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Manpower for the Coal Mining Industry: an Assessment of Adequacy through the Year 2000

Final Technical Report
Volume II: Technical Approach

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ABSTRACT

This report presents a summary of the analytical approach taken and the conclusions reached in an assessment of the supply and demand for manpower in the coal mining industry through the year 2000. A hybrid system dynamics/econometric model of the coal mining industry was developed which incorporates relationships between technological change, labor productivity, production costs, wages, graduation rates, and other key variables in estimating imbalances between labor supply and demand.

Study results indicate that while the supply of production workers is expected to be sufficient under most future demand scenarios, periodic shortages of experienced workers, especially in the Northern Great Plains can be expected. Other study findings are that the supply of mining engineers will be sufficient under all but the highest coal demand scenario, a shortage of faculty will affect the supply of mining engineers in the near-term and the employment of mining technicians is expected to exhibit the largest increase in any labor category studied.

In this volume of the report the nature of the coal mining manpower problem is discussed, a detailed description of the analysis conducted and the sources of data used is provided, and the findings of the study are presented.

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PREFACE

In this report, the work carried out in assessing the supply of and demand for manpower in the coal mining industry in the United States through the year 2000 is described. The report is in two volumes; an Executive Summary (Vol. I) and a description of the technical approach taken (Vol. II). This work was carried out over a 15 month period for the Office of Coal Mining in the U.S. Department of Energy. The objectives of this study are:

- to project manpower supply and demand for a variety of future coal production scenarios and to identify future imbalances by producing region, mining technology, and skill category
- to estimate the sensitivity of manpower supply and demand to changes in major influencing factors; e.g., labor productivity, wages and salaries, coal production, technology mix, capital costs
- to assess the adequacy of existing federal educational support programs for manpower training in the coal mining industry and the impacts of future support on manpower supply

With these objectives in mind, it is apparent that in order to understand the nature of the major influences on manpower supply and demand, it is necessary to identify and quantify many of the relationships which characterize the coal mining industry in the United States.

The analytical approach chosen to do this involves the development of a hybrid system dynamics/econometric model which simulates, on a regional and annual basis, the supply of and demand for coal mining manpower. For any desired coal production and price schedule (given on a national or regional basis), the model provides estimates of the implications of that schedule in terms mf manpower requirements and manpower supply.

As a result of this work, a tool has been developed that can be used to answer a wide variety of questions involving the coal mining industry in general and coal mining manpower in particular. For example, many questions involving the impacts on manpower of such factors as production costs, federal policies, the market penetration of new technologies, labor productivity, and total coal demand can be answered using the model which has been developed in this study.

REPORT ORGANIZATION

This volume is divided into eight sections. In Section 1.0, the study's analytical results are discussed in some detail. Model results are presented which give estimates of the sensitivity of manpower supply to federal support programs, job opportunities, and wages/salaries. Also, the sensitivity of manpower demand to changes in labor costs, productivity, technology mix, and a variety of coal production constraints is analyzed in this section. In Section 2.0 some of the major issues involving coal mining manpower are discussed and background material is presented which describes the status of manpower in the coal mining industry in terms of the changing skill and age composition of the work force, educational levels, wages and salaries, and productivity. Section 3.0 presents the analytical approach taken in this study and provides a description of the model's major assumptions, its parameters, and logical structure. In Sections 4.0 and 5.0, the labor supply and demand analysis carried out within the model are discussed in some detail. In Section 6.0, those assumptions and variables which are exogenous to the model are discussed. These include coal production estimates, GNP growth rates, the unemployment rate, and non-coal employment of mining engineers. Section 7.0 provides a description of the assumptions which underlay each of the sensitivity analyses conducted. Finally, Section 8.0 provides an assessment of the model's validity as a forecasting tool, given its ability to reproduce major industry variables (e.g., coal production by mining technology, workforce size and composition, technological change, labor costs, and labor productivity for the period 1960-1979).

The text of this volume is followed by three appendices which provide background data and supporting documentation for the relationships used in the analysis. Appendix A describes and presents data for the model mines used in the analysis. In Appendix B the current status of professional and technical education programs related to coal mining is described. In addition, this Appendix summarizes the existing public and private support available to students in these programs. Appendix C summarizes the constraints on technology penetration which were used in the model.

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CONCLUSIONS AND RECOMMENDATIONS

Study Conclusions

(1) Area Surface Mining to Dominate Coal Production by 2000

The combination of large and small area mines located in the midwestern and western regions of the nation is expected to dominate coal production by 2000. These surface mines, are expected to produce about 55 percent of the nation's total tonnage by 1990 and about 75 percent by 2000. Total employment in these mines will, however, account for 26 percent of the total on-site employment in 1990 and 52 percent in 2000. The high productivity, favorable mining conditions, and relative profitability of these mines contribute significantly to their rapid growth rates. Deep mining production, in the most probable case, exhibits a slow growth in production from a little under 300 million tons per year in 1980 to 400 million tons per year in 1990. The relatively slower growth rate of deep mining results in a continuing decline in its percentage share of national coal production.

(2) Labor Productivity in Deep and Surface Mining to Increase Moderately in the 1980s.

The labor productivity in both deep and surface mining is expected to increase moderately in the 1980s regaining some but not all of the productivity losses experienced in the 1970s. Deep mining labor productivity is expected to increase from a low of 8.3 tons/man-day in 1978 to a high of 12 tons/man-day in 1990. Similarly, surface mining labor productivity is expected to increase from a low of 26.4 tons/man-day in 1976 to 34 tons/man-day by 1992 and then decline to 31 tons/man-day by 2000. The gains in productivity in the 1980s are primarily due, in deep mining, to an increase in the percentage of production from continuous mining operations and a gradual decline in conventional mining production. In surface mining, the gains in productivity are attributable to a shift in surface production from the less productive, thin seam eastern contour mines to the larger, thick seam western and midwestern area mines. Both underground and surface mining productivity were forecasted to decline slightly during the 1990s. The shift toward more mechanized, highly productive mines in each sector achieves saturation levels (e.g., such mines account for over 90 percent of production in surface and deep mining) resulting in little additional productivity growth. At the same time, rising real coal prices still attract some number of marginal (i.e., high per ton cost) mines into operation, slightly outweighing productivity increases from other factors over this period.

(3) Periodic Shortages of Experienced Hourly Production Workers

The high turnover rate among hourly production workers having less than one year's experience (35-40 percent), when combined with fluctuating regional growth rates in coal production, is expected to result in the continued employment of large numbers of inexperienced miners (i.e., around 60,000 in 1990 in the Median Demand, or Base Case). This employment is necessary in order to fill the gap between the demand for and the supply of experienced production workers. It is not until the early 1990s that the number of inexperienced miners is forecasted to fall and remain below 20 percent of the hourly production work force in most cases.

(4) Labor Shortages Most Likely in the Northern Great Plains and Midwest Region.

For all future coal demands considered, the fastest growth rates for labor demand by the coal mining industry are in the Northern Great Plains and Midwest regions. The demand for labor in 1975 as a percentage of the available male labor force was 6.2 percent in the Northern Great Plains and 5.5 percent in the Midwest. By 1990 the demand for labor as a percentage of the available male labor force is projected to increase to 35.2 percent in the Northern Great Plains and 15.9 percent in the Midwest. The projections of the regional male labor force are based on state-level U.S. Bureau of Census projections which assume a continuation of 1970-75 interstate migration patterns. Clearly, if labor demand increases as projected in the Northern Great Plains and Midwest and migration patterns are not altered significantly, labor supply will be a major constraint to rapid coal development in these areas.

(5) Relative Predominance of Mining Engineering Within Coal Industry Facing Modest Decline

The percentage of all engineers in the coal industry who are mining engineers (currently about 60 percent) will continue a modest decline, approaching 50 percent of all engineers or about 2,000 mining engineers by the year 2000. This appears to be due to a trend toward continued growth of surface relative to underground mining which has enhanced the willingness of some producers to substitute other professionals, such as civil engineers for mining engineers, especially for positions in production supervision.

(6) Mining Engineer Shortages Unlikely by the Mid-1980s

The likelihood of mining engineer shortages affecting the coal mining industry any time after the mid-1980s appears to be rather small under most combinations of probable economic and energy demand conditions. Only in cases which combine at least two out of the following five conditions do persistent shortages of mining engineers, in the absence of Federal funding, occur:

(a) very high demand for mining engineers in non-coal mining industries (i.e., 250 new positions per year from 1985 to 2000)

(b) doubling of offsite employment (with greatest concentration of professionals) as percentage of total coal industry employment to 10 percent by 1990

(c) increased on-site personnel requirements due to regulatory changes, resulting in 20 percent greater technical support staff and 10 percent greater total employment after 1980

(d) major increase in eastern coal production reaching 0.6 billion tons per year by 2000, including almost a fourfold increase in eastern surface production (based on higher transportation costs facing midwestern and western coal producers).

(e) high coal production scenario reaching 2.8 billion tons per year by 2000

(7) <u>Current B.S. Degree Graduation Levels Sufficient Under Most Probable Future Conditions</u>

The current level of B.S. degree mining engineering graduates from both accredited and non-accredited curricula (about 630 in 1979), if maintained throughout the 1980s, would result in a surplus under all but the most optimistic demand assumptions as described above. As there is very little demand specifically for advanced degree engineers of any type in the coal industry, the projected yearly graduation rate of between 500 and 600 B.S. degree mining engineers resulting from market forces alone (i.e., in the absence of scholarship funding) is capable of meeting coal mining engineering demand in almost all cases.

(8) <u>Potential Shortages of Mining Engineers Can Be Alleviated Via Scholarship Funding</u>

Under conditions where the greatest potential for future shortages of mining engineers exists (Sensitivity Analyses #2, 4 & 7 in Section 1.2), Federal scholarship funding at the same constant dollar level as at the present, if directed toward mining engineers, is expected to eliminate these shortages usually by the late 1980s. This is based on a continuation of historical trends in which 25 to 50 percent of undergraduate students who receive most of their educational expenses under scholarships are attracted to mining engineering instead of to other disciplines by such funding. In the highest future manpower demand case (Sensitivity Analysis #8 in Section 1.2), sufficient students are attracted so that about 100 additional B.S.

degree mining engineers graduate from 1984 onward. This would eliminate the manpower shortage projected in this case by the early 1990s.

(9) Professional Manpower Availability Facing the Coal Industry for Other Engineers and Scientists Appears Adequate Through 2000

The coal industry currently accounts for about 0.1 percent of the nation's employment of non-mining engineers and scientists with degrees applicable to mining.* By 2000, these percentages are expected to increase slightly in the most probable future to about 0.17 and 0.28 percent of national employment respectively among these engineering and science disciplines. Even in those cases where the nation's demand for non-mining engineers and scientists is greatest, coal industry employment within the national totals accounts for only 0.19 and 0.30 percent, respectively. Thus, apart from a major national shortage of professionals in these disciplines, it appears unlikely that the coal industry will be faced with an insufficient professional labor supply. This conclusion is further supported by the long established tradition within industry (and recognized by the National Science Foundation in its demographic studies) that many workers performing as engineers and scientists, especially those engaged in non-academic or non-certifiable work such as that of production, often learn their skills on-the-job under the tutelage of degreed personnel.

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*Civil, mechanical, industrial, and electrical engineers, and scientists with degrees in chemistry, ecology, biology, agronomy, forestry, wildlife and range management.

(10) Shortage of Mining and Mineral Engineering Faculty

A major near-term problem affecting the supply of mining engineering graduates is the difficulty of mining schools in attracting sufficient faculty. The level of full time equivalent faculty engaged in research has declined dramatically since the 1973-74 academic year. The remaining faculty resources available for teaching has resulted in effective student/faculty ratios of between 30 and 40 to one in most schools. The Engineers Council For Professional Development (ECPD) has defined 20 to one as a desirable maximum ratio of teaching faculty to undergraduate students. Thus, a need exists for attracting more faculty to reduce undesirable teaching loads, as well as to perform more research related to the improvement of mining technologies and labor productivity.

(11) Impact of Relative Salaries in Creating Faculty Shortage

Faculty salaries relative to those which can be earned by bachelor degree engineers in the coal industry have been the cause of a major labor market distortion. Increasing industry personnel demands and salaries have resulted in more students enrolling in programs such as mining engineering, and in turn, in a requirement for more faculty. However, the number of faculty are limited by salaries that are low relative to those paid by industry. The highest faculty salaries for full professors are about $30-35,000 ($24-28,000 in 1976 dollars). These salaries are often exceeded by those paid to industry supervisors who possess only a bachelor's degree. Thus, the ability of schools to retain existing faculty, much less to train new M.S.'s and Ph.D.'s, becomes even more limited.

(12) Potential for Inter-School Competition for Scarce Faculty

If additional State Mining and Mineral Resources and Research Institutes are established without raising faculty salaries, extreme competition is likely to take place among universities for existing faculty. Although inter-school competition may marginally increase faculty salaries, all schools face the same constraint of maintaining relative salary equivalence among faculty of like rank across disciplines.

(13) Distribution of Engineers and Scientists in Salaried Work Force

Among coal industry positions grouped as salaried or non-hourly personnel,* on the average, engineers now comprise about five percent and scientists about one percent of this industry segment. Although the number of engineers as a group initially grows faster than does that of scientists, after the mid-1980's, the size of the former group grows more slowly. This slower growth is attributable mainly to the maturation of non-conventional deep mine technologies (i.e. continuous and longwall) and to the decline of eastern surface mining, which requires more engineers among non-hourly personnel than do technologies which characterize the midwest and west. However,

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*Defined to include all non-production and office personnel, on- and off-site, plus production supervisors and technical support staff (e.g., safety inspectors) involved directly in production.

the absolute growth of engineers and scientists employed in the coal industry and in related consulting companies is dependent largely on the growth of environmental, health, and safety regulations.

(14) Demand for Mining Technicians

The demand for qualified mining technicians, preferably having two-year associate degrees, will grow quite rapidly as long as the coal industry itself is expanding. This demand exists primarily for skilled production workers (e.g., electricians, heavy equipment operators, welders, and various types of mechanics, especially for diesel equipment in surface mines), and, to a lesser degree, for those in technical support positions (e.g., health and safety personnel, reclamation technicians, etc.). In the most probable employment future as identified in this study, the number of such technicians is expected to increase from less than one percent of total coal industry personnel in 1980, i.e., about 2,000 technicians, to over five percent or about 25,000 technicians by the year 2000.

(15) Support for Mining Technology Programs

Coal companies have been particularly active in establishing and supporting mining technology programs, especially two-year degree programs usually offered through community colleges. Both industry and college officials have confirmed the overall success of such programs, many of which provide on-the-job work experience and rapid placement following graduation. However, the performance of graduates, both in school and on-the-job, varies greatly. Notably, according to all faculty and coal company personnel questioned on this subject, CETA-funded students consistently have had higher-than-average drop-out rates during enrollment and higher-than-average quit rates shortly after employment.

(16) Potential Competition Between Two-Year and Four-Year Degree Graduates

A key area of potential job competition between four-year B.S. degreed engineers and two-year A.S. degreed mining technicians is that of production or first-line supervision (i.e., section foremen in deep mines, pit foremen in surface mines). Company interest in hiring more B.S. degreed engineers for supervisory and other state-certified positions stems in part from the waiver by most states of two out of the three years experience requirement for certified positions. This interest in hiring B.S. degreed engineers is mitigated by a tradition of promoting from within the production work force, and according to most coal producers interviewed, a general reluctance of B.S. degreed persons to spend much time directly in production. Moreover, several states now waive one year of experience for two-year mining technology graduates at approved schools. To the extent that two-year degreed technicians are willing to work their way up and remain in the production work force, many of them may obtain jobs that otherwise might be offered to B.S. degreed engineers.

Recommendations

(1) Enhance Federal Support to State Mining and Mineral Resources and Research Institutes but Reconsider the Establishment of New Institutes in Light of Long Term Enrollment Needs

Support should be enhanced to mining and mineral engineering programs, through increased institutional funds and continuation of the SMMRRI research/scholarship funds authorized under the Surface Mining Control and Reclamation Act of 1977. This is important both to expand faculty and thus to ease teaching loads, and also to allow research to be performed on improving labor productivity and technology innovation. It is felt in the industry and university communities alike that more research in these areas is needed to lend greater balance to the current emphasis on environmental, health and safety research. Opportunities for faculty development through creative research should not be looked upon as merely a buffer during periods of low enrollment; rather such opportunities are essential for professionals to remain current in their fields, and to perform the types of basic research necessary for later technological breakthroughs which private industry is often reluctant to fund.

Nevertheless, given the forecasted demand for new mining engineers through 2000, it is unlikely that enrollment capacity greater than that occurring at present will be required over this period. Therefore, it is necessary to reconsider the need for establishing any new SMMRRI's. The addition of new mining schools in a few years will not alleviate the current and temporary high enrollment problem which suffers mainly from a lack of available faculty. Instead, additional mining schools will enhance the likelihood of inter-school competition for limited faculty and future undergraduate enrollments which are forecasted to decline up to 50 percent by the early 1990s.

(2) Place More Emphasis on Surface Mining Skills

Major fluctuations in past enrollments in mining and mineral engineering over the last 30 years may be repeated by the mid-to-late 1980's if current high production growth forecasts for coal and other mining industries do not come to pass. To minimize this possibility, schools should consider placing greater emphasis on surface mining skills (more in demand for the coal, copper, and other mining industries) relative to deep mining techniques, perhaps through some modification of curricula.

(3) Provide Realistic Expectations to Students about Probable Job Assignments

Students in mining and other engineering disciplines should be made aware that most coal and other mining companies offer initial assignment as production supervisor trainees. Moreover, production supervision is the job function most in demand by industry, and advancement to engineering and management positions occurs only as expansion and retirements permit. Nevertheless, schools should stress that the compensation of production supervisors relative to front office positions does reflect the high demand and overall regard within industry for those involved directly in the production process.

