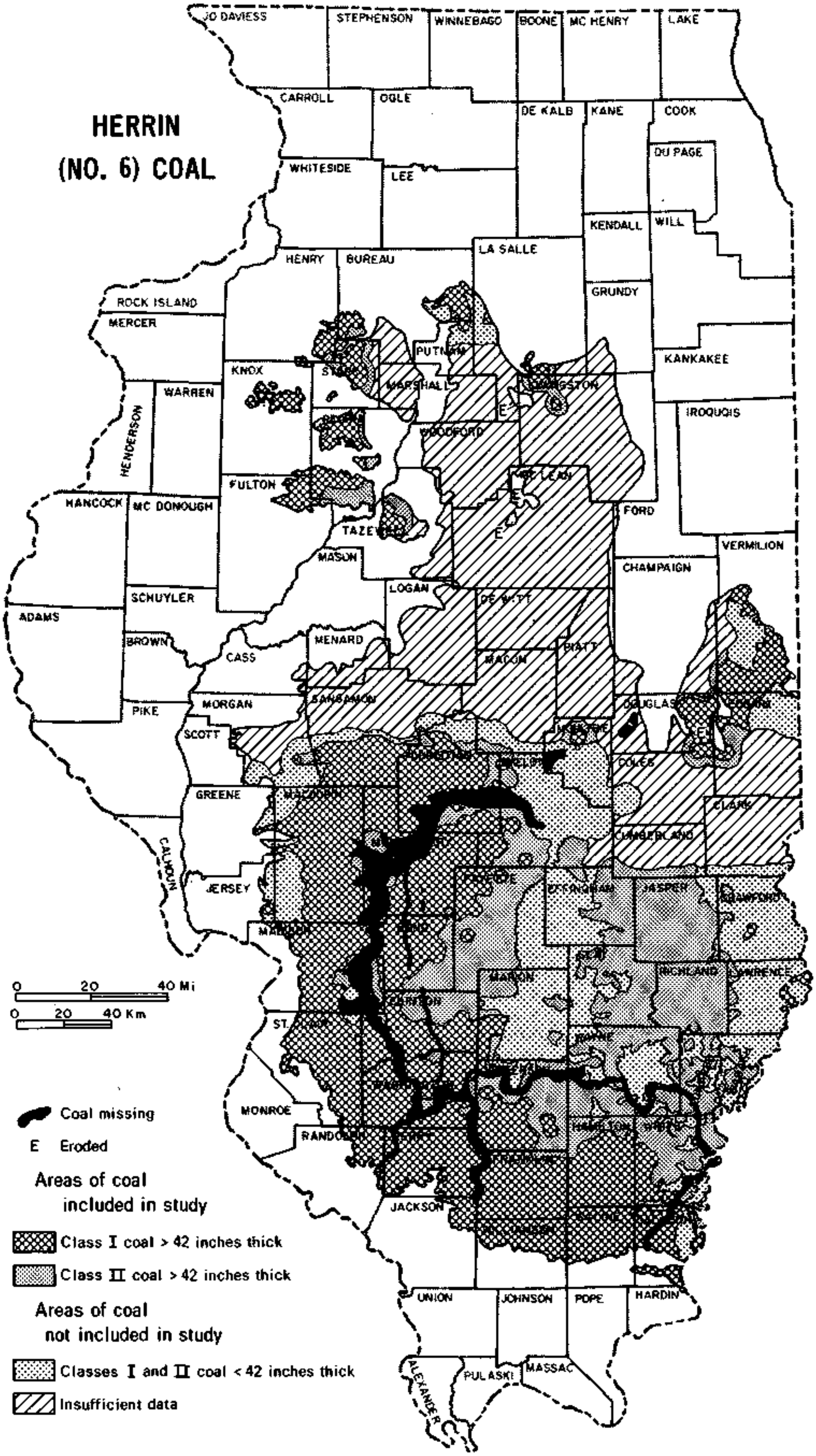


Figure 4. Classification of Herrin Coal reserves. Classes are defined in tables 3 and 4.

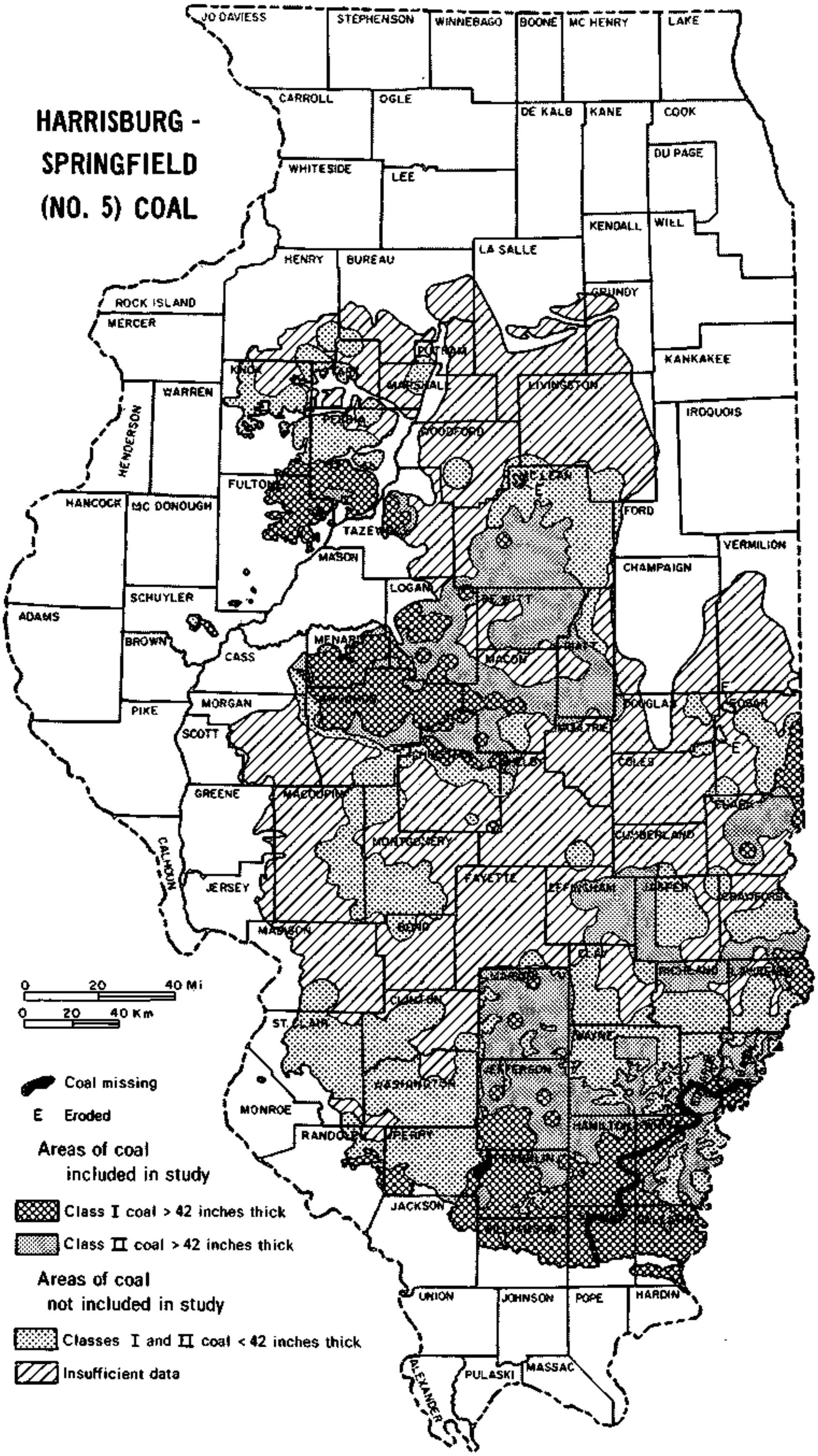


Figure 5. Classification of Harrisburg-Springfield Coal reserves. Classes are defined in tables 3 and 4.

TABLE 5-SUMMARY OF COAL RESERVES

By thickness of seams

Average*	Herrin (No. 6)		Harrisburg-Springfield (No. 5)		Total remaining reserves	
of seam (ft)	Thousands - of tons	%of sub-total	Thousands of tons	%of sub-total	Sub-total (thousands of tons)	%of grand total
4	13,300,102	22.6	20,261,331	53.0	33,561,433	34.5
5	12,657,243	21.5	11,321,567	29.6	23,978,810	24.7
6	12,290,311	20.8	5,572,030	14.6	17,862,341	18.4
7	11,586,777	19.7	806,097	2.1	12,392,874	12.7
8	7,831,170	13.3	249,413	0.6	8,080,583	8.3
9	1,018,906	1.7	24,485	0.07	1,043,391	1.1
10	256,668	0.4	9,677	0.03	266,345	0.3
					Grand total:	
Totals	58,941,177	100	38,244,600	100	97,185,777	100

By area †

	Herrin (No. 6)		Harrisburg-Springfield (No. 5)		Total remaining reserves	
Category	Sq mi	%of original reserves	Sqmi	%of original reserves	Sub-total (sq mi)	%of original reserves
Original reserves	10,196	100	7,630	100	17,826	100
Mined out	927	9.1	331	4.3	1,258	7.1
Remaining reserves	9,269	90.9	7,299	95.7	16,567	92.9

** The average thickness of all remaining reserves in the Herrin seam is 5.52 feet and in the Harrisburg-Springfield seam 4.55 feet.*

† Because the areas underlain by the No. 5 and No. 6 seams overlap in part, this represents areas of unmined coal and should not be confused with surface area.

the two coal seams the total area of each county that is underlain by reserves. Also listed in the table are the area of coal mined out from each of the seams, by county, the weighted average thickness of all of the remaining coal in each seam, and the weighted average tons of remaining coal per square mile.

Plates 1 and 2 show the average tons of coal 42 or more inches thick remaining in place per square mile in each township. The maps enable comparison of the amount of coal reserves in one area with reserves in other areas. The reserves can also be related to a variety of geologic features that influence the thickness and distribution of the coal.

GEOLOGY OF THE COAL SEAMS

Regional Relations

Illinois has greater reserves of bituminous coal than any other state. Figure 6 shows the distribution of coal fields in the United States, and Appendix table B and figure 7 compare the demonstrated coal reserves of Illinois with those of other coal-producing states. The data in table B and figure 7 are from a recent tabulation by the U.S. Bureau of Mines. Because of differences in criteria used in classification, the Bureau of Mines figures for Illinois are substantially lower than those shown in the other maps and tables of this report.

The coal fields of Illinois lie within the Eastern Region of the Interior Coal Province, which is commonly called the Eastern Interior Coal Field (fig. 8). The coals lie with-

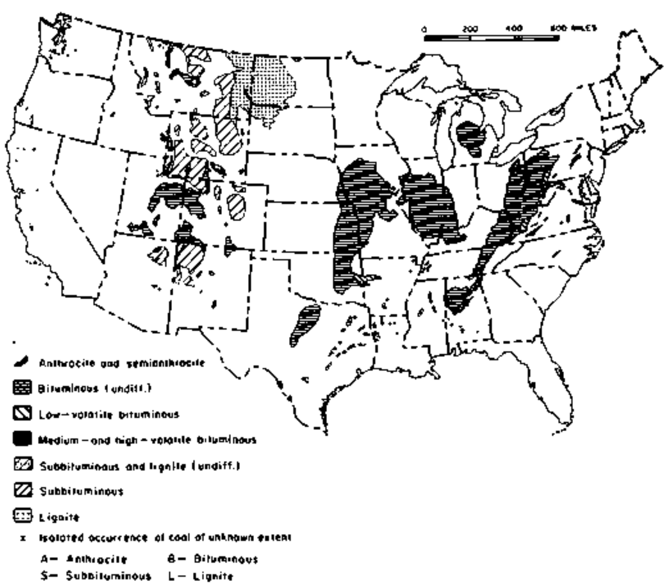


Figure 6. Coal fields of the contiguous United States.

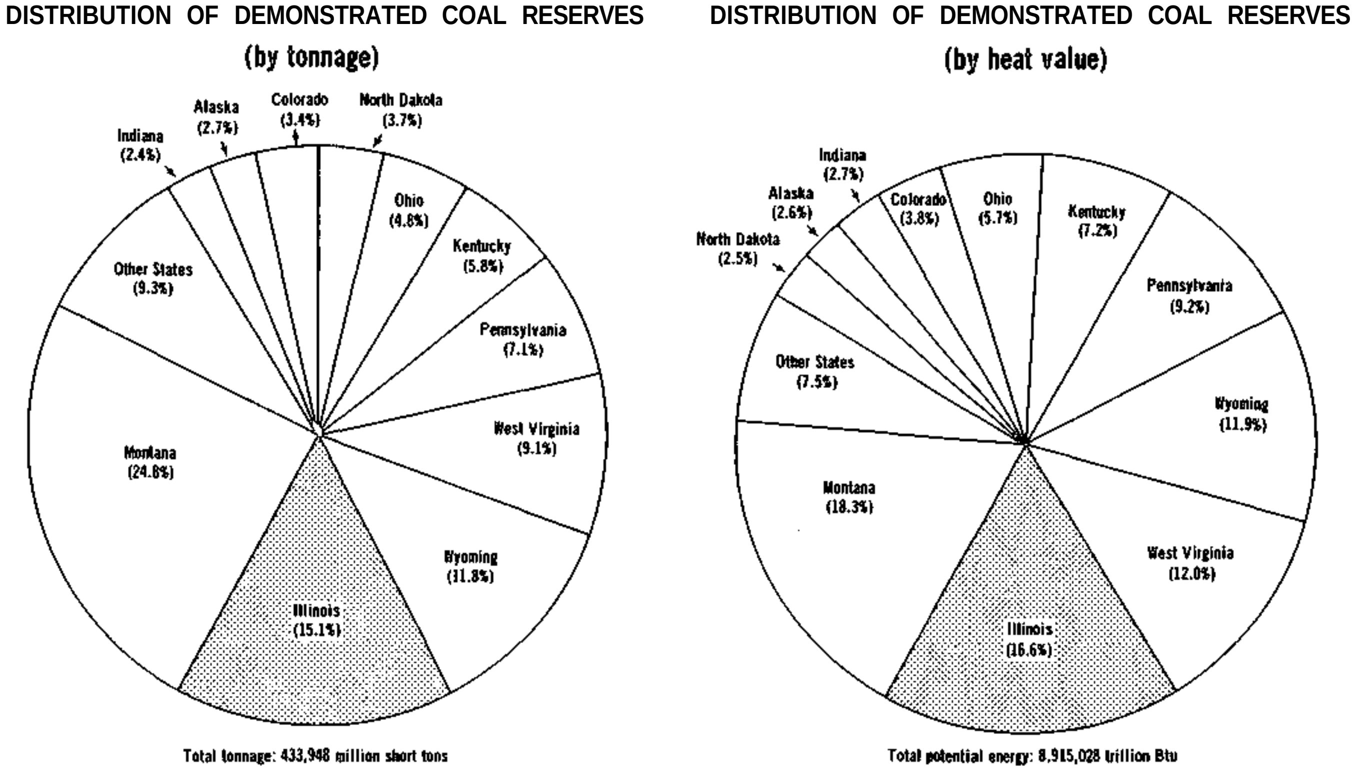


Figure 7. Demonstrated coal reserves base of the United States and estimated energy potentials by state. (Data from *US.* Bureau of Mines, 1974[51]; Library of Congress Congressional Research Service, 1973[56]. Prepared by Ramesh Malhotra, Mineral Economics Group, Illinois Geological Survey.)

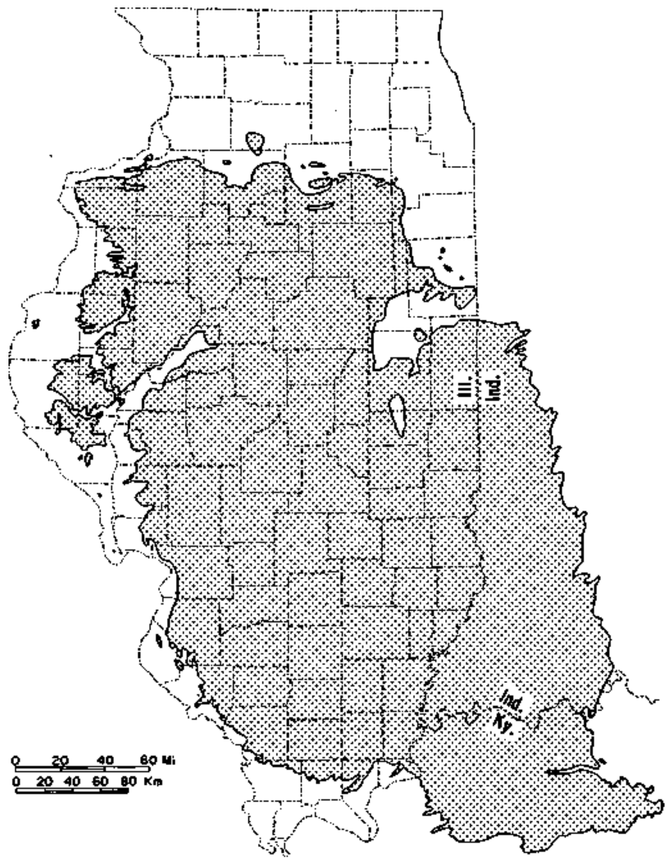


Figure 8. Eastern Interior Coal Field.

in a structural depression called the Illinois Basin (fig. 9), the position of which approximately coincides with that of the Eastern Interior Coal Field.

Within the Illinois Basin are numerous structural features, such as anticlines, synclines, and faults, that locally influence the dip, thickness, and continuity of the coal seams. The major geologic structures are shown in figure 9. The structure of the Herrin Coal and of some areas of the Harrisburg-Springfield Coal has been mapped on scales of 1 inch to the mile and half an inch to the mile for a substantial part of the Illinois coal fields.

The Herrin and Harrisburg-Springfield Coals occur near the middle of the stratigraphic sequence of Pennsylvanian rocks (fig. 10). They are separated by an interval ranging from 10 feet or less at some places in western and central Illinois to more than 120 feet in southeastern Illinois (fig. 20). The coals crop out toward the margins of the Illinois Basin, and in the deepest part of the basin they attain a maximum depth of more than 1,200 feet (figs. 15 and 17).

The regional thickness of the coals is indicated by colors on plates 1 and 2. Two major geological influences affected their regional thickness. First, on some prominent structures (fig. 9) very little coal was deposited because of their topographic influence on the depositional surface. Second, major drainage systems in the swamps promoted a more abundant accumulation of coal-forming vegetation in the vicinity of the principal channels. However, no plant material accumulated in the drainageways, and they were sub-

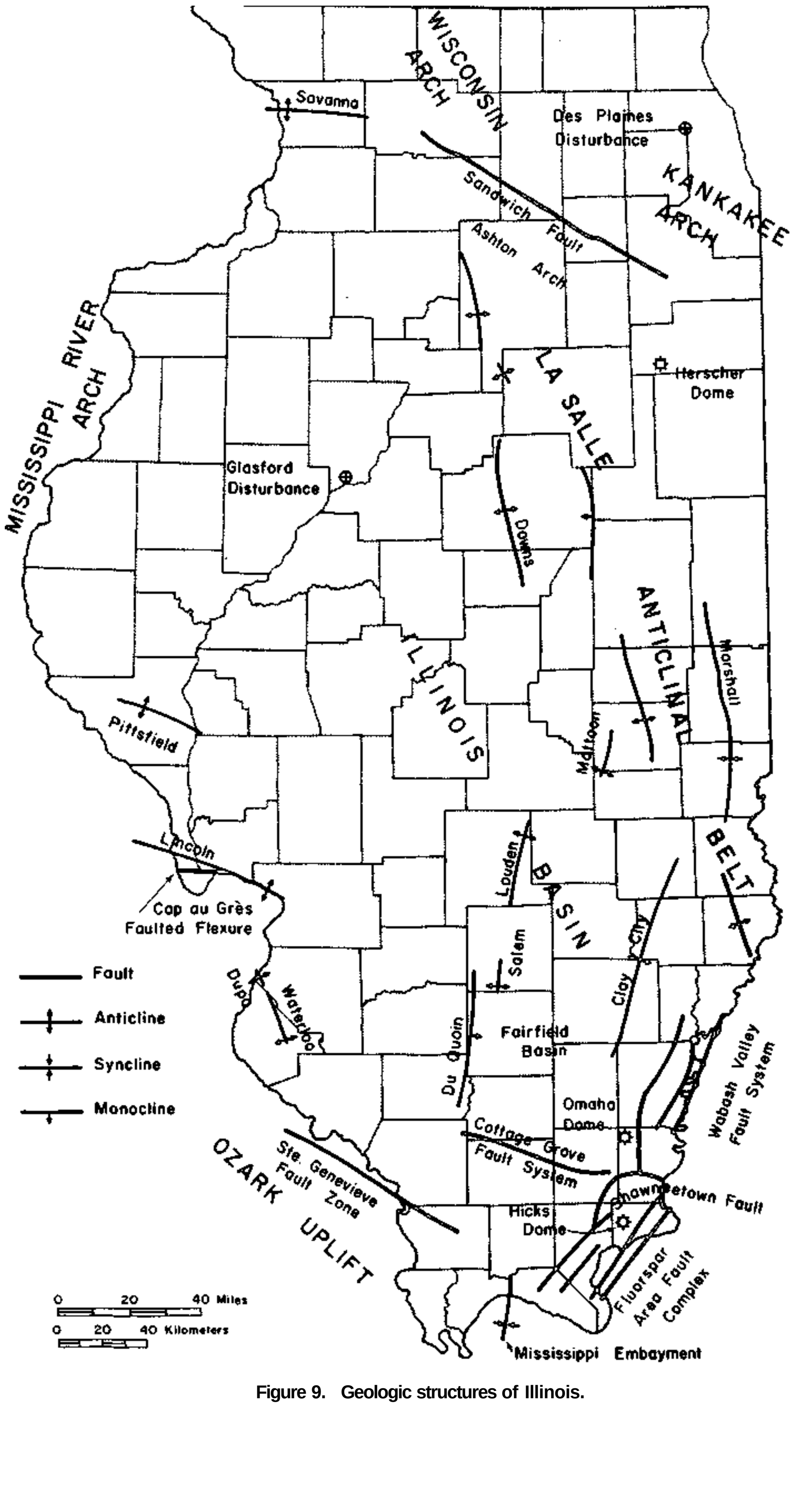


Figure 9. Geologic structures of Illinois.

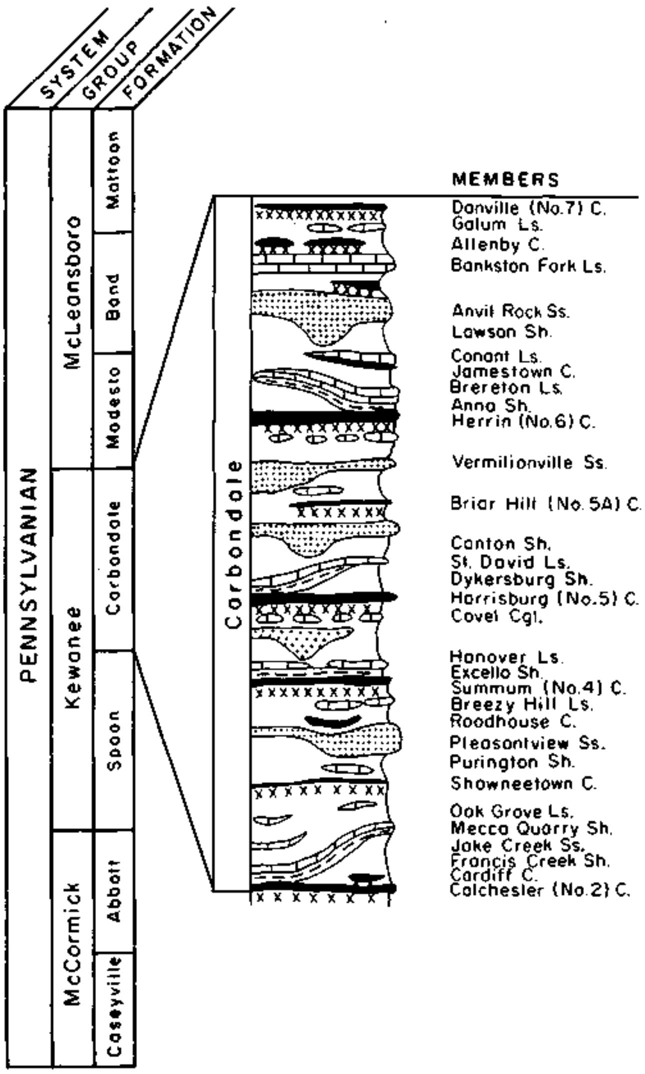


Figure 10. The stratigraphic section shows the position of the Herrin and Harrisburg-Springfield Coals within the Pennsylvanian System in Illinois.

sequently filled with sand or mud and became the sandstone or shale channels of the present coal seams.

The long, sinuous features shown in yellow on plates 1 and 2 mark the location of the former stream channels. Interlamination of coal with stream-laid silt and clay at the margins of some of the ancient streams makes it evident that these channels were contemporaneous with the coal swamp. Along the main axes of these channels, thick deposits of sandstone commonly occur and the coal is absent. Later, after the coal had formed and been buried by various layers of sediments, a new system of channels cut through the normal sequence of overlying strata, and in some places also eroded the coal. Like the contemporaneous channels, these later channels eventually filled with sand or mud. Both types of buried stream deposits are referred to on plates 1 and 2 as sandstone channels. Their occurrence is described in greater detail in the discussion of the geology of the specific coal seams, and their effect on coal mining is described in the discussion of minability of the coal seams.

The Geological Survey has made several studies of the distribution of sandstone channels that disrupt the coal. Hopkins (1958[66]) was the first to map in detail part of the Anvil Rock Sandstone Member, tracing its distribution in southern Illinois. Potter and Simon (1961[70]) mapped the sandstone channels in west-central Illinois, which Johnson (1972[67]) treated in greater detail. Hopkins (1968[37]) also mapped a prominent channel in the Harrisburg-Springfield Coal in southeastern Illinois and related it and associated strata to low-sulfur coal deposits in the area.

Quality of the Coals

The Geological Survey has long conducted a variety of studies relating to the quality of coal. Recently much of the research has involved the potential reduction of the sulfur content of Illinois coals by washing (Helfinstine et al., 1971[10], 1974[9]) and the occurrence of mineral matter and trace elements in the coal (Rao and Gluskoter, 1973[13]; Ruch, Gluskoter, and Shimp, 1974[15]).

The coal of the Herrin and Harrisburg-Springfield seams is of high-volatile bituminous rank, defined by standards of the American Society for Testing and Materials (ASTM) (table 6). Illinois coals are of high-volatile C rank in the northern part of the state, undergo a progressive increase in rank southeastward, and reach high-volatile A rank near the southeastern margin of the coal (fig. 11). The progressive increase in rank with original depth of burial has been described by Damberger (1971[5]) as a fundamental relation found in coal basins throughout the world. The greater the original depth of burial, the greater the degree of coalification and the higher the rank of the coal. In figure 11 the iso-rank lines for the Herrin Coal' closely parallel the structure lines, except in southernmost Illinois where the rank increases fairly rapidly southward but where the coals crop out at or near the present land surface. There the original coalification pattern may have been modified by heat released from a deep-seated intrusion of igneous rocks. However, a more likely reason for the higher rank in the southeast is the area's proximity to the deepest part of the basin during the Pennsylvanian and Permian Periods, when coalification presumably took place.

The heating value of Illinois coal undergoes a progressive increase (fig. 11) from about 10,500 Btu/lb (moist mineral-matter free) in northwestern Illinois to over 14,000 Btu/lb in southeastern Illinois. Table 7 shows the range of typical analyses of the Herrin (No. 6) and the Harrisburg-Springfield (No. 5) Coals from various areas of the Illinois coal fields.

TABLE 6-CLASSIFICATION OF COALS BY RANK*

(from ASTM, 1973[1])

Class	Group	Fixed carbon limits (%) (dry mineral-matter-free basis): Equal or greater than	Fixed carbon limits (%): Less than	Volatile matter limits (%) (dry mineral-matter-free basis): Greater than	Volatile matter limits (%): Equal or less than	Calorific value limits (Btu/lb) (moist† mineral-matter-free basis): Equal or greater than	Calorific value limits (Btu/lb): Less than	Agglomerating character
I. Anthracitic	1. Meta-anthracite	98			2			
	2. Anthracite	92	98	2	8			Nonagglomerating
	3. Semianthracite‡	86	92	8	14			
II. Bituminous	1. Low-volatile bituminous coal	78	86	14	22			
	2. Medium-volatile bituminous coal	69	78	22	31			
	3. High-volatile *A* bituminous coal		69	31		14,000**		Commonly agglomerating††
	4. High-volatile *B* bituminous coal					13,000**	14,000	
	5. High-volatile *C* bituminous coal					11,500	13,000	
						10,500	11,500	Agglomerating
III. Subbituminous	1. Subbituminous *A* coal					10,500	11,500	
	2. Subbituminous *B* coal					9,500	10,500	
	3. Subbituminous *C* coal					8,300	9,500	
								Nonagglomerating
IV. Lignitic	1. Lignite *A*					6,300	8,300	
	2. Lignite *B*						6,300	

** This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.*

† Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

‡ If agglomerating, classify in low-volatile group of the bituminous class.

*** Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.*

†† It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in high-volatile C bituminous group.

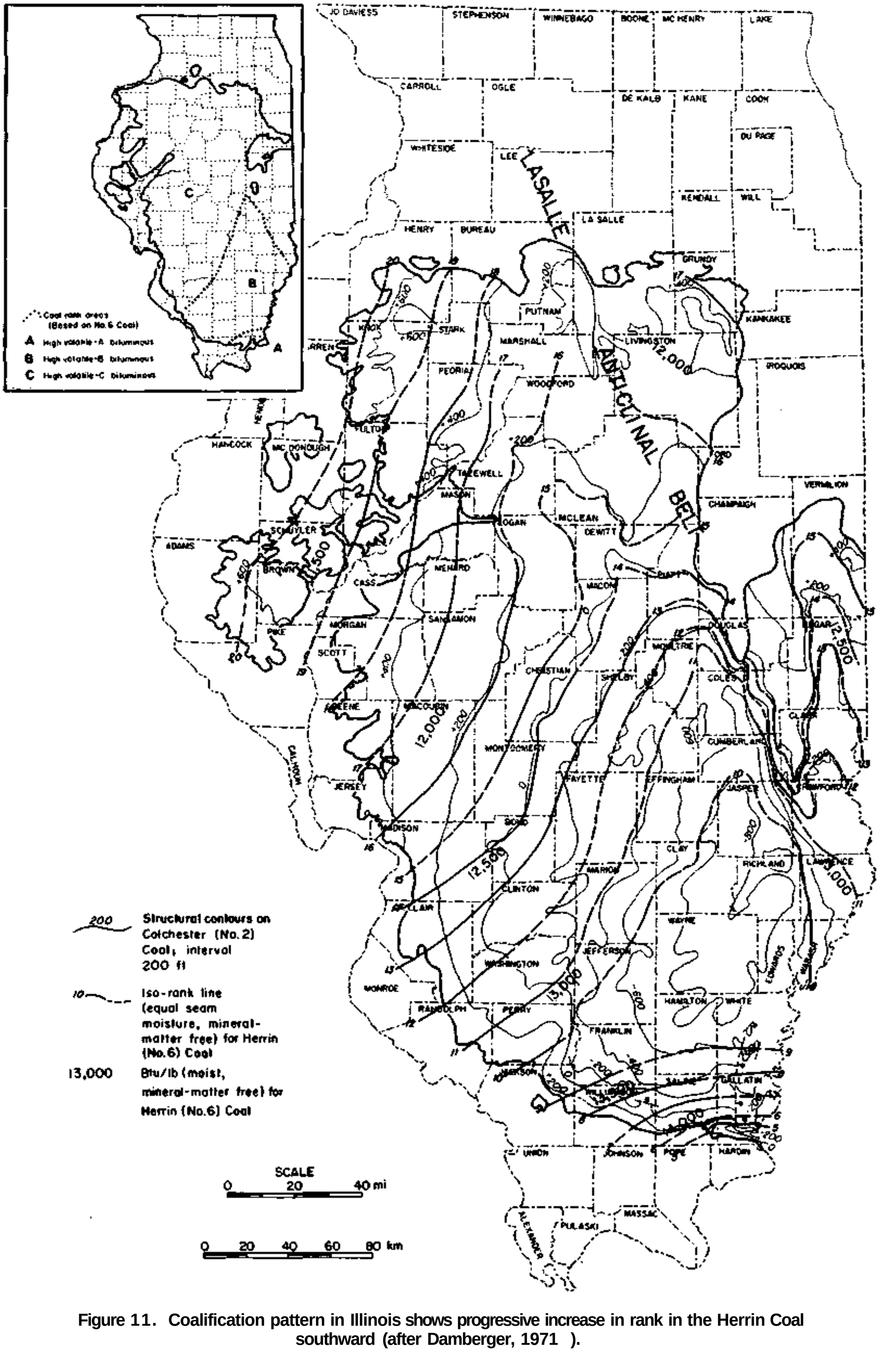


Figure 11. Coalification pattern in Illinois shows progressive increase in rank in the Herrin Coal southward (after Damberger, 1971).

TABLE 7-RANGE OF TYPICAL ANALYSES BY COUNTIES*

County	As-received basis						Rank index†	Ash fusion (°F)
	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Sulfur (%)	Btu/lb		
HERRIN (No. 6) COAL								
La Salle, Grundy	13-16	36-41	35-40	7-11	3-5	10,500-11,400	116-123	1,950-2,150
Bureau, Stark, Henry, Knox	16-20	31-35	37-40	8-13	3-5	9,700-10,300	111-118	1,900-2,120
Peoria, Fulton	15-19	32-35	37-43	8-13	2-4	9,800-10,700	111-120	
Sangamon, Macoupin	12-16	35-40	37-41	9-11	3-5	10,400-10,900	116-123	1,930-2,160
Christian, Montgomery, Bond, Madison	12-14	35-40	38-41	9-11	3-5	10,500-11,000	117-125	1,920-2,170
Vermilion	14-16	32-36	38-41	8-12	1-3	10,400-11,100	118-128	2,080-2,220
Clinton, St. Clair	10-13	35-40	37-42	9-12	1-4	10,700-11,100	121-129	1,920-2,090
Marion, Washington, Randolph, Perry	8-12	35-39	38-44	9-13	1-4	10,800-11,300	124-133	1,920-2,610
Jefferson, Franklin, Jackson	7-10	32-37	45-50	7-10	1-3	11,600-12,000	130-135	1,920-2,650
White, Saline, Williamson	4-9	30-36	46-52	7-10	1-3	11,700-12,300	130-141	1,950-2,430
Gallatin (Eagle Valley)	3-5	32-35	46-50	10-13	3-4	12,400-12,700	138-147	
HARRISBURG-SPRINGFIELD (No. 5) COAL								
Peoria, Fulton, Tazewell, Schuyler	14-18	33-38	34-40	9-12	2-4	10,100-10,800	115-122	1,890-2,270
McLean, Logan, Menard, Sangamon	13-17	34-39	36-41	9-12	3-5	10,400-11,000	117-125	1,890-2,060
Macon, Shelby	12-16	34-39	35-40	8-12	3-4	10,500-11,100	119-127	
Edgar	10-12	36-40	37-43	8-10	3-4	11,200-11,500	126-130	
Randolph, Perry	8-13	35-38	40-44	9-12	4-5	11,000-11,400	124-135	
Jackson	8-9	35-36	44-55	11	3-4	11,600-11,800	130-135	2,168-2,174
Gallatin, Saline, Williamson	5-7	33-38	47-53	8-12	2-5	11,900-12,500	132-141	1,940-2,010
Gallatin (Eagle Valley)	4-5	34-37	48-52	10-11	3-4	12,400-12,700	130-147	2,040-2,090

** Adapted from data compiled by H. H. Damberger from Cody (1935[3], 1948[4]) and from coal analyses by the Illinois Geological Survey since 1948.*

† Calorific value of moist coal on a mineral-matter-free basis to the nearest 100 Btu/lb.

Sulfur Content

About 4 percent of the total reserves of the Herrin and Harrisburg-Springfield Coals is low-sulfur coal (less than 2.5 percent sulfur), as is shown in figures 12 and 13. In most of the Eastern Interior Coal Field, the coals are overlain by black shale and/or limestone, and the sulfur content normally ranges from 3 to 5 percent. However, in certain areas near sandstone-filled channels (figs. 12 and 13), gray silty shale intervenes between the coal and the overlying black shale and limestone. In areas where the gray shale deposits (which are considered to be genetically related to the sandstone channels) exceed 20 feet thick (figs. 14 and 16), the sulfur content of the coal is normally less than 2.5 percent.

The fact that most Illinois coal contains from 3 to 5 percent sulfur has been responsible for curtailment of its use to observe environmental restrictions. Development of new mines has therefore been greatly retarded. Studies conducted in recent years at the Geological Survey to evaluate and characterize the distribution of sulfur in Illinois coals have shown that sulfur content of Illinois coals ranges between 0.5 and 6.0 percent (dry basis), the average total sulfur content being about 3.5 percent (Gluskoter and Simon, 1968[7]).

Because the low-sulfur coal meets the standards for use in blends for manufacture of metallurgical coke, a significant part of the current production is used for this purpose. In 1972, the latest year for which figures are available, 4.4 million tons of Illinois coal was consumed in coke plants.

HERRIN (NO. 6) COAL MEMBER

The Herrin (No. 6) Coal Member, the most extensively mined coal in Illinois, was named for exposures near Herrin, Williamson County (Shaw and Savage, 1912[72]). It is correlated with the No. 11 Coal of western Kentucky, the Herrin Coal Member of Indiana, the Mystic Coal of Iowa, and the Lexington Coal of Missouri and Kansas. As shown on plate 1, it is 42 or more inches thick in an area covering 9,269 square miles in Illinois. It has been and currently is being strip mined along much of the southern and western margins of the Illinois Basin. Underground mining has been most extensive in areas where the coal is thickest and can be reached at moderate depths (generally 700 feet or less), but in Franklin and Jefferson Counties coal having lower than average sulfur content has been extensively mined at depths of as much as 800 feet. Of the total coal production in Illinois in 1973 (61.5 million tons), 75 percent was from the Herrin seam. Of the original area of 10,196 square miles mapped in this study for Herrin Coal reserves, 927 square miles have been mined out. The remaining in-place reserves of Herrin Coal 42 or more inches thick are estimated at 59 billion tons. The distribution of reserves by county appears in table A.

Thickness of the Coal

The Herrin Coal is the most widely mapped and thickest coal in Illinois, and it has been mined more extensively than any other seam. Mapping for this study revealed that the weighted average thickness of all coal 42 or more inches thick in the Herrin seam is 5.51 feet. Figure 14 shows the generalized thickness of the Herrin Coal, drawn from the data used for compilation of plate 1.

The Herrin Coal is absent where the Walshville Channel occurs (fig. 14). Along the margins of the channel the coal is generally split by sandstone or shale and may be unminable because it lies in relatively thin benches. On both sides of the channel and beyond the area of split or thin coal, the thickest coal is generally found.

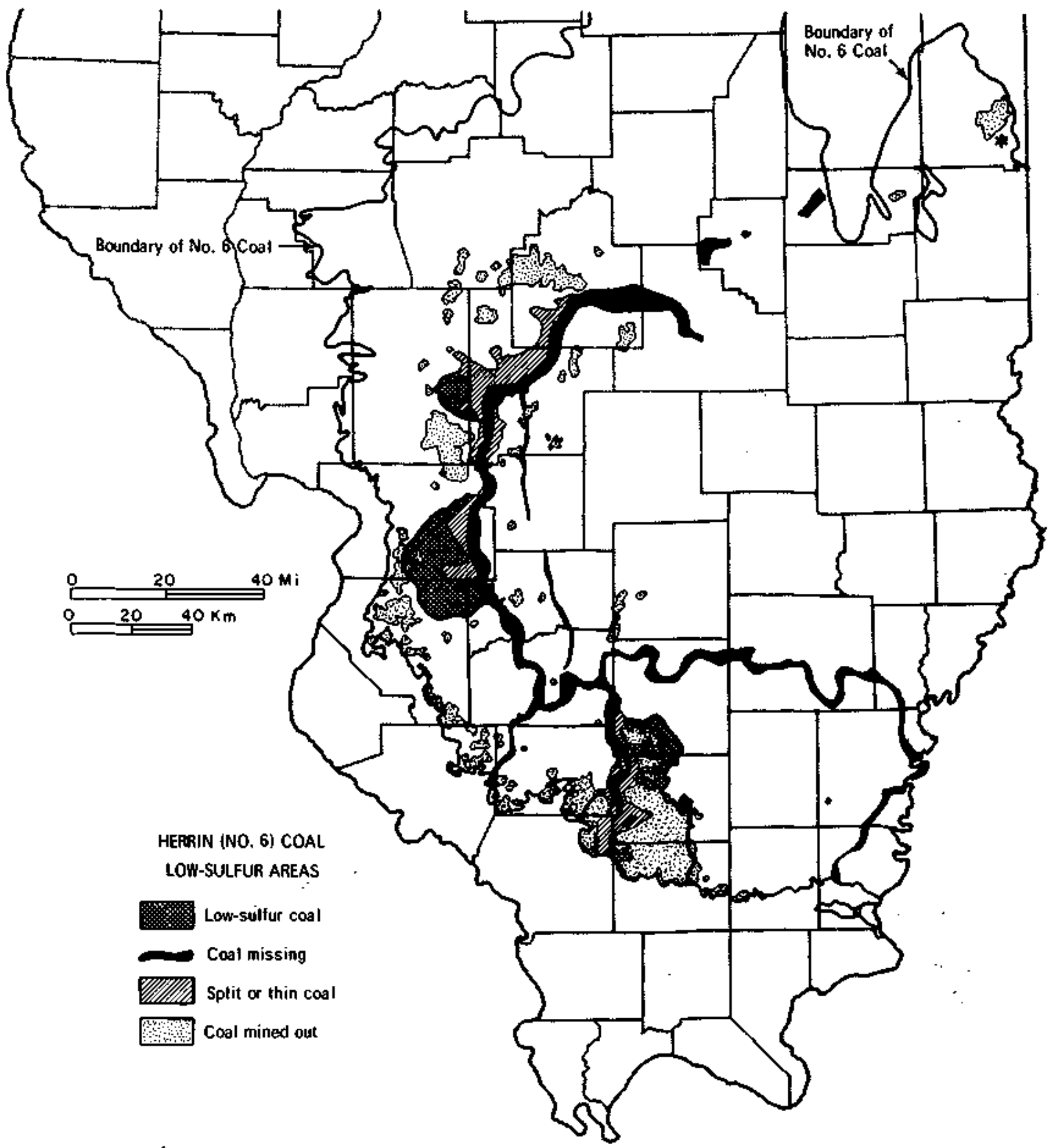
Regions in which the coal is thin (fig. 14) are those in which conditions for coal accumulation were not favorable. In several such regions geologic structures (fig. 9) appear to have been responsible. The area of thin coal in eastern Fayette County, western Effingham County, and central and northern Marion County reflects the Salem and Louden Anticlines, apparently high places in the coal swamps on which relatively little coal material was deposited. The abrupt thinning of the Herrin Coal northward from central Sangamon County and northern Christian County and a corresponding thickening of the Harrisburg-Springfield Coal in the same direction also may have been influenced by regional structure. The effect of the La Salle Anticlinal Belt and other large structural features on coal thickness suggests that most coal seams, including the Herrin Coal, become thin over positive structures and thick over negative structures, although this conclusion does not always apply.

Definition of the reserves of the Herrin Coal in north-central and east-central Illinois has been hampered by lack of sufficient data. In east-central Illinois Clegg (1959[30], 1965[32]) (fig. 3) mapped the structure of the Herrin Coal in Cumberland, Coles, Douglas, Clark, and Edgar Counties but did not modify reserves estimated by Cady and others (1952[28]) because no additional coal tests were available to indicate the thickness of the coal. Clegg (1965[32]) did, however, modify the coal correlations of the 1952 study by pointing out that the coal that was mapped as Danville (No. 7) Coal, which is being mined at Murdock, Douglas County, should have been correlated with the Herrin Coal. Therefore, substantial reserves in those counties formerly classified as the Danville Coal are mapped in this study as Herrin (No. 6) Coal.

Allgaier and Hopkins (1975[24]) mapped the thickness and estimated the reserves of Herrin Coal (fig. 3) in southeastern Illinois. They derived data primarily from electric logs of

LLINOIS LOW-SULFUR RESERVES IN GROUND

Coal	County	Millions of tons
Herrin (No. 6)	Clinton	23
(< 2.5% S,	Franklin	228
av. 1.5%,	Jackson	37
dry basis)	Jefferson	469
	Macoupin	396
'	Madison	245
	Perry	35
	St. Clair	381
	Williamson	59
		1.873



* Low sulfur reported in several of these mines.

Figure 12. Occurrence of low-sulfur coal in the Herrin seam.

ILLINOIS LOW-SULFUR RESERVES IN GROUND		
Coal	County	Millions of tons
Harrisburg-Springfield (No. 5) (<2.5% S, av.~2%, dry basis)	Edwards	54
	Franklin	243
	Hamilton	563
	Saline	627
	Wabash	262
	Wayne	89
	White	626
	Williamson	274
		2.738

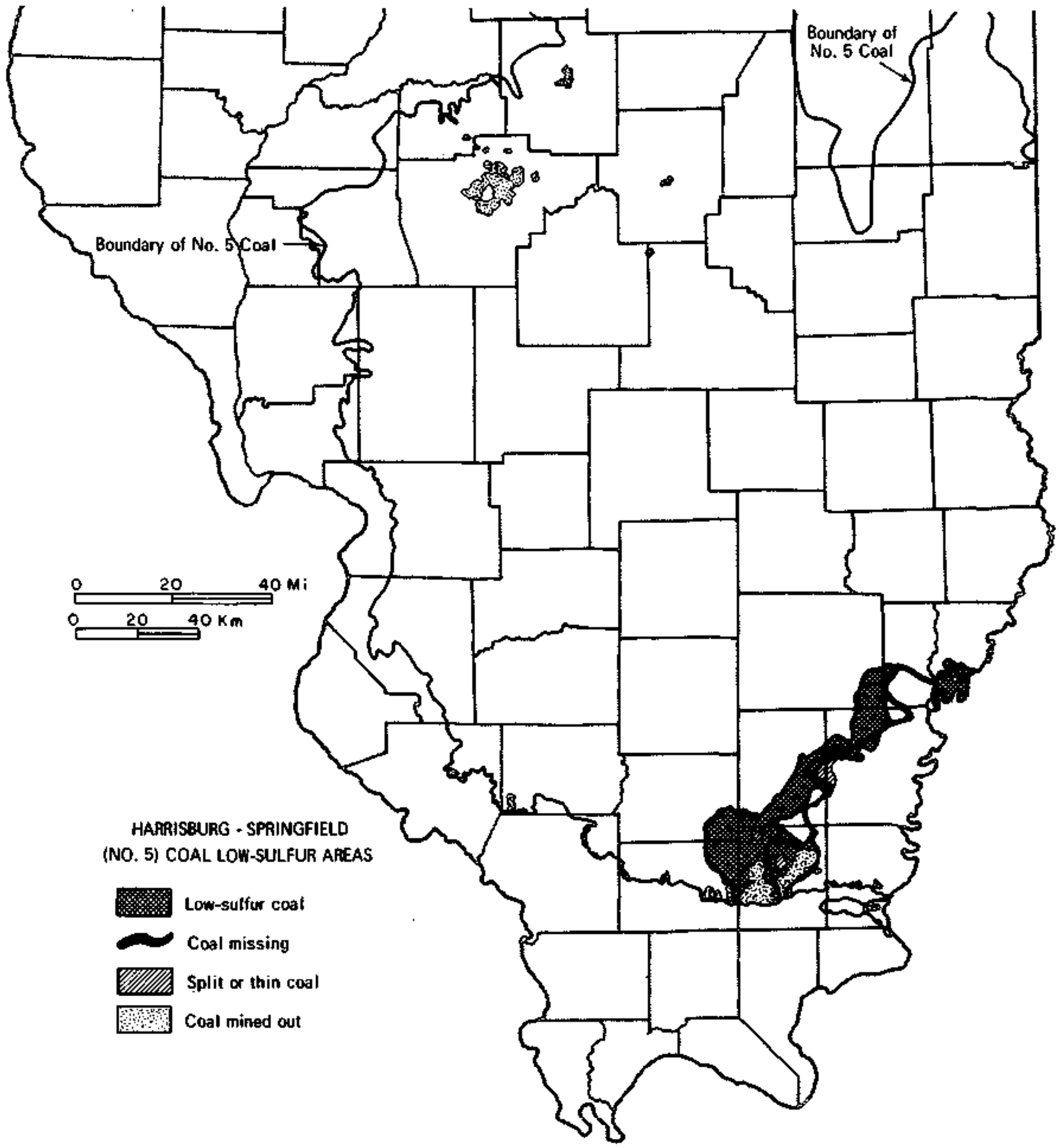


Figure 13. Occurrence of low-sulfur coal in the Harrisburg-Springfield seam.

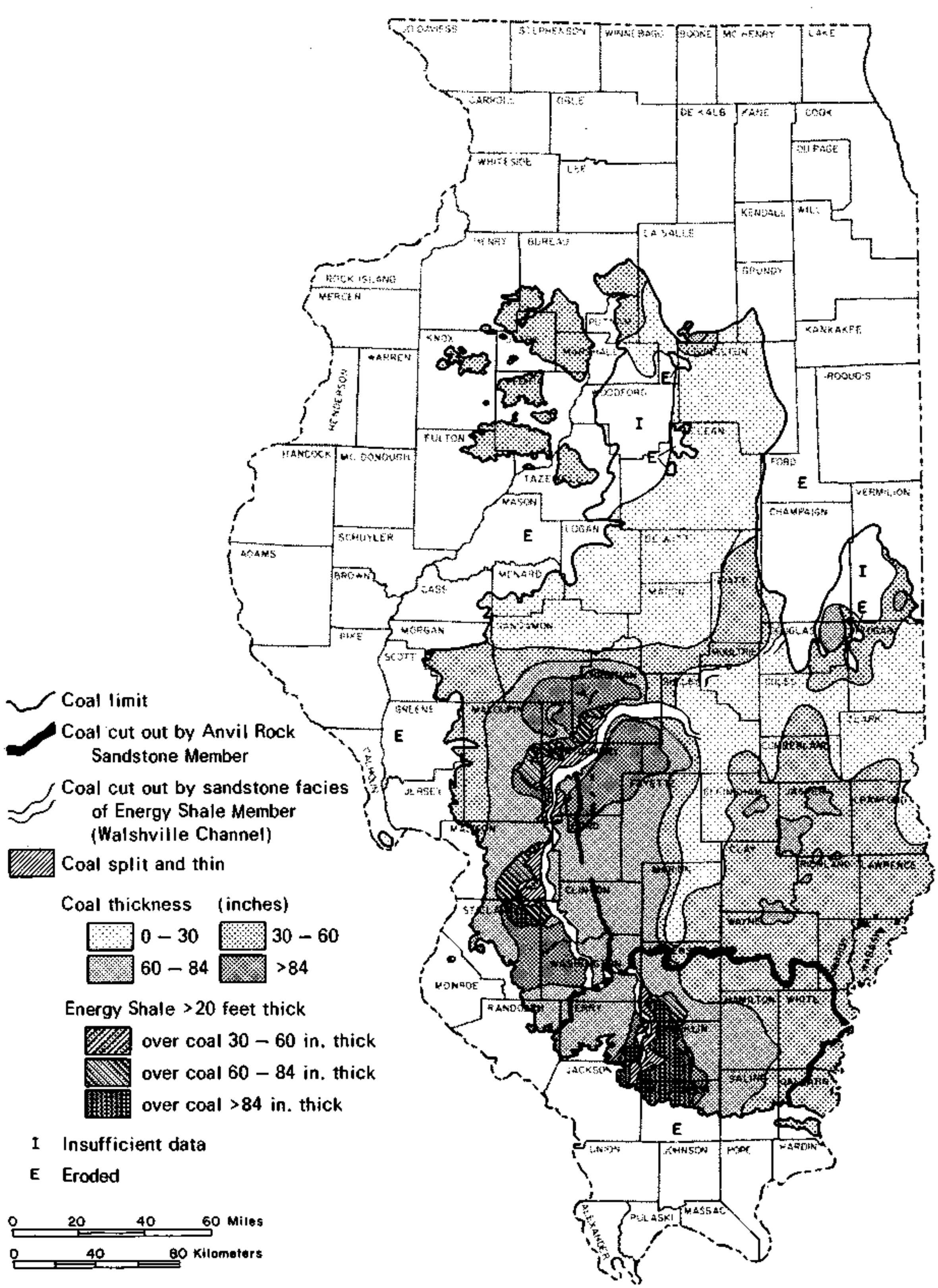


Figure 14. Generalized thickness of Herrin Coal.

oil wells and used them to interpret the coal thickness, as Hopkins (1968[37]) had done previously for the Harrisburg-Springfield Coal in much of the same region.

Depth of the Coal

The areas where the Herrin Coal is strippable lie toward the margins of the Illinois Basin; coal depth increases to a known maximum of 1,248 feet in Jasper County, near the center of the basin (fig. 15). The 150-foot depth line is shown on plate 1 to designate areas where the coal may be potentially strippable. Strippable areas of the Herrin Coal have been mapped in a series of reports (numbers 42, 43, 45, 46, 47, 48, 49 in the Bibliography) located geographically in figure 2. The strippable reserves of Herrin Coal by counties covered in that series of reports are summarized in table 8.

A comparison of the depth of the Herrin Coal throughout Illinois (fig. 15) with the overburden line on plate 1 shows that, fortunately, where the coal is thickest it also happens to be at moderate depth. None of the Herrin Coal lies deep enough to make it economically prohibitive to mine, and the availability of large volumes of thick coal at moderate depth may make it unnecessary at present to mine the coal in the deepest parts of the Illinois Basin.

Geology of the Herrin Coal Relative to Mining

The Herrin Coal has been mined more than any other coal seam in Illinois because of its thickness, its shallow-to-moderate depth throughout extensive areas, and the prevalence of suitable conditions for large-scale mining. The location of all mines operating in the Herrin Coal in Illinois in 1974 is shown in figure 15. These 37 mines, 19 underground mines and 18 strip mines, accounted for 75 percent of the 1973 production of coal in Illinois. The locations of these mines and all other Illinois coal mines are shown on a new map (Hopkins, 1975[38]) prepared on the same scale as the three plates accompanying this report.

Southern and Central Illinois

The Herrin Coal has been mined more extensively in southern Illinois than in any other part of the state. Five of the current underground mines are now operating in the low-sulfur coal area, located in Franklin and Jefferson Counties (fig. 12). In Jackson, Perry, Randolph, and St. Clair Counties, most current production is from strip mines, four of which are mining in both the Herrin Coal and the Harrisburg-Springfield Coal. In central Illinois, large underground mines in Christian, Macoupin, and Montgomery Counties (fig. 15) produce from the Herrin Coal.

In a large area in eastern Fayette County, western Effingham County, eastern Marion County, and western Clay County, the Herrin Coal is less than 42 inches thick. In part of that area it is less than 28 inches thick.

Western Illinois

All of the coal production in western Illinois in recent years has been from strip mines primarily from the Herrin, Harrisburg-Springfield, and Colchester (No. 2) Coals. All active mines except one are now producing from the Herrin and/or the Harrisburg-Springfield Coals, and extensive reserves are shown for these coals in this area (table 8).

The Herrin Coal is now being strip mined in Stark, Peoria, Knox, and Fulton Counties (fig. 15). Large areas of potentially strippable Herrin Coal also are present in southeastern Henry County and southwestern Bureau County (Smith and Berggren, 1963[49]).

In Fulton County, strip mines in the past have mined coal from both the Herrin and Harrisburg-Springfield seams from adjacent strip pits. In this area the two seams are 60 to 75 feet apart. In the counties farther north, however, the Harrisburg-Springfield Coal becomes thinner and only the Herrin Coal has been mined.

Northern Illinois

There is no current mining in the Herrin Coal in northern Illinois (fig. 15). It was formerly mined, principally by underground methods, near Streator in La Salle County and along the Illinois River in both Bureau and La Salle Counties.

The remaining coal reserves in these areas, as shown on plate 1, are small compared to those of other regions of the state. However, in a large part of northern Illinois the coal resources have not yet been adequately assessed because data on which to make an evaluation are scarce.

Eastern Illinois

Three mines are operating at present in the Herrin Coal in eastern Illinois, two near Murdock in eastern Douglas County and one, a small mine, southwest of Danville in Vermilion County (fig. 15). Substantial quantities of additional coal have been mapped in Douglas, Vermilion, and Edgar Counties. For Clark, Coles, and Cumberland Counties, because not enough data are available for mapping the Herrin Coal reserves, no estimate has been made. Farther south, in part of southeastern Illinois, large reserves of Herrin Coal are mapped, but the coal is much deeper there than in other parts of the state and numerous oil pools will seriously limit the minability of the coal in many parts of this region. In southern Cumberland County, eastern Effingham County, and western Jasper County the Herrin Coal has been mapped in large areas, principally from interpretation of geophysical logs of oil and gas wells (Allgaier and Hopkins, 1975[24]). Therefore the Herrin Coal in these Counties has been placed in the Class II category (table 3 and fig. 4).

