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Coal Resource Recoverability

A Methodology

By T. J. Rohrbacher, D. D. Teeters,
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UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

BCY	bank cubic yard	lb	pound
Btu	British thermal unit	M	million
cfs	cubic foot per second	MBtu	million British thermal unit
ft	foot	%	percent
in	inch		

DISCLAIMER OF LIABILITY

COAL RESOURCE RECOVERABILITY

A Methodology

By T. J. Rohrbacher,[1] D. D. Teeters,[2] G. L. Sullivan,[2] and L. M. Osmonson[2]

ABSTRACT

This report presents a U.S. Bureau of Mines methodology developed to incorporate factors of coal production (mining and cleaning methods, recoveries, economics, etc.) into the definition of recoverability of a coal resource. Project procedures and computer models that were developed to include mine and preparation plant production rates, recoveries, and costs are explained. The results of these procedures and models are reviewed and compared to the Energy Information Administration estimate of U.S. coal resources—the "demonstrated reserve base." The Matewan 7-1/2-minute quadrangle in eastern Kentucky was selected to demonstrate the methodology.

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INTRODUCTION

The availability and amount of coal resources in the United States has been debated for years. Past figures based on gross estimates of coal in the ground did not address the amount that might realistically be available for production after environmental and technological restraints are considered. Many technological, economic, and social changes have impacted the coal industry since the last U.S. Bureau of Mines comprehensive coal-reserve data were published in the 1970's (*1-4*).[3] The Clean Air Act Amendments of 1990 to control sulfur dioxide and nitrous oxide emissions from coal-fired powerplants will significantly change the mining and marketing of coal. Legislation and regulations on mine reclamation have increased the complexity and costs of coal mining. Also, new safety and health standards, with their associated taxes, have increased the cost of mining operations. Advancements in mining technology in underground and surface operations have changed the economic competitiveness of certain coal fields (*5-12*).

Concerns about securing environmentally acceptable and reliable energy sources that have continually surfaced during the past 15 years have resulted in many revised estimates of the coal reserves in the United States (*1-4, 13-14*). The Energy Information Administration regularly updates its estimate of U.S. coal resources—the "demonstrated reserve base" (DRB)—with new information from State geological surveys and the U.S. Geological Survey (USGS). At the present time, the DRB is estimated to be about 475 billion short tons of coal (*14*). Even at consumption rates of 1.0 billion tons per year and a previously accepted recovery rate of 50%, there would appear to be ample available coal resources for several centuries. However, if the effects of mined-out prime reserves, and environmental, industrial, economic, and social considerations are assessed and the technical aspects of the minability and washability of the individual seams are considered, the amount of coal that would be available and economically recoverable would be far less than that stated in the literature (*1-3, 14*).

In 1986, the USGS and the Kentucky Geological Survey (KGS) began a Coal Availability study (*15*) of an area within the central Appalachian coal region—the Matewan 7-1/2-minute quadrangle—in order to determine the resources available for mining after environmental and technological restrictions were considered. Success from this pilot study allowed the USGS to include the geological surveys of Virginia and West Virginia in an expanded program encompassing most of the central Appalachian coal region (*16*).

In December 1988, the USGS requested that the Bureau review its Matewan quadrangle report and associated information, and determine if a joint study could result in the development of a new methodology that would incorporate coal mining and coal cleaning recovery factors and mine operating costs into the economic recoverability of a coal seam. Relative to that review were mine evaluations the Bureau conducted during the past 5 years to support U.S. Department of Commerce studies which compared the cost of coal mining in the United States to the cost of coal mining in selected foreign countries. This continuing work has provided a broad information base of mining conditions, equipment and workforce requirements, production rates, and capital and operating costs throughout coalfields in the United States. The Bureau decided to pursue the joint study with the understanding that the USGS and State geological surveys would provide geological and environmental maps and data, coal geology model data, and software usage training. In return, the Bureau would provide coal mining, cleaning, and cost-modeling expertise in an effort to determine the amount of remaining recoverable coal and the costs to mine and process that coal and reclaim the mined land.

It was decided that the first area studied by the Bureau would be the same area first studied by the USGS—the Matewan quadrangle. The Matewan quadrangle lies on the Kentucky-West Virginia border, primarily in Pike County, KY (fig. 1). Only the Kentucky portion of the quadrangle (approximately 90% of the land area) was evaluated. Twenty-one coal seams were identified by the KGS to contain minable resources. The stratigraphic relationships, are shown in figure 2.

USGS COAL AVAILABILITY CONCEPT

Three pertinent steps were defined in the USGS Coal Availability study (*16*):

1. Study area selection.
2. Data collection and assimilation.
3. Resource estimation.

[3]Italic numbers in parentheses refer to items in the list of references preceding the appendix at the end of this report.

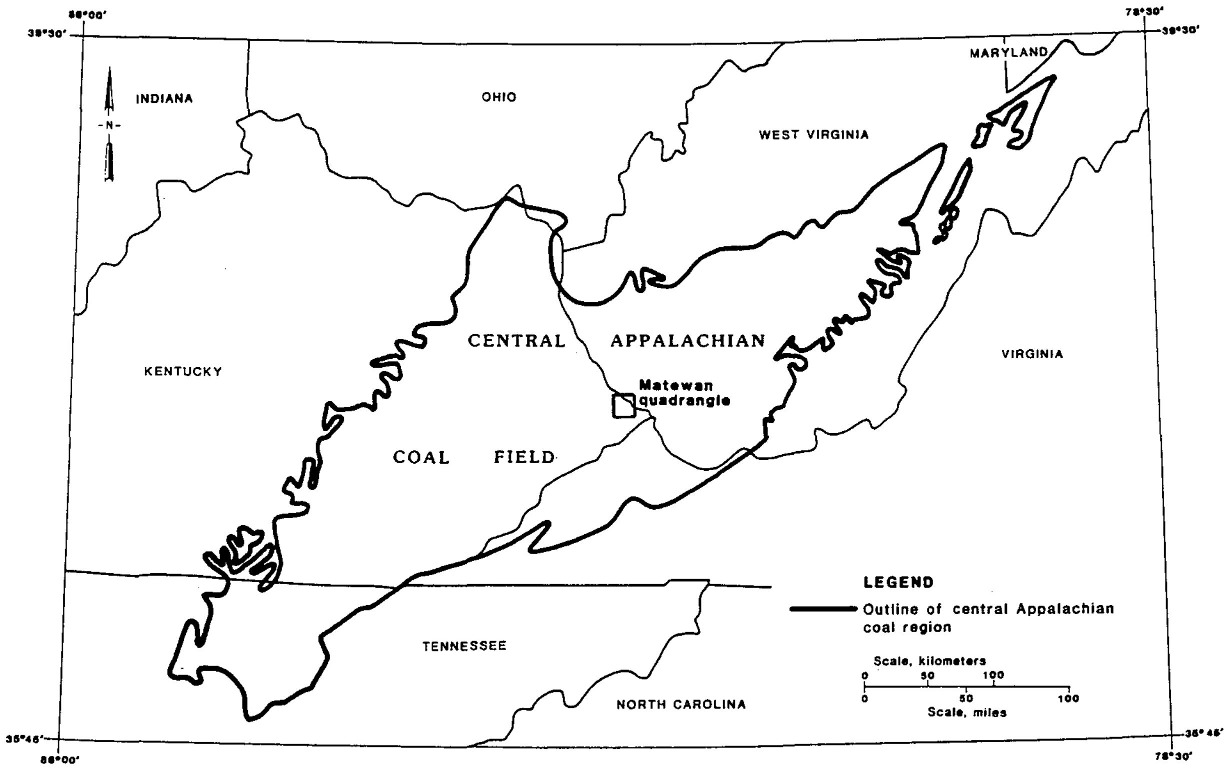

Figure 1.—Study area location.

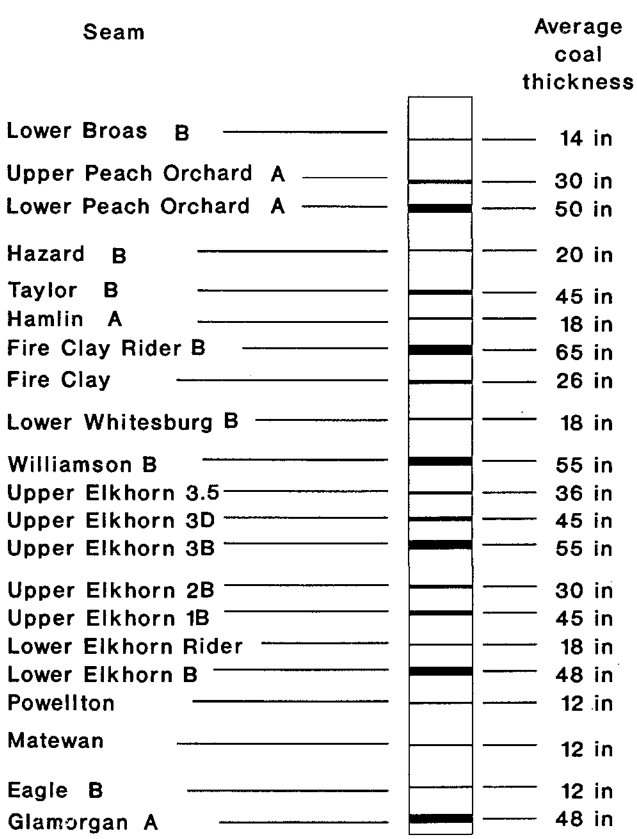

Figure 2.—Matewan quadrangle coal stratigraphy.

Minable coal was defined by the USGS Coal Availability study as follows:

ORIGINAL COAL RESOURCES
minus
COAL MINED AND COAL ABANDONED DURING MINING
equals
REMAINING COAL RESOURCES
minus
COAL RESTRICTED BY LAND USE CONSIDERATIONS
minus
COAL RESTRICTED BY TECHNOLOGICAL CONSIDERATIONS
equals
COAL AVAILABLE FOR MINING.

USBM COAL RECOVERABILITY CONCEPT

Following review meetings in Denver, CO, and Reston, VA, and preparation of a project outline, the authors conducted a preliminary recoverability and costing study of three Upper Elkhorn coal seams in the Matewan quadrangle. That preliminary evaluation showed excellent correlation with the USGS computer model for minable resources (98% agreement). Perhaps more importantly, however, the preliminary evaluation resulted in the establishment of an outline for the Bureau program methodology, as well as the development of recovery and costing models. The Bureau study incorporated the USGS methodology, reviewed the restrictions and modified the resources accordingly, addressed mining and recovery losses, and finally applied the mine operating economics. The following integrated pathway that resulted established a uniform, consistent methodology to be applied throughout the study:

COAL AVAILABLE FOR MINING
minus
MINING LOSSES
minus
WASHING LOSSES
equals
RECOVERABLE RESOURCES
restricted by
MINE OPERATING COSTS
equals
ECONOMICALLY RECOVERABLE RESOURCES
(RESERVES).

USBM PROGRAM OBJECTIVES

Realistic coal resource assessments are important for the consideration of legislation and regulations affecting coal production and for the direction and implementation of research aimed at maximizing recovery and ensuring environmental protection. Major national concerns that prompted the USGS-KGS Coal Availability program and the Bureau Coal Recoverability program are as follows:

1. Potential production disturbances in the world petroleum supply.
2. The rising requirement for low-sulfur (compliance) coal, as a result of the Clean Air Act Amendments of 1990, and the social and economic disruptions that occur as coal mining shifts from "traditional" high-sulfur coals of the East and Midwest to low-sulfur coals of the Western United States.
3. Growing recognition of the need to mitigate the environmental consequences of past, present, and future coal mining.
4. The need for accurate coal resource, recovery, and costing estimates that will contribute to relevant government policy decisions.
5. The need to determine mineral valuation and development potential of coal resources on public lands administered by the Bureau of Land Management and the National Forest Service.

The Bureau's minerals availability expertise and experience, gained in completing more than 70 detailed coal mine technical and economic assessments, and its active research role (coal mining, coal cleaning, mine safety, stability, resource recovery, equipment design, advanced mining methods, and economics) provide the background for this program. It was decided that the quadrangles studied by the Bureau would follow the USGS sequence.

The objective of the Bureau coal recoverability program is to address the following concerns:

1. Developing a methodology to calculate recoverable coal resources, and their associated mine operating costs, in the same areas that the USGS conducted its coal availability studies.
2. Using that methodology, improve estimates of the National Coal Reserve Base.
3. Determining the probable effects that clean air legislation and other environmental restrictions would have on coal production.
4. Developing baseline information to help with policy and legislative decisions affecting the competitiveness of coal mining in the United States and the State economies dependent on coal production.
5. Assisting Federal land managing agencies in the evaluation of coal resources on public lands.

ACKNOWLEDGMENTS

This report is the culmination of efforts by several State and Federal agencies working toward the common goal of determining the economically recoverable resources within a specific area of the central Appalachian coal region. The KGS and the USGS provided the geological modeling and data files from which resources were calculated. James C. Cobb, assistant State geologist (KGS), and his staff provided the detailed geological information, a tour of the Matewan quadrangle, and a review of the final report manuscript. M. Devereux Carter, Nancy K. Gardner, and Margaret F. Johnson (USGS, Reston, VA) contributed countless hours of training, resource calculations, computer guidance, and assistance in coordinating the USGS Coal Availability program with the Bureau Recoverability program. William G. Miller, manager of the USGS National Coal Resource Data System (NCRDS), Reston, VA, guided the Bureau acquisitions of hardware and software to provide compatibility with NCRDS. Carol L. Molnia and Vicky L. Clark (USGS, Denver, CO) provided computer assistance. Special thanks are extended to Anne M. Allen (mining engineer, Alaska Field Operations Center, USBM) for development of the many graphics used in this report.

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PROGRAM DESIGN

After examination of the USGS-KGS Coal Availability project in early 1989, a preliminary recoverability methodology was developed, as were map needs and formats, preliminary work schedules, and mining restriction criteria. Geological information was collected from the KGS, in Lexington, KY, and the locations of all mining, wash plant, and waste-disposal sites in the Matewan and surrounding quadrangles were obtained from the regional office of the Kentucky Department of Surface Mine Reclamation Enforcement (DSMRE), in Pikeville, KY. The Matewan quadrangle was toured so that (1) the locations of wash plants, railroads, highways, haulage roads, streams, and rivers could be verified, (2) trends in the terrain and haulage routes could be identified, and (3) any other pertinent mining infrastructure could be noted. Several mines in and around the Matewan quadrangle were evaluated for operational details. An in-depth literature and industry search for state-of-the-art mining methods and equipment and current production rates was undertaken, and recovery rates of similar mining configurations in other localities were investigated. Normal planning variables, such as seam thickness, floor and roof quality, seam hardness, seam quality, parting and coal content within a seam, and depth of seams, were collected. Industry and government sources were used for equipment costs and cost indexes, productivity, transportation costs, coal quality versus coal realization, taxation, etc.

The data from all the various sources were then evaluated in connection with the USGS methodology of determining coal resource availability. This methodology was then modified and expanded, the results of which include a different definition of coal resource availability, and herein lies a major difference between the USGS program and Bureau program methodologies. This difference between the USGS Coal Availability program and the Bureau Coal Recoverability program is the Bureau's use of total coal seam thickness in determining mining methods, resource recovery, and applicable mining costs. The Bureau assumptions and methodology reflect recovery of some coal in the mining of full seams that would have been excluded in a coal-only scenario (i.e., seam parting of up to 50% of the total seam thickness is included in the minable resource number). Also, the Bureau did not limit the mining of the coal if the coal had high sulfur or high ash content; instead, operating costs became the limiting factor for the reserve. Thus, high sulfur coal is limited in reserve by its lower sales price. Ash content, denoting in-seam parting and out-of-seam dilution, is accounted for by (1) the additional cost of washing the run-of-mine (ROM) product, and (2) the percentage of ROM product washed out during cleaning, thereby effectively lowering the clean or salable tonnage recovered and raising the cost per ton to produce the coal.

As a result of the redefinition of coal resource availability, the Bureau estimation of the total original, in-place, resource for the Matewan quadrangle is 21% more than the USGS estimate; however, due to significant differences in estimated resource losses determined for previously mined resources and restrictions to future mining, the Bureau estimate of the remaining minable resource is less than the USGS estimate by 14%. In any event, this revised minable tonnage, derived from USGS and KGS coal availability data, formed the foundation upon which the Bureau's recoverability program fully developed.

The Bureau recoverability methodology, which consists of removing the resources lost during mining and washing, results in recoverable resources. Mining economics are then applied to the recoverable resources to determine the amount of coal that can be mined at a profit. To determine the resource recovery, mining assumptions were made and preliminary mine plans were developed for each seam. Coal mining and washing recovery models were developed and applied to the resource data. The recoverable resources were then incorporated into the mine cost models to calculate the economically recoverable resources (i.e., reserves) at different levels of the coal market. This methodology easily acknowledges the fact that the reserve base, or "economically recoverable coal base," will change with changes in energy prices.

RESTRICTIONS TO MINING

Site and mine data from field investigations provided the base information necessary to evaluate the effect of the land use and technical restrictions on the mining conditions and recovery rates. Observations by Bureau investigators, the USGS, and the KGS prompted the authors to add and alter restrictions used in the evaluation.

Land Use Restrictions

The USGS identified several land use restrictions that the Federal Surface Mining Control and Reclamation Act of 1977 (SMCRA) and the Kentucky Surface Mining Law of 1982 would apply to coal resources. Rather than divide the restrictions by surface or underground mining, this report methodology divides those restrictions by industrial and environmental plus social considerations. Although some definitions were modified, the principal difference between the Coal Availability and the Coal Recoverability studies lies in the definition of the coal seam itself. For years, the Nation's coal resources have been defined by coal-only thicknesses within the seam (*13, 17*). The question is stated then as follows: If presented with varying amounts of noncoal lithology (shale, siltstone, etc.) within a seam, at what ratio of noncoal material to coal does one consider the seam no longer minable?

Field investigations of mines in the central Appalachian region that wash coal prior to sale, particularly in the Matewan quadrangle area, found that 50% to 65% recovery of the ROM coal seam was fairly common. For that reason, the assumption was made that if a coal seam contained 50% or more coal, by thickness, it could be mined. Since this is an economic restriction, it will be addressed where wash plant recoveries are factored into the cost to produce a ton of coal from a particular seam.

Industrial Restrictions

The industrial restrictions encountered in the Matewan quadrangle are powerlines, pipelines, oil and gas wells, and highways and railroads. Although these restrictions can be abated through relocation or positive abandonment (well plugs), the high cost normally associated with abatement usually prohibits economic recovery of the resource. The KGS and USGS staffs digitized the locations of major powerlines, pipelines, and oil and gas wells. No major highways or railroads were digitized since none would be affected by mining. Therefore, the Bureau's industrial restrictions are identical to those of the USGS.

Environmental and Social Restrictions

Environmental constraints addressed in the study of the Matewan quadrangle are streams and premining ground slopes where surface mining could take place.

For streams having a mean annual flow of 5 cfs or greater, mining is not allowed within 100 ft of the high-water level. All surface resources inside the buffer zone were considered restricted. As with many industrial constraints, variances can be obtained to divert or reroute streams so that surface mining can take place. However, construction and subsequent reclamation are generally cost prohibitive.

Present surface mining laws mandate the replacement of overburden to the approximate original contour, unless a variance is obtained (such as in mountain-top removal stripping). The maximum slope for reclamation is dependent upon the composition of the rock types in the overburden above the coal seam and interburden between coal seams (if more than one seam is mined) and the amount of water present. Stable reclaimed slopes are normally 62% to 70% (rise to run). When accurate digital terrain models are available with the outcrop of the coal seam, slope measurements can be done by computer. Ground slope measurements were conducted perpendicular to the contour across all outcrops, using the USGS 7-1/2-minute Matewan topographic map. No average slope measurements exceeded 62% (32°) in minable areas; therefore, no slope restrictions were placed on the minable resources.

Social constraints are cemeteries, towns, and residences. Variances can usually be obtained to move the restriction to another location, but only at significant cost and time. These mining restrictions were accepted in total as presented by Carter and Gardner (*16*). Table 1 shows the restrictions and mining assumptions used in the USGS and Bureau studies.

Table 1.—Comparisons between USBM and USGS-KGS coal availability (minability) restrictions

	USBM	USGS-KGS
Land use restrictions:		
Industrial constraints:		
Powerlines	100 ft buffer	100 ft buffer.
Pipelines	100 ft buffer	100 ft buffer.
Oil and gas wells	200 ft square	200 ft square.
Highways and railroads	NA	NA.
Environmental constraints:		
Cemeteries	100 ft buffer	100 ft buffer.
Major streams, lakes	100 ft buffer	100 ft buffer.
Towns and residences	300 ft buffer	300 ft buffer.
Ground slopes <65%	NA	NA.
Technical restrictions:		
Minimum mining thickness:		
Surface mining	12 in minimum	14 in minimum.
Deep mining	24 in minimum	28 in minimum.
Stability considerations:		
Thicker coal beds too close.	<40 ft above/ below	<40 ft above/ below.
Deep mining too close	<40 ft above/ below	<40 ft above/ below.
Overburden too thin	<100 ft	NA.
Too deep:		
Surface mines	>20:1 highwall ratio	>200 ft.
Deep mines	NA	>1,000 ft[1].
Geologic factors	NA	NA.
Barrier restrictions:		
Present mine barriers	50 ft buffer	50 ft buffer.
Future (planned) mine barriers.	Actual area	NA.

