Powell River Project Series
Information for the Virginia Coalfields

Estimation of Southwest Virginia Coal Reserves

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Introduction

Coal mining in Virginia's Richmond basin was the first recorded production in the United States (Henderson, 1985). Since that production, more than 2.1 billion tons of coal have been extracted from three primary areas within the state: the Richmond basin, the Valley coal fields, and the Southwest Virginia coal field (Brown et al., 1952; VCCER, 1998).

Coal in the Southwest Virginia coal field exists in 57 principal seams in 7 different geologic formations (Nolde et al., 1994). In 1997, the mining of coal in Virginia generated over $200 million in payroll to more than 6,500 employees (VCCER, 1998), resulting in a continuing major socio-economic impact not only on the approximately 100,000 people of southwestern Virginia, but also on the entire commonwealth. Between 1990 and 1995, production declined from a record level of 46.5 million tons to 35.9 million tons. In recent years, production has stabilized - a result which is attributable, at least in part, to a coal-production tax credit passed by the Virginia General Assembly in 1996.

If coal production continues to decline in Virginia, negative economic impacts will be felt across the state, but these impacts will be most severe in the coal-producing counties of southwestern Virginia. This publication reports results of research conducted for the purpose of accurately estimating the extent of the remaining economically mineable coal reserves in southwestern Virginia (Westman, 1999). The research was sponsored by Powell River Project in recognition of the economic importance of Virginia's coal mining industry.

Prior to this research, a comprehensive study of the Southwest Virginia coal field had not been completed in nearly 50 years. Brown et al. (1952) published a resource study identifying known coal resources from seams of greater than 14 inches in thickness. Since that time, the U.S Department of Energy has maintained an estimate of remaining mineable reserves by subtracting annual mined tonnages, adjusted for additional tonnages lost in mining. This estimate is known as the Demonstrated Reserve Base (DOE/EIA, 1999).

Methods And Procedures

Input from active mining companies was critical to the completion of a meaningful study and was used extensively in the project. Seam data obtained from mining companies were used in accuracy assessment, but only data from public sources were used to compile the resource and reserve figures reported below.

Database

A database was established for 26 Southwest Virginia coal seams, including those which have been most heavily mined. The database includes coal thickness, ash, sulfur, in-seam reject, multiple-seam interaction, land-use restrictions, property tonnage, and county data, as well as seam outcrops and previous mining locations. Data for the database were obtained from publicly available sources. The ArcView geographic information system was used as the primary data analysis and manipulation tool. Grids composed of one acre cells were generated for each of the parameters and each of the seams.

Interpolated thickness grids were evaluated for accuracy by comparison to other databases and by using a quantitative accuracy assessment method developed as a part of the project. Resource estimates based on the project database compared well with resource estimates by Brown et al. (1952) and Campbell et al. (1991) for Southwest Virginia and Lee County, respectively. The quantitative accuracy assessment method (Westman et al., 1999) showed that the thickness data accurately represent average thicknesses over large areas but do not precisely represent true thicknesses at specific locations. Due to the scale of the study, precise representation was not expected.

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Resources and Reserves

The difference between coal resources and coal reserves is essential to interpretation of study results. The commonly held distinction, which is used in this report, is that a coal resource is coal existing in the earth, whereas a coal reserve is that portion of the resource which can be economically mined.

The factors which most influence resource levels were determined by completing a parametric analysis. Multiple-seam interaction and land-use limitations affect 8% and 6% of the remaining resource, respectively. Of the thickness and quality parameters considered by this study, sulfur content, thickness, and ash content have the most influence on resource levels, while in-seam reject and property size have much less effect. Table 1 shows the amount of resources fitting three increasingly restrictive criteria. Table 2 shows the "available" coal resources by county and coal seam for both surface and underground resources.

Table 1

Estimates of unmined (as of 1997) Virginia coal resources meeting three increasingly-stringent criteria unrestricted by land-use or multiple-seam interaction.

Max Sulfur (raw, %)	Min Thickness (inches)	Max. Ash (raw, %)	Min. Prop. Size (tons)	Max. In-Seam Reject (wt %)	Resources (million tons)		
					Underground	Surface	Total
2	12	25	10,000	50	19,900	3,950	23,850
1	30	15	1,000,000	33	8,460	1,980	10,440
0.5	48	5	100,000,000	10	1	20	21

Table 2a

"Available" Underground Resources by Seam and County (2% maximum sulfur, 30 in. min. thickness, 25% max. ash, 50% max. in-seam reject, 10,000 tons min. property size; all figures in 1000's of tons.)