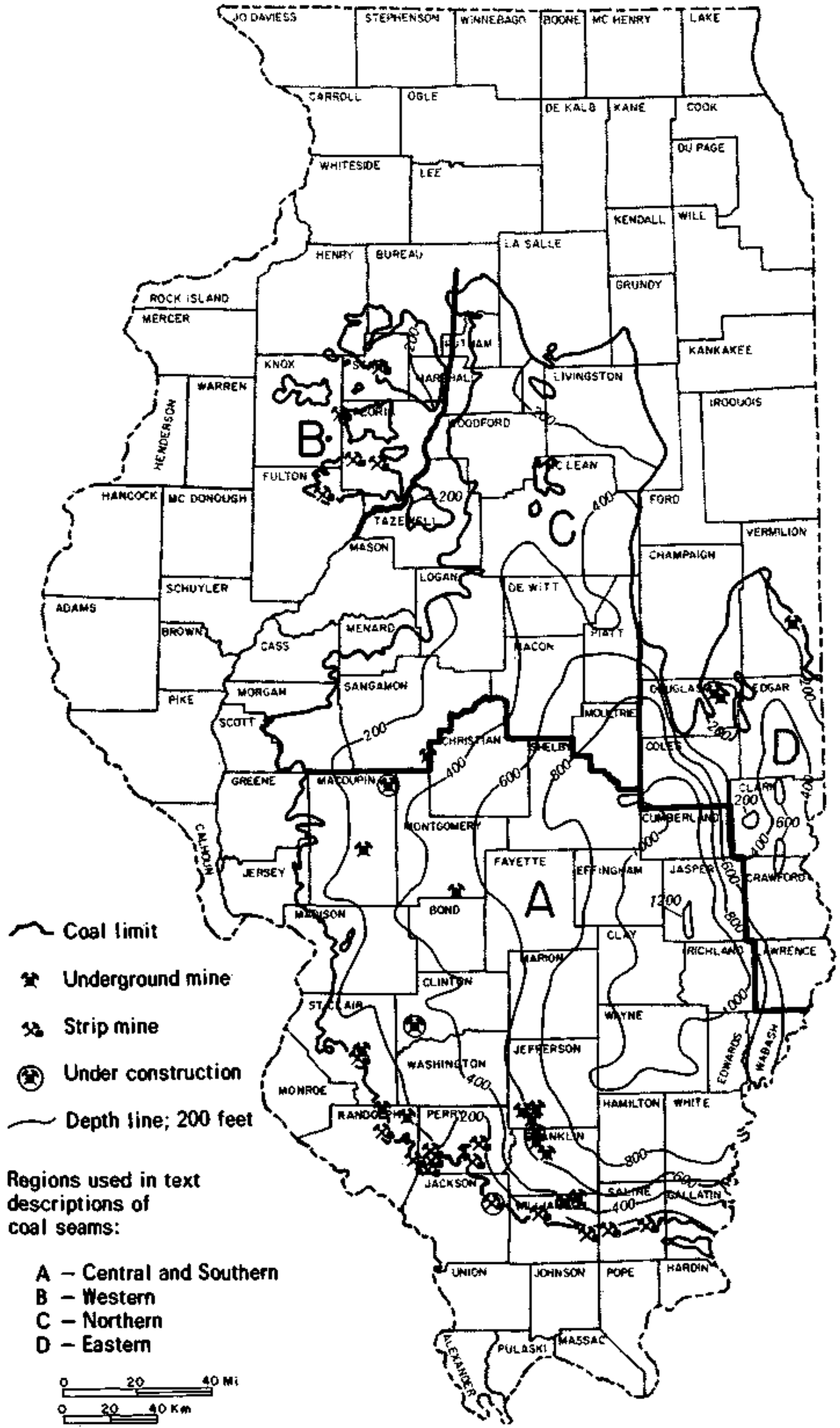


Figure 15. Generalized depth of Herrin Coal. Mines active in the Herrin seam on January 1,1975, are indicated.

TABLE 8-STRIPPABLE COAL RESERVES IN THE HERRIN (NO. 6) AND HARRISBURG-SPRINGFIELD (NO. 5) COAL MEMBERS BY COUNTY AND RELIABILITY CLASSIFICATION*†

(thousands of tons)

County	Coal seam	Class I reserves at overburden thickness (ft)				Class II reserves at overburden thickness (ft)				Totals I & II	Mined (sq mi)
		0-50	50-100	100-150	Total	0-50	50-100	100-150	Total		
Bureau	6	24,218	63,058	76,061	163,337	628	29,055	69,095	98,778	262,115	4.91
Cass	6		14,600	5,100	19,700		14,729	21,455	36,184	55,884	
Fulton	6	42,556	126,588	80,142	249,286					249,286	4.93
	5	172,925	389,624	139,837	702,386					702,386	51.19
Gallatin	6	37,104	45,035	32,367	114,506		718	6,681	7,399	121,905	
	5	2,343	29,582	83,924	115,849					115,849	1.64
Greene	6	13,831	23,988	37,540	75,359	9,069	12,555	291	21,915	97,274	
Henry	6	38,919	104,433	49,175	192,527	583	45,107	17,218	62,908	255,435	1.94
Jackson	6	26,969	73,264	49,085	149,318					149,318	9.47
	5	18,585	34,424	46,834	99,843					99,843	1.88
Jersey	6	18,159	23,910	8,452	50,521	807	4,887	1,121	6,815	57,336	
Knox	6	124,723	128,050	4,293	257,066					257,066	11.28
	5	178,543	233,719	55,960	468,222	23,282	77,659	57,346	158,287	626,509	5.50
La Salle	6	14,897	24,480	9,574	48,951	8,732	12,521		21,253	70,204	9.19
Livingston	6	5,829	17,553	1,671	25,053	1,794	2,197		3,991	29,044	3.33
Macoupin	6	36,967	64,264	90,371	191,602	246	16,949	42,013	59,208	250,810	
Madison	6	31,789	165,036	195,200	392,025	1,883	14,942	40,433	57,258	449,283	
Monroe	6	6,726			6,726					6,726	
Morgan	6	4,081	61,759	26,622	92,462	7,466	202,510	183,442	393,418	485,880	
Peoria	6	204,817	404,294	272,710	881,821	5,173	46,873	124,504	176,550	1,058,371	1.85
	5	45,712	173,645	248,778	468,135	28,489	117,689	111,236	257,414	725,549	17.83
Perry	6	136,037	510,782	249,948	896,767					896,767	35.94
	5	33,112	117,156	31,162	181,430		13,182	14,662	27,844	209,274	.58
Randolph	6	51,116	102,241	125,782	279,139					279,139	8.19
	5	41,125	86,795	32,557	160,477	196	6,283	8,934	15,413	175,890	.88
St. Clair	6	101,714	409,091	738,318	1,249,123					1,249,123	36.06
Saline	6	56,125	102,589	125,858	284,572					284,572	6.03
	5	11,782	24,044	57,596	93,422					93,422	10.67
Schuyler	5	79,664	23,204	2,186	105,054	8,340			8,340	113,394	1.03
Scott	6	583	5,537		6,120					6,120	
Stark	6	41,700	158,412	42,949	243,061	2,107	89,329	107,970	199,406	442,467	.25
Tazewell	6	6,097	16,377	35,163	57,637	140	7,034	4,875	12,049	69,686	
	5	1,211	5,851	21,085	28,147			8,928	8,928	37,075	1.35
Warren	5	807			807					807	
Williamson	6	66,461	92,603	131,654	290,718					290,718	33.62
	5	28,294	59,454	112,520	200,268					200,268	7.53
Total	6	1,091,418	2,737,944	2,388,035	6,217,397	38,628	499,406	619,098	1,157,132	7,374,529	166.99
	5	614,103	1,177,498	832,412	2,624,013	60,307	214,813	201,106	476,226	3,100,239	267.07
Totals		1,705,521	3,915,442	3,220,447	8,841,410	98,935	714,219	820,204	1,633,358	10,474,768	267.07

** Does not include studies now in progress for Springfield (No. 5) Coal in Menard and Sangamon Counties or Herrin (No. 6) Coal in Vermilion and Edgar Counties.*

t Strippable coals include coals 18 inches or more thick under 150 feet or less of overburden.

HARRISBURG-SPRINGFIELD (NO. 5) COAL MEMBER

The Harrisburg (No. 5) Coal Member was defined by Shaw and Savage (1912[72]), who named it for exposures and mines near Harrisburg, Saline County. The coal had previously been given the name "Springfield Coal" in the area of Springfield, Sangamon County (Worthen, 1883[82]). Subsequently, the coal was found to be in the same stratigraphic position in both regions, and therefore the form "Harrisburg-Springfield Coal" is used in this report. The seam is correlated with the No. 9 Coal of western Kentucky, the Springfield Coal Member (V) of Indiana, and the Summit Coal of Iowa and Missouri.

In Illinois the Harrisburg-Springfield Coal ranks second only to the Herrin Coal in total mapped reserves. Production from this seam accounted for 16 percent of the 1973 total production. It has been mapped (pl. 2) as being 42 or more inches thick throughout an area of 7,630 square miles, 331 square miles of which has been mined out, leaving 7,299 square miles of in-place reserves estimated at 38 billion tons.

The Harrisburg-Springfield Coal has been extensively mined underground in the Harrisburg region, the Springfield region, near Canton, Peoria, and Pekin, and in a large new mine near Keensburg in Wabash County. After World War II, strip mining in this seam increased, and many of the underground mines were closed. Along the outcrop in Gallatin, Saline, Williamson, Perry, and Randolph Counties, and in Fulton County, this seam has been extensively strip mined. In some areas it was, and still is in a few places, the principal seam mined, while in other areas it is strip mined along with the overlying Herrin Coal.

Thickness of the Coal

The Harrisburg-Springfield Coal averages about 1 foot thinner than the Herrin Coal. As determined in this study, its weighted average thickness in Illinois is 4.55 feet, compared to 5.52 feet for the Herrin Coal. The generalized thickness of the Harrisburg-Springfield Coal is shown in figure 16. It shows that the thickest coal is in southeastern Illinois adjacent to the prominent sandstone-filled channel mapped by Hopkins (1968[37]). The relation between coal thickness and proximity to the channel shown in figure 16 and plate 2 is similar to that shown for the Herrin Coal in figure 14 and plate 1. A similar relation is apparent between the low-sulfur areas of the two coals and the proximity of the coals to channels that existed during coal deposition, as shown in figures 12 and 13.

Other large areas of Harrisburg-Springfield Coal mapped in this study are located in the Springfield region and in the vicinity of Peoria and Canton in western Illinois. In both of these regions the coal is at least 5 feet thick in considerable areas. In the vicinity of Springfield and Peoria the coal formerly was mined rather widely in underground mines, whereas around Canton it has been extensively strip mined. In other parts of the state the Harrisburg-Springfield is either thin (less than 28 inches thick) or there is insufficient information available to warrant mapping the coal reserves.

Depth of the Coal

The depth of the Harrisburg-Springfield Coal is shown in figure 17. The Harrisburg-Springfield ranges from 10 to 130 feet below the Herrin seam (fig. 20). Like the overlying Herrin Coal, it is being strip mined near the margins of the Illinois Basin. Only 4.5 percent of the area of original Harrisburg-Springfield reserves mapped in this study has been mined out. It seems probable that the greater general thickness of the overlying Herrin Coal rather than the slightly greater depth of the Harrisburg-Springfield Coal has been largely responsible for the less extensive development of the lower coal.

Geology of the Harrisburg-Springfield Coal Relative to Mining

The Harrisburg-Springfield Coal has been extensively mined near Harrisburg, along its outcrop in southern Illinois, near Springfield, and near Peoria and Canton in western Illinois.

The locations of 16 mines operating in this coal in 1974 are shown in figure 17, 10 of them strip mines and 6 of them underground mines. In 1973 these mines accounted for 16 percent of the state's total coal production.

Southern and Central Illinois

In southern Illinois the Harrisburg-Springfield Coal is being strip mined at several places along its outcrop in Randolph, Perry, and Williamson Counties. Near Harrisburg, Saline County, it has been strip mined along its outcrop and was formerly mined underground much more extensively than it has been in recent years, although two underground mines still are operating there (fig. 17). As can be seen in figure 13, much of the coal formerly mined near Harrisburg had a lower sulfur content than that mined elsewhere in the region.

Hopkins (1968[37]) mapped reserves totaling 11.8 billion tons for coal 42 or more inches thick in the Harrisburg-Springfield (No. 5) Coal in southeastern Illinois. This included substantial quantities of low-sulfur coal in a belt along the prominent sandstone channel that extends northward from the vicinity of Harrisburg to Wabash County (figs. 13, 16, and pl. 1). Much of the coal along this belt is thicker than the coal elsewhere in the region. One new mine is now operating in this low-sulfur coal in Wabash County, and another is under construction in Hamilton County.

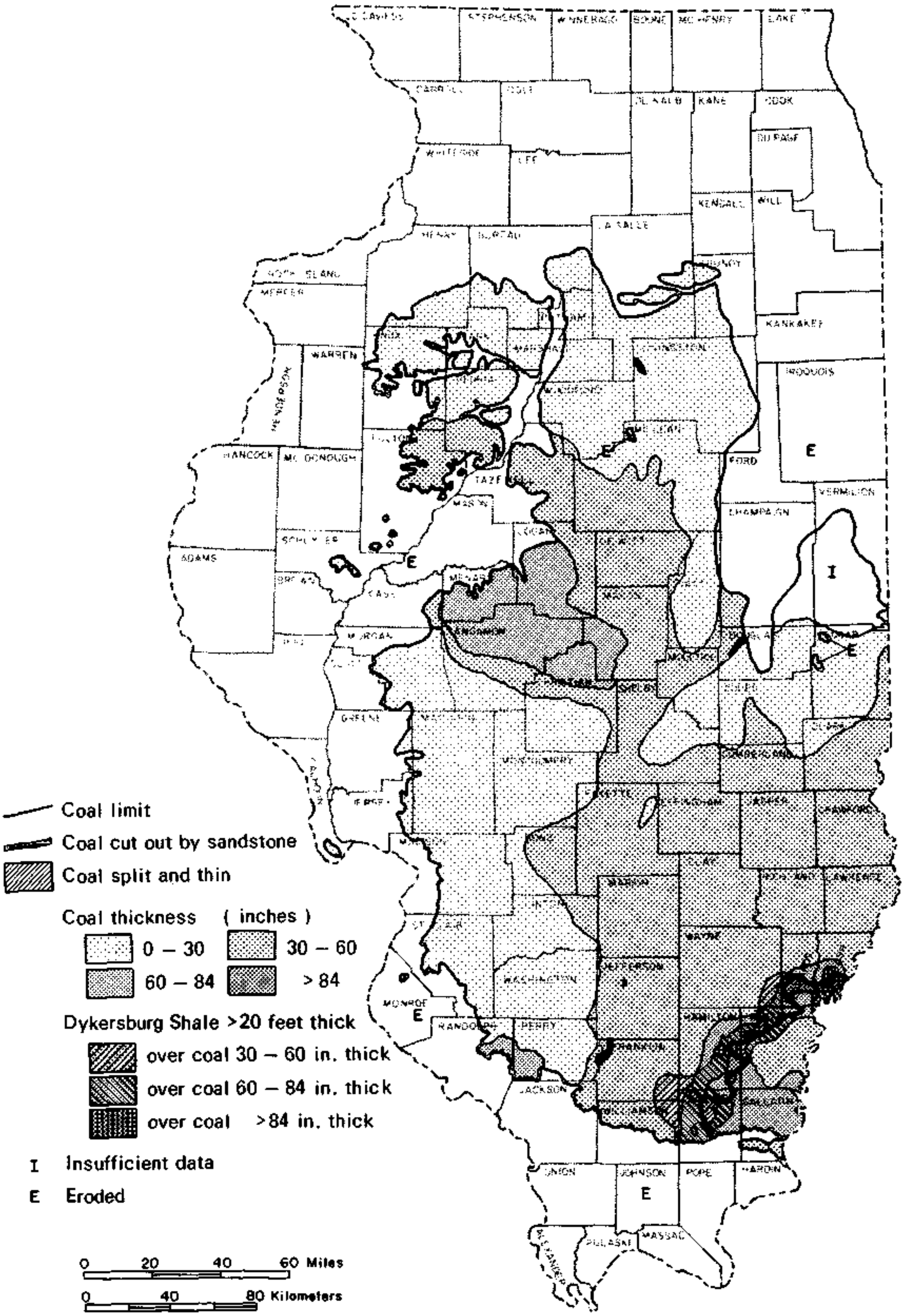


Figure 16. Generalized thickness of Harrisburg-Springfield Coal.

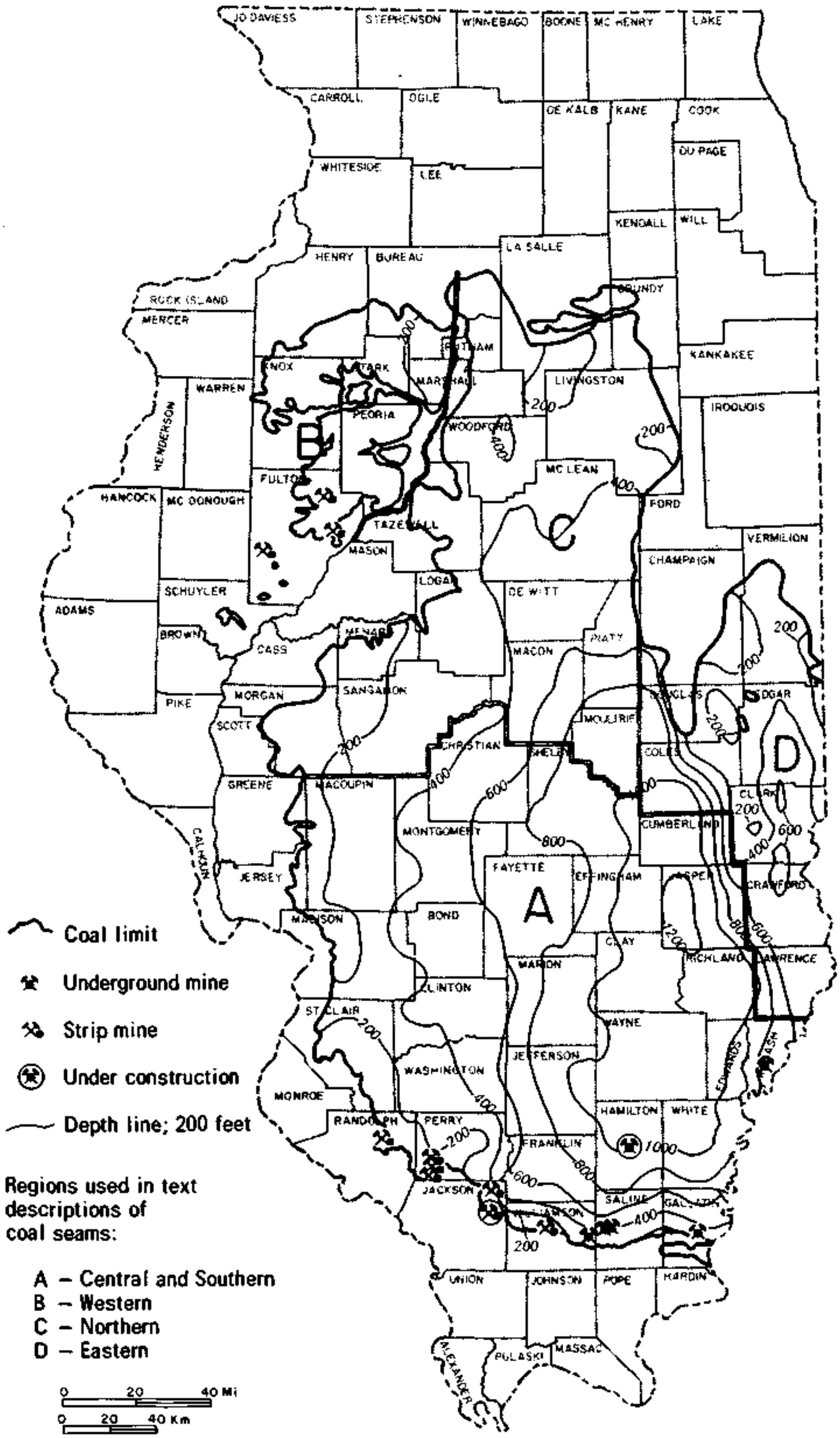


Figure 17. Generalized depth of the Harrisburg-Springfield Coal. Mines active in the Harrisburg-Springfield seam on January 1,1975, are located.

In central Illinois some of the Harrisburg-Springfield Coal that is mapped on plate 2 is less than 42 inches thick. However, for much of this region only scattered information is available from coal test drilling. In the central Illinois area where reserves have been mapped, the estimate is based mainly on interpretation of coal thickness from electric logs of oil test holes, following the procedures described by Hopkins (1968[37]).

Electric logs also have been used to interpret coal thickness and to estimate reserves in large parts of Marion County and northwestern Jefferson County. Other counties in this region were not mapped for the present study because no information is available from coal test holes. There are, however, numerous oil well logs from which a systematic study could be made of the coal reserves, as Allgaier and Hopkins (1975[24]) did for the Herrin Coal in southeastern Illinois.

Northern and Western Illinois

The Harrisburg-Springfield Coal averages 4 to 5 feet or more thick in a large area that extends from the Decatur-Springfield region northward and westward to the Peoria-Canton region. This area of relatively thick coal probably was once much more extensive, but in large areas between the Sangamon Valley north of Springfield and the Illinois Valley near Peoria (pl. 2) the coal has been eroded.

The Harrisburg-Springfield Coal was formerly mined at numerous places in western Illinois, in spite of which the remaining reserves are very large. In fact, more coal remains than has been mined. Within this region the reserves (pl. 2) are potentially great enough to support several facilities for coal conversion.

Eastern Illinois

In Edgar, Clark, Crawford, and Lawrence Counties, the reserves (pl. 2) border areas in Indiana where the coal is not as deep and therefore has been more extensively mined. Information regarding the Illinois coal has been obtained from general knowledge of Indiana mines and from limited mining and exploratory drilling in Illinois. For the remaining areas of eastern Illinois, however, reserves of the Harrisburg-Springfield seam have not been mapped because of a paucity of information.

GEOLOGICAL FACTORS AFFECTING MINABILITY OF THE COALS

A total area of 1,258 square miles has been mined to date for the Herrin and Harrisburg-Springfield Coals, 7.1 percent of the area of original reserves mapped in this study (table 5). Substantial information on mining conditions that has been garnered from past mining provides the best guide to the mining conditions that are likely to be encountered in the future.

For more than 60 years the Geological Survey has been engaged in studying the coals and their associated roof and floor strata as mining and exploratory drilling in Illinois has progressed. Much has been learned from these investigations about geological features that affect the minability of the coal seams, and the Geological Survey has published regional reports covering much of the Illinois coal field area that show structure contours on the coal, location of faults, major sandstone channels, and other geological features that are important to the planning of mines.

The Illinois Geological Survey is currently engaged in a study, partially funded by the U.S. Bureau of Mines, of the geologic characteristics of the roof of the Herrin Coal in the major areas of underground mining. The investigation is concerned with determining how the geology of the strata above the coal might be related to roof failures. Structural features and the stratigraphy of selected areas of the roof in representative mines are being mapped in detail, and regional maps showing the characteristics of the strata several feet above the coal are being prepared. The results of the study should be valuable for the planning of future mines.

Areas Depleted by Past Mining

Much of the mining in Illinois in the past was concentrated in the areas of thickest coal near the outcrop, along major railroad lines, or in the areas in which the coal is relatively low in sulfur (figs. 12 and 13). The location of all mined-out coal areas in Illinois and all mines operating on January 1, 1975, are shown on a map newly issued by the Geological Survey (Hopkins, 1975[38]). More detailed information on mined-out areas is shown on maps available from the Illinois Geological Survey (fig. 18).

The Geological Survey has for many years maintained files of geological information regarding individual mines. Observations of mining conditions relating to geology have been collected by Survey geologists and are available for public inspection. Some of the observations of mining conditions were made in the early part of this century when many more individual mines operated in Illinois than at present, and they contain information valuable for the planning of new mines.

Areas Closely Drilled for Oil or Gas

Oil and gas fields in which holes are closely spaced were excluded from the estimates of coal resources in this study. In much of southeastern Illinois a substantial portion of the original in-place coal resources lie above oil pools and are not at present considered recoverable. In these places oil wells producing from depths of less than 4,000 feet are

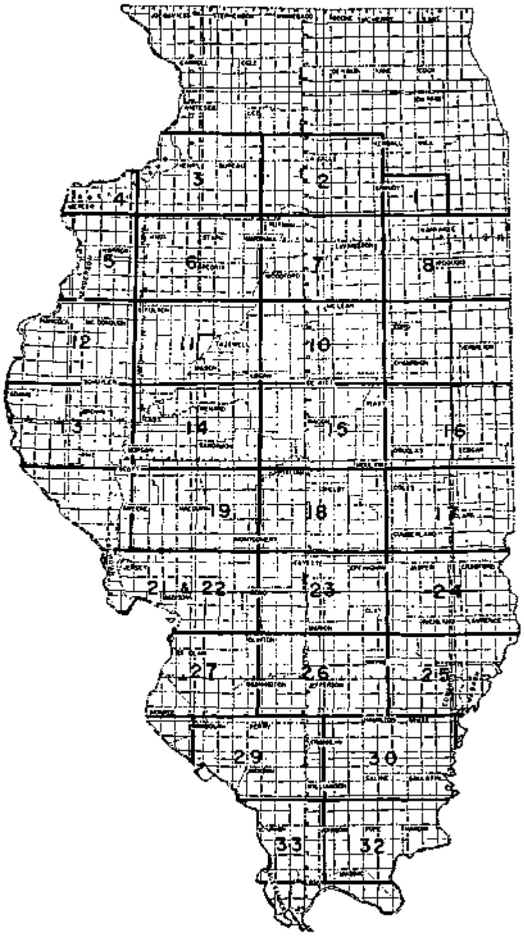


Figure 18. Index to maps of areas where coal has been mined out. Maps are available from the Illinois State Geological Survey, Urbana.

normally spaced to allow 10 acres per well (660 feet apart) where production is from sandstone and 20 acres per well where the production is from limestone. For wells producing from depths between 4,000 and 6,000 feet, the spacing is 40 acres per well. Since Federal mining law prohibits mining within an area 300 feet in diameter surrounding each well unless special precautions are taken, the coal in these areas cannot be effectively mined unless the wells are adequately plugged and permission to mine obtained from the authorities. New methods of plugging abandoned wells are being developed (Rennick et al., 1972[71]) that would permit mining without leaving the large barrier pillar around each well.

Approximately 100,000 test holes have been drilled for oil or gas within the coal-bearing areas of Illinois, many of which will affect the recoverability of the state's coal reserves. Fortunately, most oil test holes in Illinois are quite adequately recorded, and maps that show the number and distribution of wells are available for mine planners to consult. Figure 19 is the index to a series of maps (scale, 2 inches equal 1 mile) available from the Illinois Geological Survey that show the location of holes drilled for oil or gas, as well as many other kinds of test holes. Logs and other pertinent records, including information on well plugging, for essentially all of these test holes also are available for examination at the Geological Survey.

Areas Affected by Sandstone Channels and Split Coal

The presence of sandstone channels, described earlier, will influence the siting of new mines in some areas because where the channels have cut out the coal the lateral extent of the mines may be limited. Poor mine roof conditions and, in some instances, shale or sandstone partings in the coal seam occur in areas near the channels. Channel sandstone deposits in the roof strata must also be considered, even when they are at some distance above the coal, because, in addition to their direct effect on the stability of the roof strata, they may contain large amounts of water that can adversely affect roof shales. The water may also enter the mine and interfere with mining operations.

Future exploration for coal and actual mining activities undoubtedly will disclose additional channels. However, the major channels and their trends, especially those in the Herrin Coal, are now believed to be fairly well known, except in areas of east-central Illinois where there are obvious gaps in the mapped continuity of the channels (pls. 1 and 2). Sandstone was reported by Potter and Simon (1961[70], pl. 1) in many mines, either in the roof or partially or totally replacing the Herrin Coal in west-central Illinois.

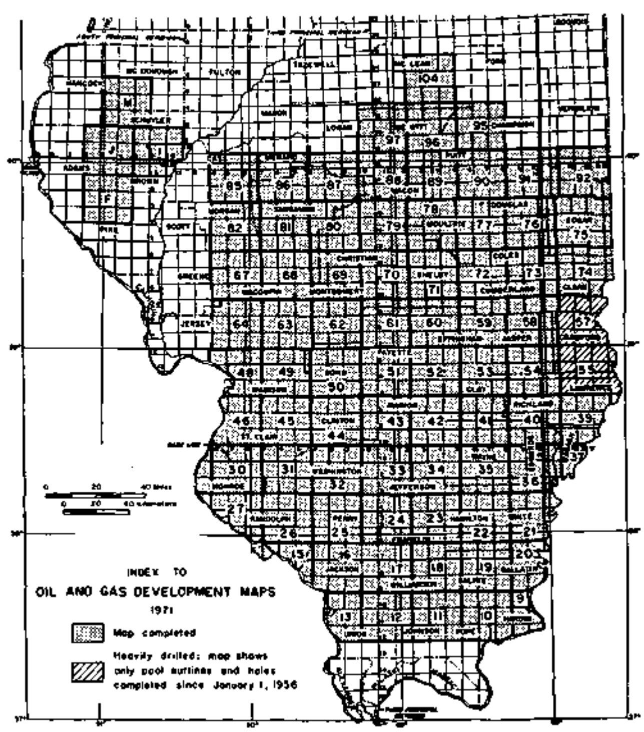


Figure 19. Index to the maps, available from the Illinois Geological Survey, that show location of oil and gas wells.