(4) Continue Support Through Existing Programs for Assistance to Community Colleges and Vocational Schools

Community colleges and vocational/technical schools offering coursework related to mining technology, including two-year and even four-year curricula, presently receive funding through a number of Federal programs. These include: Mine Safety and Health Administration funds for miner health and safety training, and HEW/Office of Education funds, both to state boards of vocational education and to state prime sponsors, under the Comprehensive Employment and Training Act. Although Federal funding levels comprise a small fraction of state expenditures (less than 10 percent of all vocational training funds spent), and although the successful use of these funds may vary, there is no need at present for massive Federal aid specifically geared toward mining technology, regardless of the rapidly growing demand for technicians. This recommendation is based on the cooperative relationship exhibited between many state agencies and coal companies in structuring practical programs most appropriate to industry needs. Although additional support through existing programs may be useful and certainly welcomed by the states and coal producers alike, it appears that coal producers have demonstrated a willingness to support such schools, in terms of financing, developing suitable curricula, and providing on-the-job training through work-study type arrangements. Since mandatory training with respect to health and safety is already ensured under MSHA regulations, any additional assistance to train skilled miners should permit the same type of state and company discretion to meet indigenous needs as presently is the case.

1.0 STUDY RESULTS

The conclusions and recommendations presented at the beginning of this report were based on an extensive analysis of all aspects of the coal mining industry which involve labor supply and demand. The major components of this analysis were as follows:

- review and assessment of recent studies and data sources concerning coal industry manpower and related issues (e.g., productivity, compensation, educational and training needs, etc.);
- extensive discussions with university, industry, union and public officials regarding matching the supply of new graduates with expected demands for skills and the need for Federal educational assistance to correct imbalances;
- development of a coal industry simulation model which incorporates criteria for industry decision-making and empirically-derived relationships among key variables in order to identify potential manpower shortages or surpluses by labor category.

It should be emphasized that the model developed in this study incorporates both the insights obtained from informed officials and statistically related variables. Combining these inputs with a number of exogenous variables, the model is intended to be a flexible tool which can assess major uncertainties and policy options. In Section 1.1, model results are presented for benchmark years, using probable high, medium and low coal demand cases. In Section 1.2, the same model outputs are presented under alternative sets of market conditions and Federal support levels, to account for those uncertainties which are likely to affect labor supply/demand imbalances. Finally, major study conclusions are presented in Section 1.3 along with appropriate supporting analysis.

1.1 Initial Case Results

The three initial cases used in the mining manpower model were developed by incorporating and extrapolating to 2000 three representative coal demand cases as well as the long-range economic forecasts of the Bureau of Labor Statistics (BLS #8, 1979). Section 6.1 describes in detail how these separate forecasts were utilized and how their assumptions were merged to provide those exogenous inputs through the year 2000 necessary to run the manpower model.

Table 1-I presents selected model outputs for the Base, High and Low Coal Demand Cases. As may be seen, each variable has the same value through 1978 among the three cases. The model was run for the period 1960-2000. Model results for the period 1960-1978 were compared with historical data to provide a means for assessing how well the model has been able to reproduce empirical and inferred values for each variable. In Table 1-I, model outputs are grouped in terms of coal production and productivity data, graduations and employment by labor supply category, and employment and wages by labor demand category. While most model outputs are within ± 15 percent of historical values, this may be exceeded in a limited number of observations. The model's ability to reproduce given variables as well as major trends can be observed by plotting for visual comparison both the predicted and actual values for the period 1960-1978. Such graphical results are presented for major variables in Section 8.0: Model Validity.

TABLE 1-I
SELECTED OUTPUTS FROM COAL
DEMAND CASES[a]

	1965		1970		1978		BASE CASE			HIGH CASE			LOW CASE		
COAL PRODUCTION DATA (10^6 TONS/YEAR)	MODEL	HISTORICAL	MODEL	HISTORICAL	MODEL	HISTORICAL	1985	1990	2000	1985	1990	2000	1985	1990	2000
Total Coal Production	512.1	512.1	602.9	602.9	595.3	653.8	1057.8	1501.1	2221.2	1057.2	1676.0	2787.8	990.1	1114.4	1515.6
Underground Coal Production	308.5	332.7	277.9	338.8	219.2	242.5	357.6	398.4	294.4	358.7	421.5	311.2	331.5	323.1	250.2
Surface Coal Production	203.6	179.4	325.0	264.1	376.0	411.3	700.2	1102.7	1926.8	698.5	1254.5	2476.6	658.6	791.3	1265.4
PRODUCTIVITY DATA (TONS/MAN-DAY)															
Underground Average Product of Labor	12.8	13.7	11.8	15.6	9.3	8.3	11.5	11.9	10.3	11.3	11.9	10.0	12.0	12.0	10.4
Surface Average Product of Labor	31.4	30.4	33.4	36.0	23.5	25.0	29.6	33.6	31.3	28.7	33.5	30.3	31.9	33.5	32.0
GRADUATIONS AND EMPLOYMENT BY LABOR SUPPLY CATEGORY (10^3 MEN/YEAR)															
Graduations of Mining Engineers															
B.S. Degree	0.1	0.2	0.2	0.2	0.4	0.5	0.6	0.3	0.3	0.6	0.6	0.3	0.4	0.3	0.3
Advanced Degree	<0.1	0.1	<0.1	0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Employment of Mining Engineers[b]															
Nationally	4.3	(4.3)	4.8	(5.1)	6.4	(6.9)	8.6	9.2	10.2	8.7	10.6	11.5	8.0	7.8	8.8
In Coal Industry	0.7	(0.7)	0.8	(0.8)	1.2	(1.4)	1.7	1.9	1.7	1.5	1.9	2.0	1.6	1.5	1.2
Graduations of Other Engineers Applicable to Mining (BS Degree)	26.8	27.1	28.0	31.3	22.6	-	25.7	30.6	40.9	27.5	38.3	52.1	23.8	24.8	31.8
Employment of Other Engineers Applicable to Mining[b]															
Nationally	776.0	(754.0)	828.4	(830.0)	893.3	(911.0)	998.8	1077.0	1229.6	1031.2	1131.4	1302.1	973.5	1035.3	1173.4
In Coal Industry	0.4	(0.4)	0.4	0.5	0.8	(0.9)	1.4	1.5	1.7	1.4	1.7	2.1	1.2	1.2	1.2
Graduations of Scientists Applicable to Mining (Adv. Degree)	6.3	6.0	8.8	9.2	9.7	-	11.5	13.3	18.1	12.0	15.2	20.8	11.1	12.0	15.9
Employment of Scientists Applicable to Mining[b]															
Nationally	147.2	(150.0)	178.9	(175.0)	248.0	-	306.6	360.6	474.4	329.4	402.7	531.4	296.3	334.3	430.2
In Coal Industry	0.3	(0.1)	0.3	0.3	0.4	0.4	0.6	0.7	1.1	0.6	0.8	1.4	0.6	0.6	0.8
Graduations of Mining Technicians (Two-Year Degree)	0	0	0	(≈0)	0.4	(0.7)	0.9	1.4	2.1	0.9	1.5	2.4	0.9	1.2	1.6
Employment of Technicians In Coal Industry[b,c]	0	-	0	-	1.3	-	4.3	9.2	24.6	4.4	9.2	26.4	4.4	9.2	21.3

TABLE 1-I (Concluded)

EMPLOYMENT AND WAGES BY LABOR DEMAND CATEGORY	1965 MODEL	1965 HISTORICAL	1970 MODEL	1970 HISTORICAL	1978 MODEL	1978 HISTORICAL	BASE CASE 1985	BASE CASE 1990	BASE CASE 2000	HIGH CASE 1985	HIGH CASE 1990	HIGH CASE 2000	LOW CASE 1985	LOW CASE 1990	LOW CASE 2000
On-Site Employment of Personnel In Coal Industry (10^3 Men/Year)															
Supervisors	11.2		11.1		14.7		19.8	24.3	34.4	20.2	26.8	42.8	17.6	13.5	24.3
Technical Support Staff	6.3		7.0		12.8		17.8	21.0	27.3	18.2	23.2	33.9	15.7	15.9	19.2
Administrative Support Staff	4.7		4.4		8.0		12.0	15.6	26.6	12.3	17.5	34.3	10.6	11.5	17.9
Skilled Production Workers	59.1		57.2		96.0		128.1	151.5	206.4	131.1	167.6	258.6	112.9	114.7	144.0
Semi-Skilled Production Workers	55.2		47.0		64.0		80.8	95.9	126.8	82.5	105.8	157.5	71.7	73.0	89.5
All Hourly Production Workers	114.3		104.2		160.0		208.9	247.4	333.2	213.6	273.4	416.1	184.6	187.7	233.8
Average Yearly Wage of Personnel In Coal Industry (10^3 1976 Dollars)															
Supervisors	25.4		28.0		28.0		28.7	29.5	34.5	29.5	30.8	34.0	27.5	28.7	34.3
Technical Support Staff	22.1		24.3		24.4		24.9	25.6	30.0	25.6	26.8	29.5	23.9	24.9	29.8
Administrative Support Staff	8.9		9.1		8.6		10.7	12.4	14.8	11.9	13.7	17.1	10.4	11.4	13.9
Skilled Production Workers	12.1		13.7		16.9		21.7	24.8	30.7	21.8	24.8	30.7	21.5	24.7	30.7
Semi-Skilled Production Workers	11.0		12.4		15.4		19.8	22.5	27.9	19.8	22.5	27.9	19.6	22.4	27.9
All Hourly Production Workers	11.6	12.0	13.1	13.3	16.3	16.6	21.0	23.9	29.6	21.0	23.9	29.6	20.8	23.8	29.6
On-Site Employment - Total (10^3 Men/Year)	136.6		126.7		195.6		258.6	308.3	421.6	264.2	340.9	527.0	227.4	233.5	295.1
At Mines	130.1		120.3		186.4		242.3	285.2	387.4	247.9	315.1	484.1	213.2	216.3	271.3
At Preparation Plants	6.5		6.4		9.2		16.3	23.1	34.2	16.3	25.8	42.9	15.2	17.2	23.3
Entire Production Work Force[d]	131.8	133.7 / 115.2	122.4	140.1 / 121.9	187.6	221.0 / 163.1	246.5	292.7	395.0	251.9	323.4	492.7	217.8	222.0	277.3
Off-Site Employment	6.4		6.0		11.4		15.0	17.9	24.5	15.4	19.8	30.7	13.3	13.6	17.2
Total Coal Industry Employment[e]	143.0	131.8	132.7	139.6	207.0	198.5	273.6	326.2	446.1	279.6	360.7	557.7	241.7	247.1	312.3

a) Data in parentheses inferred from published sources.

b) Due to the integration time period (dt) being set equal to 1.0 in the model, the employment data presented reflects a response to labor demands in the previous time period. Comparison of the model employment data in period t-1 with historical data yields a better fit.

c) MITRE survey among two-year mining technology schools indicates that about 95 percent of graduates enter the coal industry.

d) Entire production work force is defined to include all on-site personnel except administrative staff. Top number in historical data provided by the Mineral Yearbook series (BOM, 1960-1976) and since developed by DOE/EIA. Bottom number provided by BLS (BLS # 3, 1979). Definitional differences between series makes difficult explicit comparisons with model output. See text for details.

e) Historical data provided by BLS (BLS # 3, 1979).

It should be stressed that the coal mining manpower model does not attempt to explain with extreme precision how individual variables change from one year to the next. Rather, it attempts to capture basic market trends and feedback relationships among key variables in order to forecast with reasonable accuracy numerous outputs through 2000. The model's development incorporates specific sets of assumptions about market conditions and macroeconomic variables which establish probable bounds on primary model outputs.

Among the major observations which may be made in assessing the three cases presented in Table 1-I are the following:

- Surface production dominates total coal production in all three cases. In the base case, surface production accounts for 73 percent of total production by 1990 and 87 percent by 2000. This growth in surface mining is primarily due to the rapid increase in production from large and small area surface mines located in the Northern Great Plains and Interior and Gulf regions.

- Labor productivity in both deep and surface mining increases moderately through the 1980s, peaks in the early 1990s and then declines slightly in the late 1990s. In the base case, deep labor productivity peaks at 11.9 tons/man-day in 1990 and then declines to 10.3 tons/man-day by 2000. Surface labor productivity peaks at 33.7 tons/man-day in 1992 and then declines to 31.3 tons/man-day by 2000. Both underground and surface mining productivity were forecasted to decline slightly during the 1990's for the same basic reason. The shift toward more mechanized, highly productive mines in each sector achieves saturation levels (e.g. such mines account for over 90 percent of production in surface and deep mining) resulting in little additional productivity growth. At the same time, rising real coal prices still attract some marginal (i.e. high per ton cost) mines into operation, slightly outweighing productivity increases from other factors over this period.

- Mining engineer graduations peak at different times in each case, but decline to about 300 per year by 2000 in all cases; in percentage terms they decline to about 50 percent of all engineers employed in coal, with a slight absolute decline after 1990 in each case, due largely to the projected drop in deep mine production.

- Employment of mining technicians in the coal industry is expected to grow at almost 15 percent per year and to reach over 20,000 in all cases by 2000. This reflects a very high demand for their skills which is limited only by overall industry growth.

- The numbers of other engineers and scientists applicable to mining may be expected to grow continuously in all but the Low Demand Case and to reach a maximum of 2,100 and 1,400 respectively by 2000.

- Annual wages of hourly production workers experience the most rapid growth among labor demand or functional job categories; the wage gap narrows between hourly production workers and supervisors/technical support staff, with skilled production workers projected to earn slightly more than technical support staff by 2000.

- Annual wages of supervisors and technical support staff in the Low Case lag behind market wages in the other two cases through 1990. This is due to an earlier and more pronounced surplus of mining engineers in the Low Case which reduces mining engineer graduations and market wages upon which the wages of supervisors and technical support staff are based. However, due mainly to the lower graduation rate, the mining engineer surplus in the Low Case is almost eliminated by 2000, resulting in slightly greater wages being paid by 2000 in Low Case over those in the High Case.

It should be emphasized that the three cases presented in Table 1-I bracket the high and low ranges of probable future coal production. They do not necessarily bracket the range of new employment opportunities by education or experience available in coal mining over the next 20 years. Moreover, the Medium or Base Case does <u>not</u>, in our view, necessarily represent the most probable future characteristics of the coal mining industry. Rather, the three cases simply combine the exogenously assumed levels of future coal demand with a continuation of current coal industry employment patterns and Bureau of Labor Statistics forecasts of long range economic activity. Several of these assumptions and related market conditions are allowed to vary in the sensitivity analysis conducted in order to adequately address a broad range of uncertainties which face the coal mining industry.

1.2 Sensitivity Analysis Results

A number of variations of the three initial cases were tested to assess sensitivity of labor imbalances to alternative market conditions. While some of the analyses involved changing key input values by certain percentages, others involved the direct substitution of numerical input values based on alternative assumptions in areas of greatest uncertainty. Table 1-II identifies the sensitivity analyses developed in terms of their applicable assumptions. A more detailed description of these analyses is presented in Section 7.0. As may be seen in Table 1-II, the analyses were developed by modifying the assumptions made for the Base and High Coal Production Cases. Since none of the three initial cases resulted in any specific manpower shortages after 1990, one objective of the sensitivity analysis was to identify those market conditions which could result in persistent manpower shortages throughout the study period. Having identified such conditions in Analyses #4 and #7, Federal funding was

TABLE 1-II

DESCRIPTION OF SENSITIVITY ANALYSES

Analysis Number	Coal Demand Case	Assumptions Changed	Impacts
1	Base	Assumes productivity (measured as real gross output per employee in non-coal mining industries) remains constant at 1977 levels, rather than increasing through 1990 as in Bureau of Labor Statistics projections.	Increase in mining engineers demanded by non-coal mining industries, based on relationship to total work force. Impact on supply/demand balance and wages of mining engineers and, by association, supervisors and technical support staff.
2	Base	Assume high future demand specifically for mining engineers in metal and non-metal mining industries, based on 1977 American Mining Congress (AMC) survey. For new positions above replacements, assume 200 per year to 1985, and 250 per year through 2000.	Same as for Analysis #1.
3	Base	Gradual increase in off-site personnel as percent of total coal industry employment from 5.5% at present (kept constant in three initial cases) to 10.0% by 1990. Based on assumed trend toward industry concentration by large producers and oil/mining company subsidiaries, with tendency for greater off-site staffing and performance of regulatory work in-house.	Increase in demand for all types of engineers and scientists applicable to mining as well as administrative/office workers.
4	Base	Combines assumptions made in Analyses #2 and #3.	Magnifies the increased labor demands and potential imbalances cited in Analyses #2 and #3.
5	Base	Same as assumptions made in Analysis #4, but includes Federally funded scholarships at level assumed to encourage 60 additional B.S. degree mining engineer graduates per year beginning in 1983.	Same as Analysis #4 except Federal funding reduces potential supply/demand imbalance of mining engineers.