NA Not applicable.

[1]The KGS early standard depth limitation of 1,000 ft was not used in this report. The authors developed mine plans for all minable seams. In the USGS-KGS report, coal seams were not modeled below the Glamorgan seam due to this restriction.

Technical Restrictions

Technical restrictions are of two categories: coal seams that are too thin to mine with today's equipment, and restrictions where the roof or floor would be unstable due to past or future mining in seams adjacent to the one under consideration. In the Matewan quadrangle, the depth to the resource and geological factors were also considered.

Thickness Restrictions

This restriction was changed significantly from that reported by Carter and Gardener. They used the accepted mining thickness parameters—14 in of coal for surface mines and 28 in of coal for deep mines—for determining coal resources (*15*). During the authors' evaluation of central Appalachia properties, deep mines were observed to be operating in a 24-in seam of coal, and strip mine operators used a seam thickness cut-off of 12 in (usually in multiple-seam stripping). In all cases, the obvious restricting factor is economics. Further, since the USGS's definition of coal resources applied to coal only, no parting material greater than 3/8 in thick was included in the 14-in and 28-in thickness restrictions. Fortunately, the parting thicknesses had been recorded in the KGS data base, and the USGS was able to add those partings to the coal to obtain a real seam thickness model. The authors used a 12-in minimum seam thickness for surface mine planning and a 24-in minimum seam thickness for deep mining. As noted earlier, a cutoff of 50% parting in the seam was assumed as a mine planning parameter. The addition of the partings to the seam contributed to the large variance between Bureau resource calculations and the calculations of the USGS.

Stability Restrictions

Several stability factors were addressed where the rock strength was known to be too low to support mining close to vertically adjacent seams or previous mining. The KGS felt that a 40-ft thickness of interburden between seams was a good average where knowledge of specific rock strengths between the seams was lacking.

In several mine evaluations, it was found that some mines operated within 25 ft or less of overlying abandoned mines; however, even with good pillar alignment from seam to seam, poor roof conditions occurred in some interacting mines where interburden thicknesses were greater than 60 ft. In some cases operators were attempting to mine over abandoned mines with less than 60 ft of interburden. More often than not, floor and roof failure were major problems. The authors considered the 40-ft interburden thickness as a minimum and, further, restricted the mining sequence to be from the top of the stratigraphic sequence downward.

Perennial drainages were considered to negatively affect the overburden through deep weathering, which contributed to ground control problems. Several potential problem areas were identified, and buffer zones of 200 ft were decided upon and designed as appropriate restrictions.

Some past coal resource definitions assumed that deep mining was limited to depths of less than 1,000 ft. Although many coal mines are operating at depths in excess of 2,000 ft, the original resources were calculated only to a depth of 1,000 ft. In the Matewan quadrangle no coal resources below the lowest drainage (Tug Fork of the Big Sandy River) were considered by the USGS for evaluation because of this restriction. Subsequent quadrangle evaluations have not used the 1,000-ft, nor the below-drainage, parameters as restrictions.

In addition to depth restrictions on deep mining, the USGS used a depth restriction of 200 ft for surface minable seams to expedite the resource calculation. However, due to economics, a highwall ratio was found to define more realistically the surface minable resource. The authors found that by comparing effective stripping ratios (bank cubic yards of overburden moved to tons of coal recovered) to the highwall ratio (thickness of overburden to thickness of coal seam), a 20:1 highwall ratio was consistent with present economic stripping limitations. On the other hand, the 200-ft depth limitation could produce highwall ratios of as great as 200:1—well outside the economics of mining.

The final stability category reviewed was that of geologic factors such as faulting, steeply dipping seams, splits in the coal seam, etc. These factors were not major problems in the Matewan quadrangle and were not considered as a restriction to mining.

Barrier Restrictions

Two types of barrier restrictions were defined. The first restriction is the 50-ft mandatory safety barrier around old mines to prevent unexpected water inflow and interruptions in mine ventilation. The second was calculated from the feasibility-type mine plans; it included barriers left between production panels, barriers left to protect ventilation, haulage, and travelways, and barriers left between the underground mine and the highwalls of the adjacent surface mine. This second barrier restriction was not addressed by the USGS Coal Availability program and amounts to approximately 7% of the total original resource in the Matewan quadrangle. The restrictions are summarized in table 2 and detailed in table 3.

Table 2.—Coal seam resources, restrictions, and process losses (thousand tons)

Seam name	Original resources	Mined out resources	Land use restrictions	Technologic restrictions	Barrier restrictions	Mining losses	Washing losses	Recoverable resources
Broas	56	0	0	(46)	0	47	0	56
Upper Peach Orchard A	4,752	0	104	22	56	1,067	1,567	1,936
Lower Peach Orchard A	1,161	0	12	404	46	316	0	382
Hazard	3,123	0	40	1,016	80	810	476	701
Taylor B	11,566	8	173	1,662	829	3,113	811	4,969
Hamlin A	9,397	0	189	3,140	673	2,220	377	2,798
Fire Clay Rider	25,206	133	612	1,417	1,845	7,230	4,559	9,410
Fire Clay	40,782	1,346	674	1,601	3,002	11,209	7,115	15,836
Lower Whitesburg	66,291	0	991	2,316	4,498	17,217	8,136	33,133
Williamson B	115,881	2,667	1,396	7,258	8,362	26,668	19,317	50,212
Upper Elkhorn 3.5	84,194	3,230	634	13,730	5,904	20,858	8,877	30,960
Upper Elkhorn 3D	73,681	0	1,048	5,214	5,128	21,363	5,584	35,343
Upper Elkhorn 3B	132,252	3,839	1,917	18,821	9,613	34,561	18,802	44,699
Upper Elkhorn 2B	125,989	17,265	1,885	74,290	9,722	7,720	2,515	12,593
Upper Elkhorn 1B	145,030	2,729	2,609	9,140	10,404	42,141	14,009	63,998
Lower Elkhorn Rider	75,172	0	1,755	60,125	5,214	3,321	1,093	3,664
Lower Elkhorn B	224,886	116,747	3,834	15,447	17,989	21,774	9,032	40,063
Powellton	6,034	0	437	3,246	0	1,087	440	823
Matewan	9,703	0	64	5,096	682	1,574	467	1,819
Eagle B	6,802	6	206	5,203	470	396	85	436
Glamorgan	32,175	0	1,121	9,743	2,221	7,178	2,453	9,459
Total	1,194,133	147,970	19,701	238,845	86,738	231,870	105,715	363,290

Table 3.—Mining restrictions—land use, technical, and barrier restricted coal (thousand tons)

Seam name	Total original seam resource	Land use restrictions		Technical restrictions		Barrier restrictions		Total restrictions	% of seam total
		Industrial restrictions	Environmental restrictions	< minable thickness	Stability restrictions	Present mine barriers	Future mine barriers		
Broas	56	0	0	0	0	0	0	0	0.00
Upper Peach Orchard A	4,752	104	0	0	0	0	280	384	8.08
Lower Peach Orchard A	1,161	7	0	0	0	0	180	187	16.11
Hazard	3,123	40	0	1,016	0	0	80	1,136	36.38
Taylor B	11,566	173	0	1,751	0	0	828	2,752	23.79
Hamlin A	9,397	189	0	2,166	974	0	673	4,002	42.59
Fire Clay Rider	25,206	612	0	2,289	1,491	0	1,845	6,237	24.74
Fire Clay	40,782	674	0	1,777	0	91	2,914	5,456	13.38
Lower Whitesburg	66,291	988	3	5,970	0	0	4,530	11,491	17.33
Williamson B	115,881	1,293	103	3,954	266	95	8,201	13,912	12.01
Upper Elkhorn 3.5	84,194	576	57	2,002	16,914	36	5,906	25,491	30.28
Upper Elkhorn 3D	73,681	739	266	6,856	4,146	0	5,116	17,123	23.24
Upper Elkhorn 3B	132,252	1,223	694	17,586	4,634	162	9,522	33,821	25.57
Upper Elkhorn 2B	125,989	974	911	21,961	52,329	804	8,918	85,897	68.18
Upper Elkhorn 1B	145,030	1,339	1,270	10,018	6,185	347	10,045	29,204	20.14
Lower Elkhorn Rider	75,172	560	1,195	39,689	21,070	0	5,121	67,635	89.97
Lower Elkhorn B	224,886	1,099	2,735	21,109	0	2,331	15,707	42,981	19.11
Powellton	6,034	153	284	4,693	0	0	0	5,130	85.02
Matewan	9,703	16	48	5,096	0	0	682	5,842	60.21
Eagle B	6,802	7	199	5,203	0	0	470	5,879	86.43
Glamorgan	32,175	0	1,121	9,743	0	0	2,221	13,085	40.67
Total	1,194,133	10,766	8,886	162,879	108,009	3,866	83,239	377,645	31.63

MINING METHODS

Local and practical mining methods were employed in the feasibility-type mine planning. Four surface mining methods were examined: area stripping, mountain top removal, contour stripping, and auger mining. Contour stripping, auger mining and mountain top removal were considered applicable, area stripping was not. Continuous miner and longwall operations were planned for deep mining, due to their high productivity, but conventional mining was not considered; however, it is recognized that conventional methods (drill, cut, and shoot) would have to be employed where geological conditions dictated. Recovery rates were determined for the applicable mining methods, and for the deep mining methods simple regression curves were fitted to the accumulated data for production rates—these were used to assign production rates for the deep mining methods by configuration and mining height. Surface transportation of coal, both washed and ROM, was addressed by measuring haulage distances to known wash plant locations and rail loadouts.

Mine Recovery Factors

For many years a convenient rule of thumb of 50% has been used when estimating the amount of recoverable reserves in a loosely defined resource or mining area. This type of average does not consider either the minability of deposits, changes in technology, or changes in demand for coal. It is impossible to predict accurately the eventual recoverability of all coal deposits; however, a current average of recoverabilities depicting today's technology and economics will be useful for estimating deposits that are presently minable.

Lowrie (*18*) makes a very good observation that bears repeating:

> The rationale, traditionally, for using the convenient figure of 50 percent as an acceptable approximation of average recovery is that it compensated for losses which were not ordinarily included at individual mines. This is an indefinite generalization which allows broad interpretation and perhaps erroneous exclusion of potentially recoverable deposits. Marginal deposits or those not ordinarily considered profitable or minable today, such as those behind prior workings, of poor quality, under adverse physical conditions, undermined, or underlying surface structures and so on, may be minable later rather than "lost.' Subsequent reevaluation of deposits as a result of changes in technology and economics should be made from a category other than "lost', which has a permanent connotation. Definitive evaluation of losses attendant in mining such deposits should be deferred until the time of exploitation.

Each mining method considered for this project demonstrates a recovery unique to that particular method. For this reason, variations of each method were investigated. The investigation included creating several "typical" models and calculating the recoveries, analyzing published and unpublished recovery data from government and industry sources, and drawing upon personal experience.

Recovery Considerations

The mining methods considered in this report are:

1. Contour strip (surface), with two coal thickness categories: 12 in to 36 in and greater than 36 in.
2. Auger (surface), with two coal thickness categories: 12 in to 36 in and greater than 36 in.
3. Continuous miner, five-entry system (underground), using two different pillar sizes: 40 ft by 40 ft and 80 ft by 120 ft.
4. Longwall, three entry development (underground), using two different pillar sizes: 40 ft by 40 ft and actual mine plan dimensions.

The following definitions that pertain to coal recovery, as used for this study, are derived from the USGS (*17*):

1. *Recoverable coal*—The coal that is or can be extracted from a coal bed during mining. The term "recoverable" should be used in combination with "resources" and not with "reserves."
2. *Recovery percent*—The percentage of coal extracted from a bed where the total tonnage originally in the bed is equal to 100%.
3. *Recovery factor*—The estimated or actual percentage of coal, expressed as a decimal, that can be or was extracted from the coal originally in a bed or beds of an area, mine, district, field, basin, region, province, township, quadrangle, county, State, political province, Nation, and/or the world.

The following 6 factors are identified as significantly affecting recovery percentages in underground mines (*18*):

1. Pillaring system.
2. Top rock and conditions.
3. Bottom rock and conditions.
4. Marketability.
5. Coalbed thickness.
6. Productivity.

The following 13 factors are identified as significantly affecting recovery percentages in strip mines (*19*):

1. Top coal removed with overburden.
2. Bottom coal left in place.
3. Coal lost in ribs between cuts.
4. Losses due to partings.
5. Losses due to other factors such as equipment limitations and spillage.
6. Outcrops (coal exposed to weathering's degradation).
7. Utility, railway, and highway rights-of-way.
8. Streams.
9. Underground workings.
10. Oil and gas wells.
11. Property lines.
12. Buildings.
13. Other, such as landslide areas and cemeteries.

The following 5 factors are identified as significantly affecting recovery percentages in auger operations (*19*):

1. Auger diameter.
2. Auger spacing.
3. Average auger penetration.
4. Coalbed thickness.
5. Length of coalbed available for augering.

Recovery Determination

A "typical" mine plan was drafted to scale with sufficient detail to incorporate the standard pillars, entries, and development works necessary to provide a representative scenario of the particular mining type under study. The mine plan was digitized, using the **GSMAP** computer program (*20*), to provide two dimensional digital information of the mine plan. The digitized data was reproduced on paper by a pen plotter to verify its accuracy. The areas of all pillars were then calculated by the **GSMAP** program. The accuracy and methodology of digitizing using **GSMAP** were checked on three seams using multiple-pass planimetering. The mining and restriction areas were nearly identical between methods.

Standard, or "average," recovery factors were established for each of several conditions and mining methods. It is recognized these are not, and cannot be considered, definitive under all conditions, but they do reflect today's technology and economic conditions more accurately than the often used 50% factor.

The following mine recovery factors are used for this study:

1. For contour strip mines—78% where the coal seam is less than 36 in thick, and 93% where the coal seam is greater than 36 in thick.
2. For auger mines—30%.
3. For continuous miner mines—62% where the pillars are 40 ft by 40 ft, and 57% where the pillars are 80 ft by 120 ft.
4. For longwall mines—84% where the pillars are 40 ft by 40 ft, and 78% where the pillars vary in size.

Recovery Model Dependencies

The resource recoverability calculations consist of the entire process of determining, from raw data, the amount and salability of coal from the area in question. The viability and accuracy of the calculations and associated modeling is dependent upon (1) the existence of a proven geologic model of the coal bed, (2) mining methods, (3) mining recovery, (4) mining sequence, (5) coal quality, and (6) dilution factors. Also influencing the model are coal washability parameters, wash plant recovery, mine size optimization, equipment configurations, land ownership, and all of the various environmental, social, and technical restrictions to mining. Equally important is the care with which the data are collected and used. Throughout the modeling process, utmost care was taken to assure that current, state-of-the-art methods were employed and that error was minimized.

Production Rates

The rate of production for surface and underground mining operations has long been discussed, studied, and computerized. Information on many of the factors influencing production within a specific coal seam, as shown in table 4, were not available during the data collection. Rather than calculate idealized production rates from the influencing factors, actual ROM production rates from Bureau evaluations and from industry and government publications were used. Contour strip and auger mining production rates were determined from mine evaluations and heavy equipment production charts and were fairly constant. Production rates for deep mining methods employing continuous miners or longwalls varied over a wide range. Longwall productivity appeared to correlate with mining height, and linear regression analysis proved this assumption to be correct, with very little scatter of the data points from the mean. Continuous miner productivity was found to have fairly good correlation to mining height after other mining factors had been accounted for. These other factors (e.g., available spare or standby equipment, supersections, remote controlled equipment, extremely good mining conditions, and retreat pillar robbing) foster significantly higher production rates than normal. Development mining, development for longwalls, and some captive mines, have lower than normal production rates. When the mine circumstances were addressed, the continuous mining productivity could be broken out into high, normal, and low production rates, and linear regression analysis suggested good correlation between mining height and production rate. These regression analyses are shown in figures 3(*A*) through 3(*D*).

Table 4.—Factors influencing mine productivity

Surface mining conditions	Deep mining conditions
Area of movement	Roof and floor conditions.
Ground slopes—dip of coal	Methane liberation.
Production needed	Cutability.
Overburden stability	Partings.
Seam thickness	Dip of coal.
Ground water—reclamation	Seam height.
Overburden—coal interface	Ground water.
Work force experience	Production layout.
Supervisors	Width of face.
Maintenance force	Depth of cut.
Equipment operators	Working time at face.
Mining applications	Planned maintenance.
Development	Remote-controlled equipment.
Panel production	Continuous haulage.
Pillar extraction	

Average production rates were determined for several ranges of mining heights and mining methods. Tables 5 and 6 show the production rates used in this study. These seam height configurations were used to specify production equipment sizing and capital costs for the mine costing models.

Table 5.—Surface production rates by mining method

Mining method	Production per seam method	
	12 - 36 in	>36 in
Contour stripping	5,200 BCY[1]/shift	6,500 BCY[1]/shift.
Area stripping	8,500 BCY[1]/shift	8,500 BCY[1]/shift.
Auger mining	175 tons/shift	250 tons/shift.

[1]BCY Bank cubic yards.

Table 6.—Deep mine production rates by mining method

Mining method	Production (tons/shift) per seam thickness			
	24 - 42 in	42 - 72 in	72 - 96 in	>96 in
Continuous miner . .	394	516	654	839
Longwall mining . . .	NA	1,609	2,451	3,575

NA Not applicable.

Mine Design

A feasibility program utilizing the three main Upper Elkhorn seams was begun in 1989. Isopach maps of the coal, interburden, overburden, previously mined areas, and land use restrictions were obtained from the USGS. Generalized mine plans were developed and the close proximity of the three seams to each other allowed the interaction from seam to seam to be studied during mine planning. This feasibility study demonstrated that preliminary mine plans and restrictions could be merged and an estimate of the recoverable resources could be made. Based on these findings, the program was expanded to include the remaining minable seams in the Matewan quadrangle and to develop mining cost models that would allow estimates of the economically recoverable resources.

The surface mining configuration was planned to operate with two separate fleets of equipment in two different locations at the same time. This procedure utilized support equipment, enhanced coal production and blending, and allowed sequencing of auger mining. The planning process assumed common ownership of surface and mineral rights and assumed that mining would be done in a logical, orderly manner for maximum recovery of the resource. Only contour stripping methods were applied in the Matewan quadrangle. Neither area mining nor mountain top removal was planned. The production parameters in contour stripping were dependent upon seam thickness. Seams 36 in thick or greater were assumed to have stripping rates of 6,500 BCY per shift, whereas seams that ranged in thickness from 12 in to 36 in had stripping rates of 5,200 BCY per shift. Mine bench widths varied, but a minimum of 80 ft was used for all stripping. The 80-ft minimum width allowed endloaders to safely load trucks and provided the trucks with enough room to turn around on the bench. Since the average ground slope is about 26° (48.8%), the minimum bench width could be maintained with seam thicknesses of less than 24 in. These conditions, along with the thin interburden between many of the seams, would allow multiple seam stripping. For this reason, the 80-ft minimum width bench was used for all strip-minable resources with seam thicknesses between 12 in and 24 in. During the surface planning, logical portal locations were noted for underground development. Surface mine production was evaluated using a work schedule of 8 hours per shift, 2 shifts per day, 5 days per week (240 days per year). It was assumed that the surface mining equipment would develop the "face-up" area for the deep mine portals, mine offices, and applicable stockpile areas. Reclamation plans would be developed that would leave enough bench area for production haul roads from the deep mine stockpiles.