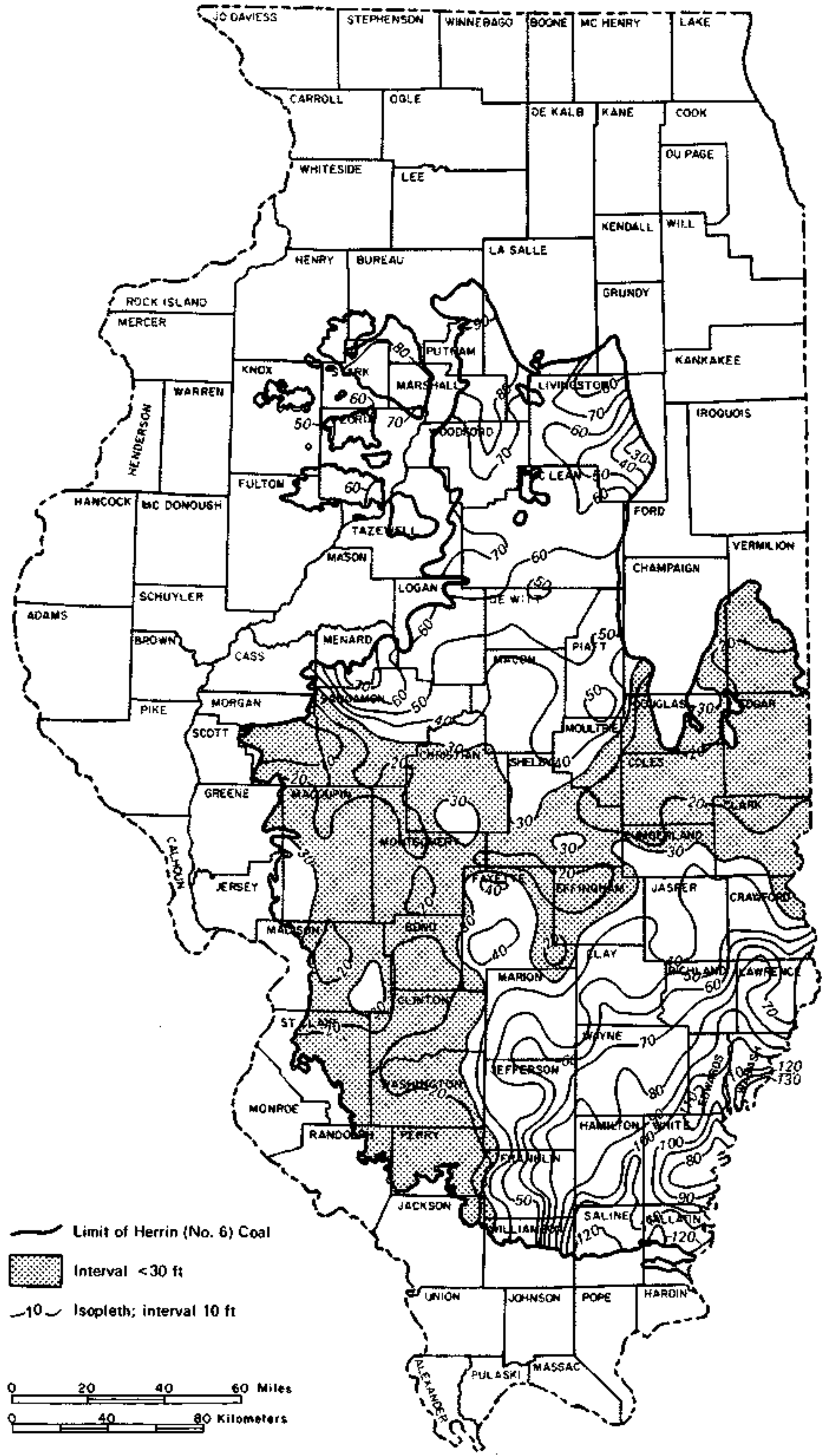


Figure 20. Generalized thickness of the interval between the Herrin and Harrisburg-Springfield Coals.

Roof and Floor Conditions

Some mine roof problems occur in all mines and many appear to be related to variations in the lithologic sequence and changes in structural properties of the roof strata into which the roof bolts are set. In spite of many local exceptions, the strata composing the roof and floor of the Herrin and Harrisburg-Springfield Coals can be described in general because of the widespread uniformity of many of the lithologic units.

Both seams are characteristically overlain by black shale, generally less than 3 feet thick, which is in turn overlain by widespread marine limestone members. Although somewhat similar in lithology, the limestone members differ characteristically in physical appearance and in fossil content. In certain areas, however, the marine limestone (especially above the Herrin Coal) is somewhat lenticular, a condition that causes roof problems where the limestone is very thin or absent. In many of the regions where the seams have been or are now being mined, the sequence of strata forming the roof is relatively uniform and provides average-to-good roof conditions.

The floor of most mines operating in the two coals commonly consists of gray claystone that causes few problems, except when it becomes wet during mining. In a few places, however, a local change in the moisture content or mineralogy of the strata below the coal may increase the tendency of the clay to "squeeze" from beneath coal pillars. When that happens, the argillaceous materials flow plastically into the floor strata of the mined-out rooms and entries, causing the floors to heave and impede mining (White, 1956[77]; report in preparation[78]).

The Illinois Geological Survey is investigating ways in which areas of unstable underclay can be identified during exploratory drilling. Mines could then be designed to cope with or avoid the problems caused by the underclays.

Interval between Herrin and Harrisburg-Springfield Coals

A map showing the thickness of the interval between the Herrin and Harrisburg-Springfield Coals (fig. 20) was prepared by using the computerized geological mapping program described in Appendix 2. The interval between the two coals ranges from 10 feet or less to more than 130 feet. Where they are less than 30 feet apart, as indicated by the stippled area on figure 20, only one of the two seams, commonly the Herrin, is likely to be more than 42 inches thick. Even in areas where both seams are thick enough for mining and are less than 30 feet apart, it is questionable whether both seams can be mined underground. However, both seams may be strip mined, and strip mines are now operating in both coals in several mines in southwestern Illinois.

In southern and southeastern Illinois where the interval separating the Herrin from the Harrisburg-Springfield Coal is greater than in the southwest, each coal exceeds 4 feet thick in many localities and they could both be mined if it proved economically feasible. However, up to the present, no underground mining of both seams has been undertaken.

Clastic Dikes and White-Top

In both the Herrin and Harrisburg-Springfield Coals, irregular claystone-filled cracks called clastic dikes have been encountered in mines (Damberger, 1970[64]). They vary in width from a few inches to a few feet and may extend vertically throughout the thickness of the coal. Many extend into the roof strata but not into the floor. The dikes have been observed in the Harrisburg-Springfield Coal, principally in the Springfield and Peoria regions, in both strip and underground mines. In the Herrin Coal they are particularly plentiful in the northwestern portion of the Illinois coal field and less numerous in west-central Illinois. When encountered in underground mines, dikes often cause problems with roof stability. In strip mines they cause only minor problems. They contribute to the ash content of the coal as mined.

In northwestern Illinois the Herrin Coal is also disturbed by white-top—in which the top layers of coal are replaced and infiltrated by light gray, often silty claystone. White-top is always associated with clastic dikes. Herrin (No. 6) Coal affected by white-top is widely mined in strip mines of northwestern Illinois, but the resultant undulating surface of the coal seam and the presence in varying thicknesses of the claystone layer and associated clastic dikes in the coal seam are hard on the equipment. It is also difficult to separate the finely dispersed clay from the coal in preparation plants.

The intensity of occurrence of clastic dikes and white-top in the two coals and their distribution in the state are shown in figure 21.

CONCLUSIONS

Reserves of approximately 97 billion tons of coal 42 or more inches thick remain in the two most productive coal seams of Illinois, the Herrin (No. 6) and the Harrisburg-Springfield (No. 5) Coal Members. This estimate does not include the coal from these two seams that cannot be mined by present methods under existing laws because it overlies oil pools. Also excluded from the estimate are areas where the coal has been mined out or is missing because geologic features such as sandstone-filled channels have disrupted the coal. Areas in which the coal is thin or for which there is a dearth of information were not included, nor were areas

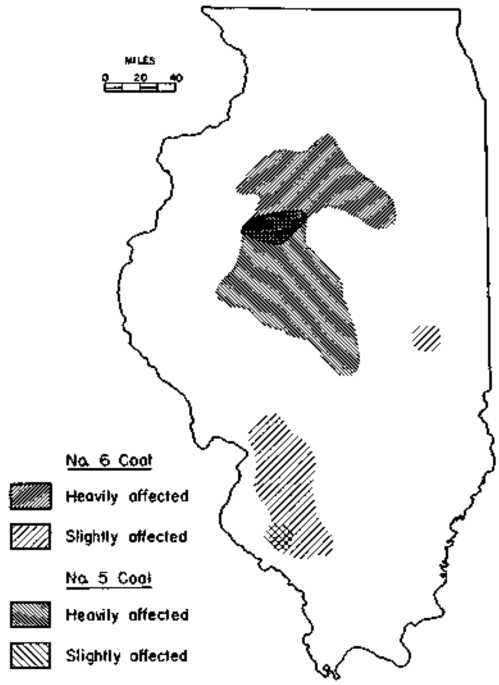


Figure 21. Areas in Illinois affected by claystone dikes and white-top (from Damberger, 1970).

adjacent to the channels where the coal is known to be split by partings of shale or sandstone.

As the large-scale underground mines needed to supply a coal conversion industry will be developed in the thicker coals, 42 inches was the minimum thickness selected for reserves estimates. Only the Herrin and Harrisburg-Springfield Coals were mapped for the study because they are the most extensive and thickest of the Illinois coals, but additional reserves are available in thinner and less extensive coal seams of the state. However, the reserves mapped in the Herrin and Harrisburg-Springfield Coals are clearly sufficient to supply coal for numerous conversion plants that will be located in Illinois.

The data base of coal and water resources in Illinois that has been compiled for this report can now be further interpreted and integrated with other data by systems analysis. Many of the variables that must be considered before selection of sites for coal conversion plants, or for other facilities that require large quantities of coal and water, can thus be comprehensively evaluated to determine the best possible locations for such installations.

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Part 2. Water Resources

John B. Stall

INTRODUCTION

Illinois has abundant water resources. Annual rainfall ranges from 32 inches in northern Illinois to 46 inches in southern Illinois. Annual runoff to streams ranges from 8 inches in the northern part of the state to 15 inches in the southern part. In addition to the water within the state, Illinois is almost surrounded by water—the Mississippi River on the west, the Ohio and Wabash Rivers on the south and east, and Lake Michigan on the northeast.

Illinois also has a large supply of ground water. Most municipal water supplies in Illinois are obtained from ground-water reservoirs. Water-bearing formations with high yields include limestone and sandstone strata in the bedrock and glacial deposits of sand and gravel.

Illinois water resources are as large today as they were when the area was a wilderness. As far as modern science can determine, they will continue to be undiminished, for they are constantly renewed by a great inflow of atmospheric moisture, or water vapor, that passes over Illinois at an average rate of 2,000 billion gallons per day. Rainfall from this moisture averages 99 billion gallons per day (bgd). The total annual runoff to streams in Illinois is 23 bgd. When the dependable flows of the Mississippi and Ohio Rivers are added, a total supply of 53 bgd is available. This is an immense amount of water—more than 3 times the amount now used in Illinois and a sixth of the water used for all purposes in the entire United States.

The quantities of water needed for coal conversion were considered in the main Introduction to this report (table 2). This section deals with locations in Illinois at which the water resource could be developed to produce 6 to 72 mgd. The sources of water considered are ground water, rivers, man-made reservoirs, and wastewater treatment plants. Each is considered separately, although more than one source may be tapped for a single coal conversion plant.

Acknowledgments

The compilation of results on water resources has been prepared in the Hydrology Section of the Water Survey. The work was under the general supervision of Dr. William C. Ackermann, Chief. The material on ground-water availability was developed by Richard J. Schicht, Thomas A. Prickett, and Adrian P. Visocky. Information on the water available from potential reservoirs was collected by Nani G. Bhowmik and Julius H. Dawes, with the help of Wyndham J. Roberts. The water supply available from major rivers was determined by Krishan P. Singh. Data on the cost of reservoir construction were compiled by Dr. Bhowmik. Illustrations for Part 2 were prepared by John W. Brother, Jr.

OCCURRENCE OF GROUND WATER IN ILLINOIS

Ground water in Illinois is affected in many ways by the geology of the state. Permeable rock formations such as sandstone, limestone, sand, and gravel serve as aquifers in which water is stored and ultimately supplied to wells. Impermeable beds, such as shale and clay, act as barriers to ground-water movement and maintain differences in pressure and water quality between aquifers. In some areas, creviced limestone or dolomite formations at land surface make the ground warer susceptible to pollution. The configuration and deformation of the bedrock commonly influence ground-water movement.

Ground water in Illinois is commonly drawn from unconsolidated deposits of sand and gravel in the glacial drift or in river valleys, or from bedrock formations of limestone or sandstone. Figure 22 shows the principal water-yielding rocks or aquifers of Illinois.

The most favorable ground-water conditions are found in the northern third of the state, where dependable sandstone and limestone aquifers occur in the bedrock and extensive sand and gravel aquifers are found in the glacial drift. In most of Illinois, the only aquifers of high potential yield are sand and gravel deposits of the Mississippi, Illinois, Wabash, Ohio, Kaskaskia, Embarras, and buried Mahomet River Valleys.

Ground Water from Sand and Gravel Aquifers

Most unconsolidated, or sand and gravel, aquifers of Illinois were deposited by meltwater from glaciers. The sand and gravel were deposited mainly in valleys leading away from the melting ice or in outwash plains at the front of the ice.

The distribution of sand and gravel aquifers and their estimated yields to individual wells are shown in figure 23. General areas are indicated where conditions are especially favorable for drilling wells with large yields. However, test drilling is required to locate satisfactory well sites, because conditions vary from place to place.

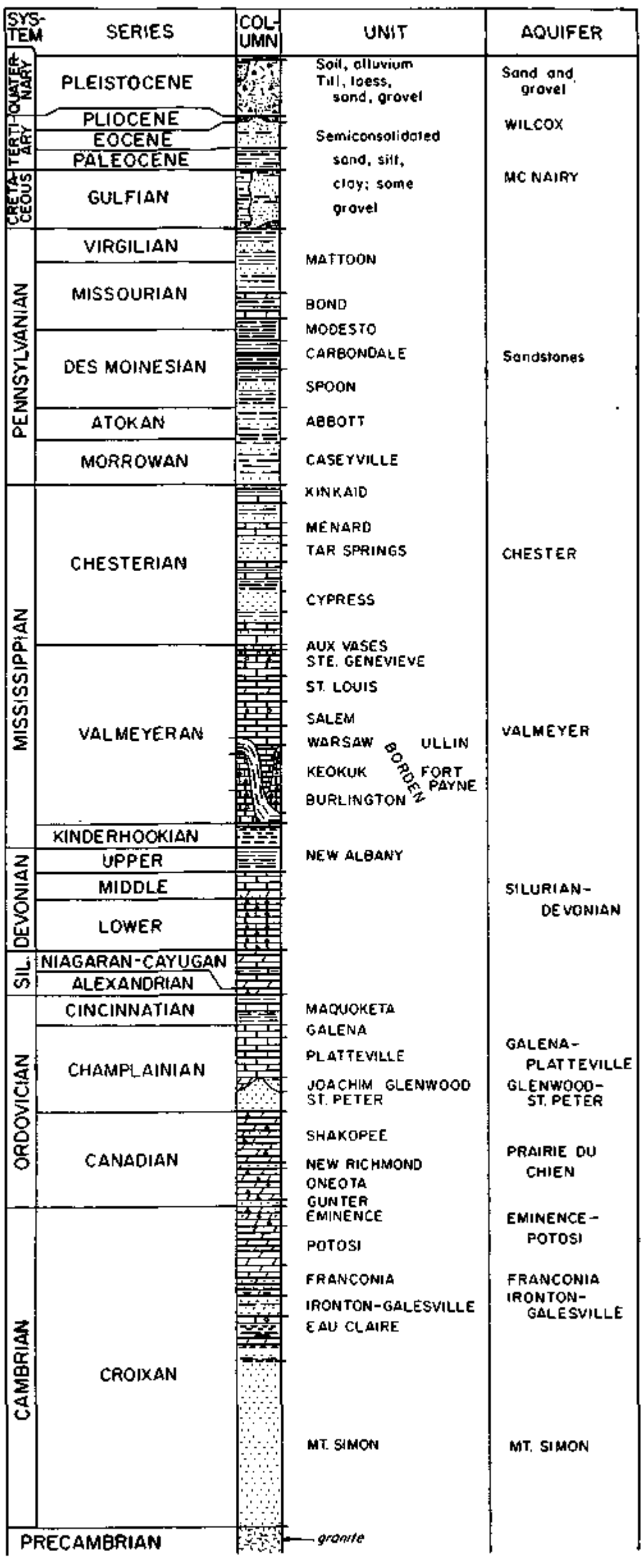

Figure 22. Geologic column of Illinois. The position of the major aquifers is indicated.

Most of the areas in which conditions are favorable for drilling sand and gravel wells that will yield more than 500 gpm contain water-yielding sand and gravel lying within major valley systems. These systems include the Mississippi, Illinois, Ohio, and Wabash River Valleys, the buried Mahomet Valley in east-central Illinois, and several buried and surface valley systems in the northern third of the state. Large quantities of water are available from relatively shallow wells, many drilled to depths of less than 300 feet.

Ground Water from Bedrock Aquifers

In the northern third of the state, large quantities of ground water for industrial and municipal use come from wells in the deep sandstone aquifers of Cambrian and Ordovician ages and from the shallow dolomite aquifers of Silurian and Ordovician ages (fig. 24). The Ironton-Galesville Sandstone is the main bedrock aquifer because of its consistently high yield. Part of the yield of many high-capacity, deep sandstone wells comes from the Glenwood-St. Peter and Mt. Simon Sandstones. Many deep sandstone wells have yields exceeding 700 gpm and have been prolific sources of water for nearly 100 years. Deep sandstone wells average about 1,300 feet deep, and many recent wells are 16 to 20 inches in diameter. Some deep wells in the northern part of the state are open to and draw water from several different aquifers, including the Galena-Platteville Dolomite, Glenwood-St. Peter Sandstone, Ironton-Galesville Sandstone, and Mt. Simon Sandstone. These water-yielding formations are sometimes grouped as the Cambrian-Ordovician aquifer.

Shallow dolomite aquifers of Silurian age and the Galena-Platteville Dolomite of Ordovician age are the main sources of ground water for many moderate-to-large public and industrial supplies in the northern third of Illinois. The average depth of shallow dolomite wells is about 140 feet, and most wells of recent design are 12 to 16 inches in diameter.

In the southern two-thirds of Illinois, thin sandstone and limestone beds of Pennsylvanian age and sandstone and limestone formations of Mississippian age yield small quantities of ground water. Although wells in these rocks commonly yield less than 25 gpm, they are the only source of water for several thousand farms and homes, several hundred small municipalities, and numerous industries. Deeper rocks in this area contain water that is too highly mineralized for most purposes. The Pennsylvanian and Mississippian rocks are also an important source of water for water-flooding operations in oil fields. The average depth of wells in Pennsylvanian rocks is 170 feet and the average in Mississippian rocks is 250 feet. Many wells are 6 to 12 inches in diameter.

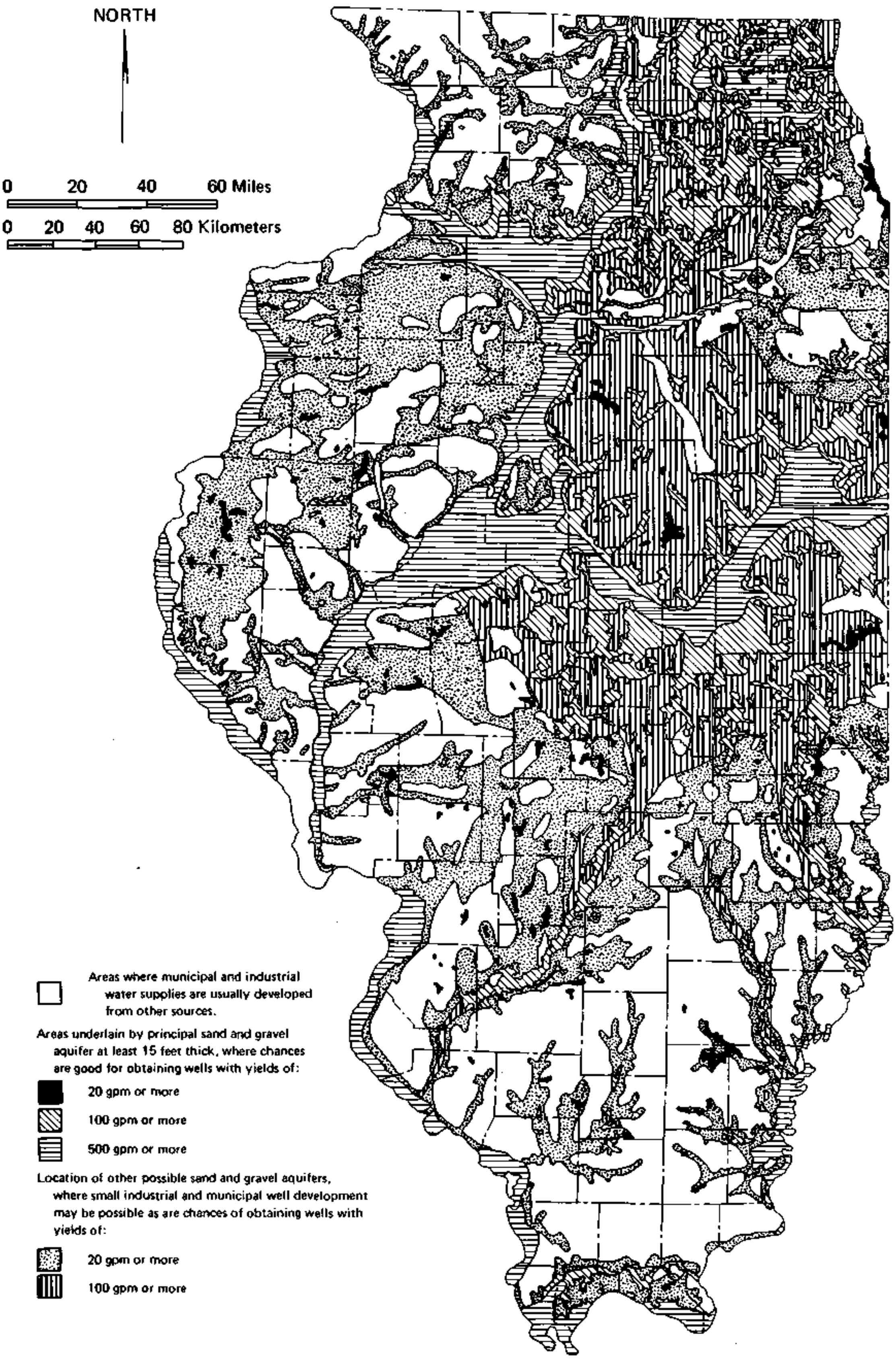

Figure 23. Yields of sand and gravel aquifers.

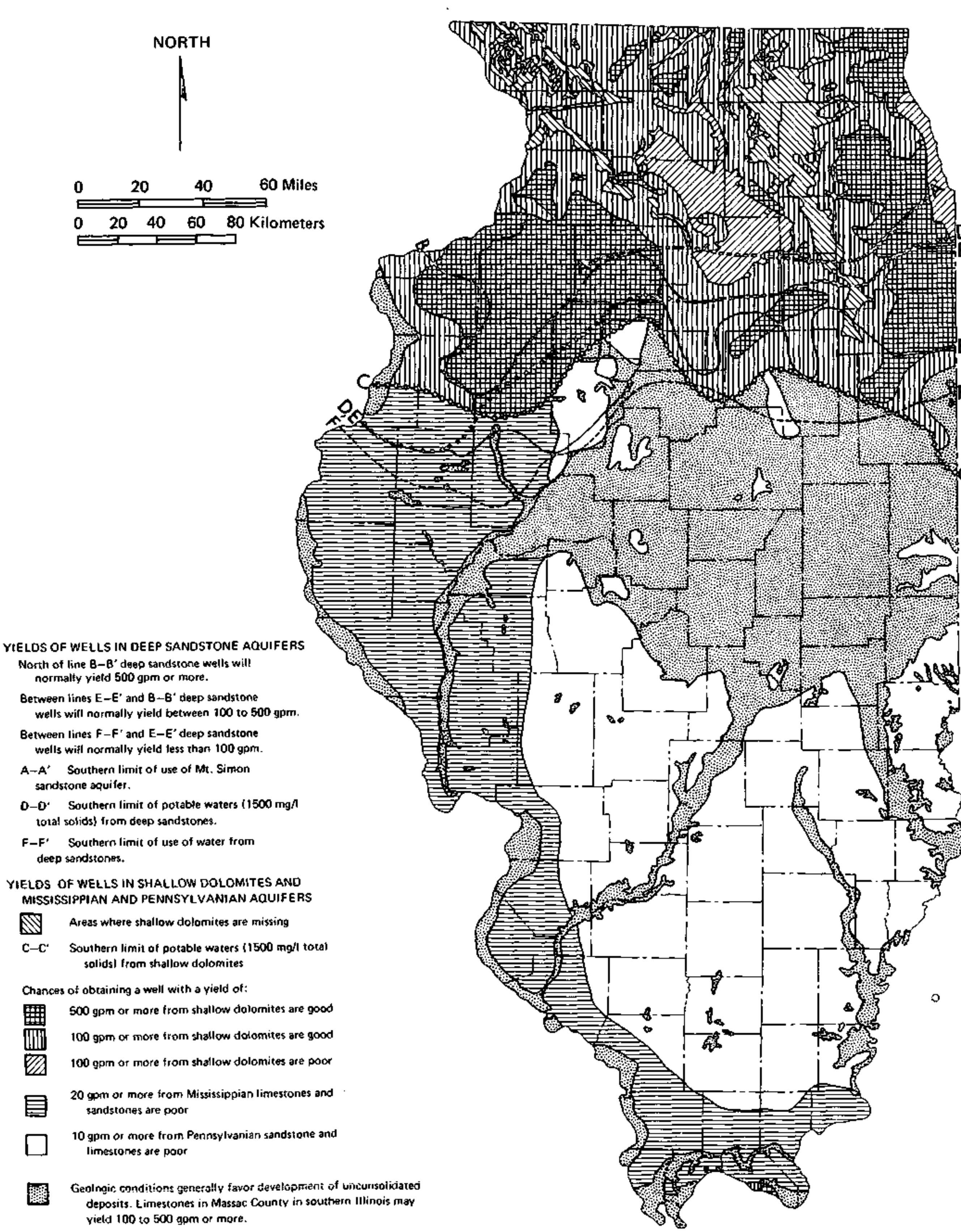

Figure 24. Yields of bedrock aquifers.

AVAILABILITY OF GROUND WATER FOR COAL CONVERSION

The quantity of water needed for coal conversion plants was estimated in table 2 as being between 6 and 72 mgd. In terms of ground-water development, that is a vast supply. Therefore, only locations where ground-water conditions are especially favorable can be considered as possible sites. In Illinois favorable conditions exist in areas where yields of wells are high (in excess of 500 gpm), where the aquifers are extensive and highly permeable, and where either the natural rate of recharge is high or water can be induced (by pumping of near-by wells) to flow from the streams into the ground-water reservoir, a process called induced infiltration.

Selected Areas for Ground-Water Development

Sand and gravel aquifers that meet the desired conditions are found in the major bedrock valleys of Illinois or their buried counterparts. Such deposits are shown in figure 23 as areas in which chances of obtaining wells with yields of 500 gpm or more are good.

Bedrock aquifers are most likely to be present in deep sandstones and shallow dolomites in the northern third of the state. Figure 24 shows the areas wherein individual bedrock well yields are estimated to be more than 500 gpm.

Conditions are not considered favorable for extensive ground-water development in areas where estimated well yields are less than 500 gpm. Available geohydrologic data from such areas strongly suggest that an unreasonably large number of wells and well fields, placed with unusually large spacings, would be necessary to produce the large supplies of water needed for coal conversion plants.

Some of the potential areas for extensive development of ground water are already supporting concentrated pumping centers that would be in direct competition with new pumpage from coal conversion plants. For this reason northeastern Illinois and the Peoria-Pekin area are excluded from consideration, and in the East St. Louis area only ground water available in excess of present pumpage is considered.