County	Buchanan	Dickenson	Lee	Russell	Scott	Tazewell	Wise	Total
Aily	0	0	0	0	0	0	0	0
Blair	0	0	0	0	0	0	0	0
Clintwood	69,300	23,854	0	0	0	0	105,955	199,110
Dorchester	209,125	15,708	51,904	0	0	0	359,601	636,337
Hagy	75,549	0	0	9	0	0	0	75,558
High Splint	0	0	1,927	0	0	0	15,535	17,463
Imboden	29,681	874	86,846	0	0	0	174,033	291,433
Imboden Marker	0	0	0	0	0	0	0	0
Jawbone	202,522	913,365	6,085	69,744	0	72,069	1,346,198	2,609,985
Kelly	0	0	6,800	0	0	0	77,739	84,540
Kennedy	334,331	400,052	0	96,212	0	9,928	125,274	965,798
Lower Banner	166,469	125,402	0	74,808	0	6,347	27,731	400,756
Low Splint	0	0	0	0	0	0	44,773	44,773
Lyons	0	0	0	0	0	0	0	0
Morris	0	0	0	0	0	0	1,995	1,995
Norton	77,573	0	0	0	0	0	530	78,103
Pocahontas #3	171,378	133,959	4,112	92,171	97,476	9,312	353,175	861,582
Pardee	0	0	6,087	0	0	0	32,272	38,359
Phillips	0	0	0	0	0	0	0	0
Raven	152,500	259,940	0	144,212	0	41,246	272,084	869,981
Splash Dam	216,395	29,093	0	5	0	0	4,299	249,791
Taggart	2,391	0	15,112	0	0	0	51,781	69,284
Taggart Marker	0	0	0	0	0	0	0	0
Tiller	815,963	1,087,128	5,384	398,224	0	85,268	515,893	2,907,861
Upper Banner	4,779	514,299	0	39,028	0	0	234,433	792,539
Wilson	3,463	0	0	0	0	0	12,238	15,701
Total	2,531,418	3,503,675	184,258	914,413	97,476	224,169	3,755,541	11,210,949

The resource quantities found in this study are approximately double those found by Brown et al. (1952). This difference was expected, however, as much more data exist currently for deeper seams than existed at the time of Brown's study. A resource study for Lee County (Campbell et al., 1991) also found approximately double the resources as the Brown study, so the current findings are considered reasonable.

To separate reserves, or economic resources, from uneconomic resources, a model simulating Central Appalachian coal production economics was developed. Extensive industry input was foundational to the model. Coal sales price was established as a function of ash and sulfur content. Mining costs were related to stripping ratio, labor cost, and productivity for surface mining and to thickness, in-seam reject, labor costs, access costs, property tonnage and productivity for underground mining. Additional costs, including transportation, preparation, taxes, royalties, and office overhead, were determined. The model's accuracy was assessed by applying it to two Virginia coal-resource properties. The model showed good correlation to actual mining costs and profitability on these properties and was therefore applied to the database. Resources were considered to constitute reserves if our model estimated that they could be mined with a profit of at least five dollars per ton. It should be noted that the coal industry typically requires relatively high projected rates of return on capital investments for mine development because the risks of mine investment are also high. Future market price changes, for example, are difficult to predict, although the tendency over the past several decades has been for real-dollar prices to decline.

Study Results

Economically mineable coal reserves of 1.6 billion tons were estimated to remain in Southwest Virginia with current economic, technical, and legislative conditions. This value reflects the tonnage that could actually be extracted and sold. In arriving at this value, a mining loss of 15% was assumed for surface mines, and a mining loss of 40% plus a washing loss of 12% was assumed for underground mines. Additionally, a factor based on the

Table 2b

"Available" Surface Resources by Seam and County (2% maximim sulfur, 12 in. min. thickness, 25% max. ash, 10,000 tons min. property size; all figures in 1000's of tons).