Auger mining followed closely behind the stripping operations and utilized the coal production equipment and support equipment. It was assumed that the stripping operation left the highwall and bench in a condition that would require little maintenance by the auger operations. Twin-headed augers were the chief production equipment, having a compliment of drill heads and auger steel matched to the coal seam thickness. Average recovery

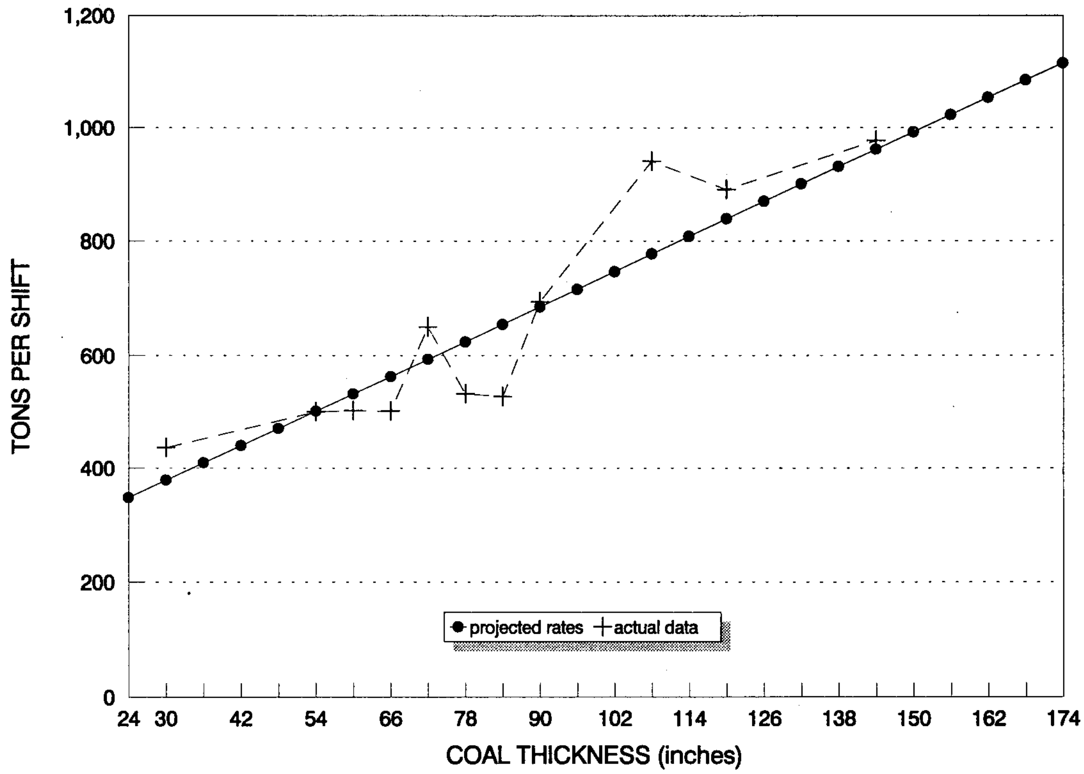

Figure 3 *(A)*.—Linear regression analysis: continuous miner—normal productivity.

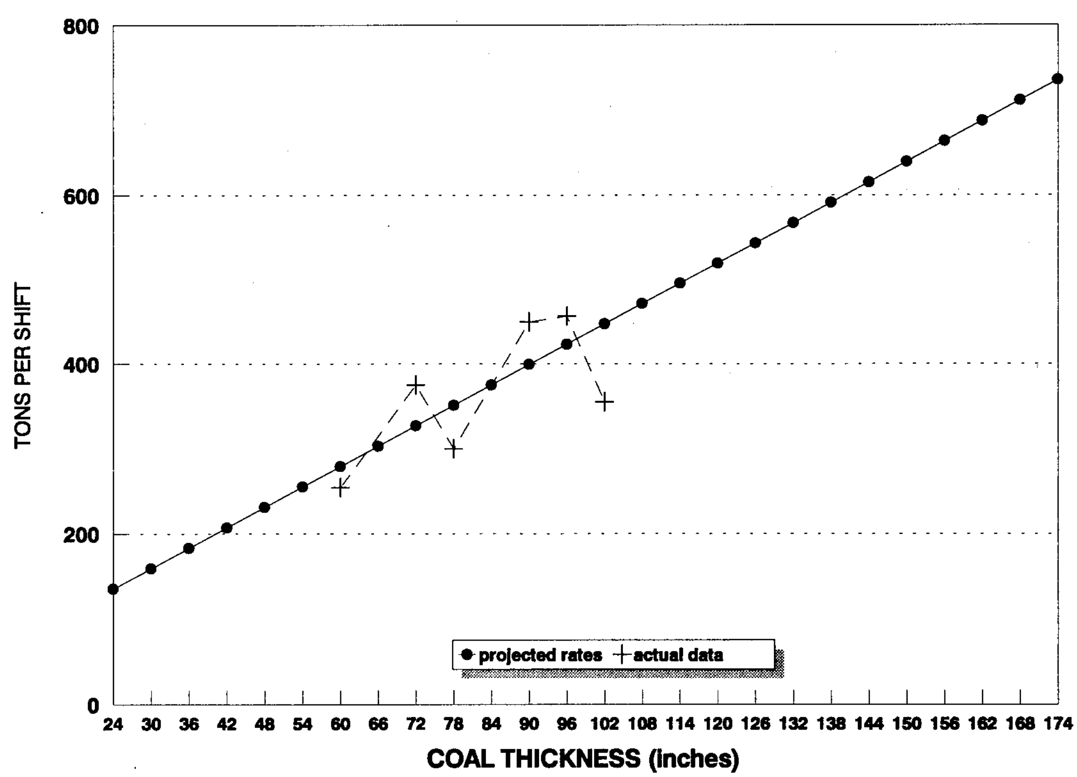

Figure 3 *(B)*.—Linear regression analysis: continuous miner—low productivity.

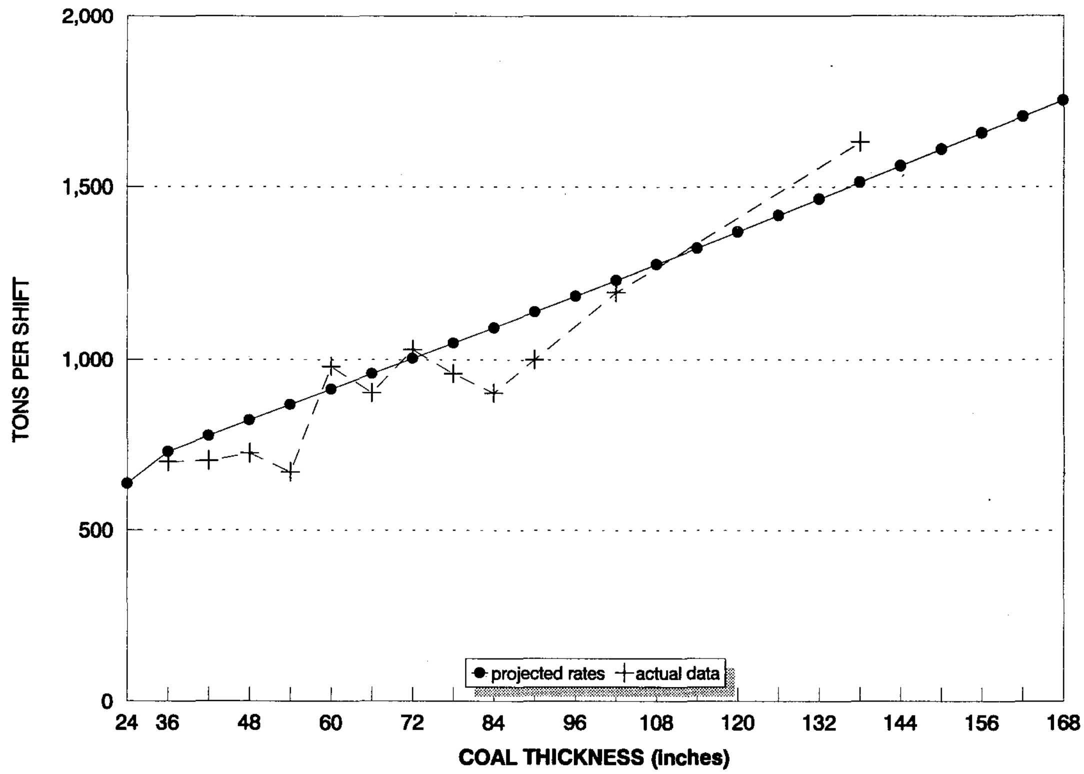

Figure 3 *(C)*.—**Linear regression analysis: continuous miner—high productivity.**

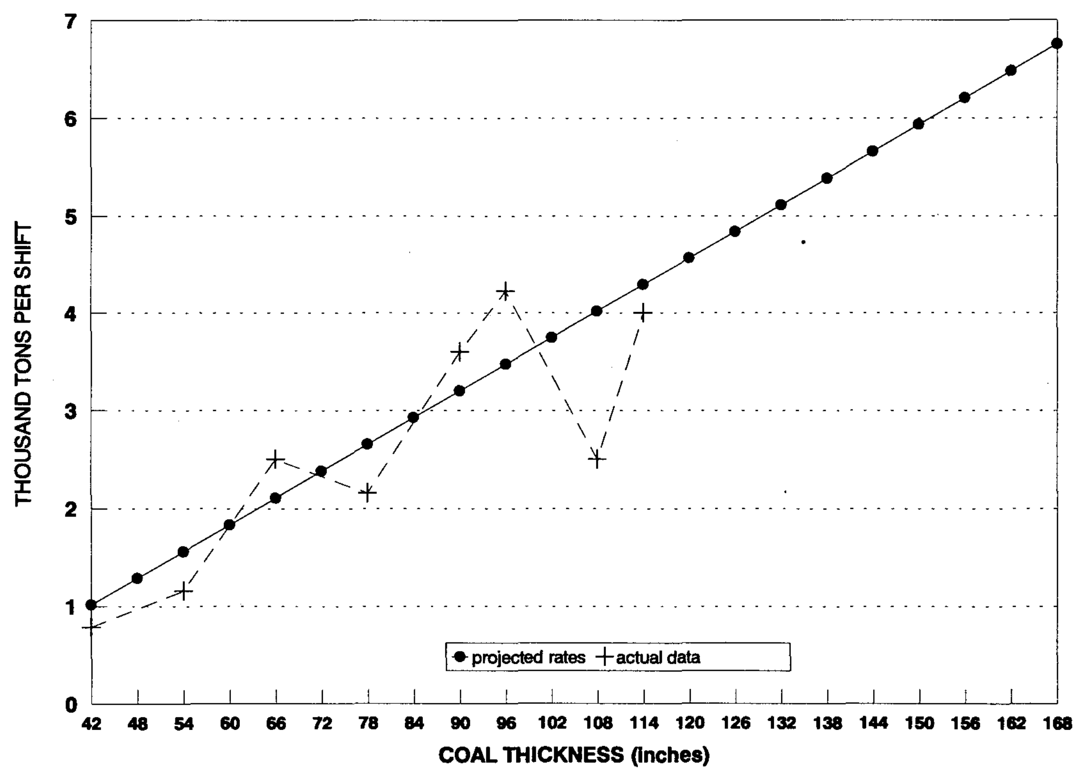

Figure 3 *(D)*.—**Linear regression analysis: longwall productivity.**

rates of 30% and average depth of holes of 60 ft were assumed. Highwall miners, while not specified, could be an option for the thicker seams.

Deep mine development was laid out with five mains, 18 ft to 20 ft wide, having normal offset barrier pillars and production panels employing room-and-pillar mining methods laid out at right angles to the mains. Submains were laid out beneath and parallel to the mountain ridges (spurs). Minimum panel widths were five entries; as the panels approached the outcrop, the minimum advance was with two entries. Only mining with continuous miners and longwalls was considered. The use of conventional room-and-pillar mining (drill, cut, and shoot) is fairly common in the Matewan quadrangle; however, wherever possible, operators are turning to continuous miners. Also, it is recognized that some coal seams are best mined by conventional methods due to particular geological conditions. That information was not available to the authors in the detail necessary for planning; therefore, conventional mining methods were not addressed in this study. The optimum-size operation was assumed to be two continuous miner production units for continuous mining methods, and two continuous miners and one longwall panel for a longwall operation. Minimum mining heights for continuous miners was set at 24 in of seam thickness and 5 in of out-of-seam dilution. The longwall minimum seam thickness was 42 in, with 3 in of out-of-seam dilution. Because of mining height restrictions on equipment, continuous miner operations had four separate height ranges: 24 to 42 in, 42 to 72 in, 72 to 96 in, and greater than 96 in. Also because of restrictions on equipment, longwall mining had three mining heights: 42 to 72 in, 72 to 96 in, and greater that 96 in. Equipment specifications, capitalization, production, etc., were all determined by these mining heights in the recovery and costing models. In addition to the minimum thickness of 42 in of seam height for longwalls, at present a machine size limitation (motor to horsepower limitations), panels were laid out with three entries on both sides of the panel, a minimum width of 550 ft, and a minimum length of 4,000 ft. Areas considered for longwall mining had to contain enough coal resource to depreciate the longwall equipment used in that seam. All deep mine production was scheduled for 8 hours per day, 2 shifts per day, 5 days per week (240 days per year). Production rates are noted in tables 5 and 6 by mining method and height.

Development methodology for the basic mine plans is listed below:

1. Understanding of the coalbed to be planned and the superjacent and subjacent minable seams.
2. Identification of the effect of the land use restrictions on the subject bed.
3. Ground slope determination, along the outcrop, to outline areas having an undisturbed slope greater than 32°—for technical restrictions and for determining the highwall stripping ratio cutoff.
4. Surface mine design using the maximum 20:1 highwall ratio to determine the bench widths and stripping areas. Where the highwall ratio could be greater than 20:1, a minimum bench width of 80 ft was used.
5. Auger mining planned to coordinate with the stripping. Production tonnages were calculated by bench length, seam thickness, depth of auger holes, and normal recovery rate.
6. Underground mine development planned using working site areas prepared during stripping. Mains and submains were planned to be driven parallel to and beneath the mountain ridges.
7. Evaluation of seams for areas that met or exceeded the minimum longwall criteria. When a potential longwall area was found, the panels were laid out and the continuous miner plans were designed around the longwall plan.
8. Integration of the coal-haulage zone map with the mine plans. Original resources, restrictions, and minable resources were calculated for each haulage zone.

Using the above guidelines, the first mine plan maps were constructed for the Upper Elkhorn 1B seam (fig. 4). Planning for the Upper Elkhorn 2B seam followed, and conflicts between the mining plans for the 1B and 2B seams were resolved where necessary (i.e., where the interburden between the two seams was less than 40 ft). Next, the Upper Elkhorn 3.5 seam was planned. Since the interburden between the 3.5 and 3D seams exceeded 40 ft in thickness, there were no mining plan conflicts between these seams; however, the interburden between the Upper Elkhorn 3.5 and Williamson seams was thinner than 40 ft in many areas and caused major mining plan conflicts between the two seams. In this same way, mine plan maps of the other eighteen coal seams were subsequently constructed.

SURFACE TRANSPORTATION

Topography in the Matewan quadrangle is rugged, having valley wall slopes ranging from 15° to 32° (27% to 63%) and valley floors sloping from 2° to 13° (4% to 23%). Four major ridges control the watersheds in the quadrangle. During the initial tour and investigation of the quadrangle, the authors noted that coal was not transported over these main ridges. Indeed, only one ridge was crossed by a paved highway. Therefore, for the sake of efficiency, local practice was for all loaded trucks to haul coal downhill by the most convenient route to their destinations. Locations of preparation plants and train

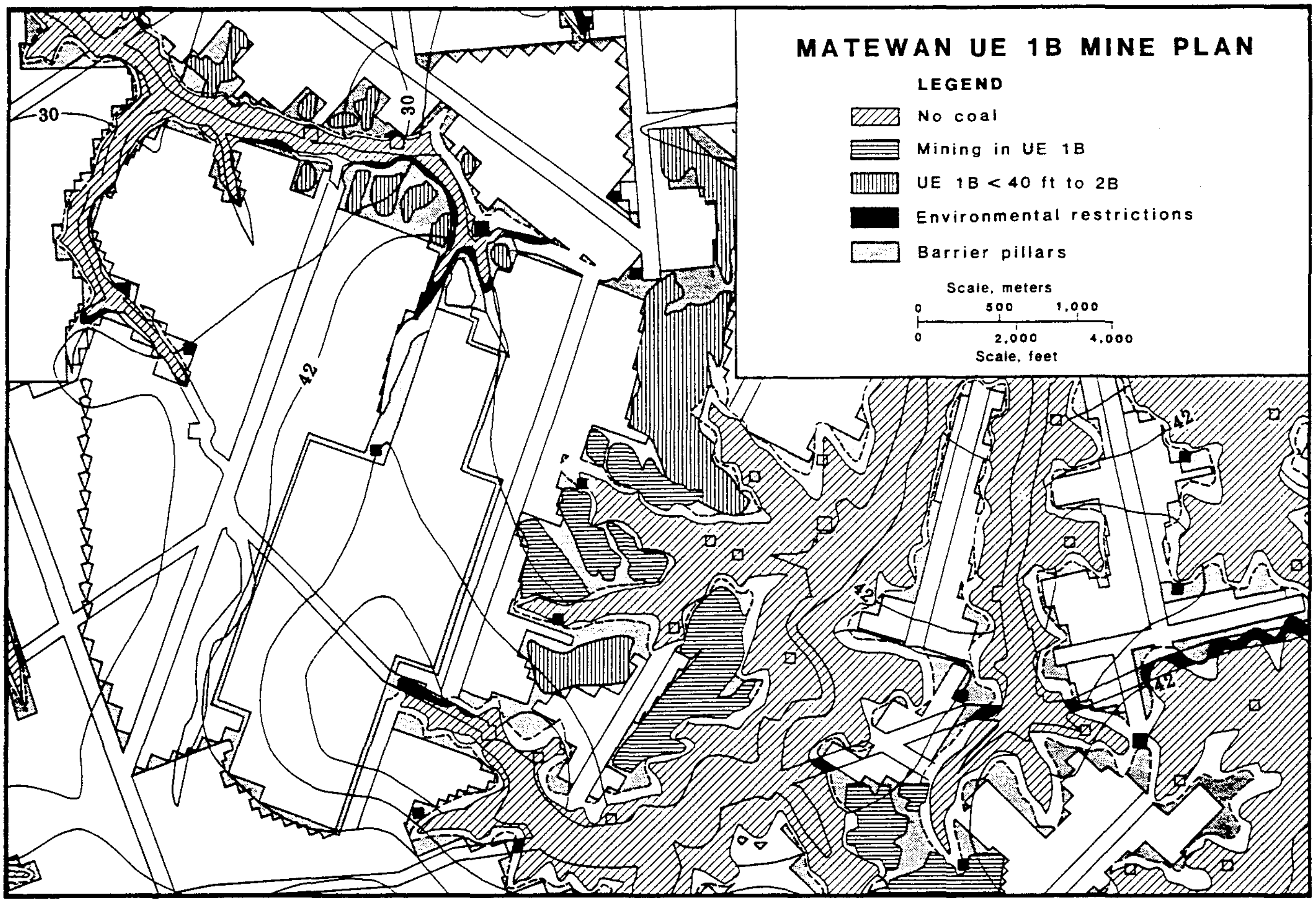

Figure 4.—Typical feasibility-type mine plan.

loadouts were obtained from the DSMRE permit maps. State, Federal, and county roads were located on the USGS 7-1/2-minute topographic map. After reviewing the geology and the potential for mining within the different watersheds, the quadrangle was divided into 16 haulage zones (fig. 5). The geographical center of all minable coal beds was located in each haulage zone and assumed to be the mine coal stockpiling area. Haulage distances were estimated from the stockpile area to the closest preparation plant and/or rail loadout. In this haulage scenario, the following assumptions were made:

1. The closest wash plant always had the capacity to handle the delivered ROM coal.
2. Only wash plants with rail loadouts were used, thus eliminating double handling of the coal. Studies were conducted to see if the costs would be less to haul to a nearby mine washing facility, clean the coal, reload the trucks, and then haul to a rail facility. However, none of the Matewan quadrangle coal seams contained enough ash to justify loading the coal in a truck the second time. Of course, this justification is valid only if enough washing capacity is available from facilities with rail loading capabilities.
3. No new washing facilities were necessary; however, it was assumed that all wash plants were operated at high efficiency rates, with idealized labor needs, and at normal operating costs.
4. All surface haulage of coal was done by contractor owned- and-operated trucks. Coal haulage contract costs for the southeast Kentucky, southern West Virginia, and southwestern Virginia areas were calculated as a fixed cost per truck plus a cost per ton-mile. These are included in the mine cost models as a basis for calculating the coal haulage costs. Escalating factors are used in the models to keep costs on a current level. Table 7 shows the one-way haulage distance and the cost assigned to each zone, for the Matewan quadrangle, as used in this study.

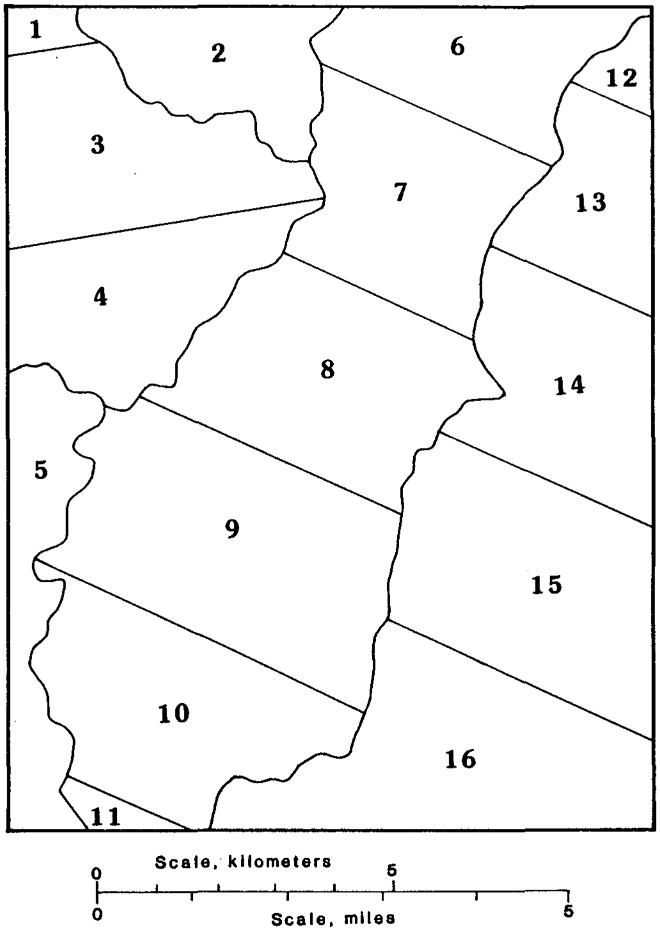

Figure 5.—Matewan quadrangle haulage zones.