In figure 25, 17 areas of Illinois are shown where water well systems can be developed that are capable of yielding an estimated 14 to 72 mgd. In each region a system of wells could be drilled, connected, and pumped together to provide the water supply needed. A digital computer model or mathematical model, based on available hydrologic and geologic data, was constructed for each of the areas. The model was used to determine the spacing of wells so that safe pumping levels could be maintained in a continuous pumping situation. Table 9 identifies the 17 areas by county, by the supply available in mgd, and by the source of the ground water.

Hydrogeologic Data

Table 10 gives the locations of the 17 selected areas noted in table 9 and the major hydrogeologic properties of each area. The properties summarized in the table are relevant to the availability of ground water. In general, the higher the rate, permeability, and thickness, the more favorable the conditions for pumping large quantities of ground water. The river infiltration rates are a measure of the quantities of water that can be drawn from the river into the aquifer by pumping wells to supplement natural recharge and thus sustain the well field. The estimated river infiltration rates in table 10 are based on a correlation study of known rates from hydrogeologically similar areas. The infiltration rates are expressed in gallons per day per acre of riverbed per foot of head difference between head in the river and that in the aquifer (gpd/acre/ft). The permeability of the aquifer expressed in gallons per day per square foot of aquifer (gpd/sq ft) is one measure of the rate of flow that the aquifer might transmit to a well. The permeability values are based on averages computed from pumping tests already made in each of the areas under study.

TABLE 9-WATER SUPPLIES AVAILABLE FROM GROUND WATER

(Locations are shown in figure 25)

Area no. on fig. 25	County	Amount (mgd)	Source
1	Carroll	14	Gravel near Mississippi River
2	Henderson and Mercer	14	Gravel near Mississippi River
3	Hancock	72	Gravel near Mississippi River
4	Pike	72	Gravel near Mississippi River
5	Monroe and Randolph	72	Gravel near Mississippi River
6	Jackson and Union	72	Gravel near Mississippi River
7	Alexander and Pulaski	72	Gravel near Mississippi River
8	Massac	28	Gravel near Ohio River
9	Gallatin and White	72	Gravel near Wabash River
10	Lawrence	28	Gravel near Wabash River
11	Greene, Jersey, and Scott	72	Gravel near Illinois River
12	Mason	72	Gravel near Illinois River in Havana Lowlands (Walker et al., 1965)
13	Bureau	72	Shallow glacial gravel
14	Ogle	72	Deep sandstone in the bedrock
15	De Witt and Piatt	72	Buried Mahomet Valley (Visocky and Schicht, 1969)
16	Ford	72	Buried Mahomet Valley (Visocky and Schicht, 1969)
17	Madison	28	East St. Louis area (Schicht, 1965)

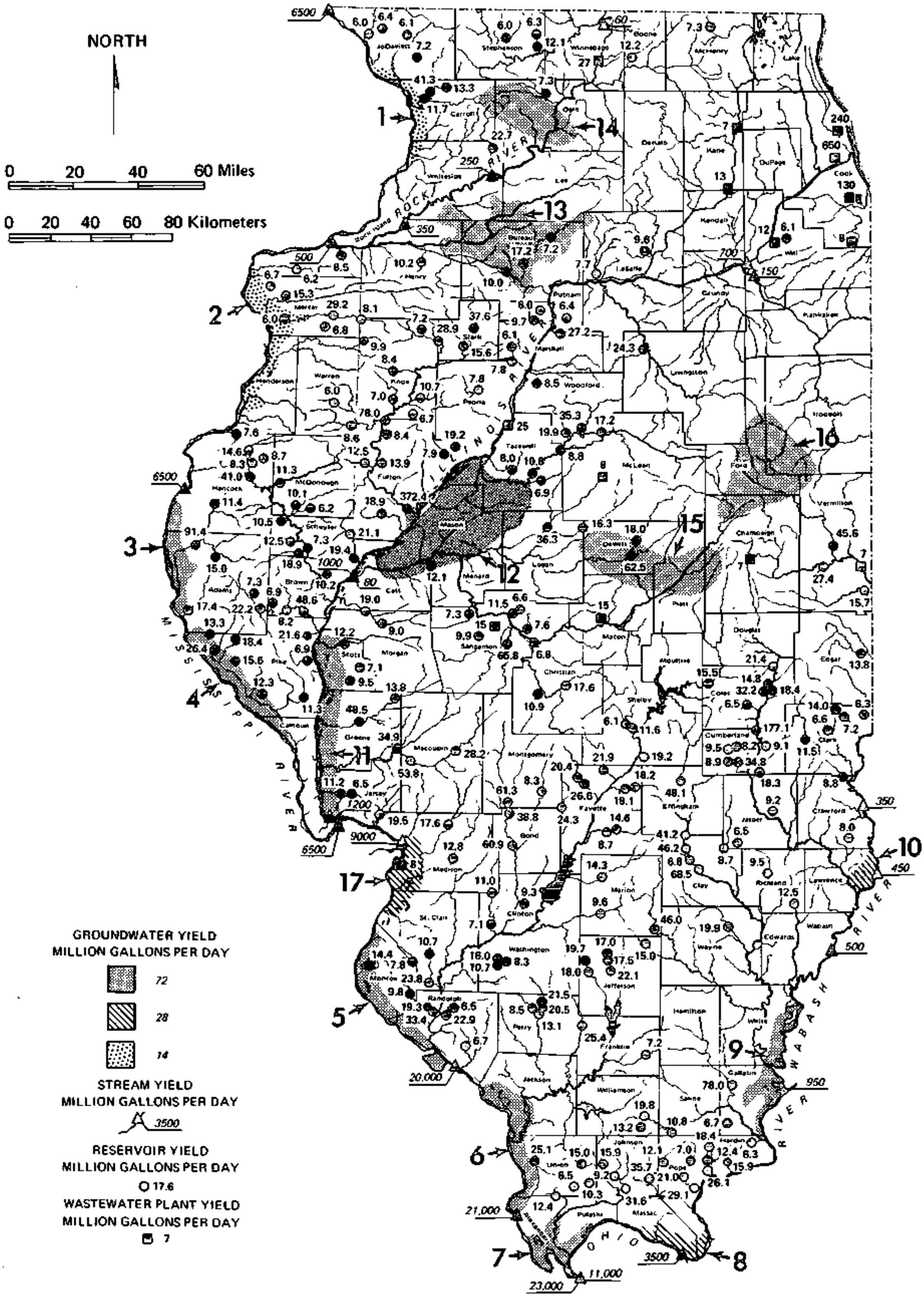

Figure 25. Water available for coal conversion.

TABLE 10-HYDROGEOLOGIC PROPERTIES OF SELECTED GROUND-WATER DEVELOPMENT SITES

Area no. on fig. 25	Location	Estimated river infiltration rate (gpd/acre/ft)	Estimated aquifer permeability (gpd/ft^2)	Estimated average aquifer thickness (ft)	General ground-water conditions
1	Along Mississippi River in Carroll County	450	2,700	100	Water table with induced infiltration from river
2	Along Mississippi River in Henderson County	450	3,500	100	Water table with induced infiltration from river
3	Along Mississippi River north of Quincy in Hancock County	22,500	3,500	100	Water table with induced infiltration from river
4	Along Mississippi River south of Quincy in Pike County	22,500	2,500	100	Water table with induced infiltration from river
5	Along Mississippi River between Valmeyer and Kaskaskia Island	45,000	2,000	90	Water table with induced infiltration from river
6	Along Mississippi River south of Grand Tower Island	45,000	1,800	110	Water table with induced infiltration from river
7	Along Mississippi River in southern Alexander County	45,000	2,000	125	Water table with induced infiltration from river
8	Along Ohio River in Massac County	45,000	2,500	70	Water table with induced infiltration from river
9	Along Wabash River in Gallatin County	22,500	2,000	95	Water table with induced infiltration from river
10	Along Wabash River in Lawrence County	22,500	3,000	85	Water table with induced infiltration from river
11	Along Illinois River centered in Greene County	22,500	2,000	110	Water table with induced infiltration from river
12	Havana Lowlands, centered in Mason County	22,500	(2 values) 2,000 in east 5,000 in west	150	
13	Princeton Valley in Bureau and Whiteside Counties	none	2,000	150	Water table
14	Deep sandstone area centered in Ogle County	none	23	800	
15	Along Buried Mahomet Valley in De Witt and Piatt Counties	none	2,120	120	Leaky artesian
16	Along Buried Mahomet Valley in Ford and Iroquois Counties	none	2,500	150	Leaky artesian
17	East St. Louis area	45,000	2,500	80	Water table with induced infiltration from river

All aquifers, with the exception of those in areas 12 and 17, were assumed to be of a uniform thickness that was based upon the difference between known static water levels in the aquifers and estimated elevations of bedrock at the base of the aquifers. Areas 12 and 17, the Havana Lowlands and the East St. Louis area, were modeled in some detail because data on aquifer thickness were available from previously published reports (Walker, Bergstrom, and Walton, 1965; Bergstrom and Walker, 1956; Schicht, 1965).

In the selected areas general conditions under which ground water occurs are of three types. First, *water table* conditions exist where an aquifer is unconfined at the top and pumped water is derived from gravity drainage of the interstices in the portion of the aquifer being dewatered. Gravity drainage of the interstices decreases the saturated thickness of the aquifer. Under these conditions, water levels in wells become critical after more than half the initial saturated thickness of the aquifer is dewatered.

Second, *leaky artesian* conditions exist where aquifers are overlain by confining beds that impede the vertical flow of the ground water that is recharging the aquifer being pumped. Under these circumstances, critical water levels in wells occur when water levels fall below the bottom of the confining layer. When that happens, the rate of flow through the confining layer reaches a limit as maximum hydraulic gradients are created.

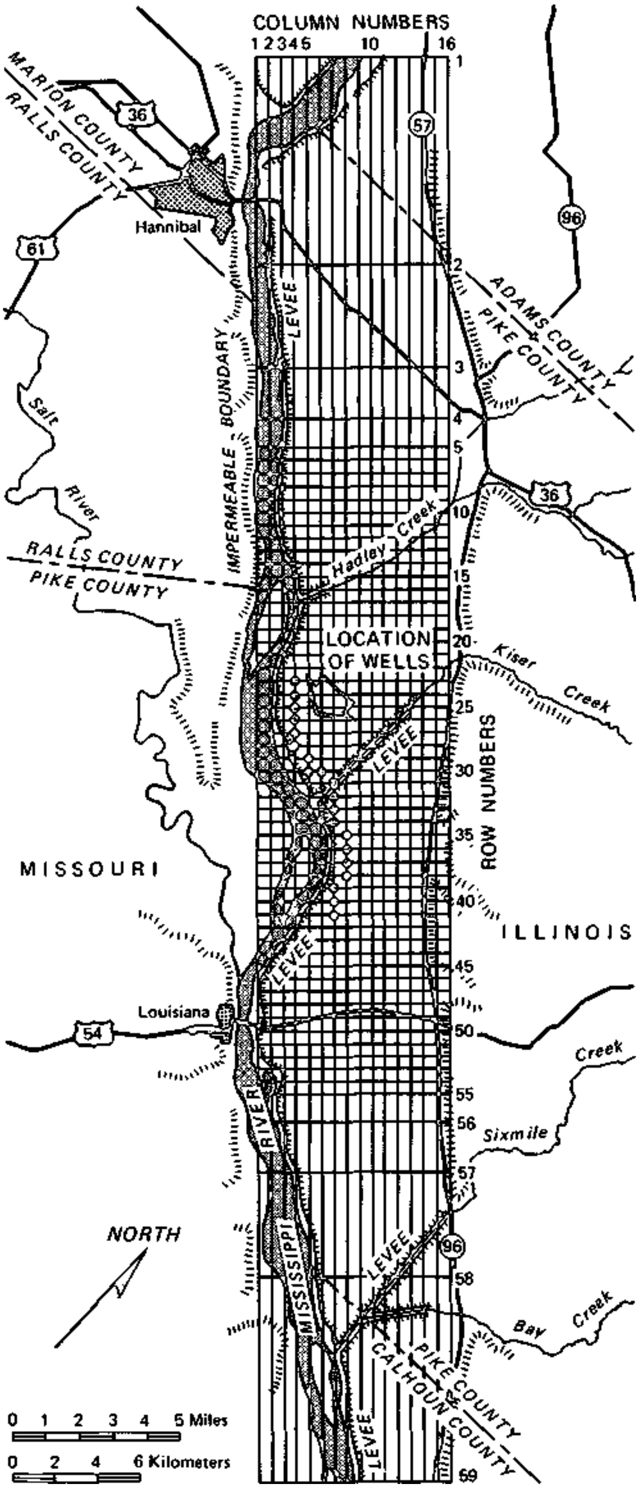

Figure 26. Computer model of discrete elements of aquifer, used for location of wells.

Third, *induced infiltration* conditions exist when wells are pumped in aquifers near, or in hydraulic connection with, streams, rivers, or other surface water bodies. In the course of pumping, water levels in the aquifer may be lowered below surface water levels and the aquifer is recharged by seepage from the surface water body. Induced infiltration conditions can occur in combination with either water table or leaky artesian conditions. However, induced infiltration coexisting with water table conditions is the only combination found in the selected areas. The critical water level in wells for this combination is the same as that for water table conditions.

Digital Computer Models

Digital computer models were developed for studying areas 1 through 13 and 17, and mathematical models were used for studying areas 14 through 16. The digital computer models are capable of simulating two-dimensional flow of ground water in aquifers under water table conditions. The models also can simulate pumpage from wells and the movement of water between surface waters and the groundwater reservoir, thus yielding data on changes in water levels. The equations governing the flow of ground water in models such as those described have been given by Prickett and Lonnquist (1971).

One of the 14 digital models is shown in figure 26. It illustrates the transmission network for a 20-well pumping scheme designed to furnish a 20,000-gpm water supply along the Mississippi River in Pike County, Illinois. The figure shows a grid (finite difference) superposed on a map of the sand and gravel aquifer that lies along the Mississippi River south of Quincy. The aquifer is thus subdivided into discrete elements associated with the numbered rows and columns of the finite difference grid. The edges of the model approximate the sides of the valley that forms the boundary of the aquifer. Sufficient rows in the grid are included upstream and downstream from the area of analysis to prevent the projected water levels from being affected by their position at the edge of the model.

Figure 26 also shows locations of 20 hypothetical wells used to predict the effects of pumping 20,000 gpm of water. The location of the wells was based on (1) reasonably close spacing to avoid mutual interference, (2) present flood control levees (all wells were placed on the land side of the levees), and (3) placement of all wells as close as possible to a river to get maximum induced infiltration from that source of recharge. Most wells were spaced 1,000 to 2,000 feet apart.

The computer produced printed water-level elevations resulting from the various well-pumping schemes. Several computer runs were made for each area to find a suitable scheme for obtaining well yields of 4,000, 10,000, 20,000, and 50,000 gpm (6 to 72 mgd) without creating critically low water levels.

To assure a dependable water supply, the only source of recharge included in the model studies for areas 1 through

11 and 17 was induced infiltration from near-by perennial rivers. No allowance for natural recharge from precipitation as such was included in any of the model simulations.

For areas 12 and 13, which have no rivers near their well fields, the computer models were designed to simulate the effects of pumping where the only recharge is from precipitation. Estimates of recharge rates for a year of normal precipitation were based on known recharge rates in hydrogeologically similar areas. To assure that the water supply in areas 12 and 13 would be dependable, allowance was also made for taking water from storage within the aquifer for a sustained 5-year period of no recharge.

The models for areas 1, 2, 8, 10, and 17 showed that even with reasonable well spacings and the estimated infiltration rates it was not possible to produce 72 mgd of water. Areas 1 and 2 were capable of yielding only 14 mgd, while areas 8, 10, and 17 were capable of supplying 28 mgd. Areas 3 through 7, 9, and 11 through 13 were estimated to be capable of supporting a 72-mgd water demand.

Mathematical Models

Mathematical models were used to study the feasibility of obtaining the supplies of water needed for coal conversion plants in areas 14 through 16. Mathematical models were used for these areas because previous analyses by the Water Survey could be directly applied to the evaluation of these aquifers.

The mathematical models were of the types outlined by Walker and Walton (1961). Mathematical models involve creation of simplified geometric forms that approximate the configuration of the aquifer. The average hydrogeologic properties of the aquifer and of the confining layer, if any, were selected on the same basis as those for the digital models previously described.

The resulting model is called an idealized aquifer. Analysis is based on the hydrogeologic properties of the idealized aquifer, an analytical technique that simulates the effects of recharge and barrier boundaries on drawdown of water levels in the pumped aquifer (image-well theory), and on an appropriate theoretical ground-water equation.

The results of analyses of areas 14 through 16 made with the mathematical models indicate that these areas are capable of producing the maximum 72 mgd of water needed for a coal conversion plant.

Cost of Ground-Water Development

Analyses of cost for developing ground water in the favorable areas include estimates for wells, pumps, electrical power for pumping, pipelines to a central point, operation, and maintenance. Other possible costs, such as test drilling, tests to determine precise aquifer properties, and land procurement are not included.

Well Costs

Production wells were designed for a maximum development of 1,000 gpm per well (1,390 gpm at areas 15 and 16). Wells in sand and gravel aquifers use screens of 24-inch diameter and from 40 to 100 feet long, whereas those in the Cambrian-Ordovician aquifer of northwestern Illinois (area 14) were 12 inches in diameter. Depths of sand and gravel wells were estimated from elevations taken from topographic and bedrock surface maps, while depths for Cambrian-Ordovician wells were estimated at 1,000 feet (Walton and Csallany, 1962).

Gibb and Sanderson (1969) developed the following cost-to-depth formula for gravel-packed wells finished in sand and gravel and for wells in the Cambrian-Ordovician aquifer:

$$C_{wg} = 680 \quad d^{0.482} \tag{1}$$

and

$$C_{wco} = 0.029 \quad d^{1.87} \tag{2}$$

where

C_{wg} is the well construction cost for sand and gravel wells and C_{wco} the cost for Cambrian-Ordovician wells in 1966 dollars; d is well depth in feet. Equations (1) and (2) were adjusted to 1973 prices by applying Engineering News-Record Cost Indexes for 1966 and 1973 (Eng. News-Record, 1974). Well construction costs then become:

$$C_{wg} = 1288 \quad d^{0.482} \tag{3}$$

and

$$C_{wco} = 0.055 \quad d^{1.87} \tag{4}$$

Annual costs for wells were obtained by amortizing capital costs at 6 7/8 percent over an assumed 30-year service life. For this determination a capital recovery factor (CRF) of 0.07985 was used.

Pump Costs

It was assumed that submersible pumps capable of operating at rates of 1,000 gpm would be used. The average pumping lift for pumps within a production field was taken to be the average drawdown (as computed in the digital model), adjusted for dewatering, partial penetration, well loss, nonpumping water level, and a nominal 25-foot head loss to allow for pipeline friction and pressure. To provide stand-by wells, the number of wells (pumps) was increased by 20 percent.

Gibb and Sanderson (1969) determined capital costs for submersible turbine pumps in Illinois to be:

$$C_p = 5.629\, Q^{0.541}\, H^{0.658} \tag{5}$$

where
C_p is individual pump cost in 1970 dollars, Q is production rate in gpm, and H is average pumping lift (as computed above). When costs are adjusted for 1973 prices, individual pump costs become:

$$C_p = 10.66\, Q^{0.541}\, H^{0.658} \tag{6}$$

Annual costs for pumps were obtained by amortizing capital costs at 6 7/8 percent over an assumed 15-year service life (CRF = 0.1089).

Electrical Costs

Determinations of electrical cost for production wells were made on the basis of an assumed unit power charge of 1.0 cents per kilowatt hour (kwhr) and on the following expression for pumping energy (Ackermann, 1967):

$$kwhr = 1.88 \times 10^{-4}\, Qht/E \tag{7}$$

where
Q is flow in gpm, h is total pumping lift in feet, t is time in hours (assumed to be 1 year or 8760 hr), and E is wire-to-water efficiency (assumed to be 0.5). The annual power cost becomes:

$$C_e = 0.0329\, Qh \tag{8}$$

Transmission Costs

The construction cost of connecting the well field to the pipeline can be expressed by the equation (Ackermann, 1967):

$$C_t = 4450\, D^{1.2}\, L \tag{9}$$

where
C_t is capital cost in 1973 dollars, D is pipeline diameter in inches, and L is pipeline length in miles.

Annual operation, maintenance, and repair costs for pipelines were estimated by Singh, Visocky, and Lonnquist (1972) and, adjusted to 1973 prices, appear as:

$$C_{omrt} = 21\, DL \tag{10}$$

Easement costs for placement of pipelines along rights-of-way (Singh, Visocky, and Lonnquist, 1972), in 1973 dollars, are expressed as:

$$C_{rowt} = 3500\, L \tag{11}$$

The total annual transmission cost for collecting ground-water supplies is the sum of operation, maintenance, and repair (C_{omrt}) and amortized capital costs (C_t and C_{rowt}). Capital costs were amortized at 6 7/8 percent for a period of 30 years.

Pipe diameters (D) in equations (9) and (10) were selected according to the method used in studies of optimum diameters by Singh (1971).

Cost Summary

Annual and unit costs for water supplies yielding 4,000, 10,000, 20,000, and 50,000 gpm from sand and gravel wells were estimated in 16 areas along the Mississippi, Ohio, Illinois, and Wabash Rivers and in the Princeton and Mahomet bedrock valleys. Similar estimates were made for bedrock wells in area 14 in Ogle County. Unit costs are summarized in table 11. In areas 1, 2, 8, 10, and 17, water is available in limited supplies only, and in area 5. the 50,000-gpm supply requires two 25,000-gpm fields whose centers are 15.7 miles apart. Area 17 also needs two well fields.

TABLE 11-ESTIMATED COST OF GROUND-WATER SUPPLY AT SELECTED SITES

	Estimated cost of supply (0/1,000 gal)			
Area	**4,000 gpm**	**10,000 gpm**	**20,000 gpm**	**50,000 gpm**
1	1.17	1.38	N. A.*	N. A.
2	1.20	1.45	N. A.	N. A.
3	1.43	1.86	2.27	3.28
4	1.41	1.87	2.33	3.36
5	1.22	1.44	1.73	4.43†
6	1.46	1.85	2.21	3.28
7	1.12	1.27	1.57	1.73
8	1.00	1.21	1.47	N. A.
9	1.10	1.30	1.85	2.01
10	0.92	1.22	1.47	N. A.
11	1.08	1.28	1.49	1.68
12	1.24	1.61	2.05	2.76
13	1.55	2.00	2.55	2.98
14‡	3.58	5.31	6.49	8.46
15	1.56	1.87	2.32	1.92
16	1.69	1.99	2.40	2.16
17**	1.42	1.76	2.27	N. A.
Average (excluding site 14)	1.29	1.59	2.00	2.69

** Supply not available.*
† From two 25,000-gpm well fields 15.7 miles apart.
‡ Bedrock aquifer.
***From two 10,000-gpm well fields 10 miles apart.*

TABLE 12-AVERAGE AMOUNTS OF MINERAL CONSTITUENTS
IN GROUND WATER AT SELECTED SITES
(mg/l)

Area	Total dissolved solids	Hard-ness	Alka-linity	Fe	Mn	Cl	F	NO_3	SO_4	Temp, (°F)
1	233	172	116	1.1	0.2	0.9	0.3	26.4	28.9	53.2
2	261	223	179	0.8	0.3	6.9	0.2	9.4	29.1	55.3
3	338	301	294	5.3	1.5	7.1		5.8	7.4	
4	305	254	227	3.9	1.7	13.6	0.4	2.3	42.2	56.4
5	515	429	307	13.4	1.0	48	0.3	7.9	72	56.3
6	347	262	251	2.0	0.2	6.4	0.1	6.5	35.6	58.3
7	377	306	315	3.6	0.2	10.1	0.2	5.6	19.1	58.5
8	134	102	103	6.1	0.1	6.3	0.3	1.9	12.0	60
9	510	342	363	1.0	0.2	54.8	0.2	1.4	9.8	59.3
10	359	266	250	0.7	0.1	11.6	0.1	11.1	55.0	
11	428	380	285	0.1	Tr	15.6	0.1	11.8	43.2	56
12	322	285	236	1.6		6.4	0.1	10.0	42.2	55.4
13	360	263	332	3.3-	0.2	1.6	0.4	0.9	0.2	54.0
14	299	295	285	0.4	0.03	2.0	0.7	0.7	25.3	51.4
15	494	306	409	1.4	0.04	46.3	0.4	1.1	1.2	56.2
16	408	332	364	1.1	0.03	4.1	0.2	1.8	19.4	55
17	504	409	296	7.4	0.40	17.6	0.4	1.8	113.6	57.5

Excluding area 14, which has bedrock aquifers, unit costs in areas 1 to 17 (sand and gravel wells) ranged from 0.92 to 1.69 cents per 1,000 gallons for a 4,000-gpm supply and from 1.68 to 4.43 cents per 1,000 gallons for a 50,000-gpm supply. Unit costs generally increase with production rate, there being no economies of scale involved in the cost factors considered. It is assumed that no treatment will be given to the water. Average costs in areas 1 to 13 and 15 to 17 for supplies of 4,000, 10,000, 20,000, and 50,000 gpm were 1.29, 1.59, 2.00, and 2.69 cents per 1,000 gallons, respectively. Corresponding costs from the deep sandstone aquifer (area 14) were approximately three times as great, 3.58, 5.31, 6.49, and 8.46 cents per 1,000 gallons. While other unit costs in areas 1 to 13 and 15 to 17 remain relatively stable, average transmission costs rise from 31.5 percent of the total costs for 4,000-gpm supplies to 56.2 percent of the total for 50,000-gpm supplies. For Cambrian-Ordovician wells, such as that in area 14, electrical costs are the largest unit cost., They decrease as the gallons per minute rate increases from 61.2 to 44.3 percent of the total, but transmission costs increase from 16.7 to 43.9 percent of the total cost.

Ground-Water Quality

The chemical quality of water supplies at the 17 study areas can be estimated from mineral analyses of near-by existing ground-water supplies. Such analyses on file at the Illinois State Water Survey were averaged for each area to determine the average quality that might be expected there. The average values of chemical concentration and temperature are summarized in table 12.

The review revealed that water in most of the areas studied is of fairly good quality, with total dissolved solids averaging between 134 and 515 milligrams per liter (mg/l). It has moderate to high hardness, averaging between 102 and 429 mg/l. Iron also is present in considerable concentration, between 0.1 and 13.4 mg/l. Average water temperature ranges from 51.4 to 60 F, the cooler temperatures appearing in the northern areas and the warmer ones in southern areas.

Legal Aspects of Ground-Water Development

It is beyond the scope of this report to deal more than briefly with Illinois water law, but several excellent sources are available as described in *Water for Illinois, A Plan for Action* (Board of Economic Development, 1967). The Illinois Supreme Court has adopted the English common law rule for cases involving percolating ground water. In essence, the rule states that the owner of the land owns all the percolating water underlying his land.

AVAILABILITY OF SURFACE WATER FOR COAL CONVERSION

Not only is Illinois bordered by the Mississippi, the Ohio, and the Wabash Rivers and by Lake Michigan, but it is also internally drained by the Rock, the Illinois, the Sangamon, the Kaskaskia, the Big Muddy, the Embarras, and the Little Wabash Rivers, as well as many smaller streams. In addition, Illinois has 368 bodies of water of 40 acres or more.

Streamflow is continuously recorded along the streams of the state. These flow data are collected and published by the U. S. Geological Survey (1974), half the cost being provided by a state sponsor. The Illinois State Water Survey is the largest of the state sponsors of this program. In 1971 records were kept at 167 locations. Continuous streamflow records for the 25-year period 1950 through 1974 are available from about 100 gaging stations.

The average runoff to streams is about 9 inches a year in most of central Illinois and about 15 inches in southern Illinois. Runoff is a major water resource because it can be taken directly from a stream and used immediately or it can be stored in a reservoir and used as needed.

One important means of conserving water is to capture flood runoff and keep it in a reservoir for use in dry seasons. Reservoir lakes can also be used for recreation and other purposes. Illinois has several large reservoirs, and more are being planned or constructed; a large potential remains for the development of additional impoundments. Man-made lakes or reservoirs have been developed throughout the state for various purposes. Some of the larger existing lakes are listed in table 13.

Except for lakes in the valleys of the larger streams, natural lakes are confined to the northeastern portion of Illinois. They are the result of juvenile drainage following the last glacial period. Most of them are in the Chain O'Lakes region in Lake and McHenry Counties.

Bodies of water of 40 acres or more have a total surface area of 138,317 acres. The northern section of the state contains 117 such lakes, 47 of them in Lake County. Of the 128 bodies of water in the north-central section, 27 are in Mason County. The south-central section contains 72 lakes, 11 in Calhoun County and 11 in Macoupin County. Of the 51 lakes in the southern section, Franklin and Williamson Counties have 9 each. A small portion of the total water surface and storage area is made up of many ponds, lakes, and reservoirs of less than 40 acres.