TABLE 1-II (Concluded)

DESCRIPTION OF SENSITIVITY ANALYSES

Analysis Number	Coal Demand Case	Assumptions Changed	Impacts
6	Base	Assumes stricter environmental, health and safety regulations affecting labor and capital requirements in coal industry. After 1980 for all deep mines, labor demand increases ranging from 2.5% more supervisors to 10% more technical support staff, while all capital, fuel and non-labor operating costs assumed to increase by 5% (with all capital and labor increases double the above for surface mines).	Increases on-site labor and capital costs which influences technology mix and surface-deep production split. Reduces profit margin on marginal mine types and accelerates shift toward higher profit mines.
7	High	Combines assumptions made in Analyses #2 (high mining engineer demand in metal and non-metal mining), #3 (increase in off-site coal industry employment) and #6 (increased labor and capital requirements in all mine types) with those of High Coal Production Case.	Provides greatest potential for professional manpower shortages, especially mining engineers, with accelerated shifts toward higher profit mines.
8	High	Same as assumptions made in Analysis #7, but includes Federally funded scholarships at a level assumed to encourage 110 additional B.S. degree mining engineer graduates per year beginning in 1983.	Same as Analysis #7 except Federal funding reduces potential supply/demand imbalance of mining engineers.
9	Base	Same as assumptions made in Analysis #3 and including a gradual 10% lower selling price for coal produced by technologies which characterize midwest and western coal regions. This reflects an assumption of lower F.O.B. selling prices for coal from these regions as a result of higher transportation costs.	Shifts the production of coal from the predominantly western surface technologies to the eastern deep and surface technologies.

applied in Analyses #5 and #8 to assess the ability and timeliness of such funding to alleviate potential mining engineer shortages. Other analyses were conducted to test the sensitivity of future technology mix to changes in capital and labor costs, and the regional distribution of production to changes in future selling prices faced by coal operators.

Table 1-III presents selected model outputs from the nine sensitivity analyses conducted on the three coal production cases. Projected values through 2000 are for the same model variables as presented in Table 1-I for the three initial cases. Table 1-III also gives the percentage change in each output variable in the sensitivity analyses with respect to the corresponding output variable in the Base or High Case, as appropriate. This enables one to readily assess which of the selected model outputs were most affected by the altered sets of assumptions described in Table 1-II. A clearer indication of some of these changes is provided graphically in Section 1.3.

Among the major observations which may be made in assessing the sensitivity analyses in Table 1-III are the following:

- The modifications of Base Case assumptions in the first three analyses directly increase the demand for and indirectly increase the supply of mining engineers. Analyses #1 and #2 increase non-coal industry demand, while Analysis #3 increases coal industry demand. These demand increases are indicated in terms of changes in national employment levels and in coal production while supply increases are indicated by B.S. degree mining engineer graduation rates from those estimated in the Base Case. The changes are greatest for total mining

TABLE I-III

SELECTED OUTPUTS FROM SENSITIVITY ANALYSIS

	ANALYSIS #1						ANALYSIS #2						ANALYSIS #3					
COAL PRODUCTION DATA (10^6 Tons/Year	1985	%	1990	%	2000	%	1985	%	1990	%	2000	%	1985	%	1990	%	2000	%
Total Coal Production	1056.8		1550.7		2221.5		1057.1		1499.9		2220.5		1057.6		1501.0		2221.3	
Underground Coal Production	356.5	-0.3	394.4	-0.3	290.3	-1.4	357.0	-0.2	396.0	-0.6	291.1	-1.1	357.4		397.8	- 0.2	293.8	- 0.2
Surface Coal Production	700.3		1105.6	+0.3	1931.2	+0.2	700.1		1103.9	+0.1	1929.4	+0.3	700.2		1103.2		1927.5	
PRODUCTIVITY DATA (Tons/Man Day)																		
Underground Average Product of Labor	11.5		11.9		10.2	-1.0	11.5		11.9		10.2	-1.0	11.5		11.9		10.3	
Surface Average Product of Labor	29.6		33.6		31.3		29.6		33.6		31.3		29.6		33.6		31.3	
GRADUATION AND EMPLOYMENT BY LABOR SUPPLY CATEGORY (10^3 MEN/YEAR)																		
Graduation of Mining Engineers																		
B.S. Degree	0.6		0.6	+100.0	0.4	+33.3	0.6		0.6	+100.0	0.5	+66.7	0.6		0.4	+33.3	0.3	
Advanced Degree	<0.1		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1	
Employment of Mining Engineers[b]																		
Nationally	8.7	+1.2	10.8	+17.4	12.9	+26.5	8.7	+1.2	10.7	+16.3	13.6	+33.3	8.6		9.4	+ 2.2	10.5	+ 2.9
In Coal Industry	1.5	-11.8	1.7	-10.5	1.6	-5.9	1.5	-11.8	1.7	-10.5	1.5	-5.9	1.8	+ 5.9	2.2	+15.8	2.0	+17.6
Graduations of Other Engineers Applicable to Mining (B.S. Degree)	25.7		30.6		40.9		25.7		30.6		40.9		25.7		30.6		40.9	
Employment of Other Engineers Applicable to Mining[b]															1077.0		1229.6	
Nationally	998.8		1077.0		1229.6		998.8		1077.0		1229.6		998.8	+ 7.1	1.9	+26.7	2.0	+17.6
In Coal Industry	1.4		1.5		1.7		1.4		1.5		1.7		1.5					
Graduations of Scientists															13.3		18.1	
Applicable to Mining (Adv. Degree)	11.5		13.3		13.1		11.5		13.3		18.1		11.5					
Employment of Scientists Applicable to Mining[b]																		
Nationally	306.6		360.6		474.4		306.6		360.6		474.4		306.6		360.6		474.4	
In Coal Industry	0.6		0.8	+14.3	1.1		0.6		0.8	+14.3	1.1		0.7	+16.7	0.9	+28.6	1.3	+18.2
Graduations of Mining Technicians (Two-Year Degree)	0.9		1.4		2.1		0.9		1.4		2.1		0.9		1.4		2.1	
Employment of Technicians In Coal Industry[b,c]	4.3		9.2		24.5	-0.4	4.3		9.2		24.6		4.3		9.2		24.6	
EMPLOYMENT AND WAGES BY LABOR DEMAND CATEGORY																		
On-Site Employment of Personnel In Coal Industry (10^3 Men/Year)																		
Supervisors	19.8		24.2	-0.4	34.3	-0.3	19.8		24.2	-0.4	34.3	-0.3	19.8		24.3		34.4	
Technical Support Staff	17.7	-0.6	20.9	-0.5	27.2	-0.4	17.7	-0.6	20.9	-0.5	27.2	-0.4	17.8		21.0		27.3	
Administrative Support Staff	12.0		15.6		26.6		12.0		15.6		26.6		12.0		15.6		26.6	
Skilled Production Workers	127.9	-0.2	151.0	-0.3	206.0	-0.2	128.0	-0.1	151.1	-0.3	205.9	-0.2	128.0	- 0.1	151.4		206.4	
Semi-Skilled Production Workers	80.7	-0.1	95.6	+1.0	126.5	-0.2	80.7	-0.1	95.7	-0.2	126.5	-0.2	80.8		95.9		126.8	
All Hourly Production Workers	208.6	-0.1	246.6	-0.3	332.5	-0.2	208.7	-0.1	246.8	-0.2	332.4	-0.2	208.8		247.3		333.2	
Average Yearly Wage of Personnel																		
In Coal Industry (10^3 1976 Dollars)														+ 0.7	29.5		34.4	- 0.3
Supervisors	29.9	+4.2	30.9	+4.7	34.7	+0.6	29.6	+3.1	31.0	+5.1	35.8	+3.8	28.9	+ 0.8	25.7	+ 0.4	29.9	- 0.3
Technical Support Staff	26.0	+4.4	26.9	+5.1	30.2	+0.7	25.7	+3.2	27.0	+5.5	31.1	+3.7	25.1		12.4		14.8	
Administrative Support Staff	10.7		12.4		14.8		10.7		12.4		14.8		10.7		24.8		30.7	
Skilled Production Workers	21.7		24.8		30.7		21.7		24.8		30.7		21.7		22.5		27.9	
Semi-Skilled Production Workers	19.8		22.5		27.9		19.8		22.5		27.9		19.8		23.9		29.6	
All Hourly Production Workers	21.0		23.9		29.6		20.9	-0.5	23.9		29.6		21.0					
On-Site Employment - Total (10^3 Men/Year)	258.1	-0.2	307.2	-0.4	420.6	-0.2	258.3	-0.1	307.5	-0.3	420.5	-0.3	258.4		308.2	- 0.3	421.5	
At Mines	241.8	-0.2	284.1	-0.4	386.4	-0.3	242.0	-0.1	284.4	-0.3	386.3	-0.3	242.1		285.1		387.3	
At Production Plants	16.3		23.1		34.2		16.3		23.1		34.2		16.3		23.1		34.2	
Entire Production Work Force[d]	246.1	-0.2	291.6	-0.4	394.0	-0.3	246.3		291.9	-0.3	393.9	-0.3	246.4		292.5		394.9	
Off-Site Employment	15.0		17.9		24.5		15.0		17.9		24.5		25.6	+70.7	34.2	+91.1	46.8	+91.0
Total Coal Industry Employment	273.1	-0.2	325.1	-0.3	445.1	-0.2	273.3	-0.1	325.4	-0.2	445.0	-0.2	284.0	+ 3.8	342.4	+ 5.0	468.3	+ 5.0

a) All labor data in 10^3 people; all wage data in \$1976 x 10^3.

b) Due to the integration time period (dt) being set equal to 1.0 in the model, the employment data presented reflects a response to labor demands in the previous time period. Comparison of the model employment data in period t-1 with historical data yields a better fit.

c) MITRE survey among two-year mining technology schools indicates that about 95 percent of graduates enter the coal industry.

d) Entire production work force is defined to include all on-site personnel except administrative staff.

TABLE I-III (Continued)

SELECTED OUTPUTS FROM SENSITIVITY ANALYSIS

	ANALYSIS #4						ANALYSIS #5						ANALYSIS #6					
COAL PRODUCTION DATA (10^6 Tons/Year	1985	%	1990	%	2000	%	1985	%	1990	%	2000	%	1985	%	1990	%	2000	%
Total Coal Production	1056.9		1499.7		2220.8		1056.9		1499.9		2220.8		1100.6	+ 4.0	1505.4	+ 0.3	2226.4	+ 0.2
Underground Coal Production	356.9	- 0.2	395.4	- 0.8	290.5	- 1.3	356.9	- 0.2	395.5	- 0.7	290.8	- 1.2	365.5	+ 2.2	401.1	+ 0.7	292.2	- 0.7
Surface Coal Production	700.0		1104.3	- 0.1	1930.3	+ 0.2	700.0		1104.4	+ 0.2	1930.0	+ 0.2	735.1	+ 5.0	1104.4	+ 0.2	1934.2	+ 0.4
PRODUCTIVITY DATA (Tons/Man Day)																		
Underground Average Product of Labor	11.5		11.9		10.2	- 1.0	11.5		11.9		10.2	- 1.0	11.4	- 0.8	11.9		10.2	- 1.0
Surface Average Product of Labor	29.6		33.6		31.3		29.6		33.6		31.3		29.8	+ 0.7	34.3	+ 2.1	32.0	+ 2.2
GRADUATION AND EMPLOYMENT BY LABOR SUPPLY CATEGORY (10^3 MEN/YEAR)																		
Graduation of Mining Engineers																		
B.S. Degree	0.6		0.6	+100.0	0.5	+66.7	0.7	+16.7	0.7	+133.3	0.5	+66.7	0.5	-16.7	0.3		0.3	
Advanced Degree	<0.1		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1	
Employment of Mining Engineers[b]																		
Nationally	8.7	+ 1.2	10.7	+16.3	14.2	+39.2	8.7	+ 1.2	11.0	+19.6	14.4	+41.2	8.6		9.2		10.1	- 1.0
In Coal Industry	1.7		2.0	+ 5.3	1.9	+11.8	1.7		2.1	+10.5	1.9	+11.8	1.7		1.8	- 5.3	1.5	-11.8
Graduations of Other Engineers Applicable to Mining (B.S. Degree)	25.7		30.6		40.9		25.7		30.6		40.9		25.7		30.6		40.9	
Employment of Other Engineers Applicable to Mining[b]																		
Nationally	998.8		1077.0		1229.6		998.8		1077.0		1229.6		998.8		1077.0		1229.6	
In Coal Industry	1.5	+ 7.1	1.9	+26.7	2.0	+17.6	1.5	+ 7.1	1.9	+26.7	2.0	+17.6	1.4		1.5		1.6	-5.9
Graduations of Scientists Applicable to Mining (Adv. Degree)	11.5		13.3		18.1		11.5		13.3		18.1		11.5		13.3		18.1	
Employment of Scientists Applicable to Mining[b]																		
Nationally	306.6		360.6		474.4		306.6		360.6		474.4		306.6		360.6		474.4	
In Coal Industry	0.7	+16.7	0.9	+28.6	1.3	+18.2	0.7	+16.7	0.9	+28.6	1.3	+18.2	0.7	+16.7	0.8	+14.3	1.1	
Graduations of Mining Technicians (Two-Year Degree)	0.9		1.4		2.1		0.9		1.4		2.1		1.0	+11.1	1.4		2.1	
Employment of Technicians In Coal Industry[b,c]	4.3		9.2		24.6	+ 4.1	4.3		9.2		24.6		4.3		9.4	+ 2.2	24.9	+ 1.2
EMPLOYMENT AND WAGES BY LABOR DEMAND CATEGORY																		
On-Site Employment of Personnel In Coal Industry (10^3 Men/Year)																		
Supervisors	19.8		24.2	- 0.4	34.3	- 0.3	19.8		24.2	- 0.4	34.3	- 0.3	19.9	+ 0.5	23.6	- 2.9	33.2	- 3.5
Technical Support Staff	17.7	- 0.6	20.9	- 0.5	27.2	- 0.4	17.7	- 0.6	20.9	- 0.5	27.2	- 0.4	19.4	+ 9.0	22.1	+ 5.2	28.5	+ 4.4
Administrative Support Staff	12.0		15.6		26.6		12.0		15.6		26.6		12.0		15.0	- 3.8	25.4	- 4.5
Skilled Production Workers	127.9	- 0.2	151.0	- 0.3	205.8	- 0.3	127.9	- 0.2	151.1	- 0.3	205.9	- 0.2	132.1	+ 3.1	150.4	- 0.7	203.1	- 1.6
Semi-Skilled Production Workers	80.7	- 0.1	95.6	+ 1.0	126.4	- 0.3	80.7	- 0.1	95.6	+ 1.0	126.5	- 0.2	83.4	+ 3.2	95.5	- 0.4	125.2	- 1.3
All Hourly Production Workers	208.6	- 0.1	246.6	- 0.3	332.2	- 0.3	208.6	- 0.1	246.7	- 0.3	332.4	- 0.2	215.5	+ 3.2	245.9	- 0.6	328.3	- 1.5
Average Yearly Wage of Personnel In Coal Industry (10^3 1976 Dollars)																		
Supervisors	29.8	+ 3.8	31.3	+ 6.1	35.6	+ 3.2	29.8	+ 3.8	31.1	+ 5.4	35.3	+ 2.3	28.8	+ 0.3	29.7	+ 0.7	34.3	- 0.6
Technical Support Staff	25.9	+ 4.0	27.3	+ 6.6	31.0	+ 3.3	25.9	+ 4.0	27.0	+ 5.5	30.7	+ 2.3	25.0	+ 0.4	25.9	+ 1.2	29.8	- 0.7
Administrative Support Staff	10.7		12.4		14.8		10.7		12.4		14.8		10.7		12.4		14.8	
Skilled Production Workers	21.7		24.8		30.7		21.7		24.8		30.7		21.7		24.8		30.7	
Semi-Skilled Production Workers	19.8		22.5		27.9		19.8		22.5		27.9		19.8		22.5		27.9	
All Hourly Production Workers	21.0		24.0	+ 0.4	29.6		21.0		23.9		29.6		21.0		23.9		29.6	
On-Site Employment - Total (10^3 Men/Year)	258.2	- 0.2	307.4	- 0.3	420.4	- 0.3	258.2	- 0.2	307.4	- 0.3	420.6	- 0.2	266.9	+ 3.2	306.7	- 0.5	415.5	- 1.4
At Mines	241.9	- 0.2	282.9	+ 0.4	386.2	- 0.3	241.9	- 0.2	284.3	- 0.3	386.4	- 0.3	250.0	+ 3.2	283.5	- 0.6	381.2	- 1.6
At Production Plants	16.3		24.5	+ 6.1	34.2		16.3		23.1		34.2		16.9	+ 3.7	23.2	+ 0.4	34.3	+ 0.3
Entire Production Work Force[d]	246.2	- 0.1	291.8	- 0.3	393.8	- 0.3	246.2	- 0.1	291.8	- 0.3	393.9	- 0.3	254.8	+ 3.4	291.7	- 0.3	390.1	- 1.2
Off-Site Employment	25.5	+70.0	34.1	+90.5	46.7	+90.6	25.5	+70.0	34.2	+91.1	46.7	+90.6	15.5	+ 3.3	17.8	- 0.6	24.2	- 1.2
Total Coal Industry Employment	283.7	+ 3.7	341.5	+ 4.7	467.1	+ 4.7	283.7	+ 3.7	341.6	+ 4.7	467.3	+ 4.8	282.4	+ 3.2	324.5	- 0.5	439.7	- 1.4

a) All labor data in 10^3 people; all wage data in \$1976 x 10^3.

b) Due to the integration time period (dt) being set equal to 1.0 in the model, the employment data presented reflects a response to labor demands in the previous time period. Comparison of the model employment data in period t-1 with historical data yields a better fit.

c) MITRE survey among two-year mining technology schools indicates that about 95 percent of graduates enter the coal industry.

d) Entire production work force is defined to include all on-site personnel except administrative staff.