Table 7.—Haulage distance one way and assigned cost by zone

Zone	Distance (miles)	Cost (dollars)
1	0.25	0.54
2	1.00	.65
3	1.00	.65
4	3.00	.95
5	1.75	.76
6	.65	.60
7	1.00	.65
8	3.00	.95
9	5.00	1.25
10	7.00	1.55
11	8.25	1.74
12	1.50	.73
13	3.00	.95
14	1.00	.65
15	1.00	.65
16	3.00	.95

COAL QUALITY

Information concerning the quality of the coals within the Matewan quadrangle ranges from extensive to nonexistent. Due to the variability of coal characteristics throughout central Appalachia, an attempt was made to determine coal quality for the various seams from analyses specifically from the Matewan quadrangle. When analyses from within the quadrangle could not be found, however, coal quality analyses from adjacent or nearby areas were then used. As may be imagined, the most productive coal seams have the greatest available amount of coal quality information, whereas the nonproductive seams have little or no coal quality information specific to the quadrangle.

Current information indicates that all the coals within the quadrangle are low- or medium-sulfur, high-volatile, bituminous varieties. If the standard of 1.2 lb of SO_2 per MBtu is considered, there are almost equal amounts of compliance coals and noncompliance coals within the quadrangle. Since coal quality data for all but two of the seams is limited, the information represents a restricted characterization of the coal within the Matewan quadrangle and is not statistically supported for precise quality portrayal.

COMPUTERIZATION

Raw data accumulated by the KGS and the USGS are in the NCRDS. The data are retrieved as ASCII (American Standard Code for Information Interchange) data files, as needed for input to the system's **GARNET** (Graphic Analysis of Resources using Numerical Evaluation Techniques) computer program, and transmitted to the computers at the Bureau Intermountain Field Office in Denver, via the USGS computer linking network—Geonet. The following data are provided:

1. Coal seam extent (outcrop) and thickness (isopachs).
2. In-seam parting distribution and isopachs.
4. Overburden and interburden isopachs and structure contours on the bottom of the coal seam.
5. Mined-out areas and their barrier pillars, both surface and underground.
6. USGS-defined environmental and land use mining restrictions.
7. USGS-defined technological mining restrictions.

Using these data, estimates of coal resource tonnages for the Matewan quadrangle were developed. First, however, mine planning was done manually on a printed plot—1 in equals 2,000 ft scale—of each coal seam; included on each plot was the appropriate data (coal and parting information, mining restrictions, etc.) for that coal seam. Then, using the **GSMAP** program, the mining plans for the coal seams were digitized to produce computer data files. These data files, along with those supplied by the USGS, were then used as input to the **GARNET** program, which does all the work of calculating the resource tonnages.

Before resource tonnage calculations are performed, however, the **GARNET** program is used to create files that designate different mining thickness categories and files that designate different geographic zones within the quadrangle. The steps required to reach the resource figures are not all the same for each mining method.

For the contour strip method—

1. The mining plan file for each coal seam consists of digitized data lines defining the toe of the final highwall within the seam outcrop. When this mining plan file is then combined[4] with the coal seam outcrop file (fig. 6), a third file is produced that delineates the possible contour strip minable areas for the seam within the quadrangle (fig. 7).
2. Areas of restricted mining are removed from the areas delineated possible for contour strip mining (fig. 8). The restriction files contain environmental and land use restrictions in addition to table 1 restrictions—federally funded highways (protected by a 100 ft buffer), historic sites, non-Federal public parks, and many Federal lands (e.g., national parks)—and mined-out surface and underground resources.
3. The contour strip minable seam file, when combined with the thickness category files derived from the isopach of the seam thickness, produces files delineating resources that are 12 in to 36 in thick and resources that are greater than 36 in thick (figs. 9 and 10).
4. The study area is partitioned into transportation zones in order to derive haulage costs. The center of each zone designates the source point for coal to be hauled to existing preparation plants or railheads. The resource is subdivided among the transportation zones by combining the thickness files with files that delineate each of the zones. The resulting data files then represent the seam area that contains the contour strip minable resources, divided by thickness categories and subdivided by transportation zones (fig. 11). The figure shows all zones and their resources as one map. In practice, however, each zone and its associated resource is a single data file, or map.

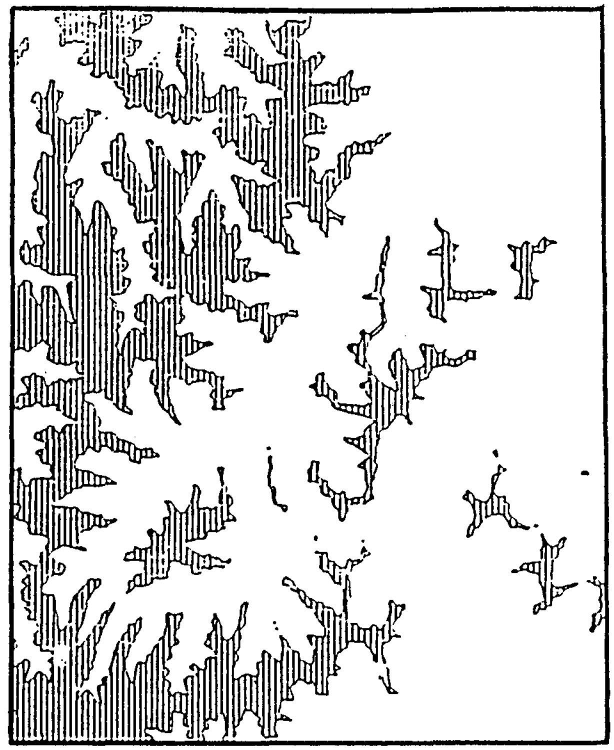

Figure 6.—Resource distribution within a Matewan quadrangle coal seam.

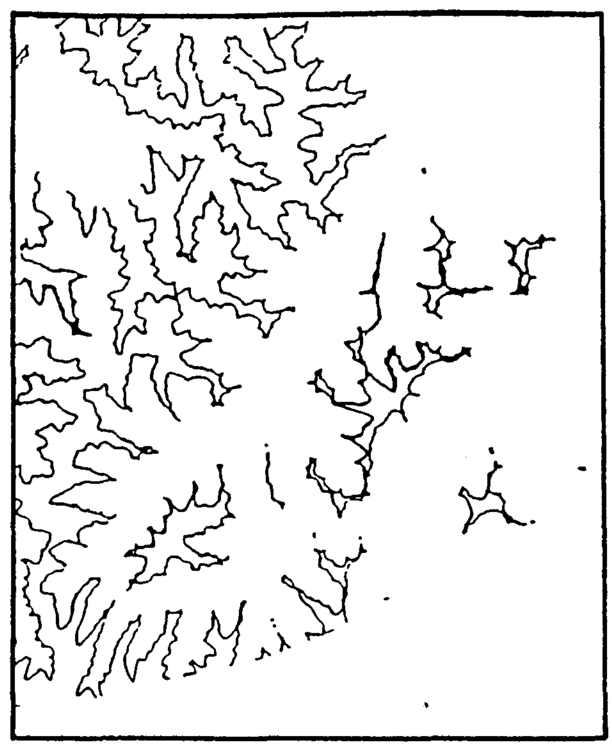

Figure 7.—Contour strip-minable coal for the seam in figure 6.

[4]Combine is the **GARNET** operation in which areas are added or subtracted.

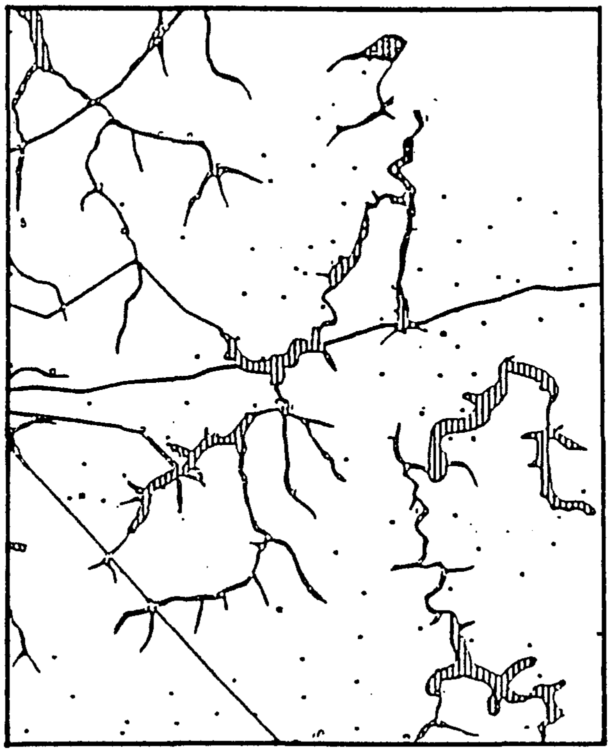

Figure 8.—Land use restrictions in the Matewan quadrangle.

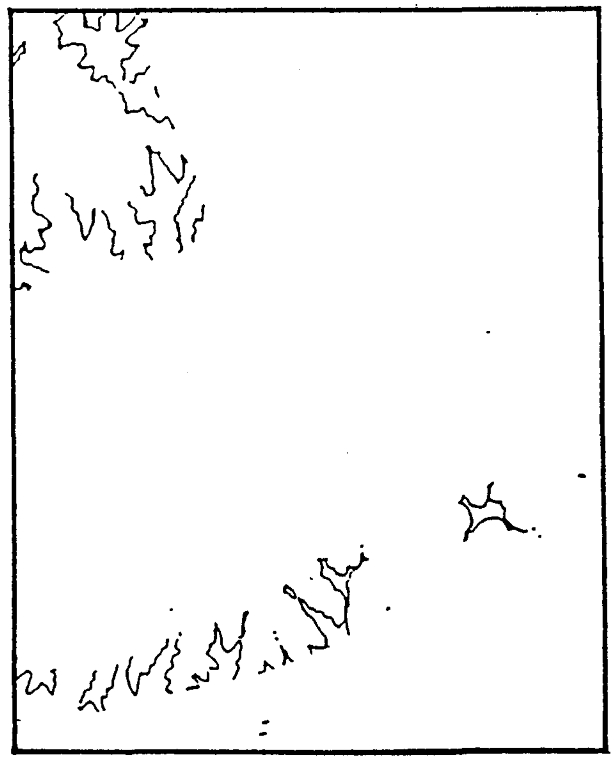

Figure 9.—Contour strip-minable coal 12 in to 36 in thick.

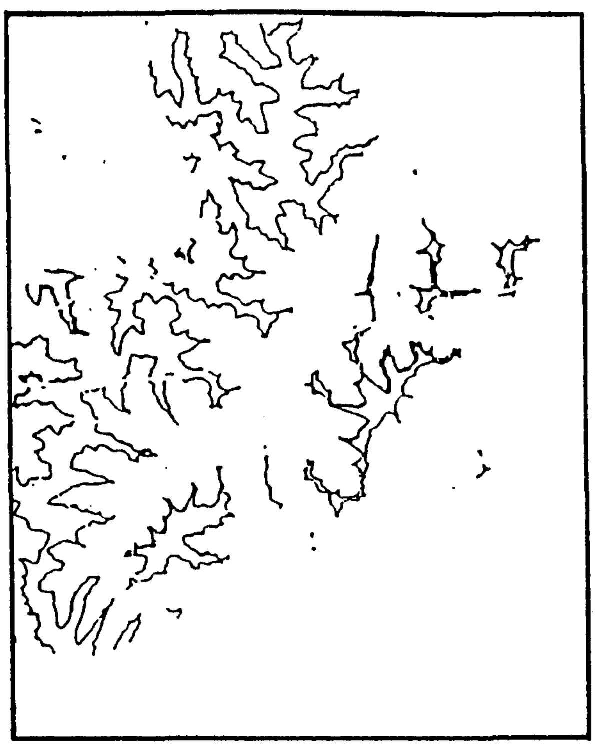

Figure 10.—Contour strip-minable coal greater than 36 in thick.

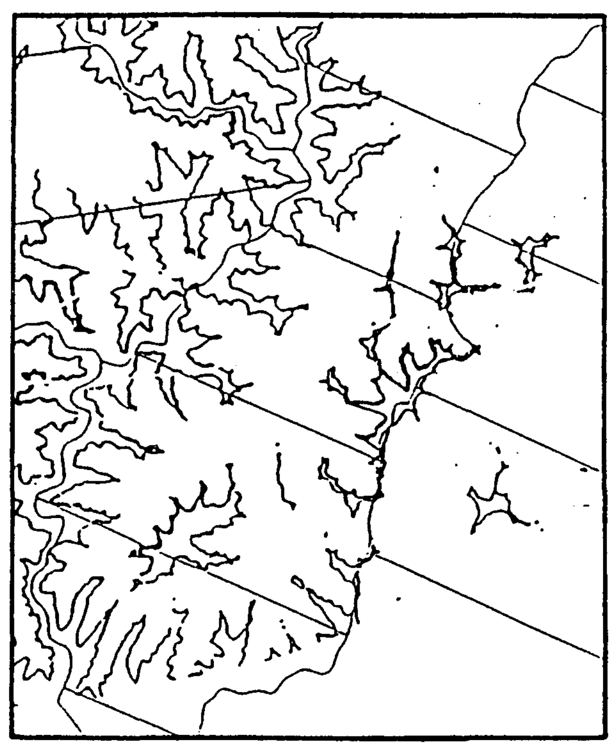

Figure 11.—Contour strip-minable coal and transportation zones.

For the continuous miner method—

1. The mining plan file for each coal seam consists of digitized data lines defining the possible underground development and production panels within the quadrangle (fig. 12).
2. Previously determined mining thickness categories of 24- to 42-in, 42- to 72-in, 72- to 96-in, and greater than 96-in seam thicknesses are used to divide the continuous miner resources.
3. The restrictions to underground mining, and thus the resources that must be eliminated, include a square (200 ft on each edge) around oil and gas wells and coal that is within 40 ft of a subjacent or superjacent seam of greater thickness. Mined-out sections of the quadrangle are not part of the data files—they are incorporated as a restriction during the mine planning and digitizing.
4. As with the surface mining resources, the continuous miner resources, already divided by thickness categories, are subdivided by transportation zones (fig. 13). The resulting data files represent the part of the seam containing the minable continuous miner resources.

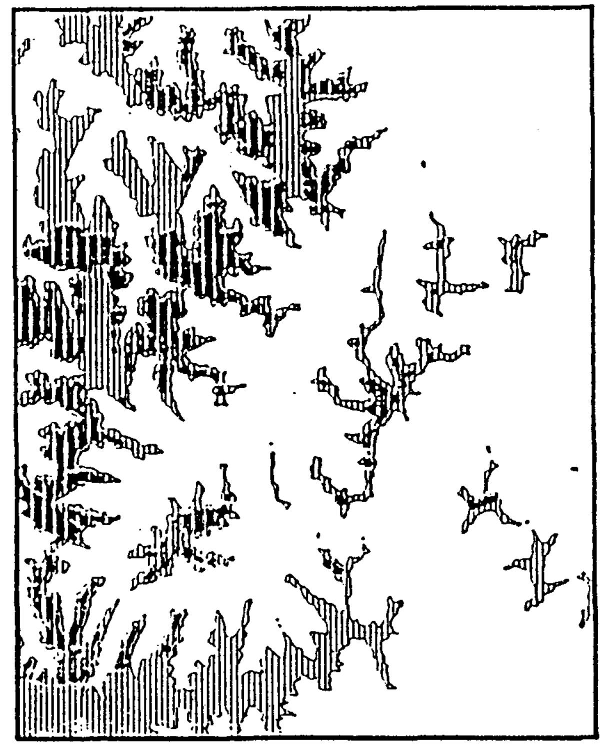

Figure 12.—Deep mining (continuous miner) areas in a Matewan quadrangle coal seam.

For the longwall mining method—

1. The mining plan file for each coal seam consists of digitized data lines that outline areas in which the panels and supportive mining would be situated within the quadrangle (fig. 14).
2. Longwall resources are divided into 42- to 72-in, 72- to 96-in, and greater than 96-in thicknesses.
3. Currently, all environmental, land use, and technological restrictions are accounted for during the mine planning; therefore, these restrictions do not need to be subsequently subtracted.
4. The resources, previously divided by thickness categories, are subdivided by transportation zones. The resulting data files then represent the portion of the seam containing the minable longwall resources (fig. 15).

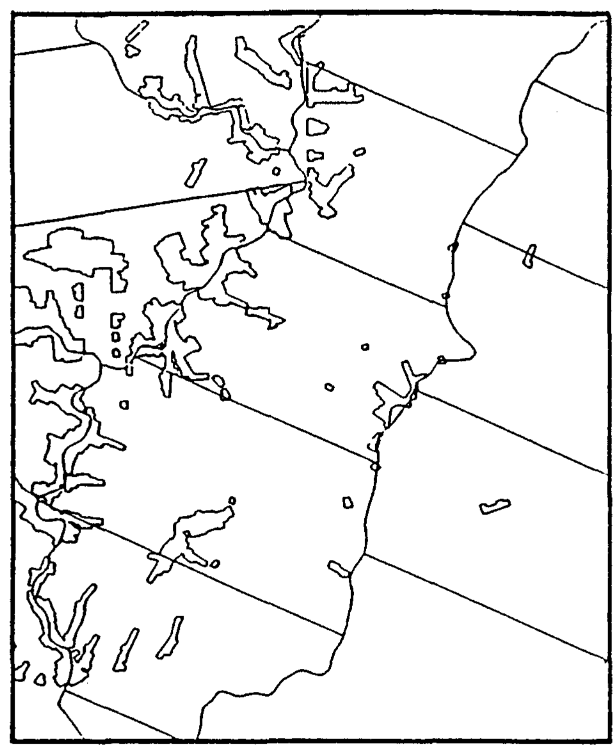

Figure 13.—Deep mining (continuous miner) areas and transportation zones.

Figure 16 shows all three methods of mining in a seam, having the coal thickness isopach lines superimposed. When the resource data files for each of the three mining methods have been created, they are checked for integrity using **GARNET**. The resulting minable resources are compared with the USGS Coal Availability results, to check for relative compatibility, and the data converted from the **UNIX** computer operating system into the **MS-DOS** operating system. If compatibility is established, the data is imported directly into a **Lotus 1-2-3**,[5] version 2.2, computer program called **COALVAL**.

[5]Reference to specific trade names or manufacturers does not imply endorsement by the U.S. Bureau of Mines.

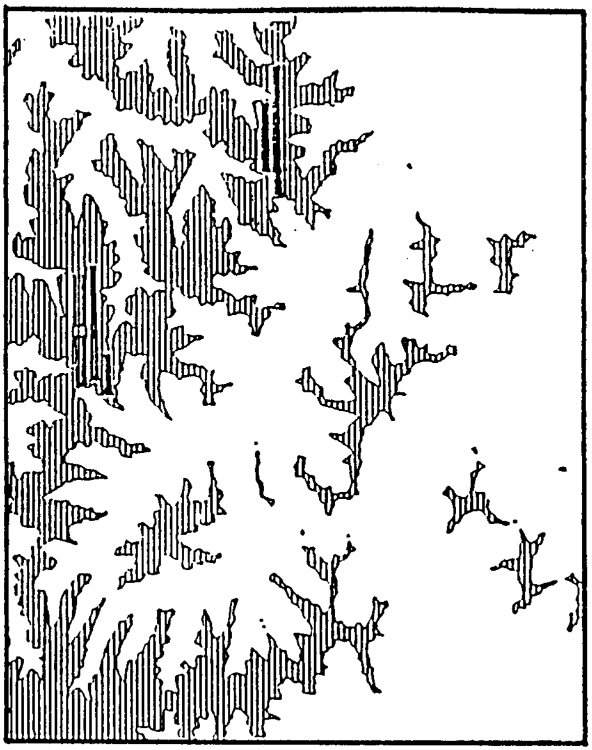

Figure 14.—Longwall mining areas in a Matewan quadrangle coal seam.