Four potential sources of surface water were studied to locate possible water supplies for coal conversion—water flowing in rivers and streams, water impounded in existing reservoirs, surface water that could be impounded in reservoirs, and treated wastewater.

Legal Aspects of Surface Water and Lake Michigan

For streams within the state, the Illinois Supreme Court has subscribed to the doctrine of riparian rights with respect to the reasonable use of water in natural water courses.

The diversion of water from Lake Michigan by Illinois is limited to 3,200 cubic feet per second (cfs) by decree of the U. S. Supreme Court (Northeastern Illinois Planning Commission, 1974). At present this water is being used for water supply, chiefly by Chicago, and to augment flow in the Chicago Sanitary and Ship Canal and the Calumet-Sag Canal. This report does not evaluate the potential application of Lake Michigan water for coal conversion.

TABLE 13-LARGE MAN-MADE LAKES OF ILLINOIS

Purpose and name	Near-by city	Lake capacity (million gal)
Flood Control and Water Supply		
Carlyle Lake	Carlyle	92,204
Lake Shelbyville	Shelbyville	68,669
Rend Lake	Benton	60,167
Recreation and Wildlife		
Crab Orchard Lake	Carbondale	19,901
Little Grassy Lake	Carbondale	8,386
Devils Kitchen Lake	Carbondale	9,122
Power Plant Supply		
Impounded Lakes		
Lake of Egypt	Marion	13,863
Sangchris Lake	Springfield	11,403
Coffeen Lake	Coffeen	7,179
Side-Channel Lakes		
Lake Baldwin	Baldwin	7,982
Con-Ed Lake	La Salle	6,540
City Water Supply		
Lake Springfield	Springfield	18,434
Lake Decatur	Decatur	7,278
Lake Bloomington	Bloomington	2,628
Evergreen Lake	Bloomington	4,473
Lake Kinkaid	Murphysboro	25,738
Lake Vermilion	Danville	1,776
Lake Taylorville	Taylorville	3,183
Lake Sara	Effingham	4,496
Lake Lou Yaeger	Litchfield	1,430

Treated Wastewater

Treated wastewater, or sewage effluent of acceptable quality, is another possible source of water for coal conversion. All cities operating wastewater treatment plants are required by the Illinois Environmental Protection Agency to submit monthly operation reports. These reports show the amount of wastewater in gallons per day leaving the plant after treatment, any wastewater bypassed untreated during rains in places where the storm and sanitary sewer systems are combined, and quality parameters such as biologic oxygen demand (BOD) and concentration of suspended solids.

The state EPA field offices supplied information on effluent flow for the year 1970, as well as for a few earlier years. Study of this information indicated that 15 municipalities in the state have 7-day low-flow sewage effluents that are within the range of the defined water consumption

TABLE 14-MUNICIPAL PLANTS WITH 7-DAY LOW-FLOW EFFLUENT OF 6 MGD OR MORE IN 1970
(Locations in figure 25)

Town or plant	County	7-day low-flow effluent (mgd)
Rockford	Winnebago	27
Aurora	Kane	13
Elgin	Kane, Cook	7
Bloom Township	Cook	8
Joliet	Will	12
Northside	Cook	240
West Southwest	Cook	650
Calumet	Cook	130
Peoria	Peoria	25
Springfield	Sangamon	15
Decatur	Macon	15
Bloomington	McLean	8
East St. Louis	St. Clair	8
Danville	Vermilion	7
Urbana	Champaign	7

needs for coal conversion. The plants are listed in table 14 and their locations are shown on figure 25.

Water from Rivers

Available flow records for the principal rivers in and bounding Illinois were used to estimate the minimum daily flow that could be expected during a 50-year period (fig. 25). These quantities of water are considered as being available for use by coal conversion plants.

The Mississippi River on the western edge of Illinois was estimated to have a minimum flow of 6,500 mgd, an amount almost 100 times greater than the maximum amount of water (72 mgd) assumed to be needed by one coal conversion plant. Along the southwestern part of Illinois, minimum flows in the Mississippi River rise to between 20,000 and 23,000 mgd. Along the Ohio River, in southern Illinois, the range of flow is from 3,500 mgd to 11,000 mgd. The Wabash River bounding southeastern Illinois has a minimum flow of between 350 and 950 mgd. The Illinois River of central Illinois has flows of 700 mgd at its upper extremity, about 1,000 mgd near Peoria, and 1,200 mgd at its confluence with the Mississippi River. All these amounts greatly exceed the amount of water used by one coal conversion plant. Values for the Rock River in northern Illinois range from 60 mgd near the Wisconsin state line to 500 mgd where the Rock River empties into the Mississippi River.

Existing Reservoirs

A number of relatively large reservoirs already exist in Illinois (table 13), but the water supply of most of them has already been committed to public supply. Only two of these present a possible, but not probable, source for conversion plants.

Rend Lake in Franklin County can provide a water supply of 40 mgd, which is already committed to the Rend Lake Intercity Water System. It is unlikely that water can be furnished for any additional use at present. The state of Illinois owns part of the water supply in Lake Shelbyville, Shelby County, and a supply of 14 mgd could be provided for coal conversion if the state so decided. The state also owns part of the water supply in Carlyle Lake in Clinton County. This lake could provide a water supply of 29 mgd. These two are the only existing reservoirs that might furnish a water supply for coal conversion.

Potential Reservoirs

From 1962 to 1967, a detailed study of Illinois was made by the State Water Survey to locate potential reservoir sites. Some 1,200 potential sites were examined, 800 of which seemed favorable for reservoir construction. Detailed information was published on the physical aspects of each of these sites. Separate reports contain results for southern Illinois (Roberts et al., 1962), south-central Illinois (Dawes and Terstriep, 1966a), north-central Illinois (Dawes and Terstriep, 1966b), and northern Illinois (Dawes and Terstriep, 1967). Most of the reservoir sites described in these four reports are of a size suitable for public water supply in Illinois but are not large enough to supply a coal conversion plant.

To evaluate the potential man-made reservoirs as sources of water for coal conversion, the Water Survey made a further study of all potential reservoir sites in Illinois. The study found 228 locations where a potential reservoir capable of supplying more than 6 mgd of water could be built. Table D (Appendix 1) gives data for each of the sites. The yield of a reservoir in million gallons per day (table D) would use only half the reservoir capacity during a drouth that had a recurrence interval of 40 years. Recreational use of the lake could therefore continue during the drouth. The yield shown in the table is the amount of water a reservoir could furnish for use by coal conversion plants. In table D there are 266 entries for the 228 sites selected because two sizes of reservoirs have been proposed for some sites, noted in the table as, for instance, 26 and 26A. Sites with letter suffixes are different versions of the sites with plain numbers, but the general location is the same.

The potential reservoirs that could be built at the 228 locations (table D) indicate the vast water resources available for coal conversion plants in Illinois. Each one of the possible reservoirs could supply at least the minimum quantity of water required for one coal conversion plant (6 mgd).

Cost of Potential Reservoirs

A typical cost analysis was made for selected reservoir capacities in different geographic locations of the state. Computation of the estimated project cost of the reservoirs followed the method proposed by Dawes and Wathne (1968). The formula given by Dawes and Wathne (1968) is based on a 1964 cost level, but the Handy-Whitman Index (1973) was used to bring the cost to a 1972 level. The price of land is based on the land values in Illinois cited in the Agricultural Census of 1969, converted to 1972 level by the cost index numbers of Illinois farmland values supplied by Dr. F. J. Reiss, Professor of Land Economics and Extension Specialist in Farm Management and Tenancy of the University of Illinois (personal communication, 1975).

The original equation for cost of reservoirs proposed by Dawes and Wathne (1968) is based on data for reservoirs constructed in Illinois since 1946 that were collected from consulting engineers, private and municipal water utilities, and state and Federal agencies. The project cost used here is the sum of the cost of construction, engineering and legal services, contingencies, and land. The term "construction cost" in the analysis encompasses costs of land clearing, dam and spillway construction, and relocations. Engineering and legal services were added as a fixed percentage—15 percent of construction cost. Contingencies were added as 10 percent of the construction cost. The amount of land required for a project was determined to be 50 percent more than the actual normal surface area of the pool. The reservoir project cost is estimated by the following equation:

$$P_c = C_1 \, C + C_2 \, L_a \, k$$

where

- P_c = total project cost in dollars
- C_1 = 1.25, a combined constant accounting for engineering and legal services (15 percent of C) plus contingencies (10 percent of C)
- C = $4287 \, S^{0.54}$, the construction cost (S = storage capacity in acre-feet)
- C_2 = 1.50, total required land area, 50 percent more area than needed for normal surface area of pool
- L_a = $0.23 \, S^{0.87}$, the required lake area
- k = land cost expressed in dollars per acre

The measure of dispersion in both the construction cost, C, and the lake area required, L_a, is given by the respective standard deviations expressed in percentages as 70.9 and 39.0. For estimates of project cost, values one standard deviation above the regression line were selected. This implies that, on the average, the actual values in excess of the estimated cost is expected only 16 percent of the time. In simplified form, the appropriate substitutions in the cost equation provide:

$$P_c = 9161 \, S^{0.54} + 0.49 \, S^{0.87} \, k$$

The ratio in the Handy-Whitman Cost Index (Whitman et al., 1973) for impounding reservoirs between 1964 and 1972 is:

$$(282.2)/(176.5) = 1.60$$

Therefore, the final equation for project cost is:

$$\begin{aligned} P_c &= (9161)\,(1.598867)\, S^{0.54} + 0.49 \, S^{0.87} \, k \\ &= 14{,}647 \, S^{0.54} + 0.49 \, S^{0.87} \, k \qquad (12) \end{aligned}$$

Equation 12 was used to compute the cost of potential reservoir sites, and the results are shown in figure 27.

As can be seen in figure 27, the cost of potential reservoirs varies with geographic location in Illinois. Costs are higher in northern Illinois than in southern, principally because land costs are higher in the northern part of the state. The project cost of potential reservoirs also varies with the reservoir capacity and ranges from about 1.8 million dollars for a reservoir capacity of 5,000 acre-ft to about 35 million dollars for a reservoir capacity of 500,000 acre-ft (fig. 27).

The relation between the reservoir yield and the reservoir capacity is given in figure 28, which provides a rough way of estimating the net yield of a reservoir, based upon reservoir capacity only. Figures 27 and 28 can be used together to relate project costs and reservoir net yield.

Quality of Surface Water

When a water supply is being planned for a coal conversion plant or for municipal, agricultural, industrial, or other uses, it is not enough to know that the water is merely potable. The amount and the kind of minerals in the water also must be known if an estimate of the cost of water treatment is to be made.

Available information and interviews with several engineers and researchers in this field reveal that no general standards can be set for the minimum water quality that is required by the various coal conversion processes. For that reason, existing surface-water qualities in Illinois are described here.

The parameters selected for defining mineral quality in this report were chosen because of their effect on general municipal and industrial use. No assessment is made here of the sanitary quality of the water.

Water dissolves minerals and other substances. The degree to which solution takes place depends on the type of mineral involved, the time of contact, and, in some cases, the presence or absence of dissolved oxygen. For example, Illinois surface waters in rivers and lakes seldom contain dissolved iron because they contain dissolved oxygen. Iron

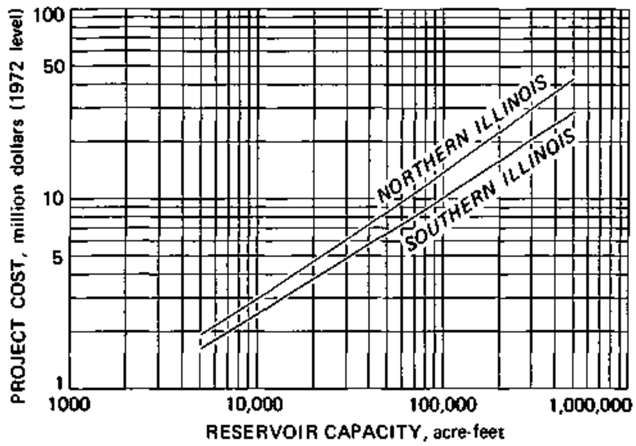

Figure 27. Reservoir capacity and cost.

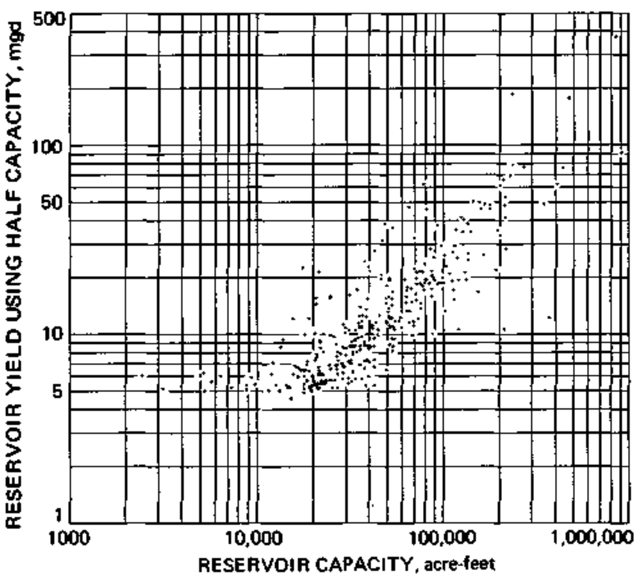

Figure 28. Relation between reservoir yield and reservoir capacity.

may be present as suspended iron oxide or in suspended silt, but it is not dissolved. On the other hand, well waters seldom contain dissolved oxygen and iron is present in the water of about three of every four wells in a concentration of more than 0.3 mg/1, which is sufficient to cause staining.

The minerals in ground water are related to the associated geologic formation. The minerals in surface water are generally those of the surface soil, although many streams are occasionally fed by ground water. Other minerals are added through public, industrial, and agricultural use of water.

For most subsurface waters, chemical analysis of a single sample is sufficient to give an accurate evaluation of the quality of the water produced from a given well. However, because the quality of the water in a stream varies almost continuously, a series of analyses must be made on numerous samples obtained by a regulated sampling program.

Most waters in Illinois are suitable for agricultural use if the mineral content is satisfactory for municipal use and if the sodium adsorption ratio (the total dissolved minerals minus the hardness, divided by 5 times the square root of the hardness) does not exceed 10. A ratio of more than 20 to 25 is generally unsatisfactory.

The surface-water quality for various parts of the state is summarized in table E (Appendix 1). Data were analyzed from samples collected by the State Water Survey in 29 watersheds from 44 sampling locations. Samples were generally collected monthly for a period of four to five years at each sampling station. Locations of the sampling stations are shown in figure 29.

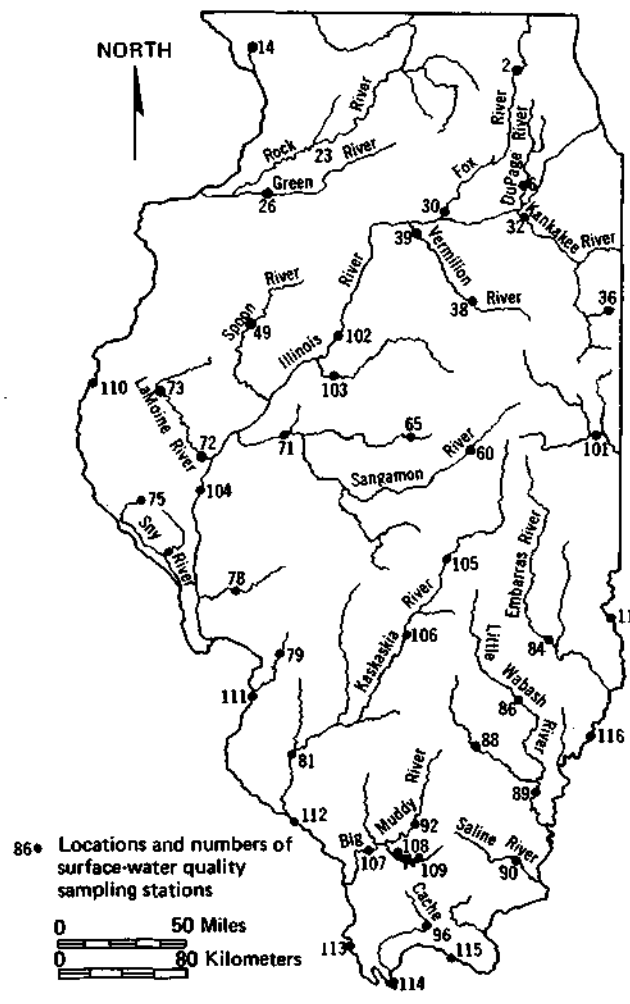

Figure 29. Location of water quality sampling stations.

CONCLUSIONS

Illinois is rich in water in the quantities needed for coal conversion. Water could be supplied to a plant anywhere along the major rivers—the Mississippi, Ohio, Wabash, Illinois or Rock. The minimum flow in the Mississippi River, as shown on the accompanying map (pl. 3), could supply numerous coal conversion plants, each using water at a rate of 72 mgd.

At 228 locations (pl. 3) at least 6 mgd could be supplied to a coal conversion plant from a man-made reservoir. At 17 locations a system of wells could be constructed to provide a water supply of at least 14 mgd for coal conversion.

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APPENDIX 1

TABLES

TABLE A-SUMMARY OF COAL RESERVES 42 OR MORE INCHES THICK IN THE HERRIN (NO. 6) AND HARRISBURG-SPRINGFIELD (NO. 5) SEAMS

County	Coal seam	Coal reserves (thousands of tons) by average thickness							County totals*			County averages†	
		4 ft	5 ft	6 ft	7 ft	8 ft	9 ft	10+ ft	Thousands of tons	Area of coal remaining (sq mi)	Area‡ mined out (sq mi)	Average thick-ness (ft)	Av. tons per sq mi (in thou-sands)
Bond	6	175,103	786,247	542,461	625,981	114,365	13,078	0	2,257,235	344.28	4.12	5.69	6,556
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		175,103	786,247	542,461	625,981	114,365	13,078	0	2,257,235				
Bureau	6	189,556	355,843	21,427	0	0	0	0	566,826	106.01	4.64	4.64	5,347
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		189,556	355,843	21,427	0	0	0	0	566,826				
Cass	6	0	0	0	0	0	0	0	0	0.0	0.0		
	5	41,564	38,477	66,355	0	0	0	0	146,396	25.30	0.0	5.02	5,786
Totals		41,564	38,477	66,355	0	0	0	0	146,396				
Champaign	6	57,180	6,409	0	0	0	0	0	63,589	13.52	0.0	4.08	4,703
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		57,180	6,409	0	0	0	0	0	63,589				
Christian	6	200,171	266,621	460,738	605,485	1,595,682	368,293	52,410	3,549,400	444.69	91.13	6.93	7,982
	5	131,633	914,911	168,860	0	0	0	0	1,215,404	211.83	0.70	4.98	5,738
Totals		331,804	1,181,532	629,598	605,485	1,595,682	368,293	52,410	4,764,804				
Clark	6	0	0	0	0	0	0	0	0	0.0	0.0		
	5	423,655	759,097	0	0	0	0	0	1,182,752	223.73	0.0	4.59	5,287
Totals		423,655	759,097	0	0	0	0	0	1,182,752				
Clay	6	583,716	360,935	109,516	0	0	0	0	1,054,167	205.18	0.0	4.46	5,138
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		583,716	360,935	109,516	0	0	0	0	1,054,167				
Clinton	6	90,536	858,601	610,684	668,059	666,902	100,339	15,831	3,010,952	423.32	13.42	6.17	7,113
	5	472	0	0	0	0	0	0	472	0.10	0.0	4.00	4,608
Totals		91,008	858,601	610,684	668,059	666,902	100,339	15,831	3,011,424				
Coles	6	175,483	0	0	0	0	0	0	175,483	38.08	0.0	4.00	4,608
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		175,483	0	0	0	0	0	0	175,483				
Crawford	6	92,185	19,287	0	0	0	0	0	111,472	23.35	0.0	4.14	4,773
	5	259,915	13,541	4,562	0	0	0	0	278,018	59.42	0.0	4.06	4,679
Totals		352,100	32,828	4,562	0	0	0	0	389,490				
Cumberland	6	33,186	359,679	19,773	0	0	0	0	412,638	72.51	0.0	4.94	5,691
	5	62,484	59,789	0	0	0	0	0	122,273	23.94	0.0	4.43	5,107
Totals		95,670	419,468	19,773	0	0	0	0	534,911				

De Witt	6	0	0	0	0	0	0	0	0	0.0	0.0		
	5	1,394,292	69,890	0	0	0	0	0	1,464,182	314.71	0.0	4.04	4,652
Totals		1,394,292	69,890	0	0	0	0	0	1,464,182				
Douglas	6	154,234	154,096	252,387	74,944	0	0	0	635,661	106.03	5.54	5.20	5,995
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		154,234	154,096	252,387	74,944	0	0	0	635,661				
Edgar	6	451,363	164,486	129,851	5,484	0	0	0	751,184	145.98	0.0	4.47	5,146
	5	427,643	0	0	0	0	0	0	427,643	92.80	1.40	4.00	4,608
Totals		879,006	164,486	129,851	5,484	0	0	0	1,178,827				
Edwards	6	339,800	75,589	16,112	0	0	0	0	431,501	89.20	0.0	4.20	4,838
	5	157,249	151,635	185,539	148,638	78,775	10,575	7,258	739,669	115.92	0.0	5.54	6,381
Totals		497,049	227,224	201,651	148,638	78,775	10,575	7,258	1,171,170				
Effingham	6	418,299	414,317	188,218	0	0	0	0	1,020,834	189.94	0.0	4.67	5,375
	5	807,967	373,478	0	0	0	0	0	1,181,445	240.18	0.0	4.27	4,919
Totals		1,226,266	787,795	188,218	0	0	0	0	2,202,279				
Fayette	6	161,744	1,136,909	1,273,194	672,067	157,974	0	0	3,401,888	517.16	0.0	5.71	6,578
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		161,744	1,136,909	1,273,194	672,067	157,974	0	0	3,401,888				
Franklin	6	59,711	184,546	463,011	492,142	193,727	163,791	26,937	1,583,865	212.17	150.94	6.48	7,465
	5	1,337,102	476,175	89,364	0	0	0	0	1,902,641	385.77	0.0	4.28	4,932
Totals		1,396,813	660,721	552,375	492,142	193,727	163,791	26,937	3,486,506				
Fulton	6	234,696	0	0	0	0	0	0	234,696	50.93	6.24	4.00	4,608
	5	334,860	293,818	21,704	0	0	0	0	650,382	126.82	81.91	4.45	5,128
Totals		569,556	293,818	21,704	0	0	0	0	885,078				
Gallatin	6	402,397	119,722	22,378	7,741	0	0	0	552,238	112.31	2.11	4.27	4,917
	5	505,402	680,624	36,081	0	0	0	0	1,222,107	233.06	7.90	4.55	5,244
Totals		907,799	800,346	58,459	7,741	0	0	0	1,774,345				
Greene	6	27,147	667	28	0	0	0	0	27,842	6.01	0.0	4.02	4,632
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		27,147	667	28	0	0	0	0	27,842				
Hamilton	6	592,976	614,598	491,903	273,987	108,064	1,866	0	2,083,394	352.43	0.0	5.13	5,911
	5	468,350	803,756	617,039	184,924	58,478	1,987	0	2,134,534	359.92	0.0	5.15	5,931
Totals		1,061,326	1,418,354	1,108,942	458,911	166,542	3,853	0	4,217,928				
Henry	6	187,294	0	0	0	0	0	0	187,294	40.65	2.53	4.00	4,608
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		187,294	0	0	0	0	0	0	187,294				

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TABLE *A-Continued*

County	Coal seam	Coal reserves (thousands of tons) by average thickness: 4 ft	5 ft	6 ft	7 ft	8 ft	9 ft	10+ ft	County totals*: Thousands of tons	Area of coal remaining (sq mi)	Area‡ mined out (sq mi)	County averages†: Average thickness (ft)	Av. tons per sq mi (in thousands)
Jackson	6	16,439	23,796	28,063	7,961	10,561	16,341	0	103,161	15.47	10.15	5.79	6,669
	5	163,722	86,170	0	0	0	0	0	249,892	50.49	3.38	4.30	4,949
Totals		180,161	109,966	28,063	7,961	10,561	16,341	0	353,053				
Jasper	6	441,899	1,067,777	751,000	0	0	0	0	2,260,676	389.93	0.0	5.03	5,798
	5	531,336	17,626	0	0	0	0	0	548,962	118.37	0.0	4.03	4,638
Totals		973,235	1,085,403	751,000	0	0	0	0	2,809,638				
Jefferson	6	504,099	584,731	748,799	305,946	128,845	41,332	52,402	2,366,154	379.70	22.17	5.41	6,232
	5	1,690,091	807,274	139,683	2,984	0	0	0	2,640,032	527.50	0.0	4.34	5,005
Totals		2,194,190	1,392,005	888,482	308,930	128,845	41,332	52,402	5,006,186				
Jersey	6	28,949	0	0	0	0	0	0	28,949	6.28	0.0	4.00	4,608
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		28,949	0	0	0	0	0	0	28,949				
Knox	6	214,687	0	0	0	0	0	0	214,687	46.59	18.57	4.00	4,608
	5	81,654	0	0	0	0	0	0	81,654	17.72	3.82	4.00	4,608
Totals		296,341	0	0	0	0	0	0	296,341				
La Salle	6	63,839	11,903	0	0	0	0	0	75,742	15.92	11.01	4.13	4,758
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		63,839	11,903	0	0	0	0	0	75,742				
Lawrence	6	266,417	0	0	0	0	0	0	266,417	57.82	0.0	4.00	4,608
	5	371,213	205,045	8,328	0	0	0	0	584,586	117.36	0.0	4.32	4,981
Totals		637,630	205,045	8,328	0	0	0	0	851,003				
Livingston	6	24,653	0	0	0	0	0	0	24,653	5.35	2.85	4.00	4,608
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		24,653	0	0	0	0	0	0	24,653				
Logan	6	0	0	0	0	0	0	0	0	0.0	0.0		
	5	555,425	907,524	981,418	687	0	0	0	2,445,054	420.16	8.24	5.05	5,819
Totals		555,425	907,524	981,418	687	0	0	0	2,445,054				
McLean	6	0	0	0	0	0	0	0	0	0.0	0.0		
	5	1,960,467	118,652	0	0	0	0	0	2,079,119	446.05	1.00	4.05	4,661
Totals		1,960,467	118,652	0	0	0	0	0	2,079,119				
Macon	6	82,195	27,732	12,505	5,214	445	0	0	128,091	25.16	0.0	4.42	5,092
	5	783,681	635,131	104,331	0	0	0	0	1,523,143	295.43	3.02	4.48	5,156
Totals		865,876	662,863	116,836	5,214	445	0	0	1,651,234				

Macoupin	6	633,538	586,183	833,410	1,173,167	410,252	19,620	4,378	3,660,548	552.10	83.67	5.76	6,630
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		633,538	586,183	833,410	1,173,167	410,252	19,620	4,378	3,660,548				
Madison	6	360,869	448,342	730,425	456,979	55,637	0	0	2,052,252	324.53	53.24	5.49	6,324
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		360,869	448,342	730,425	456,979	55,637	0	0	2,052,252				
Marion	6	289,937	361,604	110,031	68,676	1,732	0	0	831,980	150.32	10.02	4.80	5,535
	5	1,702,153	462,720	9,678	0	0	0	0	2,174,551	451.12	0.01	4.18	4,820
Totals		1,992,090	824,324	119,709	68,676	1,732	0	0	3,006,531				
Menard	6	0	0	0	0	0	0	0	0	0.0	0.0		
	5	15,315	254,914	1,232,549	31,692	0	0	0	1,534,470	229.83	2.91	5.80	6,677
Totals		15,315	254,914	1,232,549	31,692	0	0	0	1,534,470				
Monroe	6	9,719	258	0	0	0	0	0	9,977	2.15	0.0	4.02	4,632
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		9,719	258	0	0	0	0	0	9,977				
Montgomery	6	117,591	199,460	440,668	1,357,263	1,526,642	57,904	9,854	3,709,382	464.30	43.86	6.93	7,989
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		117,591	199,460	440,668	1,357,263	1,526,642	57,904	9,854	3,709,382				
Morgan	6	36,352	54,547	0	0	0	0	0	90,899	17.36	0.0	4.55	5,236
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		36,352	54,547	0	0	0	0	0	90,899				
Moultrie	6	3,917	152,467	103,956	0	0	0	0	260,340	42.36	0.68	5.33	6,146
	5	102,161	0	0	0	0	0	0	102,161	22.17	0.0	4.00	4,608
Totals		106,078	152,467	103,956	0	0	0	0	362,501				
Peoria	6	1,035,169	0	0	0	0	0	0	1,035,169	224.65	7.75	4.00	4,608
	5	523,838	212,564	0	0	0	0	0	736,402	150.58	34.02	4.25	4,890
Totals		1,559,007	212,564	0	0	0	0	0	1,771,571				
Perry	6	41,184	258,409	658,334	877,852	230,789	2	0	2,066,570	282.95	72.11	6.34	7,304
	5	287,102	24,062	0	0	0	0	0	311,164	66.48	4.61	4.06	4,680
Totals		328,286	282,471	658,334	877,852	230,789	2	0	2,377,734				
Piatt	6	0	0	0	0	0	0	0	0	0.0	0.0		
	5	1,036,517	0	0	0	0	0	0	1,036,517	224.94	0.0	4.00	4,608
Totals		1,036,517	0	0	0	0	0	0	1,036,517				
Putnam	6	16,220	6,912	0	0	0	0	0	23,132	4.72	0.0	4.25	4,901
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		16,220	6,912	0	0	0	0	0	23,132				