TABLE I-III (Concluded)

SELECTED OUTPUTS FROM SENSITIVITY ANALYSIS

	ANALYSIS #7						ANALYSIS #8						ANALYSIS #9					
COAL PRODUCTION DATA (10^6 Tons/Year	1985	%	1990	%	2000	%	1985	%	1990	%	2000	%	1985	%	1990	%	2000	%
Total Coal Production	1100.8	+ 4.1	1679.3	+ 0.2	2787.8		1100.8	+ 4.1	1679.8	+ 0.2	2787.8		1057.3		1499.7	- 0.1	2229.2	+ 0.4
Underground Coal Production	376.1	+ 2.3	422.5	+ 0.2	302.0	- 3.0	367.1	+ 2.3	422.7	+ 0.3	303.2	- 2.6	356.0	- 0.4	404.4	+ 1.5	304.1	+ 3.3
Surface Coal Production	733.7	+ 5.0	1256.9	+ 0.2	2485.8	+ 0.4	733.7	+ 5.0	1257.1	+ 0.2	2484.6	+ 0.3	701.3	+ 0.2	1095.3	- 0.7	1925.7	
PRODUCTIVITY DATA (Tons/Man Day)																		
Underground Average Product of Labor	11.3		11.8	+ 8.4	9.9	- 1.0	11.3		11.8	+ 8.4	9.9	- 1.0	11.4	- 0.9	11.8	- 0.8	9.8	- 4.9
Surface Average Product of Labor	29.0	+ 1.0	34.3	+ 2.4	31.2	+ 3.0	29.0	+ 1.0	34.3	+ 2.4	31.1	+ 2.6	29.6		32.5	- 3.3	27.9	-10.9
GRADUATION AND EMPLOYMENT BY LABOR SUPPLY CATEGORY (10^3 MEN/YEAR)																		
Graduation of Mining Engineers																		
B.S. Degree	0.6		0.6		0.7	+133.3	0.7	+16.7	0.7	+16.7	0.6	+100.0	0.6		0.4	+33.3	0.3	
Advanced Degree	<0.1		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1	
Employment of Mining Engineers[b]																		
Nationally	8.7		10.8	+ 1.9	14.7	+27.8	8.8	+ 1.1	11.4	+ 7.5	15.4	+33.9	8.6		9.6	+ 4.3	11.1	+ 8.8
In Coal Industry	1.7	+13.3	2.0	+ 5.3	2.0		1.7	+13.3	2.1	+10.5	2.1	+ 5.0	1.8	+ 5.9	2.4	+26.3	2.6	+52.9
Graduations of Other Engineers Applicable to Mining (B.S. Degree)	27.5		38.3		52.1		27.5		38.3		52.1		25.7		30.6		40.9	
Employment of Other Engineers Applicable to Mining[b]																		
Nationally	1031.2		1131.4		1032.1		1031.2		1131.4		1302.1		998.8		1077.0		1229.6	
In Coal Industry	1.6	+14.3	2.0	+17.6	2.3	+ 9.5	1.6	+14.3	2.0	+17.6	2.3	+ 9.5	1.5	+ 7.1	2.0	+33.3	2.4	+41.2
Graduations of Scientists Applicable to Mining (Adv. Degree)	12.0		15.2		20.8		12.0		15.2		20.8		11.5		13.3		18.1	
Employment of Scientists Applicable to Mining[b]																		
Nationally	329.4		402.7		531.4		329.4		402.7		531.4		306.6		360.6		474.4	
In Coal Industry	0.8	+33.3	1.0	+25.0	1.6	+14.3	0.8	+33.3	1.0	+25.0	1.6	+14.3	0.7	+16.7	0.9	+28.6	1.4	+27.3
Graduations of Mining Technicians (Two-Year Degree)	1.0	+11.1	1.5		2.4		1.0	+11.1	1.5		2.4		0.9		1.4		2.1	
Employment of Technicians In Coal Industry[b,c]	4.4		9.7	+ 5.4	26.8	+ 1.5	4.4		9.7	+ 5.4	26.8	+ 1.5	4.3		9.2		24.6	
EMPLOYMENT AND WAGES BY LABOR DEMAND CATEGORY																		
On-Site Employment of Personnel In Coal Industry (10^3 Men/Year)																		
Supervisors	20.3	+ 0.5	25.9	- 3.4	41.0	- 4.2	20.3	+ 0.5	26.0	- 3.0	41.1	- 4.0	19.9	+ 0.5	24.6	+ 1.2	35.4	+ 2.9
Technical Support Staff	19.9	+ 9.3	24.3	+ 4.7	35.2	+ 3.8	19.9	+ 9.3	24.3	+ 4.7	35.2	+ 3.8	17.8		21.6	+ 2.9	30.7	+12.5
Administrative Support Staff	12.3		16.7	+ 4.6	32.6	- 5.0	12.3		16.7	+ 4.6	32.6	- 5.0	12.0		15.8	+ 1.3	27.5	+ 3.4
Skilled Production Workers	135.2	+ 3.1	165.5	- 1.3	252.4	- 2.2	135.2	+ 3.1	165.6	- 1.2	252.6	- 2.3	128.4	+ 0.2	155.9	+ 2.9	229.4	+11.1
Semi-Skilled Production Workers	85.1	+ 3.2	104.9	- 0.9	154.2	- 2.1	85.1	+ 3.2	104.9	- 0.9	154.3	- 2.0	81.0	+ 0.2	98.4	+ 2.6	139.1	+ 9.7
All Hourly Production Workers	220.3	+ 3.1	270.4	- 1.1	406.6	- 2.3	220.3	+ 3.1	270.5	- 1.1	406.9	- 2.2	209.4	+ 0.2	254.3	+ 2.8	368.5	+10.6
Average Yearly Wage of Personnel In Coal Industry (10^3 1976 Dollars)																		
Supervisors	30.2	+ 2.4	31.9	+ 3.6	35.8	+ 5.3	30.2	+ 2.4	31.3	+ 1.6	35.0	+ 2.9	29.0	+ 1.0	29.7	+ 0.7	35.2	+ 2.0
Technical Support Staff	26.2	+ 2.3	27.7	+ 3.4	31.1	+ 5.4	26.2	+ 2.3	27.3	+ 1.9	30.5	+ 3.4	25.2	+ 1.2	25.9	+ 1.2	30.6	+ 2.0
Administrative Support Staff	11.9		13.7		17.1		11.9		13.7		17.1		10.7		12.4		14.8	
Skilled Production Workers	21.8		24.8		30.7		21.8		24.8		30.7		21.7		24.8		30.7	
Semi-Skilled Production Workers	19.8		22.5		27.9		19.8		22.5		27.9		19.8		22.5		27.9	
All Hourly Production Workers	21.0		23.9		29.6		21.0		23.9		29.6		21.0		23.9		29.6	
On-Site Employment - Total (10^3 Men/Year)	272.7	+ 3.2	337.4	- 1.0	515.4	- 2.2	272.7	+ 3.2	337.5	- 1.0	515.9	- 2.1	259.1	+ 0.2	265.4	-13.9	383.3	- 9.1
At Mines	255.7	+ 3.1	311.5	- 1.1	472.5	- 2.4	255.7	+ 3.1	311.6	- 1.1	473.0	- 2.3	242.1		242.3	-15.0	349.0	- 9.9
At Production Plants	17.0	+ 4.3	25.9	+ 0.4	42.9		17.0	+ 4.3	25.9	+ 0.4	42.9		16.3		23.1		34.3	+ 0.3
Entire Production Work Force[d]	260.5	+ 3.4	320.7	- 0.8	482.8	- 2.0	260.5	+ 3.4	320.8	- 0.8	483.2	- 1.9	247.1	+ 0.2	351.4	+20.1	513.4	+30.0
Off-Site Employment	27.0	+75.3	37.5	+89.4	57.3	+86.6	27.0	+75.3	37.5	+89.4	57.3	+86.6	25.6	+70.7	35.1	+96.1	51.3	+109.4
Total Coal Industry Employment	299.7	+ 7.2	374.9	+ 3.9	572.7	+ 2.7	299.7	+ 7.2	375.0	+ 4.0	573.2	+ 2.8	284.7	+ 4.1	300.5	- 7.9	434.6	- 2.6

a) All labor data in 10^3 people; all wage data in \$1976 x 10^3.

b) Due to the integration time period (dt) being set equal to 1.0 in the model, the employment data presented reflects a response to labor demands in the previous time period. Comparison of the model employment data in period t-1 with historical data yields a better fit.

c) MITRE survey among two-year mining technology schools indicates that about 95 percent of graduates enter the coal industry.

d) Entire production work force is defined to include all on-site personnel except administrative staff.

engineer employment and annual graduations in Analysis #2, in which the level of non-coal mining industry demand is the highest. The declines in mining engineers employed in the coal industry in both Analyses #1 and #2 (ranging from about 6 to 12 percent less than the Base Case by 2000) are based on shortages of mining engineers proportionately absorbed by all industries over the study period (see Figures 1-1 and 1-2).

- Up to 18 percent more mining engineers are employed in the coal mining industry in Analysis #3 (greater off-site employment) than in the Base Case. Somewhat lower increases (12 percent noted in Analysis #4, due to mining engineer shortages created by increased non-coal mining demand under the combined set of assumptions.

- Federal scholarship funding concentrated on mining engineers (as described in detail in Section 7.0) is estimated to raise graduations by between 10 and 15 percent over those levels achieved by market forces alone in Analyses #4 and #7 (high professional manpower demand), and up to 40 percent greater than levels achieved in the Base Case for certain years. However incremental graduations due to Federal scholarship funding decline significantly by the year 2000, as shortages are virtually eliminated by the early 1990's.

- Analysis #6 reduces employment of mining engineers in the coal industry to levels similar to those in Analyses #1 and #2. This however, does not result from a temporary supply shortage. Rather, reduced profit margins under stricter environmental, health and safety regulations tend to accelerate the shift toward more productive, less labor-intensive technologies. Thus, employment levels of mining and other engineers in the coal industry decline by about 12 and 6 percent respectively, from Base Case levels by 2000.

- Employment levels of other engineers and scientists in the coal industry are assumed equal to their demand, given the small fractions of national demand which they comprise and the established tradition of training many production-oriented engineers and scientists on-the-job. Thus, in Analyses #3, #4 and #5, the same increases in coal industry employment are forecasted for these professional labor categories over those levels of the Base Case (almost 30 percent greater for each by 1990).

- Employment of mining technicians in the coal industry is relatively unaffected by any of the sensitivity analyses applied, with a strong and growing demand throughout the study period. The greatest change in the employment of technicians is an increase of about five percent over the High Case levels in Analyses #7 and #8, based largely on higher graduation rates in the 1980's and a growing demand for skilled workers in the coal industry.

- For the first six sensitivity analyses, wages for supervisors and technical support staff (based on mining engineer wages) rise faster than those in the Base Case during the 1980's but tend to approach the same wage levels achieved in the Base Case during the mid-1990's. In Analyses #7 and #8, wage increases in the early 1980's tend to be higher, reflecting the greater shortages for mining engineers under High Case conditions. Nevertheless, by 2000, market wages in each professional labor category are restored to within a few percentage points among most of the sensitivity analyses, reflecting the relative labor balances achieved through market forces by that time.

1.3 Study Conclusions and Supporting Analyses

The coal mining manpower model developed in this study is intended to be a flexible tool for assessing the impacts of a wide variety of policies affecting the future of labor in the coal industry. The High, Medium and Low Coal Demand Cases summarized in Table I-1 give the labor impacts of three coal production futures. However, according to our assessment, the cases most representative of the low, high and most probable coal industry futures in terms of employment opportunities are, respectively, the Low Coal Demand Case, Analysis #8 and Analysis #3, as summarized in Table 1-II. Table 1-IV presents these employment futures in terms of work force composition by labor supply category. It should be emphasized that the values given in Table 1-IV represent the fulfilled demand for labor in each

TABLE 1-IV

FORECASTED WORK FORCE COMPOSITION*

LABOR CATEGORY	LOW EMPLOYMENT FUTURE (LOW CASE)			MOST PROBABLE EMPLOYMENT FUTURE (ANALYSIS #3)			HIGH EMPLOYMENT FUTURE (ANALYSIS #8)		
	1980	1990	2000	1980	1990	2000	1980	1990	2000
Mining Engineers	1,480 (0.6)	1,450 (0.6)	1,220 (0.4)	1,510 (0.6)	2,250 (0.7)	1,990 (0.4)	1,510 (0.6)	2,150 (0.6)	2,130 (0.4)
Other Engineers	1,070 (0.5)	1,210 (0.5)	1,200 (0.4)	1,090 (0.5)	1,870 (0.6)	2,040 (0.4)	1,090 (0.5)	1,990 (0.6)	2,260 (0.4)
Scientists	510 (0.2)	590 (0.2)	760 (0.3)	520 (0.2)	910 (0.3)	1,310 (0.3)	520 (0.2)	990 (0.3)	1,580 (0.3)
Experienced Workers	184,930 (79.2)	188,200 (76.6)	240,850 (79.5)	184,930 (78.7)	240,340 (72.1)	351,610 (75.0)	184,930 (78.7)	247,090 (69.2)	412,840 (74.8)
Inexperienced Workers	32,800 (14.0)	31,780 (13.0)	18,080 (6.0)	33,810 (14.4)	58,930 (17.7)	55,300 (11.8)	33,810 (14.4)	73,960 (20.7)	66,810 (12.1)
Mining Technicians	2,120 (0.9)	9,170 (3.7)	21,340 (7.0)	2,120 (0.9)	9,160 (2.7)	24,580 (5.2)	2,120 (0.9)	9,650 (2.7)	26,850 (4.9)
Administrative	10,820 (4.6)	13,280 (5.4)	19,470 (6.4)	10,990 (4.7)	19,630 (5.9)	32,270 (6.9)	10,990 (4.7)	20,890 (5.9)	38,970 (7.1)
Total Employment	233,730	245,680	302,920	234,970	333,090	469,100	234,970	356,720	551,440

* Figures in parentheses are percentages of totals for each year.

educational and experience category, based on available supplies of each labor category. For example, the slight decline in mining engineers employed from 1990 to 2000 for each employment future reflects a change in derived labor demand, based on the changing mix of technologies and mine types which is forecasted to occur by 2000. This is not to say that fewer mining engineers will necessarily be employed. Rather, it implies that if these mining engineers remain employed, they will probably be in positions that may just as easily be filled by mechanical, civil, industrial or electrical engineers. The issue of engineering skills demanded by the coal industry is addressed in greater detail in Section 5.0, and in Appendix B.

In selecting Analysis #3 as representing the most probable employment future, two assumptions were made:

- The most likely future coal production levels are those given in the Base Case. For this case, 1.1 and 2.2 billion tons per year, respectively, are expected to be produced by 1985 and 2000.

- Off-site employment will almost double as a percentage of total coal industry employment reaching about 10 percent by 1990. This is based on some combination of probable conditions, including: a greater concentration of large companies and conglomerates controlling production; a shift to large predominately area surface mines which are more productive and which require more planning and design work and less full-time on-site personnel; and some increases in regulatory requirements which occupy more front or division office personnel in terms of permit applications, monitoring and related paperwork.

In terms of the work force composition by education and experience level, the category which shows the greatest variation among the employment futures is that of inexperienced workers.*

The number of these workers fluctuates considerably depending on overall industry growth rates (12 percent of total coal mining employment by 2000 in the high employment future vs. 6 percent of total employment in the low employment future).

Table 1-IV also indicates that mining technicians are the fastest growing component of the coal industry workforce. Employment of mining technicians is forecasted to grow at rates of almost 15 percent per year in any case, unless the coal industry itself grows at a rate slower than that of the Low Coal Demand Case.

A number of more specific conclusions have been drawn from our assessment of the various model outputs and from the numerous interviews conducted during the course of this study. These conclusions, presented at the beginning of this report, are also presented below in somewhat greater detail and with graphical or tabular displays as supporting evidence documentation.

1.3.1 Area Surface Mining to Dominate Coal Production by 2000

The combination of large and small area mines located in the Interior/Gulf and Northern Great Plains regions of the nation (Figure

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*Inexperienced workers as a supply category include all workers employed in coal mining having less than one year experience except personnel with degrees related to their job function (i.e., mining engineers, other engineers, scientists and mining technicians), or clerical and general office personnel (i.e., administrative). Experienced workers exclude the same personnel categories and is comprised of all other workers employed for at least one year.

1-1) is expected to dominate coal production by 2000. These area surface mines, in the most probable case (Analysis #3), produce about 55 percent of the nation's total tonnage by 1990 and about 75 percent by 2000. Total employment in these mines will, however, account for 26 percent of the total onsite employment in 1990 and 52 percent in 2000. The high productivity, favorable mining conditions, and relative profitability of these mines contribute significantly to their rapid growth rates. Deep mining production in the most probable case (Analysis #3), exhibits a slow growth in production from a little under 300 million tons per year in 1980 to 400 million tons per year in 1990. The relatively slower growth rate of deep mining results in a continuing decline in its percentage share of national coal production.