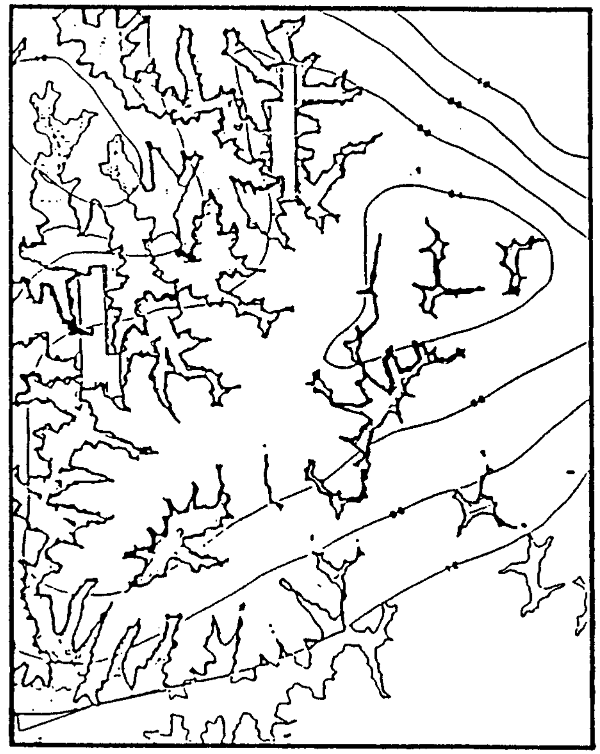

Figure 16.—All mining types in a Matewan quadrangle coal seam.

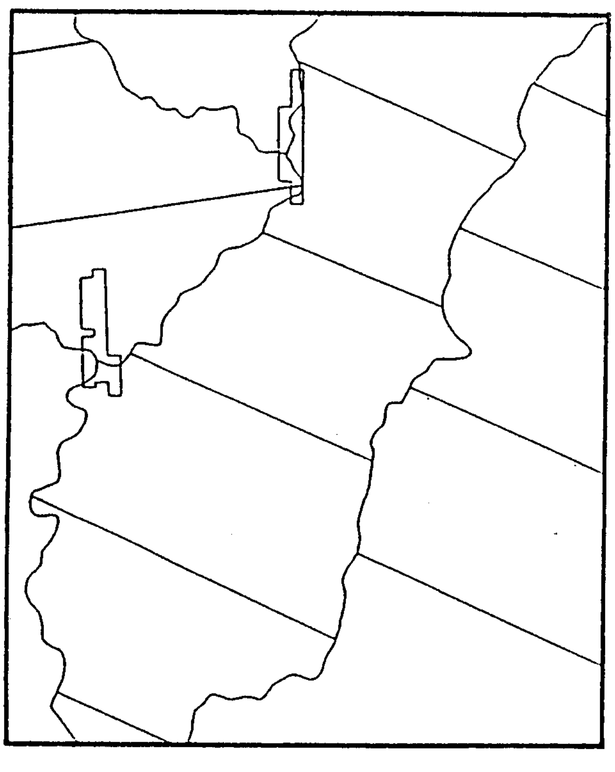

Figure 15.—Longwall mining areas and transportation zones.

The recoveries and costs derived during the study were calculated using **COALVAL**, a menu-driven interactive spreadsheet program that was written by Bureau personnel for use in this study. The program produces a cost analysis of coal reserves that have previously been mine planned. **COALVAL** uses cost models that were developed in-house for use in the Appalachian coal fields; the models are being modified for use in other areas of the country as the Bureau's Coal Recoverability program matures.

COALVAL allows mine evaluators to input their reserve data and the various production, operating, and cost variables that pertain to their property. The software can evaluate up to 25 seams, each to be mined with up to 5 different mining methods, within a given area. Summary spreadsheets are produced for each mining method-seam combination. The end result of the evaluation is the cost per ton to mine the reserve.

The advantage of using **COALVAL** is that, relative to hand generating numbers, it quickly and accurately costs mine-planned coal reserves. Prior to the development of the software package, 15 person-weeks were required to cost the Matewan quadrangle reserves using the cost models that were eventually incorporated into **COALVAL**. The same result can now be accomplished in a matter of a day or two with **COALVAL**.

COMPUTER HARDWARE

The computer operations for the Coal Recoverability study require workstations with—

1. A large (19-in), high-resolution monitor: **GARNET** is a graphics program that displays and allows editing of maps.
2. Large data storage capacity: The division and subdivision of resource files creates data representing all mining types, thickness categories, and transportation zones—over 800 files for the 21 Matewan quadrangle seams. The files may range in size from a few hundred bytes to several hundred thousand bytes and require 10 to 15 megabytes of disk space per seam. The Matewan quadrangle files required 315 megabytes of disk space and additional megabytes of memory were needed for the resident software programs and the **UNIX** working system.
3. Networking: The computer network link (Geonet) allows access to the NCRDS data and USGS software in Reston. Local workstations are networked together to share software, disk storage, and peripheral equipment.
4. Back-up facilities: Workstations have one-quarter-inch tape drives for backing up current computer files and for archiving the completed work.
5. Digitizing facilities: Digitizing is done on a PC-type computer using **GSMAP**. The data files are transferred to the workstations via the network.
6. Output devices: A dot matrix printer is used for printing the output files from **GARNET**; a 42-in plotter, which allows reproduction of large maps to scale, is used to make work copies of the seam data and mine plans. A laser printer, of graphics quality, is connected to the network to provide the screen dump capability of making work and archive copies on letter size pages.

RECOVERABLE RESOURCE CALCULATIONS

Resource recovery models were developed on **COAL-VAL** spreadsheets for each mining method used in the quadrangle. The Matewan quadrangle includes contour strip mining, underground room-and-pillar mining, longwall mining, and auger mining. **GARNET** output data files are reformatted and transferred to the spreadsheets.

Minable resource information imported from the **GARNET** calculations are (1) the haulage zone, (2) acres of minable resource by zone and thickness, (3) tons of coal by zone and thickness, and (4) tons of parting by zone and thickness. The spreadsheets calculate the recoverable resources and operating costs associated with those resources (tables 8-11). The tons of out-of-seam dilution were separated by mining height and mining method. Tonnage calculations use the same density for dilution as for in-seam parting (assumed to be 2,400 tons/acre-foot).[6] The recovery model adds the coal resource tons, in-seam parting tons, and out-of-seam dilution tons (mining dilution), applies the appropriate mining recovery factor, and calculates a ROM coal recovery for each mining method (tables 8-11).

Coal was considered minable until the in-seam parting thickness equalled 50% of the total seam thickness. Although this assumption is not based on a physical mining limitation, it is reflected in the costing models because such an in-seam parting thickness is a cost limitation. Several mine evaluations, in and around the quadrangle, indicated that the ratio of ROM coal tonnage to waste tonnage was only slightly higher than 1:1.

The next recovery calculation deals with cleaning (washing) the ROM product to produce a salable product. The preparation plant recovery, and the resulting salable product, are calculated for each haulage zone by mining method and seam thickness category (tables 8-11). Review of the central Appalachian coal quality data, modern coal preparation plants, and coal spot and contract markets provided a basis for the models. The following items were of considerable importance:

1. Coal washing did not significantly improve the sulfur content in the salable product (i.e., most of the sulfur was tied up in the organic material, not as pyrite; therefore, it could not be easily removed).
2. Most of the modern preparation facilities examined had processes that would recover an average of 94% of the available coal from the ROM tonnage and would substitute only 6% of the parting material for coal in the final washed product. These average figures were incorporated into the recovery model because definitive density and washability information was not available in sufficient detail for most seams in the quadrangle.
3. The assumed cut-off between washed and direct-shipped coal was based on an ash content of 9%, or greater, in the ROM product. In-seam parting material and out-of-seam dilution were assumed to be 100% ash. Parting material density was assumed to be 2,400 tons/acre-foot. Coal was assumed to have a density of 1,800 tons/acre-foot.

The total recoverable resource is calculated by subtracting from the total original resource (including coal, in-seam parting, and mining dilution) previously mined-out and/or abandoned resources and resources unavailable due to environmental, technical, and barrier restrictions.

[6]It is recognized that roof, floor, and in-seam parting each have different densities but due to the complexity created by trying to accommodate each density, a single standard of 2,400 tons/acre-foot was adopted.

Table 8.—Contour strip—recoverable resources and cost ranges

MATEWAN QUADRANGLE
LOWER WHITESBURG B SEAM

***** CONTOUR STRIP SALES - ALL THICKNESSES *****

Haul Zone #	Mining Thick. (in)	Acres in zone	Coal Tons	Parting Tons in seam	Dilution out of seam	Minable Resource	Washed Coal	Washed Parting	Washed Resource	% Mine Recovery	ROM Tons	%WP Recovery	Saleable Tons	Cost/ton (in car)	Saleable Tons in <$25 RANGE	Saleable Tons in $25-30 RANGE	Saleable Tons in $30-40 RANGE	Saleable Tons in $40-50 RANGE	Saleable Tons in >$50 RANGE
1	12-3	10.79	19641	2667	2158	24466	18070	193	18263	0.78	19083	0.746	14245	$29.21	0	14245	0	0	0
1	>36	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
2	12-3	54.41	225566	596	10882	237044	207520	459	207979	0.78	184894	0.877	162224	$25.77	0	162224	0	0	0
2	>36	142.32	1154726	5341	28464	1188531	1062348	1352	1063700	0.93	1105334	0.895	989241	$22.54	989241	0	0	0	0
3	12-3	105.83	346067	5478	21166	372711	318382	1066	319447	0.78	290714	0.857	249169	$26.25	0	249169	0	0	0
3	>36	58.78	426480	6947	11756	445183	392361	748	393110	0.93	414020	0.883	365592	$22.77	365592	0	0	0	0
4	12-3	97.45	393282	12839	19490	425611	361819	1293	363112	0.78	331976	0.853	283228	$26.68	0	283228	0	0	0
4	>36	207.78	1515532	62701	41556	1619789	1394290	4170	1398460	0.93	1506404	0.863	1300568	$23.50	1300568	0	0	0	0
5	12-3	19.96	71152	130	3992	75274	65460	165	65625	0.78	58714	0.872	51187	$26.02	0	51187	0	0	0
5	>36	156.7	1282155	103926	31340	1417421	1179583	5411	1184994	0.93	1318202	0.836	1102044	$23.87	1102044	0	0	0	0
6	12-3	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
6	>36	21.14	168462	3144	4228	175834	154985	295	155280	0.93	163525	0.883	144410	$22.71	144410	0	0	0	0
7	12-3	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
7	>36	185.36	1885156	355855	37072	2278084	1734344	15717	1750061	0.93	2118618	0.768	1627557	$25.37	0	1627557	0	0	0
8	12-3	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
8	>36	348.17	3393343	604605	69634	4067582	3121875	26970	3148845	0.93	3782851	0.774	2928426	$25.59	0	2928426	0	0	0
9	12-3	0.88	3944	366	176	4486	3629	22	3650	0.78	3499	0.814	2847	$28.07	0	2847	0	0	0
9	>36	282.37	2684715	336085	56474	3077274	2469938	15702	2485640	0.93	2861865	0.808	2311645	$25.10	0	2311645	0	0	0
10	12-3	97.81	287819	26114	19562	333495	264793	1827	266620	0.78	260126	0.799	207964	$28.83	0	207964	0	0	0
10	>36	141.63	1029807	129846	28326	1187980	947423	6327	953750	0.93	1104821	0.803	886987	$25.58	0	886987	0	0	0
11	12-3	0.88	1697	0	176	1873	0	0	0	0.78	1461	1.000	1461	$22.46	1461	0	0	0	0
11	>36	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
12	12-3	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
12	>36	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
13	12-3	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
13	>36	23.6	261032	108072	4720	373824	240149	4512	244661	0.93	347656	0.654	227535	$29.28	0	227535	0	0	0
14	12-3	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
14	>36	108.87	1168170	437865	21774	1627809	1074716	18386	1093102	0.93	1513862	0.672	1016585	$28.25	0	1016585	0	0	0
15	12-3	9.64	34415	8844	1928	45187	31662	431	32092	0.78	35245	0.710	25032	$30.57	0	0	25032	0	0
15	>36	28.73	216689	40722	5746	263157	199354	1859	201213	0.93	244736	0.765	187128	$25.46	0	187128	0	0	0
16	12-3	17.52	50611	4437	3504	58552	46562	318	46880	0.78	45671	0.801	36566	$28.08	0	36566	0	0	0
16	>36	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
TOTALS		2120.62	16620460	2256580	424124	19301164	15289263	107221	15396484	0.92	17713278	0.797	14121640		3903316	10193292	25032	0	0

	TONS	% OF TOTAL
TOTAL TONS <$25 RANGE:	3,903,316	27.64
TOTAL TONS $25-30 RANGE:	10,193,292	72.18
TOTAL TONS $30-40 RANGE:	25,032	0.18
TOTAL TONS $40-50 RANGE:	0	0.00
TOTAL TONS >$50 RANGE:	0	0.00
TOTAL TONS	14,121,640	100.00
CHECK	14,121,640	

Table 9.—Continuous miner—recoverable resources and cost ranges

MATEWAN QUADRANGLE
LOWER WHITESBURG B SEAM

***** CONTINUOUS MINER SALES - ALL THICKNESSES *****

Haul Zone #	Mining Thick. (in)	Acres in zone	Coal Tons	Parting Tons in seam	Dilution out of seam	Minable Resource	Washed Coal	Washed Parting	Washed Resource	% Mine Recove	ROM Tons	%WP Recovery	Saleable Tons	Cost/ton (in car)	Saleable Tons in <$25 Range	Saleable Tons in $25-30 Range	Saleable Tons in $30-40 Range	Saleable Tons in $40-50 Range	Saleable Tons in >$50 Range
1	24-42	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
1	42-72	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
1	72-96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
1	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
2	24-42	82.43	403221	926	65944	470091	370963	2675	373638	0.62	291456	0.795	231656	$29.49	0	231656	0	0	0
2	42-72	236.51	1964530	9239	94604	2068372	1807367	4154	1811521	0.62	1282391	0.876	1123143	$25.17	0	1123143	0	0	0
2	72-96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
2	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
3	24-42	54.09	272999	1249	43272	317519	251159	1781	252940	0.62	196862	0.797	156823	$29.44	0	156823	0	0	0
3	42-72	75.4	596044	7525	30160	633729	548361	1507	549868	0.62	392912	0.868	340918	$25.35	0	340918	0	0	0
3	72-96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
3	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
4	24-42	378.77	1821387	54805	303016	2179208	1675676	14313	1689989	0.62	1351109	0.776	1047793	$30.45	0	0	1047793	0	0
4	42-72	559.2	4063392	200322	223680	4487393	3738320	16960	3755280	0.62	2782184	0.837	2328274	$26.41	0	2328274	0	0	0
4	72-96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
4	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
5	24-42	89.33	326809	8255	71464	406528	300664	3189	303853	0.62	252047	0.747	188389	$31.13	0	0	188389	0	0
5	42-72	383.54	3221273	309044	153416	3683733	2963572	18498	2982070	0.62	2283915	0.810	1848883	$26.89	0	1848883	0	0	0
5	72-96	46.5	453288	85330	18600	557218	417025	4157	421182	0.62	345475	0.756	261133	$25.81	0	261133	0	0	0
5	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
6	24-42	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
6	42-72	16.24	144899	316	6496	151712	133307	272	133580	0.62	94061	0.880	82819	$25.01	0	82819	0	0	0
6	72-96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
6	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
7	24-42	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
7	42-72	143.18	1308498	93934	57272	1459703	1203818	6048	1209866	0.62	905016	0.829	750117	$26.27	0	750117	0	0	0
7	72-96	119.91	1221124	150419	47964	1419508	1123434	7935	1131370	0.62	880095	0.797	701449	$24.64	701449	0	0	0	0
7	>96	4.06	45543	15669	1624	62835	41899	692	42591	0.71	44613	0.678	30239	$25.85	0	30239	0	0	0
8	24-42	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
8	42-72	304.88	2637373	271707	121952	3031032	2426383	15746	2442130	0.62	1879240	0.806	1514120	$27.21	0	1514120	0	0	0
8	72-96	94.39	952286	165737	37756	1155778	876103	8140	884243	0.62	716583	0.765	548230	$25.81	0	548230	0	0	0
8	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
9	24-42	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
9	42-72	245.42	2248071	235785	98168	2582024	2068225	13358	2081584	0.62	1600855	0.806	1290582	$27.56	0	1290582	0	0	0
9	72-96	114.98	1118077	219650	45992	1383719	1028631	10626	1039257	0.62	857906	0.751	644339	$26.56	0	644339	0	0	0
9	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
10	24-42	111.88	420774	32829	89504	543107	387112	4893	392006	0.62	336727	0.722	243044	$33.08	0	0	243044	0	0
10	42-72	191.15	1443943	179463	76460	1699867	1328428	10237	1338665	0.62	1053917	0.788	829972	$28.44	0	829972	0	0	0
10	72-96	31.29	293011	55781	12516	361308	269570	2732	272302	0.62	224011	0.754	168827	$26.87	0	168827	0	0	0
10	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
11	24-42	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
11	42-72	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
11	72-96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
11	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
12	24-42	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
12	42-72	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
12	72-96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
12	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
13	24-42	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
13	42-72	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
13	72-96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
13	>96	5.27	60826	24448	2108	87382	55960	1062	57022	0.71	62041	0.653	40486	$27.07	0	40486	0	0	0
14	24-42	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
14	42-72	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
14	72-96	5.42	56565	15248	2168	73981	52039	697	52736	0.62	45868	0.713	32696	$26.87	0	32696	0	0	0
14	>96	11.17	126645	50174	4468	181287	116513	2186	118699	0.71	128714	0.655	84276	$26.56	0	84276	0	0	0
15	24-42	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
15	42-72	21.68	194843	33766	8672	237281	179256	1698	180953	0.62	147114	0.763	112191	$28.05	0	112191	0	0	0
15	72-96	2.32	22433	4559	928	27921	20639	219	20858	0.62	17311	0.747	12932	$25.91	0	12932	0	0	0
15	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
16	24-42	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
16	42-72	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
16	72-96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
16	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
		3329.01	25417854	2226179	1618204	29262237	23384425	153775	23538201	0.62	18172422	0.804	14613332		701449	12432658	1479226	0	0

		TONS	% OF TOTAL
TONS OF COAL	<$25 RANGE:	701,449	4.80
TONS OF COAL	$25-30 RANGE:	12,432,658	85.08
TONS OF COAL	$30-40 RANGE:	1,479,226	10.12
TONS OF COAL	$40-50 RANGE:	0	0.00
TONS OF COAL	>$50 RANGE:	0	0.00
TOTAL TONS		14,613,332	100.00
CHECK		14,613,332	

Table 10.—Longwall—recoverable resources and cost ranges

MATEWAN QUADRANGLE
LOWER WHITESBURG B SEAM

***** LONGWALL SALES - ALL THICKNESSES *****

Haul Zone #	Mining Thick (in)	Acres in zon	Coal Tons	Parting Tons in seam	Dilution out of seam	Minable Resource	Washed Coal	Washed Parting	Washed Resource	% Mine Recovery	ROM Tons	%WP Recovery	Saleable Tons	Cost/ton (in car)	Saleable Tons in <$25 RANGE	Saleable Tons in $25-30 RANGE	Saleable Tons in $30-40 RANGE	Saleable Tons in $40-50 RANGE	Saleable Tons in >$50 RANGE
1	42-7	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
1	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
1	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
2	42-7	75.74	755800	16984	60592	833376	695336	3103	698439	0.78	650034	0.838	544783	$24.62	544783	0	0	0	0
2	72-9	1.4	14115	556	560	15231	12986	45	13031	0.78	11880	0.856	10164	$28.26	0	10164	0	0	0
2	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
3	42-7	38.42	358053	25510	30736	414299	329409	2250	331659	0.78	323153	0.801	258694	$25.25	0	258694	0	0	0
3	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
3	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
4	42-7	193.68	1595734	55573	154944	1806251	1468075	8421	1476496	0.78	1408876	0.817	1151667	$25.58	0	1151667	0	0	0
4	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
4	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
5	42-7	32.57	298378	13151	26056	337584	274508	1568	276076	0.78	263316	0.818	215339	$25.58	0	215339	0	0	0
5	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
5	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
6	42-7	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
6	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
6	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
7	42-7	45.25	441210	22322	36200	499732	405913	2341	408254	0.78	389791	0.817	318438	$25.31	0	318438	0	0	0
7	72-9	37.82	380017	20877	15128	416022	349616	1440	351056	0.78	324497	0.844	273823	$21.99	273823	0	0	0	0
7	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
8	42-7	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
8	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
8	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
9	42-7	62.08	596766	43940	49664	690370	549025	3744	552769	0.78	538488	0.801	431160	$26.47	0	431160	0	0	0
9	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
9	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
10	42-7	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
10	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
10	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
11	42-7	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
11	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
11	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
12	42-7	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
12	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
12	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
13	42-7	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
13	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
13	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
14	42-7	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
14	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
14	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
15	42-7	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
15	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
15	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
16	42-7	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
16	72-9	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
16	>96	0	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
		487	4440073	198913	373880	5012866	4084867	22912	4107779	0.78	3910035	0.819	3204067		818606	2385461	0	0	0

	TONS	% OF TOTAL
TOTAL TONS <$25 RANGE:	818,606	25.55
TOTAL TONS $25-30 RANGE:	2,385,461	74.45
TOTAL TONS $30-40 RANGE:	0	0.00
TOTAL TONS $40-50 RANGE:	0	0.00
TOTAL TONS >$50 RANGE:	0	0.00
TOTAL TONS	3,204,067	100.00
CHECK	3,204,067	