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TABLE *A-Concluded*

County	Coal seam	Coal reserves (thousands of tons) by average thickness							County totals*			County averages†	
		4 ft	5 ft	6 ft	7 ft	8 ft	9 ft	10+ ft	Thousands of tons	Area of coal remaining (sq mi)	Area‡ mined out (sq mi)	Average thick-ness (ft)	Av. tons per sq mi (in thou-sands)
Randolph	6	15,030	52,666	267,942	62,835	0	0	0	398,473	58.96	30.24	5.87	6,758
	5	105,431	6,797	0	0	0	0	0	112,228	24.06	2.78	4.05	4,665
Totals		120,461	59,463	267,942	62,835	0	0	0	510,701				
Richland	6	675,791	599,156	97,498	0	0	0	0	1,372,445	264.78	0.0	4.50	5,183
	5	529,513	1,387	0	0	0	0	0	530,900	115.15	0.0	4.00	4,610
Totals		1,205,304	600,543	97,498	0	0	0	0	1,903,345				
St. Clair	6	108,749	140,802	537,296	929,395	598,890	3,852	0	2,318,984	306.39	89.91	6.57	7,569
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		108,749	140,802	537,296	929,395	598,890	3,852	0	2,318,984				
Saline	6	283,558	456,883	285,839	14,363	3,176	0	0	1,043,819	184.34	6.41	4.92	5,663
	5	138,776	444,348	245,002	52,794	4,332	0	0	885,252	149.72	80.80	5.13	5,913
Totals		422,334	901,231	530,841	67,157	7,508	0	0	1,929,071				
Sangamon	6	241,422	262,434	287,518	454,855	535,187	16,754	0	1,798,170	255.64	28.48	6.11	7,034
	5	314,194	1,564,041	1,141,701	37,867	0	0	0	3,057,803	509.59	68.18	5.21	6,000
Totals		555,616	1,826,475	1,429,219	492,722	535,187	16,754	0	4,855,973				
Schuyler	6	0	0	0	0	0	0	0	0	0.0	0.0		
	5	0	51,667	0	0	0	0	0	51,667	8.97	0.0	5.00	5,760
Totals		0	51,667	0	0	0	0	0	51,667				
Shelby	6	395,635	174,030	259,691	655,871	458,343	7,361	0	1,950,931	285.42	2.40	5.93	6,835
	5	114,371	21,082	0	0	0	0	0	135,453	28.48	0.58	4.13	4,756
Totals		510,006	195,112	259,691	655,871	458,343	7,361	0	2,086,384				
Stark	6	440,549	0	0	0	0	0	0	440,549	95.61	3.28	4.00	4,608
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		440,549	0	0	0	0	0	0	440,549				
Tazewell	6	0	0	0	0	0	0	0	0	0.0	0.0		
	5	234,446	138,002	0	0	0	0	0	372,448	74.84	7.40	4.32	4,977
Totals		234,446	138,002	0	0	0	0	0	372,448				
Vermilion	6	299,802	405,461	311,510	52,871	92	0	0	1,069,736	187.09	36.83	4.96	5,718
	5	0	0	0	0	0	0	0	0	0.0	0.0		
Totals		299,802	405,461	311,510	52,871	92	0	0	1,069,736				
Wabash	6	239,003	19,256	1,866	0	0	0	0	260,125	55.48	0.0	4.07	4,689
	5	199,304	113,251	156,803	94,336	98,427	11,923	2,419	676,463	109.34	0.0	5.37	6,187
Totals		438,307	132,507	158,669	94,336	98,427	11,923	2,419	936,588				

Washington	6	69,942	139,937	750,112	1,577,617	972,870	188,570	94,856	3,793,904	475.62	6.06	6.92	7,977
	5	13,948	0	0	0	0	0	0	13,948	3.03	0.0	4.00	4,608
Totals		83,890	139,937	750,112	1,577,617	972,870	188,570	94,856	3,807,852				
Wayne	6	908,937	332,348	97,386	17,050	2,599	0	0	1,358,320	271.44	0.0	4.34	5,004
	5	955,769	136,910	36,716	0	0	0	0	1,129,395	236.50	0.0	4.15	4,776
Totals		1,864,706	469,258	134,102	17,050	2,599	0	0	2,487,715				
White	6	783,839	301,534	141,587	12,177	3,871	0	0	1,243,008	244.87	0.80	4.41	5,076
	5	659,803	408,607	326,317	252,175	9,401	0	0	1,656,303	293.63	0.0	4.90	5,641
Totals		1,443,642	710,141	467,904	264,352	13,272	0	0	2,899,311				
Williamson	6	23,395	110,063	233,194	130,795	54,525	19,803	0	571,775	81.97	106.04	6.06	6,976
	5	838,513	68,602	0	0	0	0	0	907,115	193.88	18.52	4.06	4,679
Totals		861,908	178,665	233,194	130,795	54,525	19,803	0	1,478,890				
Seam totals													
Coal seam	6	13,300,102	12,657,243	12,290,311	11,586,777	7,831,170	1,018,906	256,668	58,941,177	9,269.00	927.18	5.52	6,359
Coal seam	5	20,261,331	11,321,567	5,572,030	806,097	249,413	24,485	9,677	38,244,600	7,298.91	331.18	4.55	5,240
State totals		33,561,433	23,978,810	17,862,341	12,392,874	8,080,583	1,043,391	266,345	97,185,777				

** Does not include coal underlying oil and gas fields.*

† Refers only to seams more than 42 inches thick.

‡ Mined-out area reflects all areas mined regardless of seam thickness.

TABLE B-DEMONSTRATED COAL RESERVES* OF THE UNITED STATES AND ESTIMATED ENERGY POTENTIALS BY STATE

(Compiled by Ramesh Malhotra, Illinois State Geological Survey Mineral Economics Group)

State	Demonstrated coal reserves base‡ (million short tons)				Coal beat content (Btu)			
	Method of mining							
	Underground	Surface	Total	Percentage of U. S. total	Range** (Btu/lb)	Av. heat content value used (Btu/lb)	Potential energy available (Trillion Btu)	Percentage of U. S. total
Alabama	1,798	1,184	2,982	0.68	12,620-14,160	13,410	79,977	0.90
Alaska	4,246	7,399	11,645	2.68	9,000-14,500	10,000	232,900	2.61
Arizona		350	350	0.08	N. A.	N. A.	N. A.	N. A.
Arkansas	402	263	665	0.15	11,910-14,600	13,255	17,629	0.20
Colorado	14,000	870	14,870	3.43	9,060-13,680	11,370	338,143	3.79
Georgia	1		1	0.00				
Illinois	53,442	12,223	65,665	15.14	9,700-12,700	11,260	1,478,776	16.59
Indiana	8,949	1,674	10,623	2.45	10,900-11,590	11,510	244,541	2.74
Iowa	2,885		2,885	0.67	N. A.	N. A.		
Kansas		1,388	1,388	0.32	10,500-13,300	11,900	33,034	0.37
Kentucky, East	9,467	3,450	12,917	2.98	12,300-14,200	13,110	338,684	3.80
Kentucky, West	8,720	3,904	12,624	2.90	11,930-12,940	12,140	306,511	3.43
Maryland	902	146	1,048	0.24	12,890-14,480	13,680	28,673	0.32
Michigan	118	1	119	0.03	N. A.	11,570	2,753	0.03
Missouri	6,074	3,414	9,488	2.18	10,312-13,485	11,000	208,736	2.34
Montana	65,165	42,562	107,727	24.82	5,675-9,500	7,587	1,634,649	18.34
New Mexico	2,136	2,258	4,394	1.01	10,150-13,500	11,825	103,918	1.16
North Carolina	31	†	31	0.01				
North Dakota		16,003	16,003	3.69	7,004	7,004	224,170	2.51
Ohio	17,423	3,654	21,077	4.85	11,006-12,919	12,070	508,726	5.70
Oklahoma	860	434	1,294	0.29	13,500-13,755	13,627	35,267	0.39
Oregon	1	†	1	0.00				
Pennsylvania	29,819	1,181	31,000	7.15	12,580-14,490	13,270	822,740	9.23
South Dakota		428	428	0.10				
Tennessee	667	320	987	0.22	10,980-14,380	13,250	26,155	0.29
Texas		3,272	3,272	0.75	7,800-11,500	10,600	69,366	0.77
Utah	3,780	262	4,042	0.93	10,400-13,220	11,200	90,540	1.01
Virginia	2,971	679	3,650	0.84	11,170-15,000	13,530	98,769	1.11
Washington	1,446	508	1,954	0.45	up to 15,000	13,000	50,804	0.57
West Virginia	34,378	5,212	39,590	9.13	10,200-15,600	13,540	1,072,097	12.02
Wyoming	27,554	23,674	51,228	11.80	7,640-13,110	10,375	1,062,981	11.92
Total	297,235	136,713	433,948	100	5,675-15,600	10,272	8,915,028	100

** Demonstrated coal reserves are defined by the U. S. Bureau of Mines as in-place coals, 28 inches or more thick in bituminous coal or anthracite and 60 inches or more thick in sub-bituminous coal or lignite. Maximum depth is 1,000 feet for all except lignite, for which only strippable beds less than 120 feet deep are considered.*

† Less than 1 million short tons.

Sources of data: (‡) U. S. Bureau of Mines, 1974; (') Library of Congress Congressional Research Service, 1973, Science Policy Research Division.*

TABLE C-REMAINING COAL RESERVES IN ILLINOIS, BY COUNTY AND COAL SEAM, JANUARY 1975*

(in millions of tons)

County	Danville (No. 7)	Herrin (No. 6)	Harrisburg-Springfield (No. 5)	Summum (No. 4)	Colchester (No. 2)	De Koven	Davis	Rock Island (No. 1)	Misc. coals	Total	Percent s;trippable	Total strippable coal
Adams					624.556					624.556	99.1	618.690
Bond		2,451.950		299.867	2.092				2.472	2,756.381	0.0	0.0
Brown					385.672					385.672	100.0	385.672
Bureau	424.110	645.286			1,221.789					2,291.185	19.6	448.260
Calhoun					15.015					15.015	100.0	15.015
Cass			104.933		452.957					557.890	43.9	244.903
Champaign		181.884								181.884	0.0	0.0
Christian	61.454	3,429.950	1,336.120						86.660	4,914.180	0.0	0.0
Clark	316.655	11.848	511.149						379.885	1,219.537	0.0	0.0
Clay		916.819	702.311							1,619.130	0.0	0.0
Clinton		3,233.922		552.248						3,786.170	0.0	0.0
Coles	312.112	153.769	44.046							509.927	0.0	0.0
Crawford	211.152	571.817	929.166						736.948	2,449.083	1.8	43.162
Cumberland		162.249	171.260						3.845	337.354	0.7	2.385
De Witt			173.619							173.619	0.0	0.0
Douglas		698.279	11.011						10.063	719.353	0.0	0.0
Edgar	950.564	721.363	441.259						878.903	2,992.089	0.0	0.0
Edwards		684.316	1,031.565							1,715.881	0.0	0.0
Effingham		622.072	1,164.351						1.248	1,787.671	0.1	1.248
Fayette	296.023	2,773.953	159.646						0.595	3,231.617	0.1	1.995
Franklin		1,932.538	1,977.950			362.147	507.878		64.989	4,845.492	0.1	2.949
Fulton	58.882	242.309	630.310	5.448	1,293.242			5.266		2,235.457	86.2	1,926.658
Gallatin		1,311.641	1,298.862			650.600	856.675		6.836	4,124.613	5.6	229.238
Greene		97.274		25.199	583.351					705.824	84.7	597.777
Grundy				32.912	843.040					875.952	39.3	344.214
Hamilton		2,611.967	2,192.953			3.557	5.336			4,813.809	0.0	0.0
Hancock					54.299					54.299	54.9	29.829
Hardin						1.177	2.421			3.598	0.0	0.0
Henderson					53.111					53.111	100.0	53.111
Henry	58.878	260.289			668.819			16.374		1,004.359	56.1	563.665
Jackson		204.036	216.742						265.346	686.124	54.1	371.489
Jasper		1,861.661	1,415.200							3,276.861	0.0	0.0
Jefferson	-	2,699.818	2,442.508						23.842	5,166.164	0.5	23.842
Jersey	10.482	71.256			197.747					279.485	78.9	220.461
Kankakee				35.845	83.903					119.748	19.8	23.657

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TABLE *C-Continued*

County	Danville (No. 7)	Herrin (No. 6)	Harrisburg-Springfield (No. 5)	Summum (No. 4)	Colchester (No. 2)	De Koven	Davis	Rock Island (No. 1)	Misc. coals	Total	Percent strippable	Total strippable coal
Knox	2.523	214.221	643.471		803.634			57.526		1,721.375	89.2	1,535.181
La Salle	489.782	217.016			1,430.898					2,137.696	13.1	280.404
Lawrence	223.427	1,186.698	985.024						424.738	2,950.929	0.0	0.0
Livingston	257.569	354.555		16.060	2,351.608					2,979.792	1.7	49.226
Logan			2,588.664							2,588.664	0.0	0.0
McDonough					584.320					584.320	100.0	584.320
McLean	603.370		316.337		296.406					1,216.113	0.0	0.0
Macon		162.928	1,689.960							1,852.888	0.0	0.0
Macoupin	15.510	3,932.400		75.354	1,657.211		126.363		697.334	6,504.160	4.2	275.605
Madison		1,917.752			660.361		4.675		8.015	2,590.802	23.8	615.350
Marion		1,216.002	748.495							1,964.497	0.0	0.0
Marshall	337.381	9.749			858.033					1,205.163	9.6	116.023
Mason			23.271							23.271	0.0	0.0
Menard			1,598.550		23.775					1,622.325	33.7	545.943
Mercer					17.859			53.959		71.818	96.1	69.024
Monroe		6.726								6.726	100.0	6.726
Montgomery	24.972	3,721.394		609.721	558.844		133.353		513.415	5,561.691	0.0	0.0
Morgan		621.585	18.021	22.531	1,322.351					1,984.488	41.7	827.534
Moultrie		355.524								355.524	0.0	0.0
Peoria	282.537	1,044.423	1,189.911		429.868					2,946.739	72.6	2,138.070
Perry		2,107.053	400.565							2,507.618	35.3	885.104
Piatt			10.698							10.698	0.0	0.0
Pike					144.401					144.401	100.0	144.401
Putnam	197.035	78.676			467.893					743.604	0.0	0.0
Randolph		424.499	171.947							596.396	64.4	384.323
Richland		1,191.832	932.509						5.192	2,129.533	0.2	5.192
Rock Island								62.133		62.133	67.6	42.000
St. Clair		2,278.792		621.565						2,900.357	36.2	1,048.720
Saline	78.422	1,327.901	917.924	6.885	7.768	691.250	1,133.060		3.178	4,166.387	11.8	491.469
Sangamon		2,139.717	3,324.204		280.804				4.086	5,748.801	7.3	418.366
Schuyler			113.394		597.672					711.066	100.0	711.066
Scott		6.120			249.499					255.619	88.7	226.609
Shelby	125.267	1,183.577	304.861						90.945	1,704.650	5.0	84.570
Stark	57.703	427.678			25.781					511.162	100.0	511.124
Tazewell	4.152	69.686	129.019		202.528					405.385	37.0	150.005

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TABLE *C-Concluded*

County	Danville (No. 7)	Herrin (No. 6)	Harrisburg-Springfield (No. 5)	Summum (No. 4)	Colchester (No. 2)	De Koven	Davis	Rock Island (No. 1)	Misc. coals	Total	Percent strippable	Total strippable coal
Vermilion	1,677.961	698.070							44.521	2,420.552	8.7	209.980‡
Wabash		575.908	880.457						158.473	1,614.838	9.8	158.473
Warren			0.807		415.271			38.928		455.006	88.5	402.593
Washington		3,461.731		650.598						4,112.328	0.0	0.0
Wayne		2,349.795	2,275.301							4,625.094	0.0	0.0
White		2,364.131	2,248.345			13.823	17.204			4,643.496	0.0	0.0
Will					9.460					9.460	100.0	9.460
Williamson	57.022	634.708	910.562	2.648		742.119	615.894		188.386	3,151.337	17.9	564.069
Woodford	38.560		144.770		990.850					1,174.180	0.0	0.0
Total	7,173.473	64,832.960	39,347.823	3,075.118	20,866.625	2,464.672	3,402.857	1,225.322	4,599.915	146,988.765	13.4	19,637.689
Additions to reserves†		3,558.602	11,098.763							14,657.365		
Revised total	7,173.473	68,391.562	50,446.586	3,075.118	20,866.625	2,464.672	3,402,857	1,225.322	4,599.915	161,646.130	12.1	19,637.689

* *Totals include coal seams 28 inches or more thick in all cases of reliability, as defined in this report and previous Illinois State Geological Survey publications. Strippable coals include coals 18 inches or more thick under 150 feet or less overburden.*

† *These additions reflect new reserves of coal identified in the remapping of the coal seams in this study.*

‡ *Not based on detailed study.*

TABLE D-POTENTIAL RESERVOIRS IN ILLINOIS

County	Reservoir site no.	Pool area (acre)	Storage (ac-ft)	Storage (million gal)	Watershed area (sq mi)	Net yield* (mgd)
Adams	12	1,980	42,900	14,000	34.7	7.3
Adams	13	3,250	69,300	22,600	206.0	22.2
Adams	26	25,885	906,010	295,178	346.9	91.4
Adams	26A	15,288	433,156	141,122	346.9	76.4
Adams	27	3,813	63,558	20,707	103.5	15.0
Alexander	2A	1,363	38,164	12,434	25.8	12.4
Bond	8	12,000	204,000	66,463	471.7	60.9
Bond	11	6,850	134,000	43,657	297.0	38.8
Boone	3	1,040	15,600	5,082	69.0	12.2
Brown	14A	1,344	53,760	17,515	30.6	8.2
Brown	15	6,100	164,700	53,700	324.0	48.6
Brown	18	1,324	35,307	11,503	37.2	6.9
Bureau	2	1,060	12,370	4,020	98.0	7.2
Bureau	3	973	17,800	5,800	85.4	10.0
Bureau	4	1,730	34,600	11,260	186.6	17.2
Carroll	1 .	2,138	57,000	18,600	35.1	11.7
Carroll	2	2,310	50,100	16,300	57.0	13.3
Carroll	6	9,646	212,212	69,139	157.8	41.3
Christian	13	2,195	29,267	9,535	83.1	6.8
Christian	14	6,466	64,659	21,066	247.3	17.6
Christian	15	3,814	50,853	16,568	97.5	10.9
Clark	2	1,410	28,200	9,185	48.0	6.3
Clark	9	1,690	30,980	10,090	80.0	7.2
Clark	9A	2,320	50,267	16,377	80.0	14.0
Clark	18	2,403	36,045	11,743	85.0	11.5
Clark	19	1,138	24,657	8,033	25.1	6.6
Clay	1	12,000	160,000	52,130	472.0	46.2
Clay	3	2,100	28,700	9,350	50.0	6.8
Clay	11	13,500	230,800	75,195	661.0	68.5
Clinton	10	3,060	21,420	6,979	131.0	9.3
Clinton	13	4,054	40,540	13,208	140.1	7.1
Coles	1	3,100	24,800	8,080	303.0	15.5
Coles	2A	1,059	21,180	6,900	30.0	6.5
Coles	8	3,700	71,500	23,290	112.7	18.4
Coles	14	6,760	65,450	21,324	915.0	47.5
Coles	14A	18,500	470,957	153,438	915.0	177.1
Coles	15	2,207	20,599	6,711	526.5	14.8
Coles	16	3,668	40,348	13,145	566.9	21.4
Coles	17	5,443	68,945	22,462	695.1	32.2
Crawford	15	2,408	40,117	13,070	34.9	8.8
Crawford	18	3,229	41,977	13,676	30.3	8.0
Cumberland	1A	2,059	37,748	12,298	32.0	8.9
Cumberland	5	2,470	54,340	17,700	32.0	9.5
Cumberland	8A	1,612	26,867	8,753	62.0	8.2
Cumberland	12A	1,922	32,033	10,436	55.0	9.1
Cumberland	19	2,922	38,960	12,693	134.8	13.4
Cumberland	19A	6,466	129,320	42,132	134.8	34.8
Cumberland	20	2,142	34,272	11,166	58.3	9.6
Cumberland	20A	3,764	85,317	27,796	58.3	18.3
De Witt	3	2,682	5,000	16,300	118.4	18.0

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TABLE *D-Continued*

County	Reservoir site no.	Pool area (acre)	Storage (ac-ft)	Storage (million gal)	Watershed area (sqmi)	Net yield* (mgd)
De Witt	8	5,000	76,750	25,005	298.3	62.5
De Witt	9	2,677	31,232	10,175	227.4	16.3
Edgar	2	2,000	58,000	15,640	145.0	13.8
Effingham	9	10,616	212,320	69,174	218.8	48.1
Effingham	10	9,372	124,960	40,712	554.1	41.2
Fayette	9	5,100	136,000	44,309	91.1	26.6
Fayette	10	4,341	86,820	28,286	119.0	21.9
Fayette	11	1,930	32,167	10,480	47.7	8.7
Fayette	12	3,394	67,880	22,115	44.4	14.6
Fayette	13	4,732	94,640	30,834	84.8	18.2
Fayette	14	3,947	78,940	25,718	93.9	19.1
Fayette	15	4,160	109,000	35,512	84.0	20.4
Fayette	16	3,900	86,000	28,019	81.0	17.8
Fayette	16A	5,929	138,343	45,072	80.2	24.3
Fayette	16B	2,998	49,967	16,279	80.2	11.7
Franklin	4A	2,014	26,853	8,749	20.8	7.2
Fulton	5	1,100	29,300	9,500	32.1	8.4
Fulton	13	2,110	35,200	11,500	91.2	13.9
Fulton	14A	1,753	35,060	11,423	50.8	12.5
Fulton	31	1,024	27,307	8,897	27.8	7.9
Fulton	32	8,911	237,627	77,419	292.9	78.0
Fulton	35	1,825	24,333	7,928	55.4	9.2
Fulton	35A	4,356	101,639	33,114	55.4	18.9
Fulton	36	11,746	234,920	76,437	1,846.5	185.6
Fulton	36A	22,926	840,620	273,873	1,846.5	372.4
Gallatin	1	5,920	39,467	12,860	417.0	22.2
Gallatin	1A	7,007	46,713	15,219	417.0	20.3
Gallatin	1B	27,510	275,100	89,644	417.0	78.0
Gallatin	1C	14,404	144,040	46,938	417.0	50.0
Gallatin	5	2,250	42,500	13,849	16.6	6.7
Greene	16	4,344	75,296	24,531	146.3	13.8
Greene	26	7,808	140,544	45,789	278.0	34.9
Greene	17	15,858	343,590	111,942	367.3	48.5
Hancock	11	1,920	30,100	9,800	61.2	8.7
Hancock	12	7,040	129,000	42,000	285.0	41.0
Hancock	32	3,521	49,294	16,060	86.2	11.4
Hancock	33	2,726	49,977	16,282	82.0	14.6
Hancock	34	1,629	21,720	7,076	84.2	8.3
Hancock	36	1,236	26,780	8,725	37.3	7.6
Hardin	1A	1,361	32,664	10,642	10.4	6.3
Hardin	5	1,830	36,600	11,926	39.0	12.5
Hardin	5A	2,711	63,257	20,609	36.9	15.9
Henry	16	2,010	20,100	6,549	57.3	10.2
Jasper	8	1,750	26,200	8,536	46.9	6.5
Jasper	11	2,345	31,267	10,187	59.3	8.7
Jasper	12	2,810	37,467	12,207	75.7	9.2
Jefferson	1A	5,795	115,900	37,760	42.0	15.0
Jefferson	1B	3,904	65,067	21,199	42.0	11.6
Jefferson	1C	2,403	32,040	10,439	42.0	7.8
Jefferson	2	4,224	77,400	25,234	47.9	18.0

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TABLE D-*Continued*

County	Reservoir site no.	Pool area (acre)	Storage (ac-ft)	Storage (million gal)	Watershed area (sq mi)	Net yield* (mgd)
Jefferson	3	3,846	66,664	21,723	48.0	17.5
Jefferson	8	6,655	133,100	43,364	46.8	19.7
Jefferson	8A	2,537	33,827	11,021	46.8	9.1
Jefferson	9	5,279	114,378	37,264	38.4	17.0
Jefferson	9A	2,215	33,225	10,825	38.4	9.2
Jefferson	10	9,739	194,780	63,459	50.2	22.1
Jefferson	10A	5,338	71,173	23,188	50.2	15.0
Jefferson	10B	3,767	50,227	16,364	50.2	12.3
Jersey	7	2,580	68,800	22,410	83.0	11.2
Jersey	9	1,980	49,500	16,130	40.8	6.5
Jo Daviess	2	662	17,700	5,800	20.6	6.0
Jo Daviess	5	810	26,400	8,600	17.1	6.1
Jo Daviess	9	877	18,400	6,000	25.2	7.2
Jo Daviess	10	667	17,787	5,795	20.4	6.4
Johnson	2	2,900	20,300	6,615	40.0	7.6
Johnson	2A .	3,773	50,307	16,390	37.9	15.9
Johnson	6A	1,981	33,017	10,757	21.7	9.2
Johnson	11	8,883	118,440	38,587	113.3	35.7
Johnson	12	1,402	46,733	15,226	269.9	31.6
Knox	4A	1,873	31,217	10,170	26.1	7.2
Knox	20	1,697	22,627	7,372	46.2	8.1
Knox	21	2,207	44,140	14,381	36.3	9.9
Knox	22	2,201	29,347	9,561	67.9	10.7
Knox	23	1,324	26,480	8,627	24.9	7.0
Knox	24	1,435	35,875	11,688	28.5	8.4
Knox	26	1,069	23,162	7,546	25.6	6.7
La Salle	5	698	20,900	6,800	123.0	7.7
La Salle	11	763	13,995	4,560	241.3	9.6
Livingston	6	2,805	37,400	12,185	1,071.1	24.3
Logan	7	2,001	21,344	6,954	316.0	21.5
Logan	7A	3,678	51,492	16,776	316.0	36.3
McDonough	13	1,170	21,060	6,900	41.1	6.2
McDonough	14	2,148	35,800	11,664	67.9	11.3
McDonough	15	1,344	29,120	9,487	60.6	10.1
McHenry	2	1,280	8,960	2,919	21.6	7.3
McLean	10	1,677	39,130	12,748	37.4	8.8
Macoupin	27	2,871	38,279	12,471	210.8	13.4
Macoupin	27A	10,833	216,660	70,588	210.8	28.2
Macoupin	29	11,859	213,462	69,546	400.0	53.8
Madison	15A	4,026	45,628	14,866	112.2	12.8
Madison	17	4,578	122,080	39,774	103.5	19.5
Madison	19	4,820	86,760	28,266	109.4	17.6
Madison	20	3,206	41,678	13,579	85.9	11.0
Marion	13	3,200	53,300	17,360	96.1	14.3
Marion	14	10.550	179,400	58,449	210.0	46.0
Marion	15	3,017	36,204	11,795	90.6	9.6
Marshall	14	941	21,957	7,154	33.4	6.1
Marshall	15	3,256	113,960	37,128	127.1	27.2
Menard	1	1,382	31,315	10,200	38.8	7.1
Menard	1A	2,296	52,808	17,205	51.6	11.0

(Continued on next page)