County	Buchanan	Dickenson	Lee	Russell	Scott	Tazewell	Wise	Total
Aily	16,154	34,219	0	1,137	0	569	1,219	53,299
Blair	29,058	9,610	81,681	0	0	0	106,025	226,374
Clintwood	13,398	8,439	87,613	0	0	0	52,018	161,469
Dorchester	31,757	19,575	102,317	0	0	0	33,691	187,340
Hagy	95,842	41,999	0	19,721	0	292	84,705	242,560
High Splint	0	0	65	0	0	0	13,719	13,784
Imboden	15,169	4,165	51,382	0	0	0	32,756	103,472
Imboden Marker	0	655	6,900	0	0	0	5,143	12,698
Jawbone	835	134	0	507	0	1,827	138	3,441
Kelly	5,791	1,968	17,455	0	0	0	19,889	45,103
Kennedy	122,512	374,463	0	53,859	0	10,902	139,966	701,701
Lower Banner	258,685	288,828	4,489	17,809	0	3,586	199,912	773,309
Low Splint	0	0	2,498	0	0	0	6,644	9,142
Lyons	46,336	31,411	221	0	0	0	22,885	100,853
Morris	0	0	986	0	0	0	7,858	8,844
Norton	118,298	163,285	34,545	8,973	0	288	147,820	473,209
Pocahontas #3	121	39	0	3,660	103,103	1,662	0	108,586
Pardee	0	0	2,237	0	0	0	3,142	5,378
Phillips	0	0	210	0	0	0	573	783
Raven	817	121	0	107	0	47	1,949	3,042
Splash Dam	136,361	76,801	0	920	0	747	86,120	300,950
Taggart	1,644	0	23,313	0	0	0	563	25,521
Taggart Marker	1,694	0	3,624	0	0	0	2,525	7,842
Tiller	290	27	0	4,238	0	2,128	3	6,687
Upper Banner	17,291	223,705	0	6,354	0	3	120,961	368,313
Wilson	2,144	0	0	0	0	0	3,102	5,246
Total	914,199	1,279,447	419,536	117,286	103,103	22,051	1,093,326	3,948,947

quantified imprecision of the study was allowed. Figure 1 illustrates that most of the reserves exist in relatively deeper seams.

Table 3 shows total production (through 1997) and remaining reserves, broken down by county. The two counties with the highest production in 1997, Wise and Buchanan, have mined more than half their original reserves. Dickenson County has significant reserves but lower current production. Few of Scott County's reserves have been mined, but that county had very limited original reserves.

A surprising result shown in Table 3 is that of the three most productive counties (Buchanan, Dickenson, and Wise), only Dickenson has more than half of its original reserves remaining. In fact, the study concludes that, of Virginia's coal-mining counties, Dickenson County has the highest reserve base. To substantiate this conclusion, these results were compared to the findings of Brown et al. (1952). While Brown's study was a resource study, as opposed to a reserve study, the results should be in rough agreement. Table 4 shows, for each of Virginia's major coal-mining counties, Brown's 1951 estimate of resources thicker than 28 inches, total production between