Table 11.—Auger—recoverable resources and cost ranges

MATEWAN QUADRANGLE
LOWER WHITESBURG B SEAM

***** AUGER SALES - ALL THICKNESSES *****

Zone #	Haul Mining Thick (in)	Acres in zone	SEAM Coal Tons @1800t/AF	Parting Tons in seam @2400t/AF	SEAM THICK. (feet)	Hiwall Length (feet)	Total Auger Resource	Dilution out of seam	Minable Resource	Washed Coal	Washed Parting	Washed Resource	% Auger Recovery	ROM Tons	%WP Recovery	Saleable Tons	Cost/ton (in car)	Saleable Tons <$25 Range	Tons $25-30 Range	Tons $30-40 Range	Tons $40-50 Range	Tons >$50 Range
	<----- Contour	strip input data				<----- Calculated	auger data -----															
1	12-36	10.79	19641	2667	1.11	8521	24479	2347	26826	19829	211	20039	0.30	8048	0.747	6012	$24.89	6012	0	0	0	0
1	>36	0	0	0	0.00	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
2	12-36	54.41	225566	596	2.31	20747	118813	5716	124528	109020	241	109261	0.30	37359	0.877	32778	$22.04	32778	0	0	0	0
2	>36	142.32	1154726	5341	4.52	27688	310982	7628	318609	284786	362	285149	0.30	95583	0.895	85545	$17.83	85545	0	0	0	0
3	12-36	105.83	346067	5478	1.84	50661	232093	13956	246049	210198	703	210901	0.30	73815	0.857	63270	$22.44	63270	0	0	0	0
3	>36	58.78	426480	6947	4.08	12677	128928	3492	132420	116713	222	116935	0.30	39726	0.883	35080	$18.00	35080	0	0	0	0
4	12-36	97.45	393282	12839	2.30	37333	214851	10285	225136	191414	683	192097	0.30	67541	0.853	57629	$22.86	57629	0	0	0	0
4	>36	207.78	1515532	62701	4.18	43763	459326	12056	471382	405791	1212	407003	0.30	141414	0.863	122101	$18.63	122101	0	0	0	0
5	12-36	19.96	71152	130	1.98	8857	43574	2440	46014	40015	101	40116	0.30	13804	0.872	12035	$22.27	12035	0	0	0	0
5	>36	156.7	1282155	103926	4.82	28596	350423	7878	358301	298217	1366	299583	0.30	107490	0.836	89875	$18.86	89875	0	0	0	0
6	12-36	0	0	0	0.00	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
6	>36	21.14	168462	3144	4.49	4144	46404	1142	47545	41909	80	41989	0.30	14264	0.883	12597	$17.95	12597	0	0	0	0
7	12-36	0	0	0	0.00	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
7	>36	185.36	1885156	355855	6.45	25288	425813	6966	432780	329542	2983	332525	0.30	129834	0.768	99757	$19.96	99757	0	0	0	0
8	12-36	0	0	0	0.00	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
8	>36	348.17	3393343	604605	6.14	49914	797909	13750	811659	623063	5377	628439	0.30	243498	0.774	188532	$20.21	188532	0	0	0	0
9	12-36	0.88	3944	366	2.66	291	1974	80	2054	1662	10	1672	0.30	616	0.814	502	$24.08	502	0	0	0	0
9	>36	282.37	2684715	336085	5.78	43004	638905	11847	650752	522397	3317	525714	0.30	195226	0.808	157714	$19.93	157714	0	0	0	0
10	12-36	97.81	287819	26114	1.75	49294	219313	13580	232893	184984	1273	186257	0.30	69868	0.800	55877	$24.77	55877	0	0	0	0
10	>36	141.63	1029807	129846	4.42	28187	320533	7765	328298	261871	1746	263618	0.30	98489	0.803	79085	$20.38	79085	0	0	0	0
11	12-36	0.88	1697	0	1.07	723	1920	199	2119	0	0	0	0.30	636	1.000	636	$19.13	636	0	0	0	0
11	>36	0	0	0	0.00	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
12	12-36	0	0	0	0.00	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
12	>36	0	0	0	0.00	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
13	12-36	0	0	0	0.00	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
13	>36	23.6	261032	108072	8.05	2579	56514	710	57225	36770	690	37460	0.30	17167	0.655	11238	$23.01	11238	0	0	0	0
14	12-36	0	0	0	0.00	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
14	>36	108.87	1168170	437865	7.64	12545	259112	3456	262568	173391	2964	176355	0.30	78770	0.672	52907	$22.12	52907	0	0	0	0
15	12-36	9.64	34415	8844	2.37	3586	22465	988	23453	16443	223	16666	0.30	7036	0.711	5000	$26.06	0	5000	0	0	0
15	>36	28.73	216689	40722	4.78	5288	65987	1457	67444	51104	476	51580	0.30	20233	0.765	15474	$20.03	15474	0	0	0	0
16	12-36	17.52	50611	4437	1.71	9014	39251	2483	41734	33200	226	33426	0.30	12520	0.801	10028	$24.03	10028	0	0	0	0
16	>36	0	0	0	0.00	0	0	0	0	0	0	0	0.00	0	0.000	0	$0.00	0	0	0	0	0
TOTALS		2120.62	16620460	2256580	4.80	472701	4779570	130221	4909791	3952319	24467	3976786	0.30	1472937	0.810	1193672		1188672	5000	0	0	0

	TONS	% OF TOTAL
TOTAL TONS <$25 RANGE:	1,188,672	99.58
TOTAL TONS $25-30 RANGE:	5,000	0.42
TOTAL TONS $30-40 RANGE:	0	0.00
TOTAL TONS $40-50 RANGE:	0	0.00
TOTAL TONS >$50 RANGE:	0	0.00

TOTAL AUGER MINABLE COAL TONS -4,208,216

TOTAL AUGER MINABLE PARTING TON 571,354

From the minable resources for each mining method, the associated mining and washing losses are subtracted. This results in the amount of recoverable resource that is available for sale, with no quality or mining cost restrictions included. Table 12 exhibits the results of the recovery calculations for one seam. The recoverable resources—by haulage zone, mining method, and seam thickness category—are then used in the mine costing models to generate the operating costs for these recoverable coal tonnages.

ECONOMIC EVALUATION

Cost evaluation of the Matewan quadrangle coal resource was developed for a prefeasibility-type estimate. Economic evaluations (in-house) of mines in and around the study area were used for reference to mining methods, recovery rates, mining equipment, labor, operating costs (through the train-truck loadout), capital costs, and taxes. Industry, government, and consulting companies were used as sources of information to supplement cost figures. Costing models for underground, contour-strip, and auger mining operations were developed for different seam thicknesses; these various costing models were then integrated with local transportation (truck), depreciation, and recovery models into one interactive model—**COALVAL**. Recoverable resources are bracketed by **COALVAL** into different operating cost ranges: less than $25/ton, $25 to $30/ton, $30 to $40/ton, $40 to $50/ton, and over $50/ton. The costing format and summaries are developed on **Lotus 1-2-3** spreadsheets and can be updated by changing the default values associated with selected items.

Once the coal resource was categorized by seam thickness, haulage zone, and mining type, the costing models were applied to determine the economically recoverable resource. The mining type (contour strip, auger, continuous miner, or longwall) dictates the type of equipment to be used, whereas the seam thickness dictates the mining type and, therefore, the cost. The authors found that for the surface operations two loader spreads use the same equipment, regardless of seam thickness; however, the productivity will be different. The equipment list and depreciation schedule for a two-spread contour strip mine is shown in table 13. As mentioned previously, underground production is affected by mining height; consequently, continuous miner operations were divided into four different height ranges, and longwall operations were divided into three different height ranges. The type and size of equipment for selected mining heights is listed in tables 14, 15, and 16.

Once the mining type and the equipment to be used were finalized, the costs and depreciations associated with the equipment were developed. This procedure was done for each mining thickness category using that mining method to develop a total cost (f.o.b., rail car) for the coal for each haulage zone. In addition, these models were designed so that they can be updated by entering new information in the assumption list at the front of each model. Only the underground costing model is presented in table 17, but a costing model was developed for each mining thickness category using each mining method.

The number of calculations involved in doing 21 seams, with as many as 16 haulage zones per seam and 9 types of mining per seam, required that an interactive model be developed. As stated previously, **COALVAL** accomplished this with **Lotus 1-2-3** macros and linkage of spreadsheets. Furthermore, it soon became apparent as this interactive model was being developed that the model would be useful and timesaving for the Bureau, people in the coal industry, and others looking into large resource modeling projects. Therefore, a fully developed and documented model that can be used in generic situations has been published (*21*).

Costing Models Layout

As mentioned before, the productivity of a mine is often directly related to the thickness of the coal seam being mined. This is true for both surface and underground mining operations. After deciding on the ranges of seam thickness that represented logical breaks in the productivity, the authors collected the mine equipment cost, production data for the equipment, and manning information that was based on the seam thickness involved with the model. As much as possible, the model was fashioned after a corporate cost sheet. The major factors were divided into direct and indirect operating costs, overhead, and preparation. The layout of the costing model includes a front page of 32 assumptions used in the cost calculations and a second-page summary of the cost involved in operating the particular type of mine. Following that is the heart of the cost model—the specific information and detailed calculations that are used to develop the summary on page 2 of the cost model. Since the same thinking and assumptions are used in all models, only the values change from model to model. For each mining method, the model takes into account the following:

1. Mining unit: The major equipment required to make up a mining unit is listed. The number of operating units and shifts worked by each piece of equipment are noted. Then the repair and maintenance (R&M) cost per hour, fuel and lubrication (F&L) cost per hour, and depreciation (DEPREC.) cost per hour are entered. These values are derived from industry data and manufacturers' specifications and pricing lists. The respective costs for R&M, F&L, and DEPREC. are then calculated for the predefined shift and daily totals. This result is then used in the line item, "DEPRECIATION," on page 2 of the cost sheet. Costs for depreciation are on a straightline basis, and equipment life is relative to industry standards.

Table 12.—Recoverable resources—one seam summary

Metewan Quadrangle

Lower Whitesburg B

***** Recoverable Resource Calculation *****

	Coal tons	Parting tons	Dilution tons	Total in place tons	% of total	% Mine recovery	R.O.M tons recovered	% Wash recovery	Tons finished product
Total in place resources	57,459,000	5,887,298	2,945,034	66,291,332	100.00				
Act/abn undgrd. mines	0	0	0	0	0.00				
Ac./abn surface mines	0	0	0	0	0.00				
Mined out resources	0	0	0	0	0.00				
Environ. restrictions	853,393	115,866	21,777	991,036	1.49				
Technical restrictions	2,011,792	176,199	128,079	2,316,070	3.49				
Barrier restrictions	3,907,212	342,207	248,749	4,498,168	6.79				
Total restrictions	6,772,397	634,272	398,605	7,805,274	11.77				
Surface minable resources:									
Auger	4,208,216	571,354	130,221	4,909,791	7.41	30	1,472,937	81	1,193,672
Contour strip	16,620,460	2,256,580	424,124	19,301,164	29.12	92	17,713,278	80	14,121,640
Mountain top removal	0	0	0	0	0.00	00	0	0	0
Underground minable resources:									
Continuous miner	25,417,854	2,226,179	1,618,204	29,262,237	44.14	62	18,172,422	80	14,613,332
Longwall	4,440,073	198,913	373,880	5,012,866	7.56	78	3,910,035	82	3,204,067
Total minable resources	50,686,603	5,253,026	2,546,429	58,486,058	88.23	71	41,268,673	80	33,132,712

Auger resources		Percent
Minable resources	4,909,791	100.00
Mine loss rate	0.70	
Tons lost in mining	3,436,854	70.00
Wash plant loss rate	0.19	
Tons lost during washing	279,266	5.69
Total tons recovered	1,193,672	24.31

Contour strip resources		Percent
Minable resources	19,301,164	100.00
Mine loss rate	0.08	
Tons lost in mining	1,587,886	8.23
Wash plant loss rate	0.20	
Tons lost during washing	3,591,638	18.61
Total tons recovered	14,121,640	73.16

Mountain top resources		Per unit
Minavle resources	0	0.00
Mine loss rate	0.00	
Tons lost in mining	0	0.00
Wash plant loss rate	0.00	
Tons lost during washing	0	0.00
Total tons recovered	0	0.00

Continuous miner resources		Percent
Minable resources	29,262,237	100.00
Mine loss rate	0.38	
Tons lost in mining	11,089,815	37.90
Wash plant loss rate	0.20	
Tons lost during washing	3,559,090	12.16
Total tons recovered	14,613,332	49.94

Longwall resources		Percent
Minable resources	5,012,866	100.00
Mine loss rate	0.22	
Tons lost in mining	1,102,830	22.00
Wash plant loss rate	0.18	
Tons lost during washing	705,968	14.08
Total tons recovered	3,204,067	63.92

Restricted resources		Percent
Restricted tons	7,805,274	100.00
Barrier restrictions	4,498,168	57.63

Recoverable resources		Percent
Total resources	66,291,332	100.00
Resources prev. mined	0	0.00
Restricted resources	7,805,274	11.77
Mining-loss resources	17,217,385	25.97
Wash-loss resources	8,135,961	12.27
Recoverable resources	33,132,712	49.98

Recoverable tons cost summary

	Auger	Cont.strip	Mtn.top	Cont. miner	Longwall	Total	Percent
Tons of coal in <$25 range:	1,188,672	3,903,316	0	701,449	818,606	6,612,043	19.96
Tons of coal in $25-$30 range:	5,000	10,193,292	0	12,432,658	2,385,461	25,016,411	75.50
Tons of coal in $30-$40 range:	0	25,032	0	1,479,226	0	1,504,258	4.54
Tons of coal in $40-$50 range:	0	0	0	0	0	0	0.00
Tons of coal in >$50 range:	0	0	0	0	0	0	0.00
Totals	1,193,672	14,121,640	0	14,613,332	3,204,067	33,132,712	100.00
Check	1,193,672	14,121,640	0	14,613,332	3,204,067	33,132,712	

Assumptions and relevant information:

Coal acres in area	2,120.62	Coal density (t/ac-ft)	1,800
Ave. auger penetration	60	Sq.ft./acre	43,560
Highwall effective ratio	20	Barrier resource (tons in int./ext. barriers)	9,407,715

Table 13.—Equipment—contour strip (two loader spreads)

Capital equipment selection

Contour stripping - two single loader spreads (two loaders total)

Production equipment	No.	Total hrs	Unit cost	Depr.term	Hourly deprec.	Annual str line Deprec.	Total eqipment Costs	Development amortization
50 ton trucks	6	96	$483,600	26,000	$18.60	$428,544	$2,901,600	-
13.5cy loaders	2	32	$899,700	18,000	$49.98	$383,872	$1,799,400	-
350 hp dozers	2	32	$368,900	15,000	$24.59	$188,877	$737,800	-
6" rotary drills	2	16	$432,900	28,000	$15.46	$59,369	$865,800	-
275 hp grader	1	16	$328,300	28,000	$11.73	$45,024	$328,300	-
Spare 50 ton truck	1	8	$483,600	26,000	$18.60	$35,712	$483,600	-
Auxiliary equipment								
8 cy loader (375hp)	1	8	$422,300	18,000	$23.46	$45,045	$422,300	-
7 cy loader (270hp)	1	8	$287,100	18,000	$15.95	$30,624	$287,100	-
270 hp dozer	1	16	$342,500	15,000	$22.83	$87,680	$342,500	-
70 hp backhoe	1	8	$93,000	28,000	$3.32	$6,377	$93,000	-
4000 gal water truck	1	16	$65,000	20,000	$3.25	$12,480	$65,000	-
Coal broom	1	8	$20,000	20,000	$1.00	$1,920	$20,000	-
Fuel/lube truck	2	32	$80,000	20,000	$4.00	$30,720	$160,000	-
Spare broom	1	0	$20,000	20,000	$1.00	$0	$20,000	-
Leased coal trucks	0	0	$0	26,000	$0.00	$0	$0	-
Surface support facilities								
Power centers	2	48	$89,300	87,600	$1.02	-	$178,600	$11,744
Feeder breakers	2	48	$149,000	87,600	$1.70	-	$298,000	$19,595
Shop/warehouse facilities	1	24	$40,000	87,600	$0.46	-	$40,000	$2,630
Office/change facilities	1	24	$36,000	87,600	$0.41	-	$36,000	$2,367
Access/haul roads	1	24	$250,000	87,600	$2.85	-	$250,000	$16,438
Surface power/trans lines	1	24	$96,600	87,600	$1.10	-	$96,600	$6,352
Stacker conveyors	1	24	$90,000	87,600	$1.03	-	$90,000	$5,918
Site-surface development	1	24	$18,000	87,600	$0.21	-	$18,000	$1,184
Water/sewage treatment	1	24	$6,000	87,600	$0.07	-	$6,000	$395
Development capital costs							$1,013,200	
Annual depreciation costs						$1,356,244		
Total capital equipment costs							$9,539,600	
Mine development amortization								$66,621

Table 14.—Equipment—continuous miner (two production units)

Capital equipment selection
Underground continuous miner - 2 production units (24-42 in mining height)

Production equipment	No.	Total hrs	Unit cost	Depr term	Hourly Deprec	Annual str line deprec	Total equipment costs	Annual development amortization
Continuous miners	2	32	$600,000	20,000	$30.00	$230,400	$1,200,000	-
Shuttle cars	4	64	$131,300	20,000	$6.57	$100,838	$525,200	-
Roof bolters	2	32	$154,800	20,000	$7.74	$59,443	$309,600	-
Scoops	2	32	$61,800	20,000	$3.09	$23,731	$123,600	-
Surf-4 cy loader	1	4	$206,000	40,000	$5.15	$4,944	$206,000	-
Grader	1	1	$134,000	28,000	$4.79	$1,149	$134,000	-
Auxiliary equipment								
Utility scoop	1	24	$61,800	20,000	$3.09	$17,798	$61,800	-
Personnel carriers	3	7	$46,000	40,000	$1.15	$1,932	$138,000	-
Rock duster	1	1	$38,500	40,000	$0.96	$231	$38,500	-
Spare shuttle cars	2	4	$131,300	20,000	$6.57	$6,302	$262,600	-
Feeder/breakers	2	48	$109,800	20,000	$5.49	-	$219,600	$63,245
Ventilation system	1	24	$96,000	87,600	$1.10	-	$96,000	$6,312
Belt system	1	24	$873,000	87,600	$9.97	-	$873,000	$57,403
Power centers	2	4	$43,200	87,600	$0.49	-	$86,400	$5,681
Surface support and facilities								
Shop/warehouse facilities	1	24	$40,000	87,600	$0.46	-	$40,000	$2,630
Office/change facilities	1	24	$36,000	87,600	$0.41	-	$36,000	$2,367
Access/haul roads	1	24	$250,000	87,600	$2.85	-	$250,000	$16,438
Site-surface development	1	24	$18,000	87,600	$0.21	-	$18,000	$1,210
Ug compressors & lines	2	48	$50,000	40,000	$1.25	-	$100,000	$14,400
Water/sewage treat. fac.	1	24	$60,000	87,600	$0.68	-	$60,000	$3,945
Surf power sub/trans lines	1	24	$96,600	87,600	$1.10	-	$96,600	$6,352
Surface equipment								
120' stacker conveyors	1	24	$80,000	87,600	$0.91	-	$80,000	$5,260
Leased coal truck haulage			-					
Annual depreciation/amortization costs						$446,769		$185,243
Total capital equipment costs							$4,954,900	

Table 15.—Equipment—longwall

Capital equipment selection

Longwall mining (42-72 in mining height)