TABLE *D-Contmued*

County	Reservoir site no.	Pool area (acre)	Storage (ac-ft)	Storage (million gal)	Watershed area (sq mi)	Net yield* (mgd)
Menard	1B	2,751	73,360	38,573	51.3	12.1
Mercer	1	804	16,100	5,200	31.6	6.7
Mercer	2	2,496	49,900	16,300	54.0	15.3
Mercer	11	145	2,420	788	3.7	6.0
Mercer	12	1,158	15,800	5,100	35.8	6.8
Mercer	13	5,000	116,700	38,000	92.5	29.2
Monroe	4A	2,562	51,240	16,694	36.1	9.8
Monroe	8	2,363	75,616	24,636	56.2	14.4
Monroe	9	5,941	79,213	25,808	164.8	23.8
Montgomery	10	9,859	177,460	57,816	326.5	48.5
Montgomery	10A	17,555	403,765	131,547	331.6	61.3
Montgomery	14	2,571	35,994	11,727	62.6	8.3
Morgan	6	2,125	37,525	12,200	104.4	9.0
Morgan	20	5,619	112,380	36,613	159.6	19.0
Peoria	3	1,062	27,612	9,000	42.7	7.8
Peoria	8	1,312	27,985	9,100	34.4	7.8
Peoria	20	3.155	90,422	29,500	61.3	19.2
Perry	2	2,080	28,400	9,254	48.0	8.5
Perry	12	4,855	64,733	21,090	45.9	13.1
Perry	13	9,055	120,733	39,335	99.0	25.4
Perry	14	5,729	76,387	24,887	109.9	21.5
Perry	15	6,511	86,813	28,284	107.2	20.5
Pike	2	4,950	132,000	43,000	92.0	21.6
Pike	10	1,410	28,200	9,200	39.1	6.9
Pike	22	2,574	85,800	27,954	59.0	15.6
Pike	23	3,034	96,077	31,302	39.1	18.4
Pike	24	4,150	166,000	54,083	50.2	26.4
Pike	26	1,903	66,605	21,700	27.8	13.3
Pike	26A	1,196	33,887	11,040	27.8	8.7
Pike	28	1,854	58,710	19,128	27.7	12.3
Pike	30	2,511	50,220	16,362	79.0	11.3
Pope	2	2,830	75,467	24,590	37.0	18.4
Pope	3	900	26,000	11,730	24.0	8.8
Pope	3A	1,260	50,400	16,420	23.8	12.1
Pope	4	780	18,200	5,330	39.0	7.0
Pope	6	3,600	96,000	31,281	81.0	29.1
Pope	8	1,886	50,293	16,385	42.0	12.4
Pope	9	3,375	101,250	32,987	54.8	26.1
Pope	10	2,155	71,833	23,403	54.4	21.0
Putnam	1	1,100	25,700	8,400	53.9	9.7
Putnam	2	570	16,200	5,300	35.0	6.0
Putnam	3	698	18,600	6,100	35.4	6.4
Randolph	1	2,650	35,333	11,513	84.0	10.8
Randolph	1A	10,032	200,640	65,369	83.2	33.4
Randolph	2	1,460	17,520	5,709	90.0	6.5
Randolph	14	1,500	21,000	6,843	71.0	6.7
Randolph	20	4,802	80,033	26,075	81.8	19.3
Randolph	21	5,211	104,220	33,955	84.7	22.9
Randolph	21A	3,231	53,850	17,544	84.7	16.6
Richland	9	3,474	34,742	11,318	59.4	9.5

(Continued on next page)

TABLE *D-Continued*

County	Reservoir site no.	Pool area (acre)	Storage (ac-ft)	Storage (million gal)	Watershed area (sq mi)	Net yield* (mgd)
Richland	11	27,794	370,591	120,738	23.9	12.5
Rock Island	1	1,037	15,500	5,100	46.6	6.2
Rock Island	4	1,320	21,600	7,000	60.4	8.5
St. Clair	12	2,204	29,387	9,574	41.9	7.8
St. Clair	13	3,665	36,650	11,941	81.8	10.7
Saline	4	3,300	121,000	39,428	26.9	10.7
Saline	4A	4,546	212,147	69,117	28.5	10.8
Saline	4B	1,902	50,720	16,525	28.5	8.7
Sangamon	9B	3,837	66,508	21,668	84.5	9.9
Sangamon	21	12,500	208,300	67,864	869.0	65.8
Sangamon	22	2,088	38,280	12,472	93.9	7.3
Sangamon	23A	2,475	37,950	12,364	38.5	6.6
Sangamon	24A	1,932	25,760	8,393	54.6	6.9
Sangamon	24B	4,131	68,850	22,431	54.6	11.5
Sangamon	25	2,105	29,470	9,601	52.9	7.6
Schuyler	8	1,856	52,580	17,100	52.0	12.5
Schuyler	21	4,440	78,440	25,600	87.0	18.9
Schuyler	25	1,559	33,778	11,005	62.0	10.5
Schuyler	26	2,883	86,490	28,178	33.4	10.2
Schuyler	26A	1,706	39,807	12,969	33.4	8.3
Schuyler	27	2,324	46,480	15,143	161.8	19.4
Schuyler	28	1,912	28,680	9,344	94.5	11.5
Schuyler	28A	3,491	75,638	24,643	94.5	21.1
Schuyler	30	1,500	37,500	12,218	27.3	7.3
Scott	5	2,029	39,221	12,800	63.8	7.1
Scott	11	2,628	42,048	13,699	127.1	9.5
Scott	14	2,815	51,608	16,814	125.2	12.2
Shelby	8	3,246	43,280	14,101	114.2	11.6
Shelby	9	2,216	22,160	7,220	102.7	6.1
Shelby	10	4,080	89,760	29,244	85.1	19.2
Stark	6	2,770	53,500	17,400	64.4	15.6
Stark	7	5,070	92,950	30,283	194.3	37.6
Stark	8	5,041	84,017	27,373	130.6	28.9
Stephenson	2	640	6,400	2,100	27.4	6.0
Stephenson	5	448	5,200	1,700	31.0	6.3
Stephenson	7	1,427	19,000	6,200	49.7	12.1
Tazewell	8A	1,507	32,652	10,638	33.6	8.0
Tazewell	11	1,206	24,120	7,858	42.9	6.9
Tazewell	12	2,079	41,580	13,547	49.0	10.8
Union	10	1,830	39,650	12,920	38.6	15.0
Union	10A	2,138	35,633	11,609	35.0	12.5
Union	14A	1,013	16,883	5,500	19.3	6.5
Union	15	1,200	12,000	3,910	24.3	6.1
Union	15A	2,277	30,360	9,891	22.4	10.3
Union	16	3,310	88,267	28,762	48.6	25.1
Union	16A	2,536	50,720	16,525	47.7	19.2
Vermilion	2	2,500	42,500	13,900	500.0	27.4
Vermilion	13	3,800	81,067	26,412	434.4	45.6
Vermilion	14	1,345	20,175	6,573	175.1	15.7
Warren	9	1,146	19,482	6,300	31.5	6.0

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TABLE *D-Concluded*

County	Reservoir site no.	Pool area (acre)	Storage (ac-ft)	Storage (million gal)	Watershed area (sqmi)	Net yield* (mgd)
Warren	11	954	13,356	4,400	102.3	8.6
Washington	11	2,696	35,000	11,403	52.2	8.3
Washington	11A	3,351	44,680	14,557	51.8	10.7
Washington	13	5,529	71,877	23,418	71.0	16.0
Wayne	5	6,204	62,040	20,213	160.7	19.9
Whiteside	7	1,304	17,387	5,665	142.5	22.7
Will	5	580	5,025	1,636	40.0	6.1
Williamson	8A	3,456	103,680	33,779	32.9	13.3
Williamson	8C	1,808	42,187	13,749	32.9	8.5
Williamson	11	5,357	71,667	23,349	58.4	19.8
Woodford	3A	1,593	53,114	17,304	28.8	8.5
Woodford	11	1,574	34,090	11,100	71.8	8.1
Woodford	11A	3,741	99,772	32,505	1.8	19.9
Woodford	13	3,251	55,270	18,000	130.9	11.9
Woodford	13A	8,401	196,021	63,863	130.9	35.3
Woodford	20	3,940	63,032	20,536	340.5	17.2

** Based on using half the reservoir capacity during a 40-year■ drouth.*

TABLE E-QUALITY OF SURFACE WATER FROM THE MAIN WATERSHEDS OF ILLINOIS

(Highest concentration or highest measured value in mg/l for indicated percentage of samples analyzed)

Watershed	Sampling station		Alkalinity			Hardness			Total dissolved minerals			Nitrate			Turbidity			Temperature (°F)			Sampling	Number	Watershed
	Location	Number	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	period	of samples	area (sq mi)
WISCONSIN DRIFTLESiS REGION																							
Apple River	Hanover	14	195	285	315	240	325	345	285	345	370	2	5.5	8.5	7	2	0.4	32	54	75.5	1957-1961	46	244
ROCK RIVER HILLS																							
Rock River	Como	23	175	240	270	225	290	330	280	340	390	2	6.5	12	7	3	0.6	32	56	78	1957-1961	59	8,700
WHEATON MORAINAL REGION																							
Fox River	Algonquin	2	200	230	280	275	315	380	340	385	450	3	6	11	5	2	0.5	33	55	77	1957-1961	60	1,364
Du Page River	Troy	6	160	240	285	330	400	470	420	530	630	2.5	10.5	17	10	3	0.2	33	56	79	1945-1950	51	325
GREEN RIVER LOWLAND																							
Green River	Geneseo	26	165	235	255	255	350	385	315	405	445	0.5	4	12	20	4	0.5	32	60	74	1945-1950	53	958
BLOOMINGTON RIDGED PLAIN-NORTH																							
Fox River	Dayton	30	185	230	290	275	320	375	350	400	480	3.5	7.5	13.5	7	3	0.7	32.5	60	78	1956-1961	60	2,570
KANKAKEE PLAIN																							
Vermilion River	Pontiac	38	170	220	255	265	350	455	340	415	530	2	9	28	25	4	0.7	33	56	80.5	1957-1961	51	568
Vermilion River	Lowell	39	155	220	260	250	355	460	310	445	685	3	11	28	10	2	0.4	32	57.5	78.5	1957-1961	54	1,230
Iroquois River	Iroquois	36	95	200	225	140	305	355	220	375	420	2	10	17	10	4	0.1	32	49.5	78	1950-1956	51	682
Kankakee River	Wilmington	32	145	190	210	255	315	345	330	390	435	1.5	6	19	20	2	0.4	32.5	56	78	1956-1961	52	5,250
GALESBURG PLAIN																							
La Moine River	Colmar	73	80	205	250	105	255	285	190	320	380	1.5	3.5	10	100	4	0.8	32	57	74	1957-1961	50	655
La Moine River	Ripley	72	70	165	220	110	225	290	150	270	350	1.5	5	10.5	90	10	2	33	57	76	1945-1950	49	1,310
Spoon River	London Mills	49	110	230	270	175	315	375	210	385	495	0.5	6.5	13.5	55	7	2	32	55	80	1945-1950	47	1,070
Spoon River	London Mills	49	160	260	310	230	350	440	315	440	625	1.5	6.5	14.5	45	4	0.7	32.5	59	78	1957-1961	48	1,070
INTERSECTIONAL																							
Illinois River	Meredosia	104	125	155	180	195	245	300	295	360	415	4.5	17	27.5	25	8	4	33	56	81	1955-1960	60	25,300
Illinois River	Peoria	102	120	150	180	200	250	300	255	330	400	5.5	9.5	16	100	31	10	34	59	80	1945-1949	48	
Illinois River	Peoria	102	135	160	180	225	260	320	330	385	450	3.4	10	18	70	37	13	32	54	81	1957-1961	50	
LINCOLN HILLS																							
Hadley Creek	Barry	75	80	160	190	110	180	215	165	230	260	0.5	2	6	25	2	0.5	34.5	61	85	1956-1961	59	40.6
SPRINGFIELD PLAIN																							
Embarras River	Ste. Marie	84	145	210	270	200	280	310	255	330	385	1	5.5	16	25	3	0.5	33	59.5	79	1956-1961	60	1,513
Kaskaskia River	Vandalia	106	105	210	265	130	275	315	170	345	445	1	3.5	12.5	25	3	0.5	34	54	81	1950-1956	50	1,980
Kaskaskia River	New Athens	81	40	125	215	75	185	305	130	285	435	2	5	10	50	10	2	34	59	78	1945-1950	55	5,220
Kaskaskia River	New Athens	81	50	135	215	80	210	300	150	315	500	1.5	4.5	9	55	9	2	34	57	78	1957-1961	48	
Sangamon River	Oakford	71	155	235	265	205	305	330	265	380	430	1.5	5	13.5	25	2	0.5	34	60.5	75.5	1957-1961	60	5,120
Little Wabash River	Wilcox	86	50	105	190	85	175	275	165	285	435	0.5	2	5.5	20	3	0.9	33.5	53	80	1950-1955	60	1,130
Indian Creek	Wanda	79	125	210	250	175	305	355	245	385	440	1.5	4	8	30	5	1	34	55	77	1945-1950	58	37
Macoupin Creek	Kane	78	75	200	250	125	265	345	160	330	440	1	4	8	70	7	1	34	56	78.5	1945-1950	60	875
BLOOMINGTON RIDGED PLAIN-SOUTH																							
Kaskaskia River	Shelbyville	105	80	200	255	125	320	625	170	405	1080	0.5	8	23.5	10	2	0.2	33	60	78	1956-1961	60	1,030
Sangamon River	Monticello	60	165	235	300	225	320	350	270	375	485	2.5	8.5	27	8	2	0.3	33	51.5	74.5	1956-1961	60	550
Salt Creek	Rowell	65	140	260	315	180	305	335	230	355	460	3	7	17.5	20	2	0.3	33.5	54	76	1950-1956	59	334
Mackinaw River	Green Valley	103	150	250	320	195	320	350	260	350	390	1.5	6.5	18.5	25	2	0.5	35	50	80	1950-1956	60	1,100
Vermilion River	Catlin	101	170	230	300	225	290	340	285	390	560	4	13.5	20.5	7	1	0.4	34	52	78	1950-1956	60	959

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TABLE E-*Concluded*

Watershed	Sampling station: Location	Sampling station: Number	Alkalinity 10%	Alkalinity 50%	Alkalinity 90%	Hardness 10%	Hardness 50%	Hardness 90%	Total dissolved minerals 10%	Total dissolved minerals 50%	Total dissolved minerals 90%	Nitrate 10%	Nitrate 50%	Nitrate 90%	Turbidity 10%	Turbidity 50%	Turbidity 90%	Temperature (°F) 10%	Temperature (°F) 50%	Temperature (°F) 90%	Sampling period	Number of samples	Watershed area (sq mi)
MT. VERNON HILLS																							
Skillet Fork	Wayne City	88	15	60	105	60	170	260	115	295	435	0.5	2	3.5	30	6	2	33	56.5	76.5	1945-1950	54	475
Skillet Fork	Wayne City	88	25	55	115	60	135	295	125	260	530	1	2.5	4.5	25	5	2	33	60	78	1957-1961	51	475
Big Muddy River	Plumfield	92	10	30	70	60	145	335	110	295	675	1	2.5	6.5	20	10	2	35	57	79.5	1945-1950	58	753
Big Muddy River	Murphysboro	107	25	50	100	100	200	440	205	425	795	1.5	3.5	5	30	5	2	36	58.5	77	1956-1961	55	2,170
Crab Orchard Lake	Wolf Creek	109	20	40	60	100	120	140	175	210	240				5	3	1	37	58	82.5	1951-1956	55	
Crab Orchard Lake	Station 5	108	20	35	50	85	100	120	150	165	220	0.5	1	2.5	5	1	0.5	37	56.5	83	1951-1956	55	
Little Wabash River	Carmi	89	30	75	150	65	150	240	140	280	470	1.5	3	5.5	35	5	2	33.5	61	78	1957-1961	50	3,111
Saline River	Junction	90	20	75	165	65	265	655	120	460	1010	1.5	2.5	3.5	20	5	1	35	60	79	1945-1950	41	1,040
SHAWNEE HILLS																							
Cache River	Forman	96	30	55	95	40	70	110	75	120	165	1	2	3.5	40	6	2	34	59	77	1957-1961	60	243
INTERSECTIONAL																							
Wabash River	Riverton, Ind.	117	110	180	220	165	260	325	225	340	405	3.5	12	26	45	9	2	38	59.5	82	1955-1960	60	13,100
Wabash River	Mt. Carmel	116	115	180	225	165	250	310	215	305	395	2	6	10.5	25	3	1				1950-1956	56	28,600
Ohio River	Metropolis	115	45	70	90	85	120	150	125	170	215	1.5	3.5	6	9	3	0.5	34	59	77	1950-1956	52	203,000
Ohio River	Cairo	114	60	75	95	100	135	165	150	205	255	1.5	4	6.5	10	4	0.9	34.5	66	83	1958-1961	42	
Mississippi River	Keokuk, Iowa	110	100	135	160	125	170	190	165	200	230	0.5	3	6.5	30	3	0.7	32.5	54	81	1950-1955	56	119,000
Mississippi River	East St. Louis	111	120	150	180	155	205	245	210	280	300	2.5	6	11	60	8	1	34	62	82.5	1958-1961	41	
Mississippi River	Chester	112	110	135	190	160	200	250	230	290	360	1.5	7	18	75	20	6	33	56.5	82	1955-1960	60	712,600
Mississippi River	Thebes	113	115	150	175	160	200	240	235	300	370	2	4.5	7.5	75	20	5				1951-1956	59	717,200

APPENDIX 2

METHODS USED TO COMPILE ESTIMATES OF COAL RESERVES

METHODS USED TO COMPILE ESTIMATES OF COAL RESERVES

Jay P. Hoeflinger and Lawrence E. Bengal

INTRODUCTION

The basic data for this report were drawn from the Illinois Geological Survey's comprehensive compilation of the estimated coal reserves of the state, made in 1952 (Cady and others, 1952). For that study, the Illinois coal field was divided into 33 areas (text figure 18). For each area a base map on a scale of approximately 1 inch to the mile was constructed by combining eight 15-minute quadrangle maps in two horizontal rows of four. Drill holes, mined-out areas, coal outcrops, and the thickness of each coal seam were plotted on the base maps. The reserves were then planimetered by hand to obtain area measurements for each increment of thickness and reliability used in the classification scheme shown in text table 3. The results were tabulated on punched cards by county, township, coal seam, coal seam thickness, and reliability of data. Tabulating machines (Parker, 1946) were then used to compute and tally the total tonnages of coal.

For the present study, two computer programs, the Coal Resource System and GEOMAPS, were developed at the Illinois Geological Survey for computing areas and volumes of coal within each of the reserve categories. The heart of the two systems is ILLIMAP, which also was developed at the Illinois Geological Survey in 1970 by Swann and his co-workers. ILLIMAP draws base maps of all or any part of Illinois to any desired scale. Its effectiveness lies in its data base, which consists of coordinates obtained from U.S. Geological Survey 7.5-minute quadrangle maps on which every section corner in the state is expressed in rectangular coordinates of the Lambert coordinate system (DuMontelle et al., 1968). This is a significant feature because it provides a basis for accurate location of datum points. ILLIMAP also includes all of the county and state boundaries and Indian treaty lines in Illinois.

COAL RESOURCE SYSTEM

Data Preparation

At the beginning of this study of coal reserves, the maps showing the thickness of the Herrin (No. 6) and Harrisburg-Springfield (No. 5) Coals that were made for the 1952 study were updated to include all the information that had been collected since 1952. To simplify the updating, transparent Mylar base maps were prepared on the same scale as the 1952 base maps, and new drill-hole information, boundaries of areas mined out since 1952, and information from studies of specific areas made in recent years were plotted on the Mylar bases. The Mylar maps were then placed over the 1952 base maps so that information from both could be used in mapping the extent of the Herrin and Harrisburg-Springfield Coals in Illinois and in interpreting the thickness of the coals.

After the interpreted maps of the coal seams had been prepared, the operation was fully computerized. The first step was the entry of the updated information and the reinterpreted coal-thickness lines. An Autotrol digitizer at the State Water Survey was used for this process. To be handled by the digitizer, our basic map unit had to be reduced from the eight quadrangles used in the 1952 study to two quadrangles. Each map unit was digitized and given a specific code to identify its location within the state.

Because of the type of data available, interpreted coal isopachs and other hand-drawn lines representing coal features, rather than actual point data, were digitized. This information was then recorded on a magnetic tape for entry into the computer.

Program Procedure

The digitizer-tape loading program reads successive records from the tape and records the Lambert coordinates of the map corners for use by ILLIMAP and other routines in the system. Every point is assigned a two-digit decimal value, which identifies that point. Because interpreted data instead of actual point data were digitized, the two-digit decimal value represents an isoline on the map. The coordinates of every point on an isoline and the value for each are stored in the coordinate files. The coordinate files include a feature-coordinate file and a coal-coordinate file. The coal-coordinate file holds only coal isopachs, while the feature-coordinate file holds lines representing all other coal features affecting the calculation of reserves (fig. A). Both types of files are then read by the Coal Resource System and are used for calculations of area and volume.

The Coal Resource System program accesses the coal-coordinate and feature-coordinate files for a particular map. In several steps the program builds a numerical surface that represents the coal surface portrayed on the hand-drawn coal-reserve work maps. This numerical surface is then used by the program to calculate the coal reserves for that particular map and to categorize the reserves into the classes that are necessary for further processing. By interfacing this coal surface with ILLIMAP, the coal reserves can be calculated by township, county, and seam thickness, as is demonstrated in table A (Appendix 1). These estimates of coal reserves are then stored in a statis-

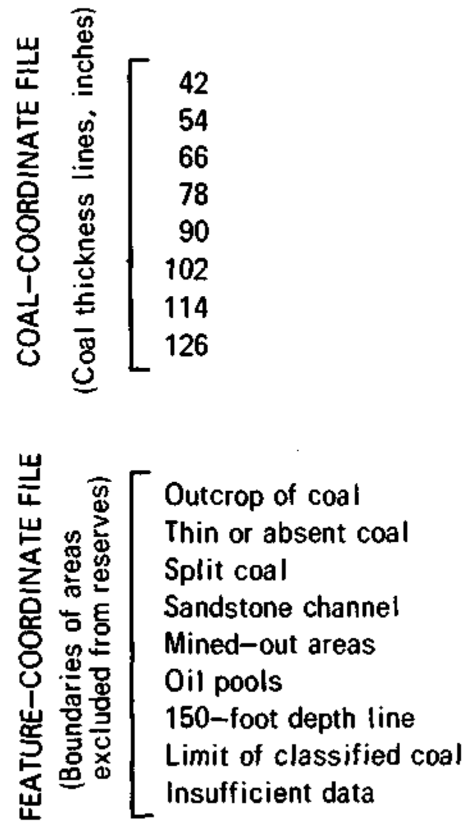

Figure A. The two types of coordinate files used to form the computer-generated mathematical surfaces for coal reserve estimates.

tics file, where they can be accessed by several display and correction programs.

GEOMAPS

GEOMAPS is the mapping and surface graphics system developed at the Illinois State Geological Survey. The system is composed of the ILLIMAP program, the FORMATION program, and IBM's STAMPEDE (IBM Corporation, 1968). STAMPEDE is a series of programs for forming and manipulating numerical surfaces. It can approximate arrays of datum points by a uniform grid, generate trend surfaces of the first through the eighth order, evaluate polynomial representations of surfaces, and perform normal contouring on a plotter or printer.

The basic ILLIMAP program was modified to convey base-map parameters to the STAMPEDE program and the Coal Resource System. These modifications allow an individual program to interrogate the ILLIMAP coordinate file in order to orient itself to the geographical area under study. ILLIMAP also conveys the scale, map limits, angle of orientation, plotter limits, and scale-conversion factors. The Geological Survey's routine called FORMATION was added to facilitate plotting the coal-feature lines from digitized point data.

MAPPING TECHNIQUES

An important feature of the Coal Resource System is its ability to plot information. Digitized lines for coal thickness and coal features are stored in coordinate files that can be accessed by the system's plotting routines, which are based on GEOMAPS. GEOMAPS can draw on a plotter unlimited combinations of digitized lines to any desired scale for any part of Illinois.

With format-free control cards the user can (1) call for particular lines by name; (2) cause symbols to be drawn on any of these lines at a predetermined frequency; (3) cause characters to be entered in the townships of any or all counties to represent tons per square mile, total tons of coal, total area of coal, weighted average thickness, or total square miles of mined-out area; and (4) cause lines to be drawn in different colors.

In this study the reserve estimates for each coal were factored into tons of coal in the average square mile for each township that contained Herrin or Harrisburg-Springfield Coals 42 or more inches thick. Six categories were set up for tons of coal in the average square mile, beginning with 4 to 5 million tons and progressing in million-ton increments to 9 or more million tons. Each category was assigned an alphabetic symbol, with A the smallest and F the largest. These symbols were plotted on a base map (fig. B) (Smith and Miller, 1975). The lettered map was translated into colors that represented the coal reserves in individual townships, as shown on plates 1 and 2, which accompany this report.

CONCLUSIONS

A unique feature of the system devised for this study was the use of interpreted coal-thickness data as computer input in place of actual point data. This approach had the advantage of saving much time and expense in the making of a point-oriented data base.

The key factor in the development of the Coal Resource System was the availability of the computer-based mapping system, ILLIMAP. ILLIMAP was used not only to plot the final maps, but also to locate input maps in relation to each other and to provide tabulations of coal reserves by geographical area. A coal reserves mapping system with the capabilities outlined here could probably not be developed without a mapping system similar to ILLIMAP.

The relative error of the computerized approach was compared to that of a manual approach by planimetering

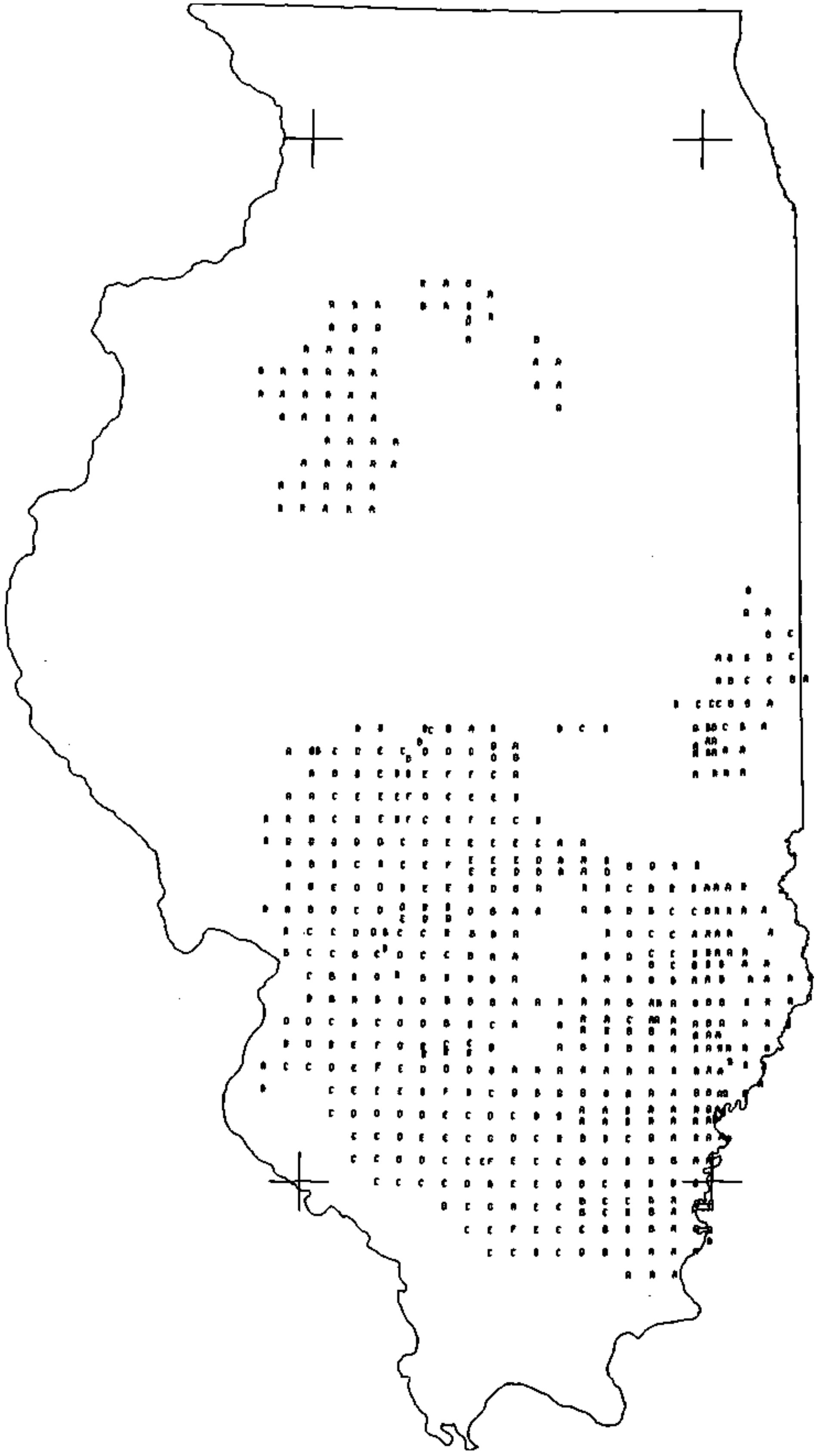

Figure B. A computer-generated map of letter symbols that represent colors to be used for a choropleth map of the average tons of coal in place per square mile for each township in which the Herrin Coal has been mapped. A similar map was made for the Harrisburg-Springfield Coal. The values range from letter A (4 million tons per square mile) to the letter F (9 *or* more million tons per square mile). The crosses are registration marks.

several test townships. In general, the difference between the two approaches was 5 percent or less. The errors in this computerized approach are inherent in any uniform-grid, numerical-surface technique; they arise from the size of the grid used to represent the coal surface. This error becomes insignificant as the grid interval approaches zero; however, the execution time, and therefore the cost factor, increases rapidly as the grid interval decreases.

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