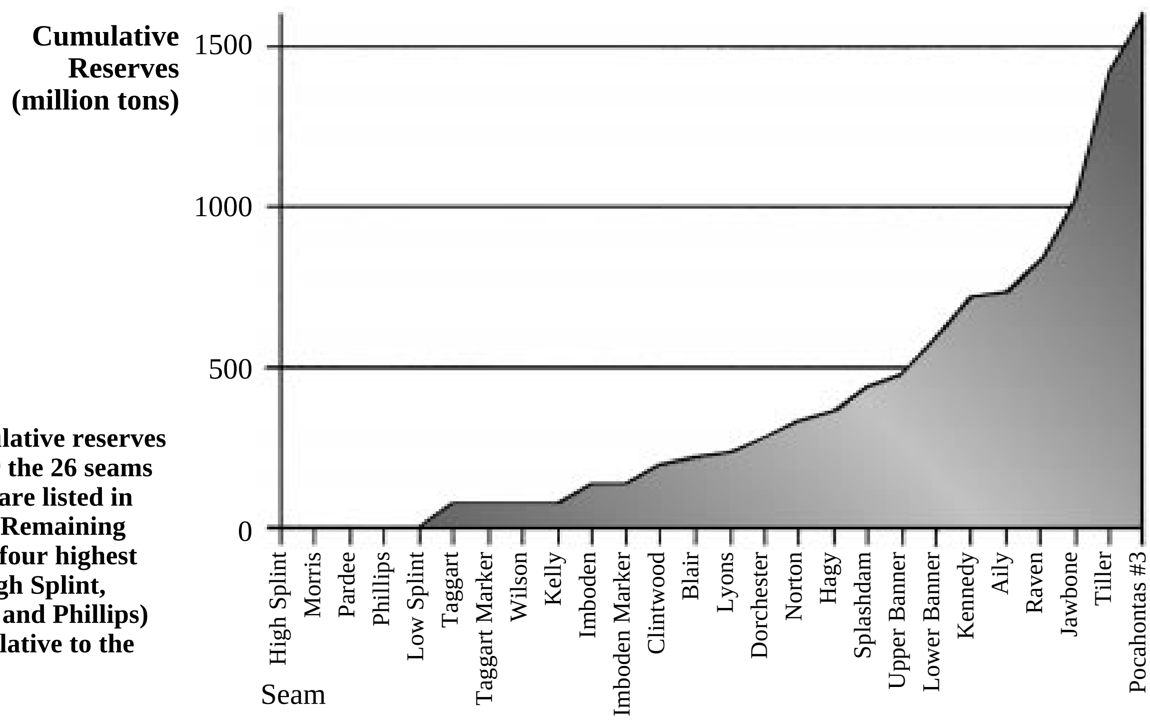

Figure 1. Cumulative reserves versus depth for the 26 seams studied. Seams are listed in order of depth. Remaining reserves for the four highest seams listed (High Splint, Morris, Pardee, and Phillips) are negligible relative to the graph scale.

Table 3

Previous production and reserves, by county.

County	Production through 1997 (million tons)	Surface Reserves (million tons)	Underground Reserves (million tons)	Total Reserves (million tons)	% initial mined
Buchanan	730.5	79.4	287.2	366.6	66.6
Dickenson	336.5	159.0	380.9	539.9	38.4
Lee	116.0	27.5	19.0	46.5	71.4
Russell	129.2	17.7	114.4	132.1	49.5
Scott	1.6	20.8	13.9	34.6	4.5
Tazewell	192.6	4.2	31.1	35.3	84.5
Wise	666.3	89.5	357.0	446.5	59.9
Total	2,172.8	398.1	1,203.4	1,601.5	57.6

1951 and 1997, and a calculated estimate of unmined resources as of January, 1998. Unmined resources are calculated as the 1951 resource tonnage minus twice the 1951-1997 production (the factor of two allows for mining losses and other restrictions). The results of this exercise also indicate that Dickenson County retains a relatively large unmined resource base. The apparent abundance of estimated reserves in Dickenson County could, however, be limited by difficult geologic conditions which were not accounted for in the current study.

Future Production

While it is important to have an estimate of remaining reserves, it is also important to estimate annual production in the short term. Such an estimation was completed by Crabtree (1995), based on a multiple linear regression model. Crabtree's results, seen in Figure 2, show past production from 1979 through 1993 as well as the projected production assuming pessimistic, moderate, and optimistic conditions. The actual production for 1994 through 1997 has been included and falls between the moderate and pessimistic predictions.

A model proposed by Milici, based on prior work by Hubbert (1962, 1972), states that the production history of a natural resource follows a bell-shaped curve. As a non-renewable natural resource, such as a fossil fuel, goes through the cycle of discovery, development, and exploitation, production generally increases to reach a maximum at the point at which one-half of the original reserves are depleted. Production then decreases as depletion continues. The production curve is not smooth because of changing economic conditions.

Milici outlines this model for Central Appalachia and Southwest Virginia in several publications (Milici and

Table 4

Unmined resource estimates based on Brown's 1951 coal-resource study.

County	Resources thicker than 28 in. in 1951 (million tons)[1]	Production between 1951 and 1997 (million tons)	Unmined resources thicker than 28 in., as of 1/1/98 (million tons)[2]
Buchanan	1,652	655	342
Dickenson	1,395	290	815
Wise	1,441	457	527

[1] Estimates from Brown et al., 1952
[2] Calculated as 1951 resources minus twice 1951-1997 production. (The factor of two accounts for reserves lost in mining).