Small area and large area mines denoted as technologies #5 and #6 in the model (defined in Appendix A) are characteristic of the surface mining technologies located in the Interior/Gulf and Northern Great Plains coal producing regions. Table 1-V presents projections of the quantity and percentage of the nation's total tonnage produced by each of the six mining technologies evaluated in the model. The data indicate that for the most probable future (Analysis #3), the area surface technologies (#5 and #6) grow from 36.3 percent of the national production in 1980 to 43.7 percent in 1985, 56.4 percent in 1990, and 78.8 percent by 2000. The major factors contributing to the growth of these technologies are their high labor

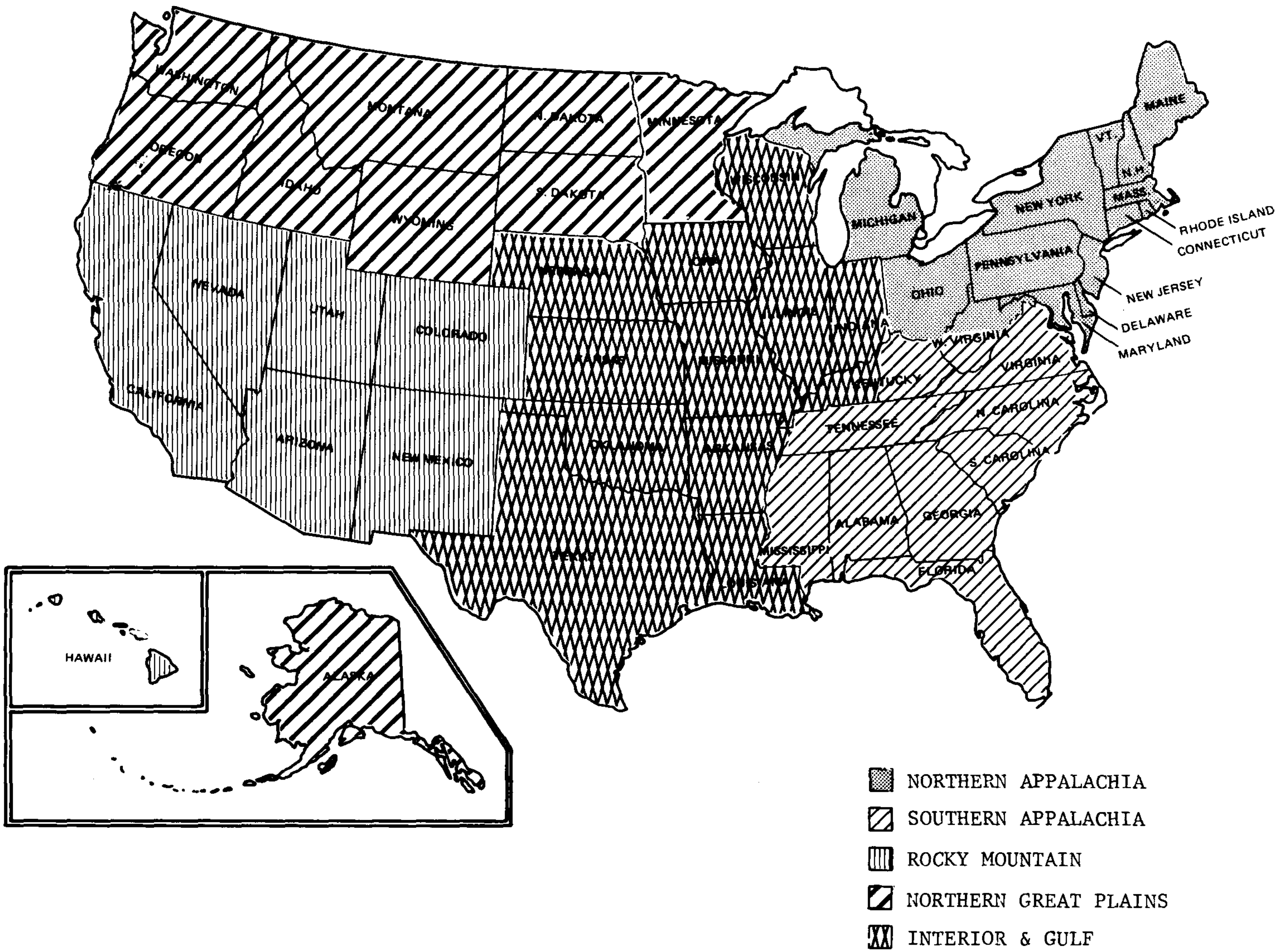

FIGURE 1-1
COAL SUPPLY REGIONS USED IN ANALYSIS

TABLE 1-V

PROJECTIONS OF COAL PRODUCTION, PRODUCTION COSTS AND SELLING PRICE BY TECHNOLOGY

YEAR/TECHNOLOGY		ANALYSIS #3				ANALYSIS #9			
		PRODUCTION		AVG.PROD.COSTS	AVG.F.O.B.PRICE	PRODUCTION		AVG.PROD.COSTS	AVG.F.O.B.PRICE
		10^6 TONS/YEAR	%	$/TON	$/TON	10^6 TONS/YEAR	%	$/TON	$/TON
1980	#1	91.6	11.8	18.55	23.91	91.6	11.8	18.55	23.91
	#2	170.0	21.8	16.40	23.91	170.0	21.8	16.40	23.91
	#3	24.7	3.2	15.00	23.91	24.7	3.2	15.00	23.91
	#4	209.1	26.9	13.22	21.52	209.1	26.9	13.22	21.52
	#5	111.1	14.3	5.18	9.57	111.1	14.3	5.18	9.57
	#6	171.8	22.0	7.55	14.35	171.8	22.0	7.55	14.35
	TOTAL	778.3				778.3			
1985	#1	81.5	7.7	21.91	22.83	81.1	7.7	22.07	23.13
	#2	235.7	22.3	19.84	22.83	234.9	22.2	20.07	23.13
	#3	40.3	3.8	15.83	22.83	40.0	3.8	15.95	23.13
	#4	238.0	22.5	14.45	20.55	241.7	22.8	14.52	20.82
	#5	200.5	19.0	5.90	9.70	198.3	18.8	5.80	9.25
	#6	261.7	24.7	8.94	14.27	261.3	24.7	8.82	13.88
	TOTAL	1057.7				1057.3			
1990	#1	62.8	4.2	24.39	24.38	62.8	4.2	24.59	24.87
	#2	278.0	18.5	21.38	24.38	284.3	19.0	21.61	24.87
	#3	57.0	3.8	16.96	24.38	57.3	3.8	17.16	24.87
	#4	256.2	17.1	15.45	21.94	293.1	19.5	15.77	22.38
	#5	396.7	26.4	6.25	10.97	362.5	24.2	6.12	9.95
	#6	450.3	30.0	9.54	15.85	439.7	29.3	9.46	14.92
	TOTAL	1501.0				1499.7			
2000	#1	27.8	1.3	33.43	32.79	27.1	1.2	34.53	34.88
	#2	209.6	9.4	28.32	32.79	220.3	9.9	29.43	34.88
	#3	56.5	2.5	20.32	32.78	56.8	2.5	20.95	34.88
	#4	177.5	8.0	22.65	29.51	340.7	15.4	22.87	31.39
	#5	910.5	41.0	7.80	16.40	748.1	33.5	7.47	13.95
	#6	839.6	37.8	12.52	22.95	836.9	37.5	12.08	20.93
	TOTAL	2221.5				2229.9			

#1 = Conventional Deep Mining
#2 = Continuous Deep Mining
#3 = Longwall Deep Mining
#4 = Contour Surface Mining
#5 = Large Area Surface Mining
#6 = Small Area Surface Mining

productivities,* low production costs and relatively high profit margins. Table 1-V presents data for the estimated average production costs and F.O.B. selling price associated with each technology. The data indicate the relatively high profitability of the area surface mining technologies.

The data for Analysis #3 also indicate a slow growth in deep mining production up to 1990 and then a slight decline between 1990 and 2000. Total deep mining production is projected to increase from 286 million tons per year in 1980 to 398 million tons per year by 1990. However, deep mining is then projected to decline to 294 million tons per year by 2000. The major factor in this decline is the decreasing relative marginal profitability of deep mining when compared to area surface mining technologies. The market penetration of longwall mining, which is relatively more competitive with the surface mining technologies, has been exogenously constrained in the model to a maximum of 25 percent of total underground production by the year 2000. This constraint is based on discussions with both D.O.E. technology personnel and knowledgeable industry personnel.

A gradual drop of 10 percent** in the F.O.B. selling price of coal facing the area surface technologies results in a decline from

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*The labor productivities for technologies #5 and #6 average around 70 tons/man-day and 35 tons/man-day respectively. The high productivities are primarily due to the thick seams and favorable mining conditions associated with these technologies.

**The drop in the F.O.B. price of 10 percent is based on a weighted drop in the F.O.B. prices for technologies #5 and #6. The details of the price change used in Analysis #9 are discussed in Section 7.0.

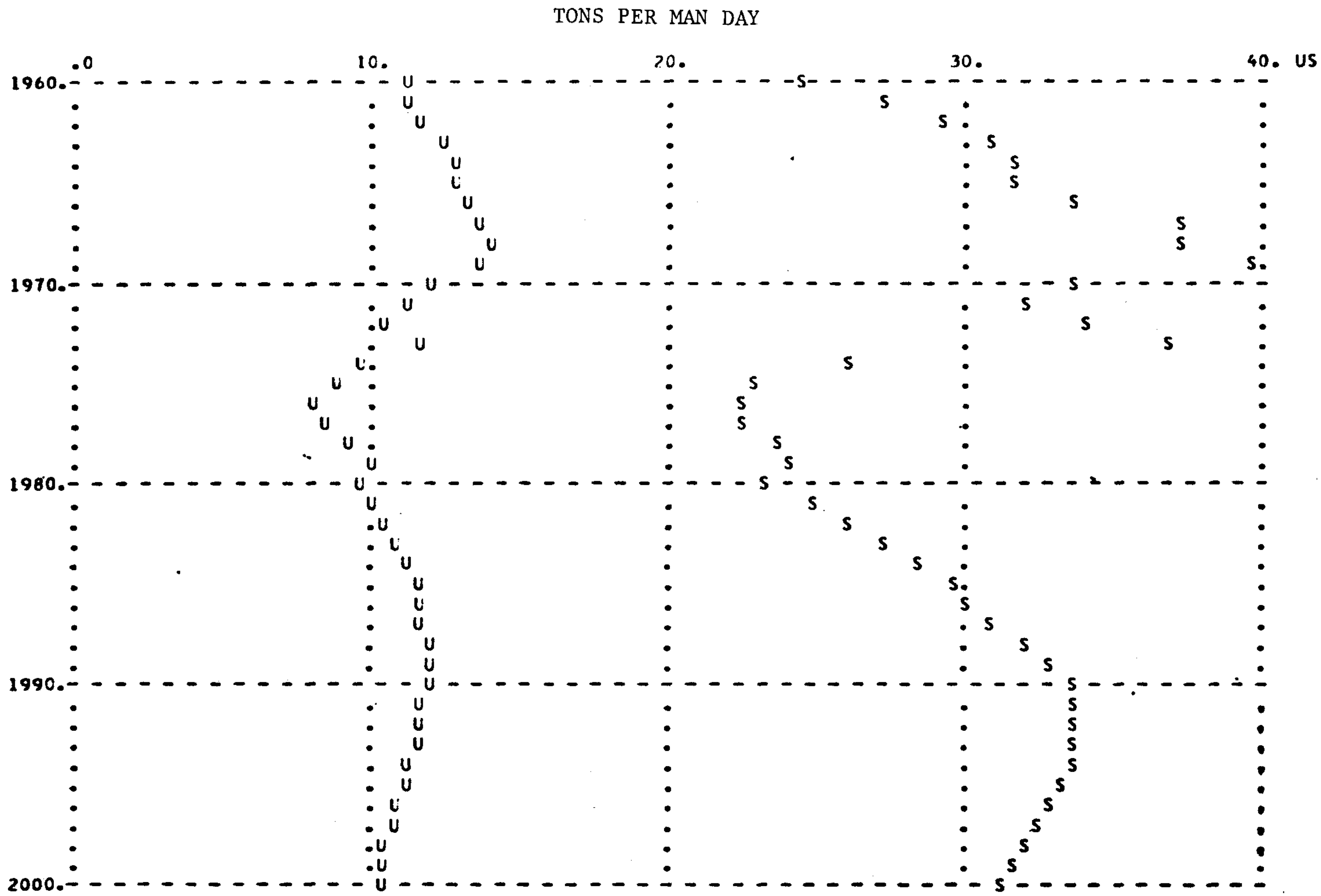
78 percent of the national production (Analysis #3) to 71 percent of the national production (Analysis #9) by 2000. The data for Analysis #9 presented in Table 1-III indicated that area surface mining will dominate production even if the F.O.B. selling price facing these technologies drops significantly. For example, the price facing technology #5 (large area surface mines located predominantly in the Northern Great Plains) is 50 percent in Analysis #3 and 40 percent in Analysis #9 of the price facing the deep mines (located predominantly in Northern and Southern Appalachia). This price differential is essential for the competitiveness of western coals due to the major impact of transportation costs associated with utilizing these coals. However, the high productivity and low production costs associated with these mines are a major reason for their projected rapid growth.

1.3.2 Increasing Labor Productivity in Deep and Surface Mining in the 1980s

Labor productivity in both deep and surface mining is expected to increase moderately in the 1980s, regaining some but not all of the productivity losses experienced in the 1970s. Deep mining labor productivity is expected to increase from a low of 8.3 tons/man-day in 1978 to a high of 12 tons/man-day in 1990 and then to decline slightly to 10 tons/man-day by 2000. Similarly, surface mining labor productivity is expected to increase from a low of 26.4 tons/man-day in 1976 to 34 tons/man day by 1992 and then decline to 31 tons/man-day by 2000. The gains in productivity are primarily due, in deep mining, to an increase in the percentage of production from continuous mining operations and a gradual decline in conventional mining production. In surface mining, the gains in productivity are attributable to a shift in surface production from the less productive, thin seam eastern contour mines to the larger, thick seam western and mid western area mines. As discussed previously in presenting Table 1-I, the slight productivity declines forecasted after 1990 in both surface and deep mining are due to the saturation effect of high productivity technologies and the continued market entry of less productive or marginal mines, due to increasing real coal prices.

Figure 1-2 presents a plot from 1960 to 2000 of the deep and surface mining labor productivities that are determined in the MITRE model for the most probable employment future (Analysis #3). A comparison of historical productivity data (for 1960 through 1978) with those determined in the model indicate that for most years the model is within ± 15 percent of the historical data. A discussion of the accuracy of the model results for the historical period is presented in Section 8.0. The plots in Figure 1-2 indicate, for this case, that labor productivity in both deep and surface mines will rise through the 1980s and decline slightly in the 1990s. This pattern is consistent for all cases analyzed by MITRE (See Tables 1-I and 1-III).

Technology shifts in the 1980s are the main reason for the rise in productivity. Table 1-VI presents the data for both labor



U = Underground Productivity
S = Surface Productivity

FIGURE 1-2
TRENDS IN LABOR PRODUCTIVITY
(MOST PROBABLE EMPLOYMENT FUTURE)

TABLE 1-VI

BASE CASE LABOR PRODUCTIVITY AND TECHNOLOGY SHIFTS IN DEEP AND SURFACE MINING

YEAR	DEEP MINING LABOR PRODUCTIVITY TONS/MAN-DAY	PERCENT OF DEEP MINING BY CONTINUOUS MACHINES	SURFACE MINING LABOR PRODUCTIVITY TONS/MAN-DAY	PERCENT OF WESTERN AREA SURFACE MINING
1980	9.8	68.0	23.2	54.0
1985	11.5	77.2	29.6	62.3
1990	11.9	84.2	33.6	72.7
1995	11.1	87.9	33.3	81.3
2000	10.3	90.6	31.3	86.4

productivity and technology shifts in deep and surface mines. In deep mining, production from continuous mining methods (continuous and longwall machines) is projected to rise from 68 percent of underground production in 1980 to 84 percent in 1990. In surface mining, production from small and large area mines is projected to rise from 54 percent of surface production in 1980 to 73 percent in 1990. We assume no major breakthroughs in technology to enhance productivity during the projection period. This assumption results in a peaking of productivity by the early 1990s as most of the productivity gains available with existing technologies are realized. Two additional assumptions incorporated in the labor productivity equation are:

1) The impacts of health and safety on labor productivity remain constant after 1980, and
2) The impacts of coal preparation on labor productivity also remain constant after 1980.

Both assumptions can be varied in the model to determine their impacts on productivity. However, for the purposes of this study, both of those variables were held constant in the post-1980 period for all cases.

1.3.3 Periodic Shortages of Experienced Hourly Production Workers

The high turnover rate among hourly production workers having less than one year's experience (35-40 percent), when combined with fluctuating regional growth rates in coal production, is expected to result in the continued employment of large numbers of inexperienced miners, i.e., around 60,000 in 1990 in Sensitivity Analysis #3 (most probable employment future). This employment is necessary in order to fill the gap between the demand for and the supply of experienced workers.

Table 1-VII presents the number of inexperienced miners with respect to the total production work force and the total industry work force in the most probable future. As may be seen, the number of inexperienced miners in a given year varies substantially (from 20 thousand to 60 thousand persons), based on the rate of overall industry growth at a given point in time. After the early 1990's, the level of inexperienced miners still fluctuates but remains below 20 percent of the hourly production work force in most cases.

1.3.4 Labor Shortages Most Likely in the Northern Great Plains and Interior/Gulf Regions

For all future coal demands considered, the fastest growth rates for labor demand by the coal mining industry are in the Northern Great Plains and Interior/Gulf regions. The demand for labor by the coal industry in 1975 accounted for 6.2 percent of the available male labor force* in the Northern Great Plains region and 5.5 percent in the Interior/Gulf region. By 1990 this demand is projected, for the base case, to increase to 35.2 percent and 15.9 percent respectively. The projections of the available male labor force in each region are

*The available male labor force is defined as the male population over sixteen years old residing in the coal producing counties within the region. Data on the available labor force was obtained from the Conference Board.

TABLE 1-VII

INEXPERIENCED MINERS IN COAL MINE WORK FORCE

	1975	1980	1985	1990	1995	2000
Inexperienced Miners (10^3)	22.1	33.8	24.2	58.9	22.9	55.3
Percent of Hourly Production Workforce	23.1	22.7	13.9	28.7	9.7	19.8
Percent of Total Coal Industry Employment	14.1	14.4	8.4	17.7	5.7	11.8

Estimates are based on model results

based on county-level population data for 1975 and state-level population growth projections from the U.S. Bureau of Census (Conference Board, 1979, Census#3, 1977). Clearly, if labor demand increases as projected in the Northern Great Plains and Interior/Gulf regions and if migration patterns are not altered significantly, labor supply in these regions will be a major constraints to rapid coal development.