Longwall equipment	NO.	TOTAL HRS	UNIT COST	DEP TERM	HOURLY DEPREC	ANNUAL STR LINE DEPREC	TOTAL EQUIPMENT COSTS	ANNUAL DEVELOPMENT AMORTIZATION
Longwall shearer	1	16	$1,875,000	20,000	$93.75	$360,000	$1,875,000	-
Shields	1	16	$7,350,000	30,000	$245.00	$940,800	$7,350,000	-
Face cnvr+stge loader	1	16	$1,503,500	20,000	$75.18	$288,672	$1,503,500	-
Scoop/retriever	1	16	$110,000	20,000	$5.50	$21,120	$110,000	-
Personnel carrier	2	5	$52,000	40,000	$1.30	$1,560	$104,000	-
48" belt system	1	24	$975,100	87,600	$11.13	-	$975,100	$64,116
Vent support	1	24	$96,000	87,600	$1.10	-	$96,000	$6,312
Powr cntr+hydrl sys	1	24	$500,000	40,000	$12.50	-	$500,000	$72,000
Capital and annual depreciation/ammortization costs						$1,612,152	$12,513,600	$142,428
Development equipment								
Continuous miners	3	34	$780,000	20,000	$39.00	$318,240	$2,340,000	-
Shuttle cars	4	64	$165,000	20,000	$8.25	$126,720	$660,000	-
Roof bolters	2	32	$204,000	20,000	$10.20	$78,336	$408,000	-
Scoops	2	32	$110,000	20,000	$5.50	$42,240	$220,000	-
Utility scoop	1	24	$110,000	20,000	$5.50	$31,680	$110,000	-
Personnel carriers	3	7	$52,000	40,000	$1.30	$2,184	$156,000	-
Rock duster	1	4	$38,500	40,000	$0.96	$924	$38,500	-
Spare shuttle cars	2	4	$161,000	20,000	$8.05	$7,728	$322,000	-
Feeder/breakers	2	48	$109,800	20,000	$5.49	-	$219,600	$63,245
Ventilation system	1	24	$96,000	87,600	$1.10	-	$96,000	$6,312
48/60" belt system	2	48	$2,451,400	87,600	$27.98	-	$4,902,800	$322,376
Power centers	2	48	$43,200	87,600	$0.49	-	$86,400	$5,681
Capital and annual depreciation/ammortization costs						$608,052	$9,559,300	$397,614
Surface support and facilities								
Shop/warehouse facilities	1	24	$80,000	87,600	$0.91	-	$80,000	$5,260
Change facilities	1	24	$54,000	87,600	$0.62	-	$54,000	$3,551
Mine offices	1	24	$60,000	87,600	$0.68	-	$60,000	$3,945
Access/haulage roads	1	24	$250,000	87,600	$2.85	-	$250,000	$16,438
Site/surf development	1	24	$50,000	87,600	$0.57	-	$50,000	$3,288
Ug compressors & lines	2	48	$50,000	40,000	$1.25	-	$100,000	$14,400
Water/sewage treat. facilities	1	24	$60,000	87,600	$0.68	-	$60,000	$3,945
Surf. power sub/trans. lines	2	48	$96,600	87,600	$1.10	-	$193,200	$12,704
Mine dewater system	1	24	$90,000	87,600	$1.03	-	$90,000	$5,918
Capital and annual depreciation/amortization costs						$0	$937,200	$69,449
Surface equipment/coal loading								
Surface-8 cy loader	1	16	$449,000	40,000	$11.23	$43,104	$449,000	-
Grader	1	8	$134,000	28,000	$4.79	$9,189	$134,000	-
180 ft stacker conveyors	1	24	$389,300	87,600	$4.44	-	$389,300	$25,598
Capital and annual depreciation/amortization costs						$52,293	$972,300	$25,598
Total capital equipment costs						$2,272,497	$23,982,400	$635,089

Table 16.—Equipment—auger (twin head)

Capital equipment selection

Auger mining (twin-head auger)

Production equipment	No.	Total hrs	Unit cost	Depr term	Hourly deprec	Annual Str line deprec	Total equipment costs	Mine devel amort
Twin-head auger	1	16	$400,000	40,000	$10.00	$38,400	$400,000	-
Auger head/flites	1	16	$575,000	30,000	$19.17	$73,600	$575,000	-
4 cy coal loader	1	16	$206,000	40,000	$5.15	$19,776	$206,000	-
Annual depreciation costs						$131,776		
Total capital equipment costs							$1,181,000	
Mine development amortization								$0

Table 17.—Standard costing model (example)

CONTINUOUS MINER/ROOM & PILLAR (WITH RETREAT CAVING)- MINE COSTS
(24-42" MINING HEIGHT)

ASSUMPTIONS:

240	-DAYS WORKED/YEAR - PRODUCTION EMPLOYEES
240	-DAYS WORKED/YEAR - AUXILIARY EMPLOYEES
2	-NUMBER OF CONTINUOUS MINER UNITS
2	-SHIFTS/DAY - PRODUCTION
5	-DAYS/WEEK - PRODUCTION EMPLOYEES
5	-DAYS/WEEK - AUXILIARY EMPLOYEES
3	-SHIFTS/DAY - PRODUCTION PLUS MAINTENANCE
35%	-BURDEN RATE - HOURLY AND SALARY
110%	-BLACK LUNG TAX (SAME AS $1.10/TON)
$548	-OP. SUPPLIES/UNIT/SHIFT (ROOF SUPPORT MATERIALS, PIPE, ETC.)
$0	-EQUIPMENT RENT/UNIT/YEAR
$15,508	-GENERAL UTILITIES/MONTH
$700	-AUTO EXPENSES/SALARIED EMPLOYEE (PER MONTH)
$0.30	-PROPERTY INSURANCE/$100 OF CAPTIAL VALUATION
$0.05	-$/TON PROFESSIONAL SERVICES (PERMITTING, ENGINEERING, ETC)
$362	-GENERAL EXPENSES/UNIT-SHIFT (CONTRACT SERVICES, MISC. EXPENSES)
$2.50	-$/TON ROYALTY RATE
$0.15	-$/TON RECLAMATION TAX (SMCRA)
$0.60	-$/TON DEPLETION
$90,000	-OVERHEAD ALLOCATED/YEAR
$0.06	-RECLAMATION PROVISION (COST/CLEAN TON)
$1.00	-$/TON RAIL LOADOUT COSTS
$2.85	-PREPARATION PLANT COST/RAW TON OF COAL
$0.65	-TRUCK HAULAGE COST ($/RAW TON)
80%	-% COAL RECOVERED FROM WASH PLANT
0%	-% RAW MINED COAL DIRECTLY SALEABLE (WITHOUT WASHING)
13%	-% FACTOR FOR HOURLY PAYROLL (FOR O.T.& PERS. DAYS @ <= FIVE DAYS/WEEK WORK SCHED.)
18%	-% FACTOR FOR HOURLY PAYROLL (FOR O.T.& PERS. DAYS @ SIX DAYS/WEEK WORK SCHED.)
18%	-% FACTOR FOR HOURLY PAYROLL (FOR O.T.& PERS. DAYS @ SEVEN DAYS/WEEK WORK SCHED.)
$27.00	-COAL SALES PRICE/CLEAN TON (BASED ON QUALITY)
128,640	-TOTAL EMPLOYEE-HOURS/YEAR
18.82	-CLEAN TONS/EMPLOYEE-SHIFT
23.52	-RAW TONS/EMPLOYEE-SHIFT
$29.24	-COST IN CAR

ALSO:

- THE CM MINE IS SET UP WITH TWO COMPLETE PRODUCTION UNITS. EQUIPMENT IS SCHEDULED FOR TWO SHIFTS/DAY, FIVE DAYS/WEEK, WITH GENERAL AND PREVENTATIVE MAINTENANCE AND BELT MOVES SCHEDULED FOR THE THIRD SHIFT EACH DAY, FIVE DAYS/WEEK.
- REPAIR, SUPPLY, AND SUPPORT EQUIPMENT WILL BE SHARED BETWEEN PRODUCTION UNITS.
- ALL SURFACE SITE MAINTENANCE (SUCH AS, SNOW REMOVAL AND ROAD MAINTENANCE) WILL BE DONE BY THE SURFACE MINING OPERATIONS.
- PRODUCTIVITY IS ASSUMED TO BE A FUNCTION OF MINING HEIGHT AND MINING HEIGHTS ARE ASSUMED TO BE SEAM THICKNESS
- UNDERGROUND MINING CONFIGURATIONS LESS THAN 42" CONTRIBUTE 4" OF OUT-OF-SEAM DILUTION. CONFIGURATIONS GREATER THAN 42" CONTRIBUTE 2" OF DILUTION (UNDER IDEAL CONDITIONS).

Table 17.—Standard costing model (example)—Continued

TWO CONT. MINER UNITS (24-42" MINING HEIGHT)		
RAW TONS PER YEAR	378,240	
CLEAN TONS	302,592	
DIRECT COSTS		COST/TON
PAYROLL	$2,484,775	$8.21
BURDEN	$869,671	$2.87
FUEL & LUBES	$88,932	$0.29
EXPLOSIVES	$0	$0.00
OTHER PRODUCTION SUPPLIES	$526,132	$1.74
REPAIR PARTS/MAINT.	$417,720	$1.38
UTILITIES	$186,094	$0.62
EQUIPMENT RENTAL	$0	$0.00
AUTO EXPENSE	$58,800	$0.19
PROFESSIONAL SERVICES	$15,130	$0.05
RECLAMATION PROVISION	$18,156	$0.06
TRUCKING	$245,856	$0.81
GENERAL EXPENSES	$347,603	$1.15
TIPPLE COST	$1,077,984	$3.56
DEPRECIATION	$446,769	$1.48
TOTAL DIRECT COSTS	$6,783,621	$22.42
INDIRECT COSTS		
DEPLETION	$181,555	$0.60
MINE DEV. AMORTIZATION	$185,243	$0.61
OVERHEAD	$90,000	$0.30
INSURANCE	$14,865	$0.05
TOTAL INDIRECT COSTS	$471,663	$1.56
TAXES	$836,458	$2.76
ROYALTIES	$756,480	$2.50
COST IN CAR	$8,848,222	$29.24

Table 17.—Standard costing model (example)—Continued

EQUIPMENT OPERATING COST CALCULATIONS

PRODUCTION EQUIPMENT	# UNITS 1ST SHIFT	# UNITS 2ND SHIFT	# UNITS 3RD SHIFT	HRS WORKED PER SHIFT	TOTAL R&M PER DAY	TOTAL F&L PER DAY	TOTAL DEPR PER DAY	R&M PER HOUR	F&L PER HOUR	DEPR PER HOUR	
CONTINUOUS MINERS	2	2	0	8	$848.00	$123.20	$960.00	$26.50	$3.85	$30.00	CONTINUOUS MINERS
SHUTTLE CARS	4	4	0	8	$416.00	$112.00	$420.16	$6.50	$1.75	$6.57	SHUTTLE CARS
ROOF BOLTERS	2	2	0	8	$176.00	$48.00	$247.68	$5.50	$1.50	$7.74	ROOF BOLTERS
SCOOPS	2	2	0	8	$136.00	$32.00	$98.88	$4.25	$1.00	$3.09	SCOOPS
SURF-4cy LOADER	1	0	0	4	$20.00	$17.44	$20.60	$5.00	$4.36	$5.15	SURF-4cy LOADER
GRADER	1	0	0	1	$4.00	$3.16	$4.79	$4.00	$3.16	$4.79	GRADER
DAILY TOTAL	12	10	0		$1,600.00	$335.80	$1,752.11				
ANNUAL TOTAL					$384,000	$80,592	$420,505				

AUXILIARY EQUIPMENT	# UNITS 1ST SHIFT	# UNITS 2ND SHIFT	# UNITS 3RD SHIFT	HRS WORKED PER SHIFT	TOTAL R&M PER DAY	TOTAL F&L PER DAY	TOTAL DEPR PER DAY	R&M PER HOUR	F&L PER HOUR	DEPR PER HOUR	
UTILITY SCOOP	1	1	1	8	$96.00	$24.00	$74.16	$4.00	$1.00	$3.09	UTILITY SCOOP
PERSONNEL CARRIERS	3	3	1	1	$17.50	$3.50	$8.05	$2.50	$0.50	$1.15	PERSONNEL CARRIERS
ROCK DUSTER	1	0	0	1	$1.00	$0.25	$0.96	$1.00	$0.25	$0.96	ROCK DUSTER
SPARE SHUTTLE CARS	2	2	0	1	$26.00	$7.00	$26.26	$6.50	$1.75	$6.57	SPARE SHUTTLE CARS
DAILY TOTAL	7	6	2		$140.50	$34.75	$109.43				
ANNUAL TOTAL					$33,720	$8,340	$26,264				
ANNUAL GRAND TOTAL					$417,720	$88,932	$446,769				

Table 17.—Standard costing model (example)—Continued

PAYROLL	# OF EMPS 1ST SHIFT	# OF EMPS 2ND SHIFT	# OF EMPS 3RD SHIFT	HRS/ SHIFT	PAYROLL RATE/DAY	GRADE	BASE RATE	RATE/HR 1st SHIFT	RATE/HR 2nd SHIFT	RATE/HR 3rd SHIFT
PRODUCTION EMPLOYEES									+0.30/hr	+0.40/hr
CONT. MINER OPER.	2	2	0	8	$561.40	5	$16.615	$17.39	$17.69	$17.79
CONT. MINER HELPER	2	2	0	8	$547.84	4	$16.210	$16.97	$17.27	$17.37
SHUTTLE CAR OPER.	4	4	0	8	$1,071.08	3	$15.843	$16.59	$16.89	$16.99
ROOF BOLTER OPER.	4	4	0	8	$1,122.81	5	$16.615	$17.39	$17.69	$17.79
SCOOP OPERATOR	2	2	0	8	$535.54	3	$15.843	$16.59	$16.89	$16.99
TOTAL-1ST. SHIFT	14				$1,902.53					
TOTAL-2ND. SHIFT		14			$1,936.13					
TOTAL-3RD. SHIFT			0		$0.00					
TOTAL PRODUCTION PAYROLL	28				$3,838.66					
OVERTIME FACTOR					0.13					
TOTAL WITH O.T. PAY					$4,337.69					
	# OF EMPS 1ST SHIFT	# OF EMPS 2ND SHIFT	# OF EMPS 3RD SHIFT	HRS/S HIFT	PAYROLL RATE/DAY	GRADE	BASE RATE	ADJ RATE/HR 1st SHIFT	ADJ RATE/HR 2nd SHIFT	ADJ RATE/HR 3rd SHIFT
AUXILIARY EMPLOYEES									+0.30/hr	+0.40/hr
SCOOP OPERATOR	1	1	0	8	$267.77	3	$15.843	$16.59	$16.89	$16.99
POCKETMEN	2	2	0	8	$535.54	3	$15.843	$16.59	$16.89	$16.99
SUPPLYMEN	1	1	0	8	$262.83	1	$15.548	$16.28	$16.58	$16.68
LAMPMAN/WAREHSE	1	1	0	8	$262.83	1	$15.548	$16.28	$16.58	$16.68
BELT MAINT/CLEANUP	2	2	2	8	$792.49	1	$15.548	$16.28	$16.58	$16.68
MECHANICS	2	2	4	8	$1,130.81	5	$16.615	$17.39	$17.69	$17.79
ELECTRICIANS	1	1	1	8	$423.05	5	$16.615	$17.39	$17.69	$17.79
SURF. UTILITY OPER.	1	0	0	8	$132.69	3	$15.843	$16.59	$16.89	$16.99
TOTAL-1ST. SHIFT	11				$1,469.05					
TOTAL-2ND. SHIFT		10			$1,360.37					
TOTAL-3RD. SHIFT			7		$978.58					
TOTAL AUXILIARY PAYROLL	28				$3,808.00					
OVERTIME FACTOR					0.13					
TOTAL WITH O.T. PAY					$4,303.04					
TOTAL HRLY EMPLS PER SHIFT	25	24	7							
TOTAL HOURLY EMPLOYESS	56									
TOTAL ANNUAL HOURLY PAYROLL					$2,073,775					

Table 17.—Standard costing model (example)—Continued

MINE MANAGEMENT AND STAFF	# EMPL 1ST SHIFT	# EMPL 2ND SHIFT	# EMPL 3RD SHIFT	BASE SALARY PER YEAR	TOT SALARY PER YEAR
GENERAL MANAGER	1			$57,000	$57,000
PRODUCTION FOREMEN	2	2		$42,000	$168,000
MAINT. FOREMEN	1		1	$40,000	$80,000
MINE ACCNT/PUR.AGENT	1			$40,000	$40,000
MINE CLERK	1			$18,000	$18,000
TECHS./SURVEYORS	2			$24,000	$48,000
TOTAL ANNUAL SALARY					$411,000
NUMBER OF EMPLOYEES WITH COMPANY AUTOS		7			
TOTAL SALARIED EMPLOYEES		11			

TOTAL RAW TONS PROD. COAL PER YEAR	378,240
%RAW SALABLE	0%
RAW TONS SALABLE	0
RAW TONS COAL TO WASHER	378,240
% REC	80%
CLEAN TONS WASHED COAL	302,592
TOTAL TONS COAL SOLD	302,592

TIPPLE COST	COST PER TON	TONS/ YEAR	COST/ YEAR
RAIL LOADOUT (RAW COAL)	$1.00	0	$0
PREP PLANT (WASHED COAL)	$2.85	378,240	$1,077,984
TOTAL TIPPLE COST			$1,077,984

TAXES	TAX RATE	TAXED PRODUCT	COST/ YEAR	COST PER TON
SALES	5.00%	$1,652,146	$82,607	$0.27
SEVERANCE	4.50%	302,592	$356,586	$1.18
REAL PROPERTY	$1.09	$185,243	$604	$0.00
TANGIBLE PROPERTY	$1.13	$4,954,900	$16,855	$0.06
RECLAMATION (SMCRA)	$0.15	302,592	$45,389	$0.15
STATE MINL TAX (UNMINED)	$0.21	302,592	$1,566	$0.01
BLACK LUNG TAX	$1.10	302,592	$332,851	$1.10
TOTAL TAX / YEAR			$836,458	$2.76

TAX DEFINITION: 1) Sales taxes are based on the total capital cost/8 yr. ave. life + annual taxable items.
2) Severance taxes are based on the sold tons times their realization, minus the cost of road transportation.
3) Real property taxes are based on 30% of the assessed valuation times the amortization (property + buildings + improvments) times the tax rate.
4) Tangible property tax is based on the total capital cost times the property assessment rate times the tax rate.
5) Federal reclamation taxes are based on the sold tons times the tax rate.
6) State mineral taxes on unmined reserves (annual planned production) is based on the sold tons times the coal value (usually the royalty rate) times the tax rate.
7) Black lung taxes are based on sold tons times tax rate.

TAX RATES: PER $100 OF ASSESSED VALUATION

STATE MINL TAX	STATE REAL PROP	COUNTY REAL PROP	STATE TANG PROP	COUNTY TANG PROP
$0.21	0.45	0.6365	0.45	0.6839
		COAL VALUE/T	PROP ASSESS	BLACK LUNG TAX
	CONSTANTS:	$2.50	30.00%	$1.10
		SEVERANCE TAX	SALES TAX	
		4.50%	5.00%	

Table 17.—Standard costing model (example)—Continued

CAPITAL EQUIPMENT SELECTION

UNDERGROUND CONTINUOUS MINER - 2 PRODUCTION UNITS

			(24-42" MINING HEIGHT)					
PRODUCTION EQUIPMENT	NO. UNITS	TOTAL HRS PER DAY	UNIT COST	DEPR TERM (IN HRS)	HOURLY DEPREC	ANNUAL STR. LINE DEPREC	TOTAL EQUIPMENT COSTS	ANNUAL DEVELOPMENT AMORTIZATION
CONTINUOUS MINERS	2	32	$600,000	20,000	$30.00	$230,400	$1,200,000	-
SHUTTLE CARS	4	64	$131,300	20,000	$6.57	$100,838	$525,200	-
ROOF BOLTERS	2	32	$154,800	20,000	$7.74	$59,443	$309,600	-
SCOOPS	2	32	$61,800	20,000	$3.09	$23,731	$123,600	-
SURF-4cy LOADER	1	4	$206,000	40,000	$5.15	$4,944	$206,000	-
GRADER	1	1	$134,000	28,000	$4.79	$1,149	$134,000	-
AUXILIARY EQUIPMENT								
UTILITY SCOOP	1	24	$61,800	20,000	$3.09	$17,798	$61,800	-
PERSONNEL CARRIERS	3	7	$46,000	40,000	$1.15	$1,932	$138,000	-
ROCK DUSTER	1	1	$38,500	40,000	$0.96	$231	$38,500	-
SPARE SHUTTLE CARS	2	4	$131,300	20,000	$6.57	$6,302	$262,600	-
FEEDER/BREAKERS	2	48	$109,800	20,000	$5.49	-	$219,600	$63,245
VENTILATION SYSTEM	1	24	$96,000	87,600	$1.10	-	$96,000	$6,312
BELT SYSTEM	1	24	$873,000	87,600	$9.97	-	$873,000	$57,403
POWER CENTERS	2	48	$43,200	87,600	$0.49	-	$86,400	$5,681
SURFACE SUPPORT AND FACILITIES								
SHOP/WAREHOUSE FACILITIES	1	24	$40,000	87,600	$0.46	-	$40,000	$2,630
OFFICE/CHANGE FACILITIES	1	24	$36,000	87,600	$0.41	-	$36,000	$2,367
ACCESS/HAUL ROADS	1	24	$250,000	87,600	$2.85	-	$250,000	$16,438
SITE-SURFACE DEVELOPMENT	1	24	$18,000	87,600	$0.21	-	$18,000	$1,210
UG COMPRESSORS & LINES	2	48	$50,000	40,000	$1.25	-	$100,000	$14,400
WATER/SEWAGE TREAT. FAC.	1	24	$60,000	87,600	$0.68	-	$60,000	$3,945
SURF POWER SUB/TRANS LINES	1	24	$96,600	87,600	$1.10	-	$96,600	$6,352
SURFACE EQUIPMENT								
120' STACKER CONVEYORS	1	24	$80,000	87,600	$0.91	-	$80,000	$5,260
LEASED COAL TRUCK HAULAGE	-	-	-	-	-	-	-	-
ANNUAL DEPRECIATION/AMORTIZATION COSTS						$446,769		$185,243
TOTAL CAPITAL EQUIPMENT COSTS							$4,954,900	

Table 17.—Standard costing model (example)—Continued

UMWA WAGES - 1988 CONTRACT, UNDERGROUND MINING

EFFECTIVE DATE	02/01/90
GRADE 5 - BASE HOURLY RATE	$16.615
GRADE 4 - BASE HOURLY RATE	$16.210
GRADE 3 - BASE HOURLY RATE	$15.843
GRADE 2 - BASE HOURLY RATE	$15.620
GRADE 1 - BASE HOURLY RATE	$15.548
TRAINING RATES	$14.974

UNION WORK CLASSIFICATIONS - UNDERGROUND MINING

GRADE 5

A. CONTINUOUS MINING MACHINE OPERATOR
B. ELECTRICIAN
C. MECHANIC
D. FIREBOSS
E. LONGWALL MACHINE OPERATOR
F. WELDER, FIRST CLASS
G. ROOF BOLTER

GRADE 4

A. CUTTING MACHINE OPERATOR
B. DISPATCHER
C. LOADING MACHINE OPERATOR
D. MACHINE OPERATOR HELPER
E. GENERAL INSIDE REPAIRMAN AND WELDER
F. ROCK DRILLER
G. CONTINUOUS MINER HELPER - TRAINEE
H. ROOF BOLTER HELPER - TRAINEE
I. MAINTENANCE TRAINEE (MAX. 12 MOS.)
J. ELECTRICIAN TRAINEE (MAX. 12 MOS.)