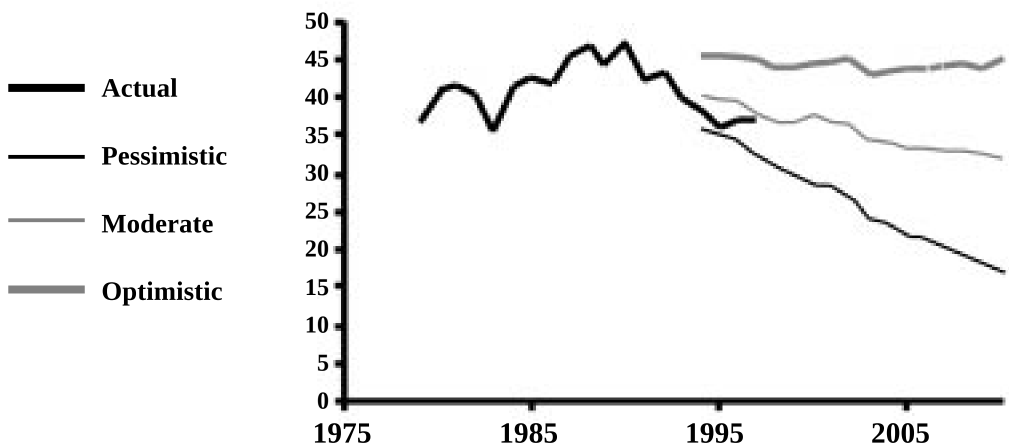

Figure 2. Virginia coal production forecasts with optimistic, pessimistic, and moderate predictions (after Crabtree, 1995).

Campbell, 1991a; Milici and Campbell, 1991b; Milici, 1997). For Southwest Virginia, he estimated that Virginia's maximum annual production would occur between 1989 and 2011 and then decrease to 20- to 30-million tons per year between 2020 and 2080 (Milici and Campbell, 1991a). Several key assumptions are made in the use of this model, including:

1) the definition of original reserves. Original resources are defined by a region's geology, but mineable coal reserve levels change in response to changes in mining technologies, economics, and legislative restrictions.
2) the analysis of a relatively large area. Production from a small, localized area typically does not follow a bell-shaped curve.

For this analysis the economic, technologic, and legislative conditions of January 1, 1998, were assumed. Curves were generated for the sum of all seven counties, for Buchanan, Dickenson, and Wise counties individually, and for Lee, Russell, Scott, and Tazewell counties combined. The four small-reserve counties were combined to satisfy the requirement that a bell-shaped curve be fitted to production of a relatively large reserve.

The bell curves were fit by adjusting the area, mean, and standard deviation of the equation for a normal distribution (bell curve) of production versus time. The area under the bell curve is the original reserve tonnage. This was calculated by adding the tons mined through 1997, adjusted for losses in mining, and the total reserves (listed in Table 3). The mean (peak) of the bell curve is located at the year in which 50% of the original reserves were mined. This was found by accumulating production within a county until the mean was achieved. For example, 50% of Buchanan County's 1.1 billion tons of original reserves had been mined by 1986. Finally, the standard deviation (or width of the bell curve) was determined by adjusting its value until the cumulative production described by the bell curve through 1997 matched the actual cumulative production through 1997. Curves for the seven county total, Buchanan County only, and Wise County only are shown as Figures 3, 4, and 5, respectively. Generally, as the reserve size increased, the curve matched the actual production more closely. The curves for Buchanan, Wise, and the sum of all seven counties matched the normal distribution fairly closely, while those for Dickenson and the combined four smaller counties did not agree as closely.

Future production can be projected based on the generated curves. Table 5 shows 1997 production and the projected change within ten years. Projected changes were calculated in two ways and are thus reported as ranges. Projected changes were calculated by comparing the projected production in 2007 (as determined by the

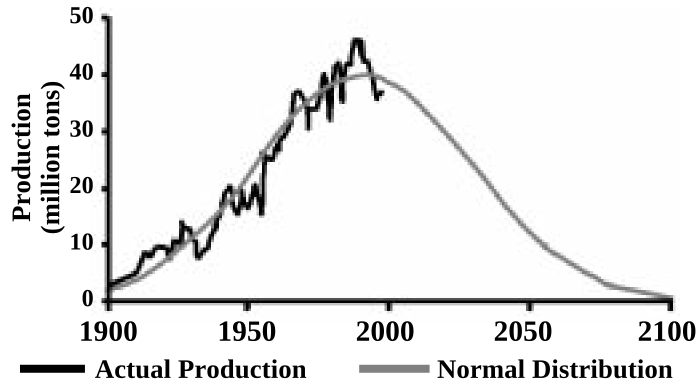

Figure 3. Actual production and production described by a bell curve (normal distribution) for the combination of all seven Southwest Virginia counties.