Table 1-VIII presents the regional projections of labor demand for the Base Case. These labor demand projections are compared with projections of the available male labor force (i.e., labor supply) developed by the Conference Board (Conference Board, 1979). The actual regional labor supply available to the coal industry will be smaller than that suggested by the available male labor force projections. Employment of labor in other industries and in community supporting functions as well as the retired portion of the male labor force will reduce considerably the actual supply of labor available to the industry. Regional projections of the actual labor force available to the industry is beyond the scope of this study. However, data on the available male labor force can serve as a proxy for a general analysis of the labor supply versus demand outlook.

The data in Table 1-VIII indicate that in 1975, total labor demand in the coal industry as a percentage of the available male labor force was less than 10 percent in all regions and averaged only 6 percent across regions. However, by 1990 the average demand across regions increases to approximately 11 percent. This increase is due

TABLE 1-VIII

LABOR SUPPLY VERSUS LABOR DEMAND BY REGION

Year	Region	Available Male Labor Force $X10^3$	Total Demand For Labor TDCTP#		Total Demand For On-Site Labor DCTP#		Demand For On-Site Production Labor DCTPW#		Total Demand For Non-Production Labor TDCTP# - DCTPW#	
			$X10^3$	%*	$X10^3$	%*	$X10^3$	%*	$X10^3$	%*
1975	1	1,542	63.62	4.13	60.12	3.90	49.86	3.23	13.76	0.89
	2	867	84.05	9.69	79.43	9.16	65.78	7.59	18.27	2.11
	3	646	35.28	5.46	33.34	5.16	27.47	4.25	7.81	1.21
	4	83	5.17	6.23	4.89	5.89	3.84	4.63	1.33	1.60
	5	115	5.98	5.20	5.65	4.91	4.63	4.02	1.35	1.17
	Total	3,253	194.10	5.97	183.43	5.64	151.58	4.66	42.52	1.31
1985	1	1,653	95.97	5.81	90.69	5.49	73.95	4.47	22.02	1.33
	2	930	101.05	10.87	95.49	10.27	78.29	8.42	22.76	2.45
	3	786	81.16	10.32	76.69	9.76	61.90	7.88	19.26	2.45
	4	126	33.62	26.68	31.77	25.21	23.74	18.84	9.88	7.84
	5	174	13.65	7.84	12.90	7.41	10.43	5.99	3.22	1.85
	Total	3,669	325.44	8.87	307.54	8.38	248.31	6.77	77.13	2.10
1990	1	1,706	111.58	6.54	105.45	6.18	86.17	5.05	25.41	1.49
	2	959	104.78	10.93	99.02	10.32	81.34	8.48	23.44	2.44
	3	821	130.22	15.86	123.05	14.99	99.29	12.09	30.93	3.77
	4	137	48.23	35.20	45.58	33.27	34.06	24.86	14.17	10.34
	5	190	19.70	10.37	18.62	9.80	15.04	7.92	4.66	2.45
	Total	3,813	414.51	10.87	391.71	10.27	315.89	8.28	98.62	2.59

*Labor demand as a percent of the available male labor force.

Region 1 = Northern Appalachia
" 2 = Southern Appalchia
" 3 = Interior and Gulf (Midwest)
" 4 = Northern Great Plains
" 5 = Rocky Mountains

to relatively large increases in industry labor demands in the Interior/Gulf, Northern Great Plains, and Rocky Mountain regions (regions 3,4 and 5). These increases in both absolute and relative terms indicate the potential for labor shortages. For example, in 1975 the estimated total industry labor demand in region 4 is 5,980. By 1990 this demand increases to 48,230, an increase of more than eight-fold. However, the available male labor supply grows from 83,000 in 1975 to 137,000 in 1990, an increase of only 65 percent. These growth rates are based on the U.S. Bureau of the Census Series II-B state-level data (Conference Board, 1979). The impacts of a rapid coal industry growth and associated increases in labor demand in these regions are not completely accounted for in the Census projections. Actual migration patterns will be a function of the labor demand, employement opportunities and wage rates that result as the industry expands within these regions. However, the above analyses does indicate those regions that may face potential labor supply-demand imbalances.

1.3.5 Relative Predominance of Mining Engineering Within Coal Industry Facing Modest Decline

The percentage of all engineers in the coal industry who are mining engineers (currently about 60 percent) will continue to decline modestly, approaching 50 percent of all engineers or about 2,000 mining engineers by the year 2000. This appears to be due primarily to a trend toward continued growth of surface relative to underground mining.

Based on the numerous interviews conducted, coal companies appear to vary greatly in their hiring practices. Company preferences ranged from those which hired predominently mining engineers for both deep and surface mines to those which sought non-mining engineers (particularly civil engineers), for all on-site positions at surface mines. These preferences were matched by engineering consulting firms, several of which indicated that civil engineers perform more work on surface mine design and permit applications than do mining engineers. Based on discussions with about a dozen coal companies and on available historical data, we estimated that currently, mining engineers comprise about 80 percent of all engineers involved in deep mine production and about 35 percent of all engineers involved in surface mine production. Applying these percentages to all engineers demanded in coal mining, future demands for mining and other engineers were derived in each case and sensitivity analysis. Based on available labor supplies, the future employment levels of mining and other engineers in the coal industry were then projected under different sets of market conditions. As was seen in Table 1-IV, mining engineers are expected to comprise about 50 percent of all engineers in each of these futures by the year 2000. Unless the deep mining of coal recaptures a significantly larger share of the total market than is projected, the trend toward more non-mining engineers is likely to continue.

1.3.6 Mining Engineer Shortages Unlikely by the Mid-1980 s

The likelihood of mining engineer shortages affecting the coal mining industry any time after the mid-1980's appears to be rather small under most combinations of probable economic and energy demand conditions. Only in cases which combine at least two out of the following five conditions, (see discussion of Analyses 2, 4, 7 and 9 in Section 7.0) do persistent shortages of mining engineers, in the absence of Federal funding, occur:

(a) very high demand for mining engineers in non-coal mining industries (i.e., 250 new positions per year from 1985-2000);

(b) doubling of off-site employment (with greatest concentration of professionals) as percentage of total coal industry employment to 10 percent by 1990;

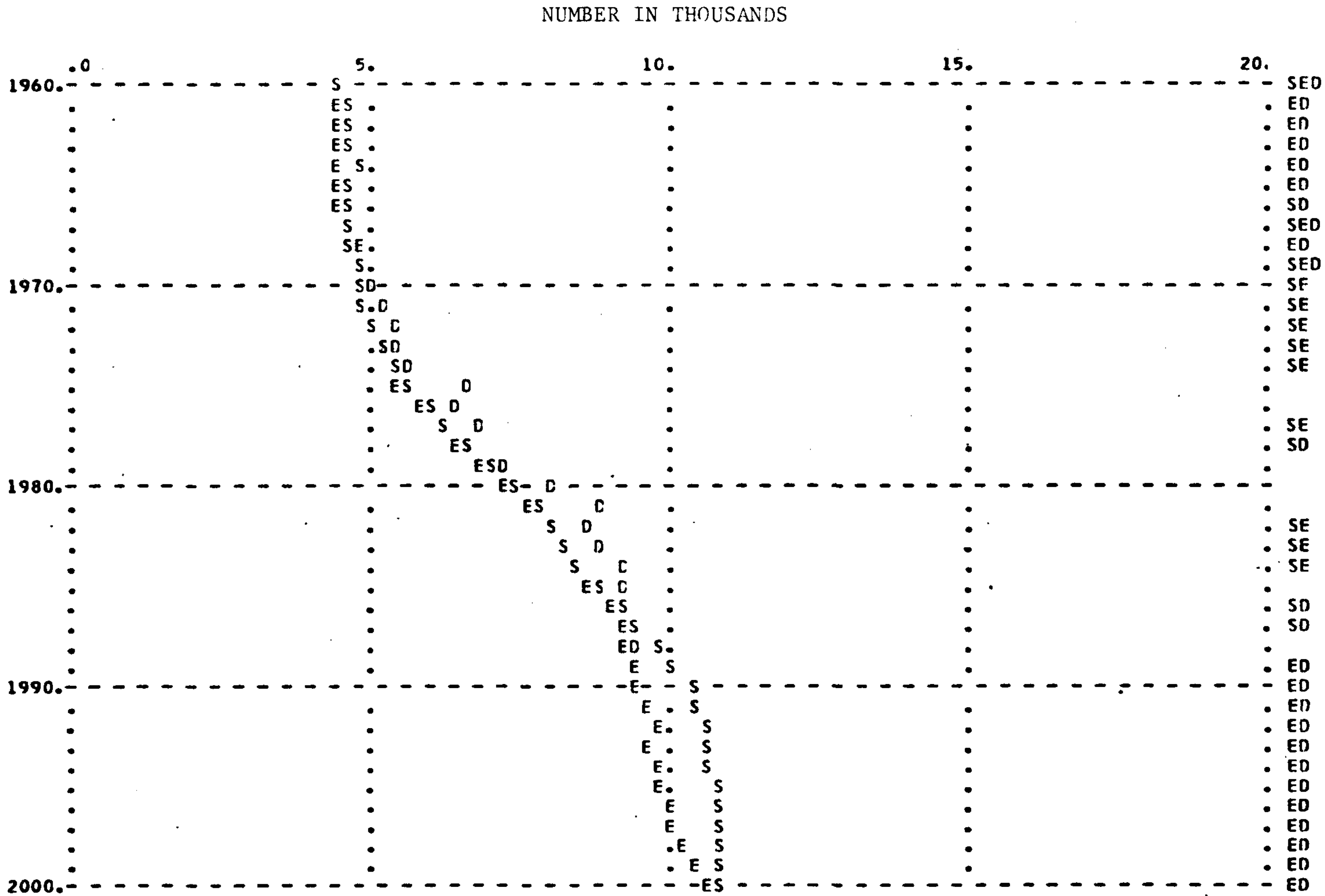
(c) increased personnel requirements due to regulatory changes, resulting in 20 percent greater technical support staff and 10 percent greater total employment after 1980;

(d) major upsurge in eastern coal production reaching 0.6 billion tons per year by 2000, including almost a fourfold increase in eastern surface production (based on higher transportation costs facing mid-west and western coal producers)*

(e) High Coal Demand Case reaching 2.8 billion tons per year by 2000

Figure 1-3 presents the supply/demand balance for mining engineers forcasted in the most probable employment future (Analysis

*Engineers of all types (and thus mining engineers) comprise a greater percentage of the non-hourly workforce in contour mines, which are a majority of eastern surface mines.



S = Supply of Mining Engineers
D = Demand for Mining Engineers
E = Employment of Mining Engineers

FIGURE 1-3
SUPPLY/DEMAND BALANCE FOR MINING ENGINEERS
(MOST PROBABLE EMPLOYMENT FUTURE—ANALYSIS #3)

#3).* As mentioned briefly in the beginning of Section 1.3 and discussed in greater detail in Sections 4.0 and 6.0, off-site employment levels are determined by factors such as industry concentration, mix of mine sizes and types, propensity to perform design and regulatory work in-house, and overall volume of regulatory requirements.

Assuming that some combination of these factors results in an approximate doubling of off-site employment vis-a-vis the entire industry work force, the demand for professionals such as mining engineers, other engineers and scientists should increase almost proportionately.** Figure 1-3 indicates that under the most probable employment future, a mining engineer surplus is likely to occur beginning in the mid-1980s.

By way of contrast, Figures 1-4, 1-5, 1-6 and 1-7 present the supply/demand balance for mining engineers forecasted in Analyses #2, #4, #7, and #9 respectively. The first three of these analyses forecast a mining engineer shortage at least through the mid-1990's. Analysis #9, on the other hand, forecasts such a shortage only through the mid-1980's, although a slight shortage reappears in the

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*In this and other figures which are taken from model outputs, time is represented on the vertical axis and the variables being estimated are given on the horizontal axis. Where plotted values overlap, only one of these is printed by the model and symbols for all overlapping variables are given on the extreme right of the figure.

**Engineers and scientists were forcasted as percentages of the non-hourly workforce which includes all off-site personnel as well as on-site supervisors, technical support and administrative staff.

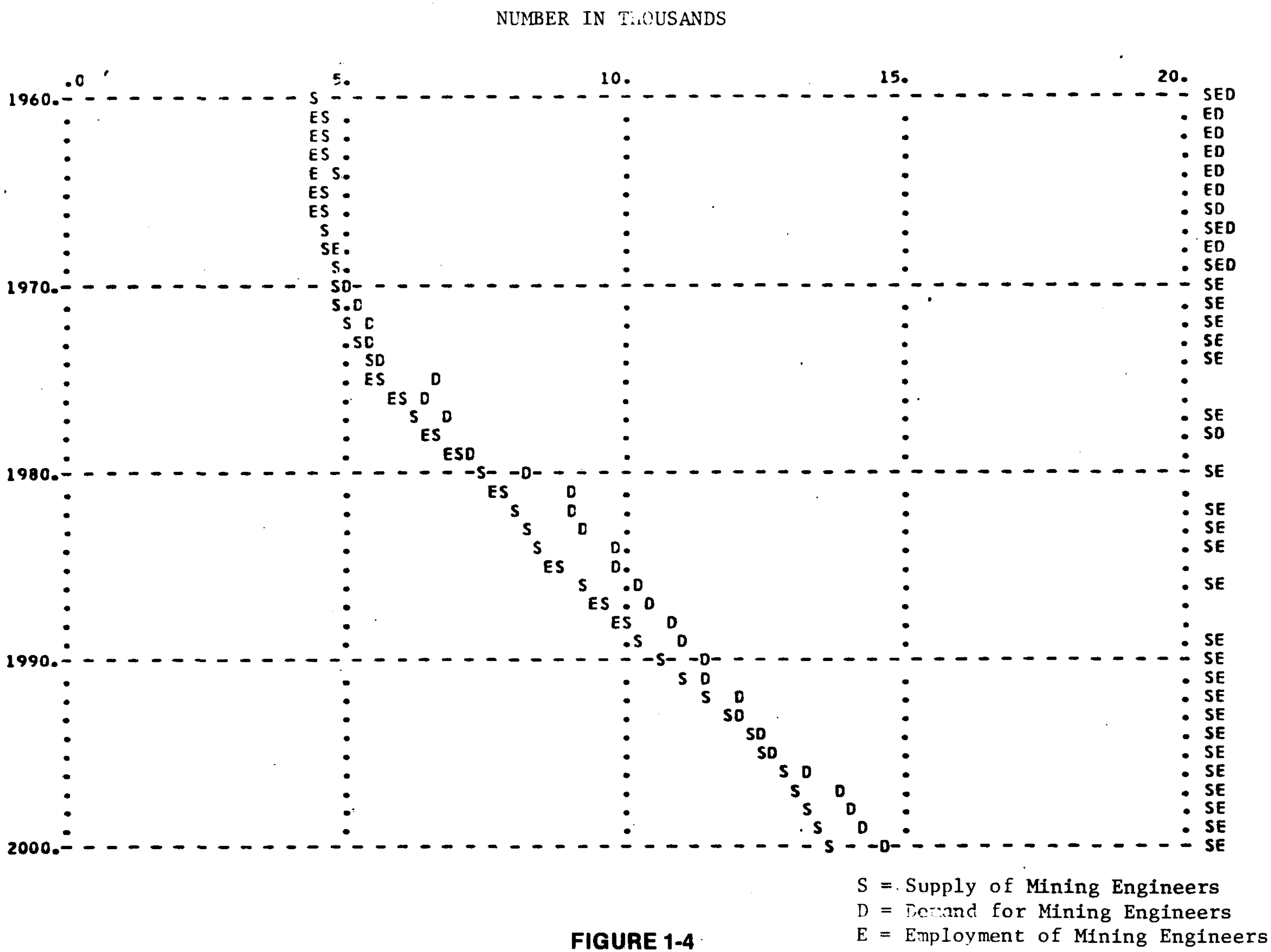


FIGURE 1-4
SUPPLY/DEMAND BALANCE FOR MINING ENGINEERS
(ANALYSIS #2)