GRADE 3

A. DRILLER - COAL
B. SHOOTER
C. PRECISION MASON
D. FACEMAN
E. DUMPER
F. SHUTTLE CAR OPERATOR

GRADE 2

A. MOTORMAN
B. MAINTENANCE TRAINEE (MAX. 6 MOS.)
C. ELECTRICIAN TRAINEE (MAX. 6 MOS.)
D. ELECTRICIAN HELPER
E. MECHANIC HELPER

GRADE 1

A. BELTMAN
B. BONDER
C. BRAKEMAN
D. BRATTICEMAN
E. GENERAL INSIDE LABOR
F. MASON
G. PUMPER
H. TIMBERMAN
I. TRACKMAN
J. WIREMAN
K. LABOR - UNSKILLED

2. Payroll: Labor costs are made up of three general categories—production manpower, auxiliary employees, and mine management and staff. The number of hourly and salaried employees needed to operate a mining unit is determined from Bureau publications, in-house property evaluations, published articles, "Coal Mining Technology" (*12*), and industry experience. The number of divisional and corporate staff (listed in "OVERHEAD" on page 2) depends on the size and structure of the corporation. Since it has been assumed that one entity owns or manages the entire resource (for maximum recovery), this study assumes that some divisional and corporate staff is needed, though the numbers are minimized to have the least effect on the profit. For hourly costs, both nonunion and United Mine Workers of America (UMWA) labor wages and burden must be considered. For this study, a range is used that uses information from the present UMWA contract and the norm for nonunion mines that have been evaluated in each geographical area. For salary costs, a norm between the most recently published "Coalfield Salary Survey" (*22*) and salaries observed in Bureau mine evaluations has been used. The burden used is from Bureau mine evaluations.

3. Taxes: Tax rates are generally available from each State office of taxation.

4. Development costs: Development costs are the costs associated with developing a property and are amortized on an annual basis.

Other items on the page 2 summary for each model are developed from the original page 1 list of assumptions, and include the following:

1. Explosives: Drilling and blasting costs applicable to underground mining are not considered due to the exclusive use of continuous miners and longwall mining methods in the study. Surface drilling and blasting costs are derived from industry and Bureau publications.

2. Utilities: Utility costs, such as electricity and water, are public information available from the applicable rate control agency.

3. Auto expense: This cost is incurred for the use of vehicles by the supervisory personnel. Industry contacts and Bureau mine evaluations are the sources for this information.

4. Insurance: Property insurance is based on a percentage per $100 property valuation. The sources for this expense are industry contacts and Bureau mine evaluations.

5. Professional services: The costs of professional services address such subjects as engineering and environmental services, coal crushing and processing, accounting, project management, safety, and training. These costs were obtained from industry contacts.

6. Trucking: One of the highest cost items in the mine operating cost is the transportation cost from the mine to the wash plant-loadout facilities served by the railroad. Based on present preparation plant locations within and around the Matewan quadrangle, truck haulage routes and zones were developed so that loaded trucks haul downhill. Although paved roads pass through some gaps, all travel is confined to the same watershed from which the coal is mined. Mileage calculations are made from the estimated geographic center of each zone and the cost per ton-mile applied to haul distances. Haulage costs vary from $0.65 per ton to more than $3 per ton.

7. Other: Several generalized costs, including road maintenance, roof control material, coal transportation, supplies, licenses, and permits, are accounted for within various other cost categories. These costs were obtained from industry contacts and Bureau mine evaluations.

Costing Considerations

Many elements influence the cost of mining a ton of coal. Major factors to be considered are (1) geology of the resource to be mined; (2) Federal, State, and local taxes; (3) royalties; (4) payroll; (5) productivity; (6) transportation; and (7) preparation costs. The geology of the resource, as well as that of the area, not only includes the roof and floor of the seam (which directly effect the mine recovery possible from a resource and may add external dilution to the seam) but also includes the amount of parting (internal dilution found in the coal seam); this dilution directly affects the wash plant recovery that, in turn, affects the cost per ton of clean or salable coal. The mining, transportation, and cleaning of large amounts of noncoal material greatly increases the cost of mining. Federal, State, and local taxes often have little correlation to efficiency or productivity and can be a large cost consideration. Royalties can be considered a form of tax whether levied by private, State, or Federal landowners. They can often become a very large part of the total cost, as they frequently do not vary with the price of coal and usually have minimum payments required; therefore, as the coal price (or realization) or productivity decrease, the royalties become a larger percentage of the overall costs. Payroll, and the related burden rates, is usually the single largest contributor to coal mine costs. Productivity (tons of coal per employee shift) is sometimes the deciding factor between profit and loss. The term "productivity," as used in this study, includes the production of rock and shale that are mined with the coal. Transportation of the coal from the mine to the preparation facility and/or the train or barge loadout facility may account for 10% to 20% of the total operating cost. Preparation costs can have a significant impact on the cost per ton of clean coal produced, and although the Bureau has used a cost per raw ton figure in the cost models, the models allow analysis of the ROM product recovery from the plant and establish the preparation costs per clean ton of salable coal (e.g., \$2 per ton for a ROM coal preparation cost, coupled with a 50% recovery in the preparation plant, equals \$4 per ton for a clean coal preparation cost).

The quality of the coal being mined does not necessarily have a direct effect on the cost to mine or wash that coal; however, the quality does affect the price that can be received for the salable product. The USGS has defined three broad ranges of coal quality based on sulfur: on an as-received basis, (1) low-sulfur coal contains less than 1% sulfur; (2) medium-sulfur coal contains between 1% and 3% sulfur; and (3) high-sulfur coal contains greater than 3% sulfur (*15*). Compliance coal meets the current EPA standard for potential emissions from utilities burning the coal, when no sulfur dioxide (SO_2) reduction processes are used (*23*); the current standard is dependent upon the minimum allowable total emissions within an affected area and is no more than 1.2 lb of SO_2 per MBtu of heat input.

After the amount of recoverable coal and the quality of the coal is determined, the costing models calculate the cost to mine the coal by economic increments and quality (table 18). Figure 17 diagrammatically illustrates the procedure developed and the results produced during this study. The percentages used in the diagram all refer to the original Matewan quadrangle coal resource.

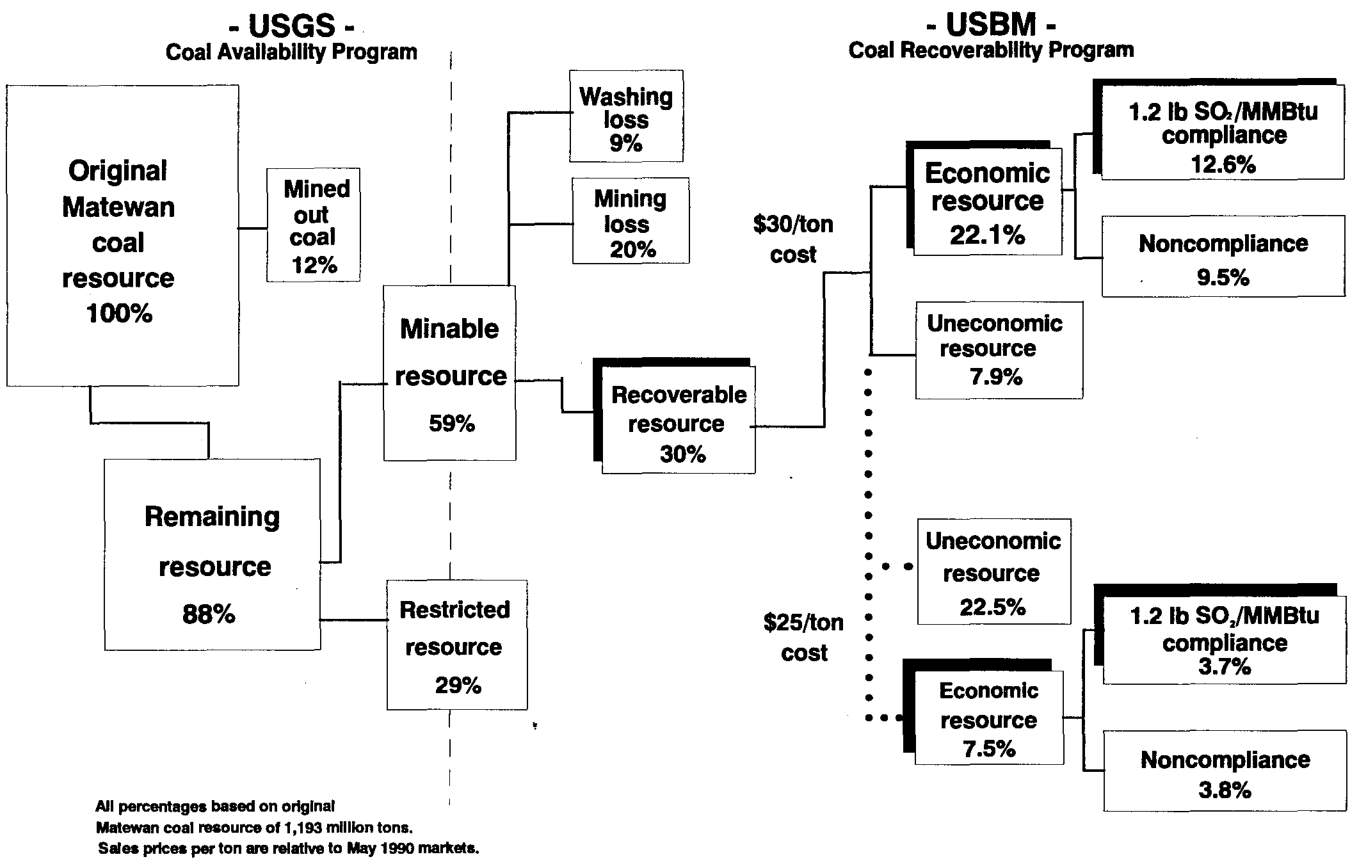

Figure 17.—USGS/USBM coal resource programs—Matewan quadrangle results chart.

Table 18.—Economically recoverable compliance resources, Matewan quadrangle (thousand tons)

Seam name	Recoverable resource	SO_2 lb/MMBtu	Economically recoverable resources: Recoverable @ <$25/ton: Total	<1.2 lb/MMBtu	<1.0 lb/MMBtu	Recoverable @ <$30/ton: Total	<1.2 lb/MMBtu	<1.0 lb/MMBtu
Broas	56	1.35	56	0	0	56	0	0
Upper Peach Orchard A	1,936	1.03	1,087	1,087	0	1,402	1,402	0
Lower Peach Orchard A	382	0.99	382	382	382	382	382	382
Hazard	701	.89	166	166	166	217	217	217
Taylor B	4,969	1.03	1,713	1,713	0	4,779	4,779	0
Hamlin A	2,798	1.09	1,268	1,268	0	2,325	2,325	0
Fire Clay Rider	9,410	2.34	915	0	0	5,121	5,121	0
Fire Clay	15,836	1.16	3,126	3,126	0	9,129	9,129	0
Lower Whitesburg	33,133	1.01	6,612	6,612	0	31,628	31,628	0
Williamson B	50,212	3.09	16,257	0	0	38,242	0	0
Upper Elkhorn 3.5	30,960	2.65	7,436	0	0	18,421	0	0
Upper Elkhorn 3D	35,343	2.65	12,823	0	0	28,665	0	0
Upper Elkhorn 3B	44,699	2.65	8,128	0	0	22,235	0	0
Upper Elkhorn 2B	12,593	1.08	4,567	4,567	0	11,044	11,044	0
Upper Elkhorn 1B	63,998	.80	11,065	11,065	11,065	49,442	49,442	49,442
Lower Elkhorn Rider	3,664	.81	524	524	524	2,223	2,223	2,223
Lower Elkhorn B	40,063	.81	13,006	13,006	13,006	39,463	39,463	39,463
Powellton	823	.58	108	108	108	324	324	324
Matewan	1,819	1.93	251	0	0	1,049	0	0
Eagle B	436	1.54	110	0	0	326	0	0
Glamorgan	9,459	.86	153	153	153	6,130	6,130	6,130
Totals	[1]363,290		89,753	43,777	25,404	272,603	163,609	98,181

[1]Indicates coal, inseam parting, and minimal dilution.

CONCLUSIONS

Without accurate data regarding the amounts and quality of economically recoverable coal, it is not possible to make informed decisions regarding National, regional, or local energy policies. Traditional procedures and methodologies used to estimate the coal reserve base have utilized historical mining recovery factors and applied them throughout coal regions to obtain the estimated recoverable coal tonnage. Restrictions relative to the environment and social concerns, site specific geology, mining technology, and economics were not considered.

The quality of a coal is not considered a restriction to its minability; however, quality can be a factor in the marketability of that coal. Increasing concerns for the environment and subsequent new regulation of environmental pollutants require a better understanding of the coal qualities than is now available.

Technical and barrier restrictions account for 27% (325 million tons) of the coal resource lost from the total original, in-place, resource. Research is needed on these areas of loss, to improve mining methods and efficiencies and to reduce mining costs. In addition, many more tons of coal are in the thinner seams (less than 12 in thick for surface mines and less than 24 in thick for underground mines), and research is needed on methods to enable recovery of these resources.

The information presented in this report is specific to one quadrangle; however, it does point out that the DRB appears overstated and that the DRB should be used with caution until further data are available. The Bureau Coal Recoverability program is continuing to study the central Appalachian coal region and, due to the importance of redefining the Nation's coal reserves, the next phase of the program will be to investigate the northern Appalachian coal region. Studies of the Illinois Basin and the Western coalfields will follow thereafter.

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APPENDIX.—GLOSSARY

Available coal resources.—Coal resources, minable by either surface or underground methods, that are unencumbered by land use, environmental, societal, regulatory, or technologic restrictions as applied within a specific State or region. In this study, available resources are derived by the following formula:

ORIGINAL COAL RESOURCES
-minus-
COAL MINED AND LOST-IN-MINING
-equals-
REMAINING COAL RESOURCES
-minus-
COAL RESTRICTED BY LAND USE CONSIDERATIONS
-minus-
COAL RESTRICTED BY TECHNOLOGIC CONSIDERATIONS
-equals-
AVAILABLE COAL RESOURCES

Buffer zone.—The area surrounding a restrictive feature (mine, town, cemetery, oil or gas well, stream, etc.) in which mining is not permitted.

Coal availability/minable resource.—Refer to "Available coal resources."

Coal realization.—The conversion, economically, of coal into cash (i.e., the price for which coal sells).

Coal recoverability.—Refer to "Recoverable coal."

Coal reserve.—Refer to "Reserve."

Coal resources.—Deposits of coal in the earth's crust in such amounts that physical extraction is currently or potentially feasible.

Coal seam.—A bed or stratum of coal.

Coal washing/preparation.—The process of cleaning (i.e., removing ash, etc.) or preparing run-of-mine coal to meet market specifications and to make it suitable for a particular use.

Compliance coal.—Coal that meets New-Source Performance Standards (NSPS), set forth by the EPA, for SO_2 emissions. This is coal that is in compliance without use of SO_2-reduction processes, such as scrubbers. The current maximum limit from new-source coal-fired power plants is 1.2 lb of SO_2 per MBtu of heat input.

Deep coal resources.—Coal resources that would most probably be mined by underground mining methods.

Deep-mine barrier pillars.—Unmined coal left around the peripheries of active or abandoned underground mines due to mine-safety requirements. Also referred to as deep-mine barriers.

Dilution.—The contamination of coal with barren rock from the roof and floor of an excavation.

Environmental restrictions.—Refer to "Land-use restrictions." Examples of these restrictions are cemeteries, towns and residences (social constraints), ground slopes <65%, major streams, and lakes (environmental constraints).

Floor rock.—The rock immediately underlying a coal bed. Where the coal section is overturned (inverted), the mining floor is actually above the coal bed, stratigraphically.

Interburden.—The rock between two coal beds. When two potentially minable coal beds occur within a minimum acceptable distance above or below one another, one (often the thinner of the two) will not be mined.

Land use restrictions.—Constraints placed upon mining by societal policies to protect those surface features or entities that could be affected by mining. Since laws and regulations can be modified or repealed, the restrictions, including industrial and environmental restrictions, may change.

Lost-in-mining.—Unrecoverable coal remaining in the ground within a mine after all feasible extraction is completed. Includes coal that is (1) left to support mine roofs, (2) too thin or impure to mine, (3) unsafe for mining (e.g., bad roofs, faults, etc.), and (4) unmined around oil, gas, water, and disposal wells, shafts, conduits, haulageways, tunnels, and airways.

Mining methods.—The systems employed in the exploitation of coal seams and ore bodies. The method adopted depends on a large number of factors, the main ones being the quality, shape, size, and depth of the deposit, accessibility, and capital available.

National Coal Resources Data System (NCRDS).—The U.S. Geological Survey computer system for storage, retrieval, and manipulation of stratigraphic, geochemical, and coal resource-related data. The NCRDS stratigraphic data base contains information on more than 150,000 coal data points; the NCRDS geochemical data base includes analyses on nearly 13,000 coal samples. NCRDS graphics programs calculate and tabulate resources according to the specifications of the USGS coal-resources classification system. A national network of users and State cooperators is tied into NCRDS for interactive data retrieval, manipulation, and coal resource assessment.

Original coal resources.—Coal resources, containing 33% or less ash, that lie under less than 6,000 ft of overburden and are either 14 or more inches thick (for anthracite and bituminous coal) or 30 or more inches thick (for subbituminous coal and lignite); the coal must exist in such form and amount that physical extraction is currently or potentially feasible.

Operating costs.—The sum of mining, beneficiation, and administration costs.

Outcrop.—That part of a coal bed or rock strata that appears at the surface (crops out).

Overburden.—Any material, consolidated or unconsolidated, that lies between a coal deposit and the surface.

Parting.—A small layer of rock in a coal seam.

Perennial stream.—A stream that flows continuously throughout the year.

Process losses.—Coal losses due to mining and washing.

Production.—The yield or output of a mine, metallurgical plant, or quarry.

Recoverable coal.—Coal that is, or can be, extracted from a coal bed during mining (See "Reserve").

Recovery.—The proportion, or percentage, of coal (or ore) that is mined from the original deposit.

Recovery factor.—The percentage of total, estimated in-place coal that is potentially recoverable; or for a more precise determination, the percentage of total, estimated in-place coal that is actually mined. Recovery factors are generally about 50% for underground mining methods and from 80% to 90% for surface mining methods.

Reserve.—That part of a mineral deposit that could be economically and legally extracted or produced at the time of the reserve determination. When dealing with metalliferous minerals, reserves are customarily stated in terms of "ore;" however, when other materials (coal, oil shale, tar sands, limestone, etc.) are involved, a more appropriate term (such as "recoverable coal") may be substituted.

Restricted coal resources.—Coal resources that are determined to be unminable because of current land use or technologic restrictions.

Roof rock.—In underground mining, the rock immediately overlying a coal bed. Often the upper part of a coal bed is left unmined to serve as a roof for the mining operations.

Strip ratio.—A numerical expression showing the proportional relationship of a unit amount of waste material to a similar unit amount of ore or mineral material; the waste material must be removed in order to gain access to the target material.

Surface coal resources.—Coal resources, usually within a few hundred feet of the surface, that would most probably be mined by surface mining methods.

Technologic restrictions.—Constraints, relating to economics and safety, placed upon mining by the state of technology or prescribed by law; the restrictions could change with advances in science or modifications in the law. In this report, geological factors are included as technologic restrictions.

Yield-Mine.—See "Recovery."

Yield-Plant.—Ratio of salable product produced, including impurities, to the total input of the mine to the plant.

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