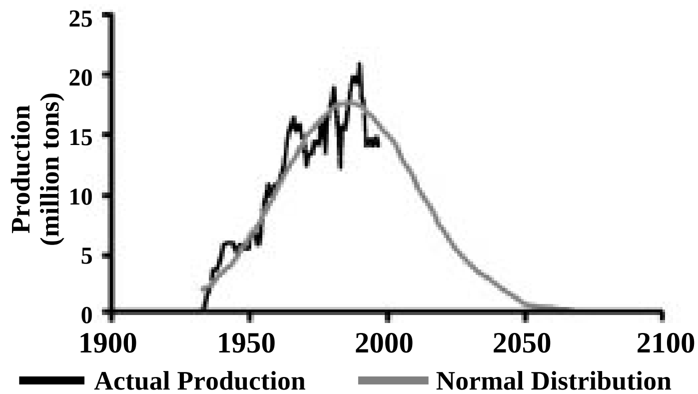

Figure 4. Actual production and production described by a bell curve (normal distribution) for Buchanan county.

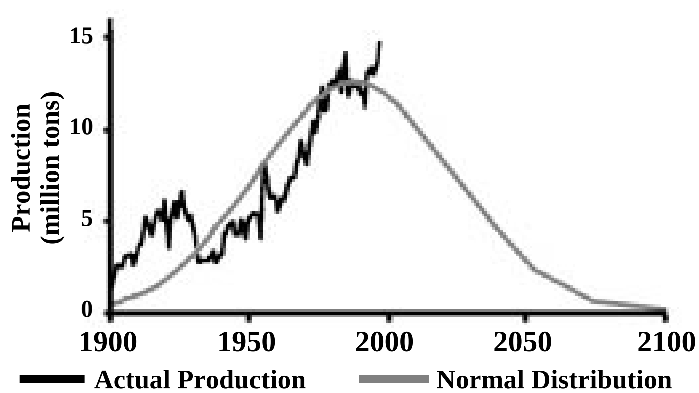

Figure 5. Actual production and production described by a bell curve (normal distribution) for Wise county.

bell-shaped curve) to both the actual production from 1997 and to the 1997 bell-curve estimate for 1997. The model indicates a potential for production growth in Dickenson County over the next ten years. Annual production levels in Buchanan and Wise counties are projected to decline approximately 10 to 25 percent over the next ten years. Combined production from the four smaller counties is projected to remain fairly stable. The model projects a likely drop in statewide production.

Table 5

1997 coal production, and projected 10-year change in annual production levels.

County	1997 Production (million tons)	Projected Change in Annual Production over 10-years, as % of 1997 Production Level[1]
Buchanan	14.0	-12 to -23
Dickenson	3.4	+4 to +160
Lee, Russell Scott, Tazewell	4.8	- 15 to +22
Wise	14.7	-11 to -26
Total	36.9	-13 to 2

[1] Assumes no major change in mining technology, and that production follows the bell-shaped curve model.

Conclusions

A database of the characteristics of 26 Southwest Virginia coal seams was established in order to analyze and estimate remaining coal resources. An economic model was developed and validated to determine the portion of the resources which are economically mineable reserves.

The results of this research indicate that approximately 27.7 billion tons of coal remain in Southwest Virginia. Of this resource, approximately 15.2 billion tons are unrestricted by land-use (or multiple-seam interaction if underground), less than 2% sulfur, less than 25% ash, greater than 12 inches thick if surface, and greater than 30 inches thick if underground. These "available" resources are split into 11.2 billion tons of underground resources and 4.0 billion tons of surface resources.

The resource quantities found in this study are approximately double those found by Brown et al. (1952) in the most recent comprehensive resource study for Southwest Virginia. This difference was expected, however, as much more data exist currently for deeper seams than existed at the time of Brown's study. A resource study for Lee County (Campbell et al., 1991) also found approximately double the resources as the Brown study, so the current findings are considered reasonable.

Using current industry definitions, 1.6 billion tons of economically mineable reserve were estimated, given current market conditions and mining technology. As with the resources, the majority of coal reserves are in deeper seams which require expensive development to access. These development costs significantly increase the risk involved with these seams, making them less attractive in the currently volatile coal market.

By assuming that coal production over time follows a bell-shaped curve, future production can be estimated. This analysis indicates that the production from Dickenson County may increase over the next 10 years while that of Buchanan and Wise Counties is likely to decrease. Overall, this analysis indicates that annual Virginia coal production is likely to decline over the next decade, perhaps by 5 to 10 percent.

Maintenance of an accurate assessment of Virginia coal reserves can aid Southwest Virginia officials in their efforts to plan for a viable economic future. If a means could be developed for incorporating coal-resource data collected by area coal-mining firms into the database on a continuous basis, while maintaining confidentiality, the result would be an improved regional-planning capability.

Additional Information

More detailed results of this research can be found on the world wide web at http://www.energy.vt.edu/reserves/

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