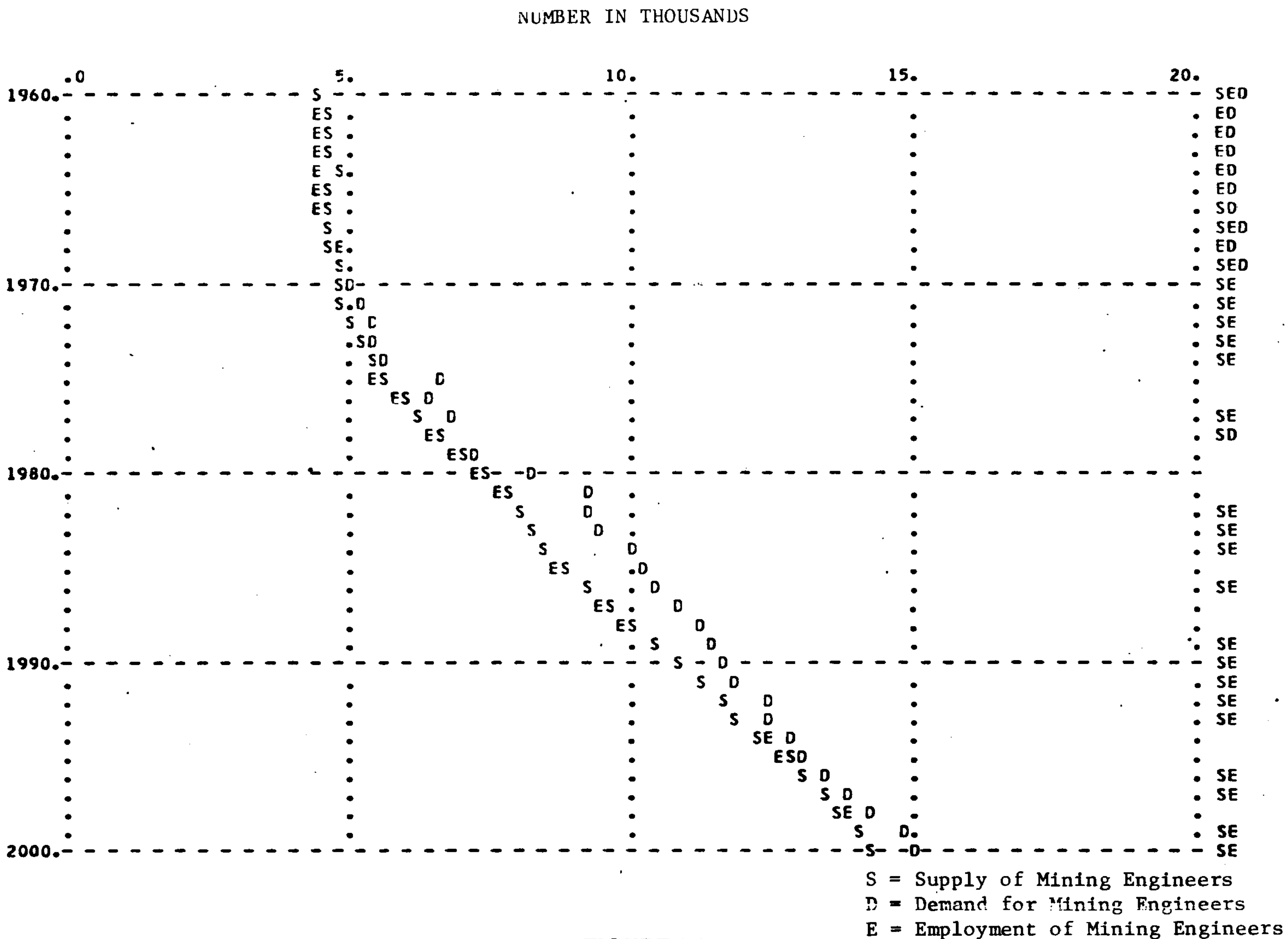
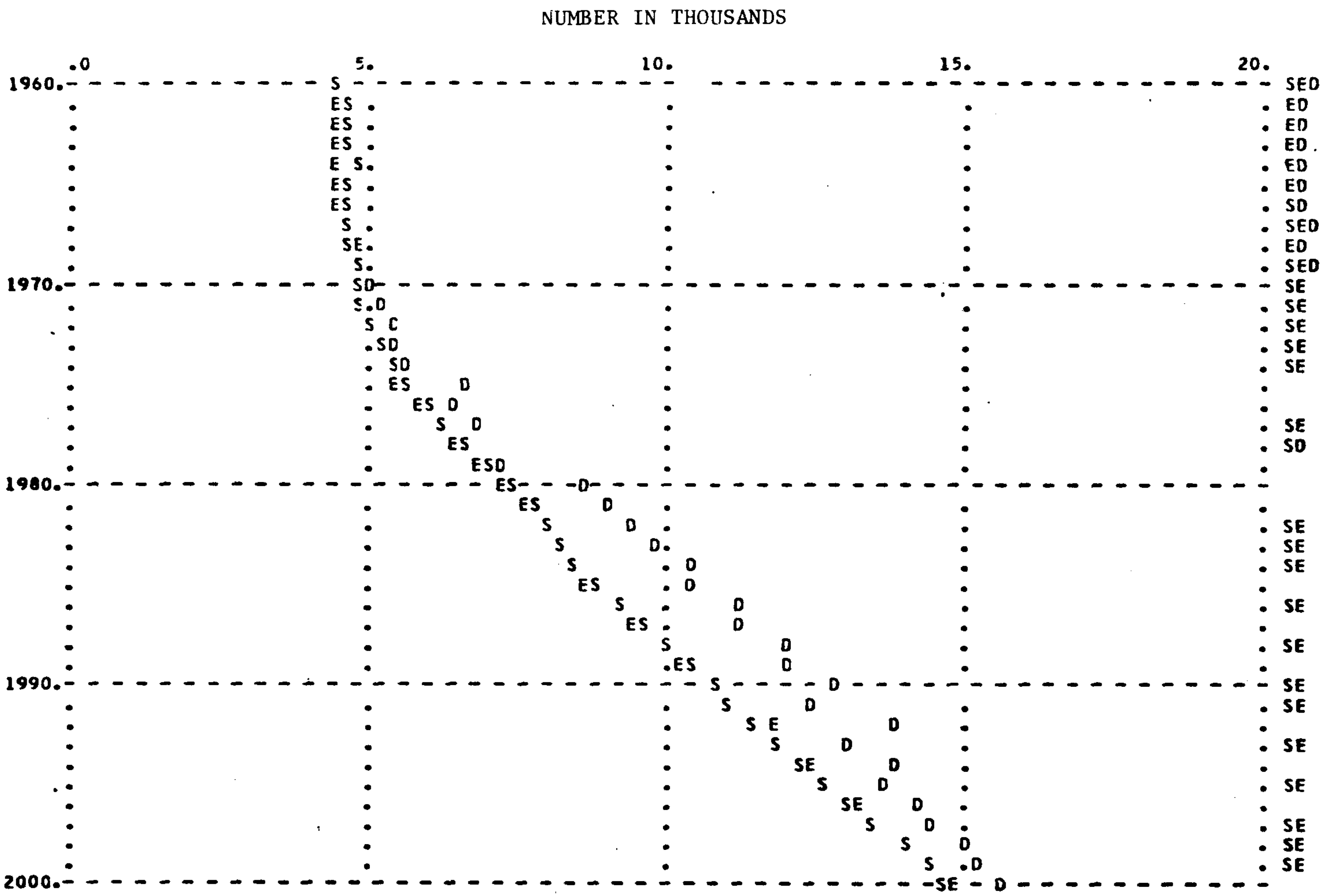


FIGURE 1-5
SUPPLY/DEMAND BALANCE FOR MINING ENGINEERS
(ANALYSIS #4)



S = Supply of Mining Engineers
D = Demand for Mining Engineers
E = Employment of Mining Engineers

FIGURE 1-6
SUPPLY/DEMAND BALANCE FOR MINING ENGINEERS
(ANALYSIS #7)

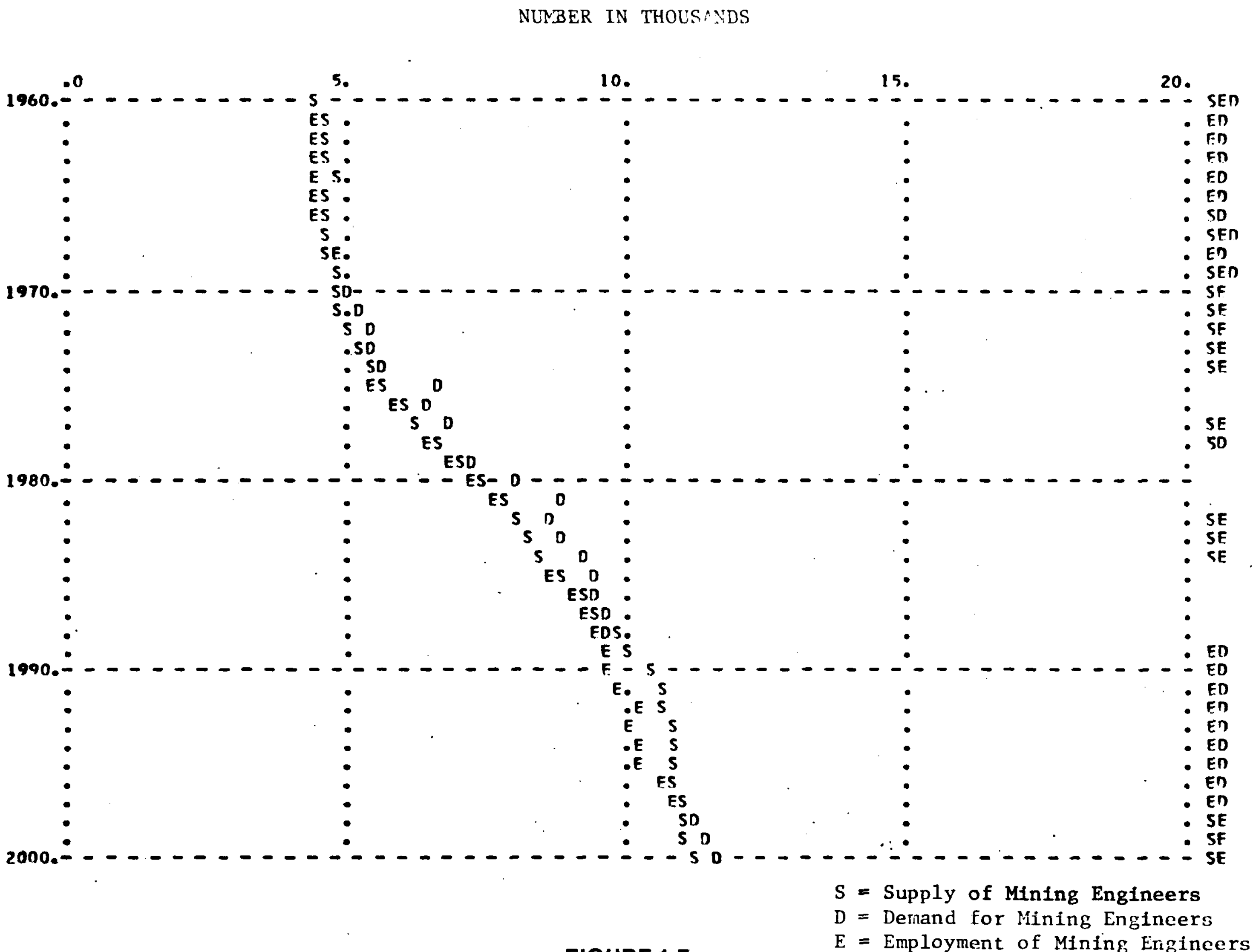


FIGURE 1-7
SUPPLY/DEMAND BALANCE FOR MINING ENGINEERS
(ANALYSIS #9)

late 1990's. Analysis #7, which assumes all but condition (d)* among those listed above, forecasts a persistent shortage of mining engineers throughout the entire study period beginning in the late 1970's. Its assumptions result in more than a doubling of mining engineer demand from the present to almost 16,000 nationwide (including 2,100 by the coal industry) by 2000. By contrast, under the most probable employment future total mining engineer demand is forecasted to reach only about 10,500 nationwide (including 2,000 by the coal industry), a total which is readily satisfied by forecasted supply based on normal market forces.

1.3.7 Current B.S. Degree Graduation Levels Sufficient Under Most Probable Future Conditions

The current level of B.S. degree mining engineering graduates from both accredited and non-accredited curricula (about 630 in 1979), if maintained throughout the 1980's would result in a surplus under all but the most optimistic demand assumptions as described above. As there is very little demand specifically for advanced

*Condition (d) was developed to test the sensitivity of regional production to the freight-on-board (FOB) selling prices faced by coal operators in each region. This was tested by arbitrarily decreasing the FOB prices available to mine types indigenous to the mid-west and the west to 10 percent lower by 2000 than those FOB prices assumed in the Base Coal Production Case. As a result, eastern surface coal production is forecasted to reach 424 million tons by 2000, almost four times the 1976 total of 115 million tons (and almost double that forecasted in the Base Case). The relative improbability of this occurrence, given the large number of new contour mines which would be required, resulted in the omission of condition (d) in combining the set of high mining engineer demand conditions assumed in Analysis #7.

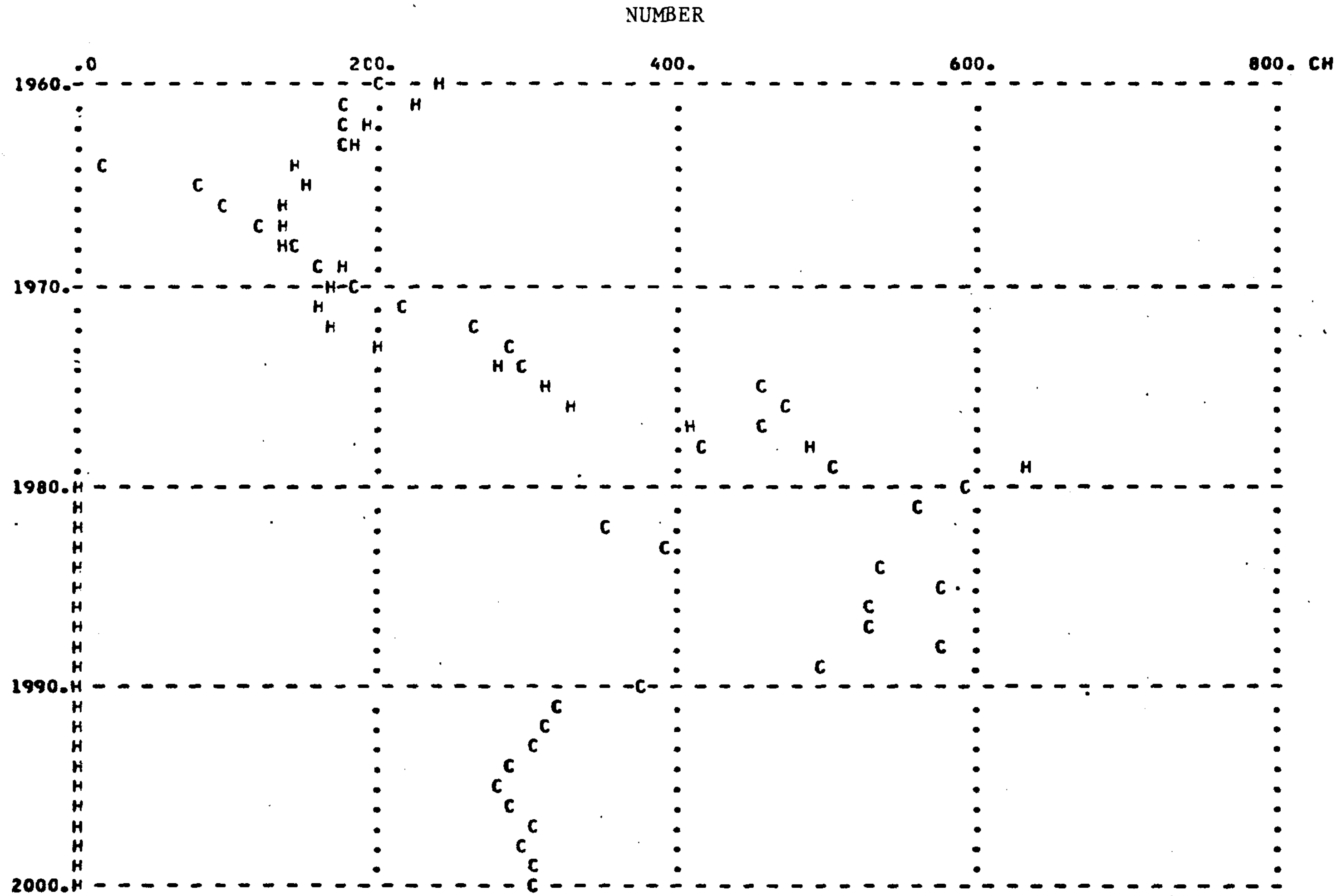
degree engineers of any type in the coal industry, the projected yearly graduation rate of between 500 and 600 B.S. degree mining engineers is capable of meeting the demand under almost all sets of conditions, except those assumed in Analyses #'s 2, 4 and 7.

Figure 1-8 presents B.S. degree mining engineer graduates forecasted in the most probable future. By assumption, this case does not assume the need for substantial scholarship funding of B.S. degree candidates and therefore estimates the number of graduates based solely on their attraction from market forces alone. Instead, what appears more likely to occur is that graduation rates in the 1990's will decline to those levels observed in the mid-1970's, i.e., around 300 graduates per year.

1.3.8 Potential Shortages of Mining Engineers can be Alleviated Via Scholarship Funding

Under conditions where the greatest potential for future shortages of mining engineers exist (Analyses #'s 2, 4, 7 and 9) Federal scholarship funding at the same constant dollar level as at the present, if directed toward mining engineers, is expected to eliminate these shortages, usually by the late 1980's. This is based on a continuation of historical trends in which 25 to 50 percent of undergraduate students who receive most of their educational expenses under scholarships are attracted to mining engineering instead of to other disciplines by such funding.

Analyses #5 and #8 assume different concentrations of Federal funding applied to B.S. degree mining engineer candidates. Federal



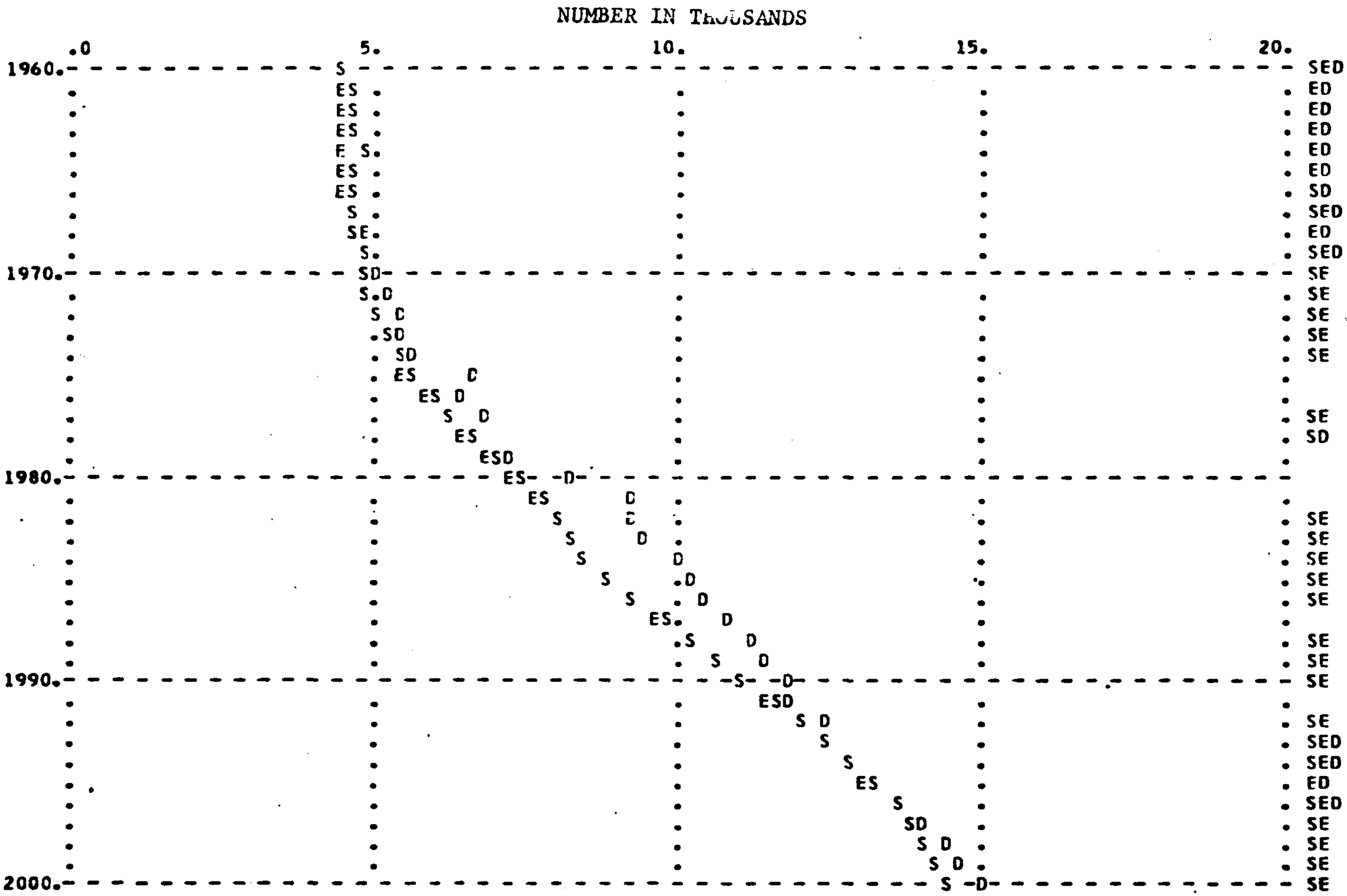
H = Historical
C = Calculated in Model

FIGURE 1-8
B.S. DEGREE MINING ENGINEER GRADUATES
(MOST PROBABLE EMPLOYMENT FUTURE—ANALYSIS #3)

scholarship funding in these cases results in a direct increase in the number of graduates, beginning in 1983 (four years after initial funding). Analysis #5 assumes an increase in graduations of 60 per year and Analysis #8 an increase of 110 per year (see Section 7.0 for details about the underlying assumptions).

Figures 1-9 and 1-10 present the supply/demand balances for mining engineers forecasted in Analyses #5 and #8, respectively. To assess the impact of such funding on the mining engineer supply/demand balance, Figure 1-9 should be compared with Figure 1-5, and Figure 1-10 compared with Figure 1-6.

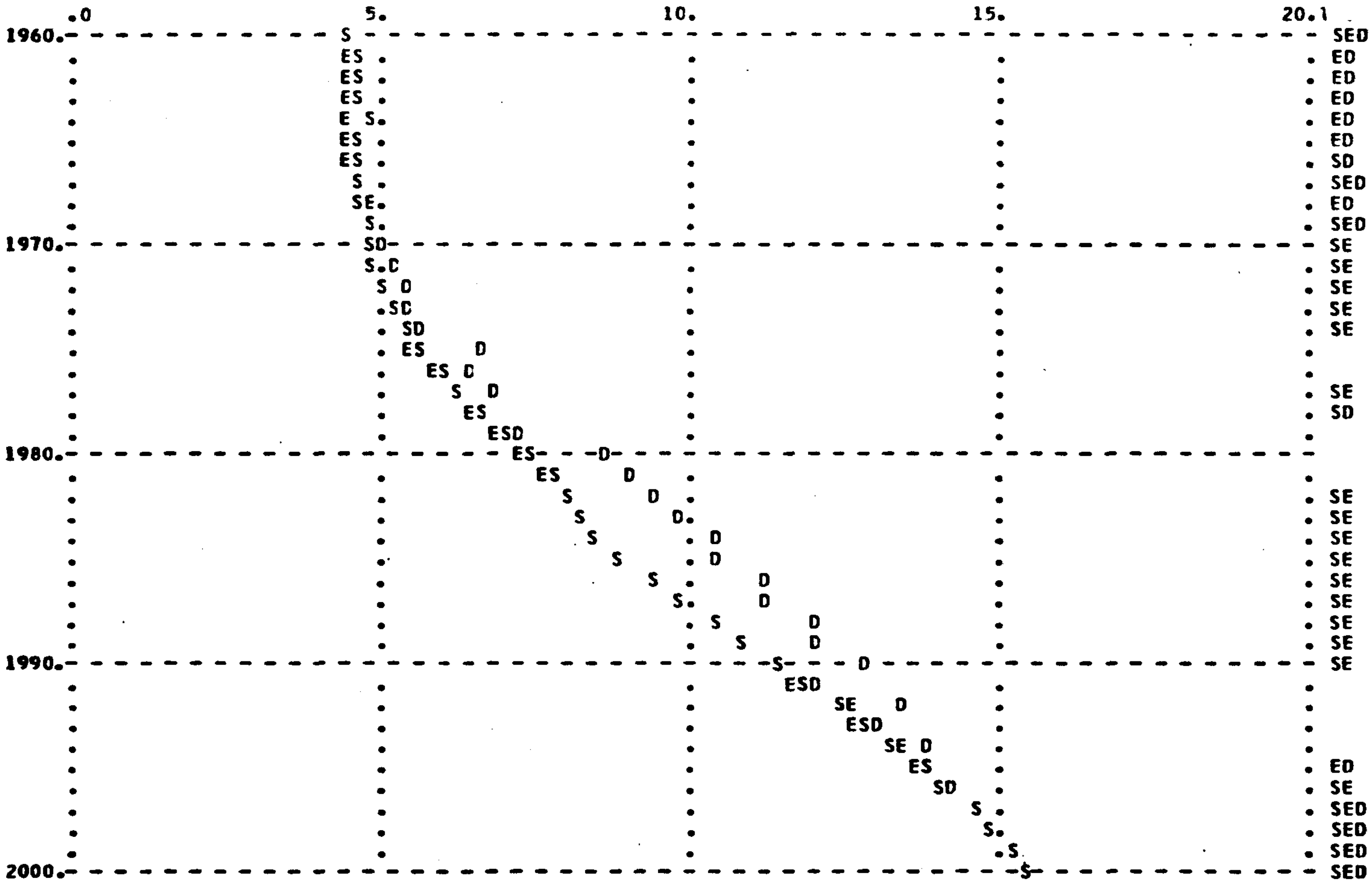
As may be seen, Federal funding at these levels can alleviate the shortages of mining engineers, but not until the early to mid-1990s. The elimination of such a potential shortage prior to that time is hampered by the four year delay in the graduation of new students once funding begins. Also, the application of SMMRRI funds to scholarships in general, much less to undergraduate mining engineers in particular, are largely discretionary decisions made within each state institute. Therefore, the relationship between the level of B.S. degree mining engineer funding and overall support levels is tenuous at best. Thus, if the greater concentration of funding assumed in Analysis #8 was also applied in Analysis #5, an earlier elimination of the forecasted shortage would occur (as well as the prevention of a slight shortage re-emerging in the late 1990's as seen in Figure 1-9).



S = Supply
D = Demand
E = Employment

FIGURE 1-9
SUPPLY/DEMAND BALANCE FOR MINING ENGINEERS WITH FEDERAL FUNDING (ANALYSIS #5)

NUMBER IN THOUSANDS



S = Supply
D = Demand
E = Employment

FIGURE 1-10
SUPPLY/DEMAND BALANCE FOR MINING ENGINEERS WITH FEDERAL FUNDING (ANALYSIS #8)

1.3.9 Professional Manpower Availability Facing the Coal Industry for Other Engineers and Scientists Appears Adequate Through 2000

The coal industry currently accounts for about 0.1 percent of the nation's employment of non-mining engineers and scientists with degrees applicable to mining.* By 2000, these percentages are expected to increase slightly in the most probable future to about 0.17 and 0.28 percent of national employment respectively among these engineering and science disciplines. Even in those cases where the nation's demand for non-mining engineers and scientists is greatest, coal industry employment within those national totals accounts for only 0.19 and 0.30 percent, respectively. Thus apart from a major national shortage of professionals in these disciplines, it appears unlikely that the coal industry will be faced with an insufficient professional labor supply. This conclusion is further supported by the long established tradition within industry (and recognized by the National Science Foundation in its demographic studies) that many workers performing as engineers and scientists, especially those engaged in non-academic or non-certifiable work such as that of production, often learn their skills on-the-job under the tutelage of degreed personnel.

Table 1-IX presents the projected supplies of other engineers (B.S. degree graduates) and scientists (advanced degree graduates)

*Civil, mechanical, industrial, and electrical engineers; and scientists with degrees in chemistry, ecology, biology, agronomy, forestry, wildlife and range management.

TABLE 1-IX

SUPPLY OF DEGREED PROFESSIONALS
AS PERCENTAGES OF TOTAL EMPLOYMENT OF OTHER ENGINEERS
AND SCIENTISTS

	Other Engineers Applicable to Mining	Scientists Applicable to Mining
1970	68	79
1980	79	81
1990	82	84
2000	90	88

applicable to mining as percentages of total projected employment in those fields for selected years under the most probable employment future. It appears from this table that in the future the demand for other engineers and scientists will be filled by appropriately degreed personnel to at least the same extent as has traditionally been the case. Thus, the small demands for degreed personnel placed on these groups of engineers and scientists by the coal industry are likely to be met.

1.3.10 Shortage of Mining and Mineral Engineering Faculty

A major near-term problem affecting the supply of mining engineering graduates is the difficulty of mining schools in attracting sufficient faculty. The level of full time equivalent faculty engaged in research has declined dramatically since the 1973-74 academic year. The remaining faculty resources available for teaching has resulted in faculty/student ratios of between 30 and 40 to one in most schools. The Engineers Council For Professional Development (ECPD) has defined 20 to one as a desirable maximum ratio of teaching faculty to undergraduate students. Thus, a need exists for attracting more faculty to reduce undesirable teaching loads, as well as to perform more research related to the improvement of mining technologies and labor productivity.

Trying to estimate the number of faculty members that have been demanded in a given time period was made difficult by a lack of empirical data. Such data needs include enrollments, student attrition rates, job security, average faculty salaries vis a vis those obtainable in the private sector, as well as non-quantifiable information such as relative attractiveness of teaching vs. employment in industry. However, the total demand for faculty under various conditions was estimated based on two key assumptions:

- to derive desired teaching faculty from graduations, it was assumed that 3.5 graduates per teacher would approximate the level of enrollments and would allow for an estimated 40 percent attrition (or 60 percent full matriculation);

$$\frac{\text{3.5 graduates X 4 years/ .6 attrition factor}}{\text{teaching faculty member}} = \frac{\text{23 students}^*}{\text{teaching faculty member}}$$

  The desired faculty available for teaching could be approximated by the formula:

$$\frac{GRME_t/3.5}{\text{1-research fraction}} = \text{desired faculty}$$

  where $GRME_t$ is the number of B.S. mining engineer graduates and the research fraction is the percent of full time equivalent faculty engaged in research. For example, in 1978 the desired faculty available for teaching is estimated to be:

$$\frac{484/3.5}{1.0 - 0.3} = 197$$

- the research fraction, or percentage of full time equivalent faculty engaged in research, may fluctuate from below 25 percent (which some universities temporarily may accept but most consider unacceptable) to about 75% (a common level during years of relative declines in enrollment, such as from the early 1960's up to the oil embargo of 1973).

Based on the above approach, Table 1-X presents the results in the most probable case. This shows the level of total faculty demand

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*This ratio of 23 to 1 is slightly higher than the ECPD recommended 20 to 1 ratio, but was considered conservative, as schools are less likely to fully staff up unless faculty demand remains pronounced.

TABLE 1-X

TOTAL FACULTY DEMAND IN MOST PROBABLE EMPLOYMENT FUTURE

Total Faculty Demand \ Research Fraction	25% (Maximum Teaching Minimum Research)	50%	75% (Minimum Teaching Maximum Research)
1960			
Historical	92	138	277
Model	77	116	231
1970			
Historical	64	97	194
Model	69	104	208
1978			
Historical	117	176	352
Model	159	239	477
1980	226	338	677
1985	219	328	657
1990	142	213	426
1995	107	161	322
2000	117	176	351

that would be required to satisfy teaching requirements based on various levels of research time spent by faculty. Given 1979 faculty employment of about 160 mining engineers* with about 30 authorized openings yet to be filled, Table 1-X indicates the magnitude of the probably shortage throughout the 1980's. University officials feel that the opportunity to perform research is necessary for a number of reasons, including the need to attract new faculty, to retain existing faculty, and also to allow professors the opportunity to remain current in their fields. Assuming that between 25 and 50 percent of full time equivalent faculty time is acceptable to devote for research, Table 1-X indicates that probable faculty shortages will remain through most of the 1980's, based on forecasted graduation rates.

1.3.11 Impact of Relative Salaries in Creating Faculty Shortage

Faculty salaries relative to those which can be earned by bachelor degree engineers in the coal industry have been the cause of a major labor market distortion. Increasing industry personnel demands and salaries have resulted in more students enrolling in programs such as mining engineering, and in turn, in a requirement for more faculty. However, the number of faculty are limited by salaries that are low relative to those paid by industry. The highest faculty salaries for full-professors are about $30-35,000 ($24-28,000 in

*Mining engineer faculty teaching in other programs were presumed to be cancelled out by non-mining engineer faculty teaching in mining engineering programs.

1976 dollars). These salaries are often exceeded by those paid to industry supervisors possessing only a bachelor's degree. Thus, the ability of schools to retain existing faculty, much less to train new M.S.'s and Ph.D.'s, becomes even more limited.

1.3.12 Potential for Inter-School Competition for Scarce Faculty

If additional State Mining and Mineral Research and Resources Institutes are established without raising faculty salaries, extreme competition is likely to take place among universities for existing faculty. Although inter-school competition may marginally increase faculty salaries, all schools face the same constraint of maintaining relative salary equivalence among faculty of like rank across disciplines.

This point may be illustrated by referring back to Table 1-X. To maintain a minimum research fraction of 25 percent of faculty time, by 1985 approximately 60 new faculty members would need to be hired, including about 30 positions at existing schools of mining engineering. However, by 1990, to maintain a more balanced 50 percent research fraction, no additional faculty positions would be needed. Stated another way, the level of B.S. degree graduations are presently at about the peak levels forecasted under most future cases; therefore, the establishment of more mining schools over the next few years would do little to alleviate the current problem of classroom overcrowding. Moreover, unless faculty salaries become more competitive with those paid to many mining engineers in industry, the possibility exists of filling many new faculty positions from within the existing academic community.

1.3.13 Distribution of Engineers and Scientists

Engineers and scientists are demanded to fill various positions grouped in this study as non-hourly or salaried personnel.*
Table 1-XI presents the absolute demand for engineers and scientists expressed as percentages of non-hourly personnel and total industry personnel. On the average, engineers currently compromise about five percent and scientists about one percent of non-hourly worker demand. The phrase "minimum employment" in Table 1-XI refers to the availability of each labor supply pool to satisfy demands for new positions (i.e., total positions minus separations). Thus the slight decline in minimum employment levels for mining engineers after 1990 implies a reduction in absolute demand for services which can best be performed by mining engineers. This does not necessarily mean that absolute employment will actually decline to this level by 2000, given typical industry employment practices. Rather, some mining engineers may perform work that is more closely associated with other engineering disciplines, while others may advance sooner to managerial positions which are not strictly defined as engineering functions.

*Defined to include all non-production and office personnel, on and off-site, plus production supervisors and technical support staff (e.g., safety inspectors) involved directly in production. (See Appendix A).

TABLE 1-XI

MINIMUM EMPLOYMENT OF DEGREED ENGINEERS AND SCIENTISTS WITHIN THE COAL MINING INDUSTRY

	1970	1980	1990	2000
Mining Engineers	770	1510	2240	1990
Other Engineers	450	1090	1870	2040
All Engineers	1220	2600	4110	4030
Engineers as Percent of Non-Hourly Worker Demand	4.3	4.5	4.3	3.0
Engineers as Percent of Total Industry Demand	0.9	1.1	1.2	0.9
All Scientists	280	520	910	1310
Scientists as Percent of Non-Hourly Worker Demand	1.0	0.9	1.0	1.0
Scientists as Percent of Total Industry Demand	0.2	0.2	0.3	0.3

It should be noted that the demands for degreed engineers and scientists were forecasted as percentages of the non-hourly (salaried) work force, based on major structural changes in the industry. Engineers within this work force segment were found to be in greater demand as non-conventional technologies (i.e., continuous and longwall) captured a larger share of deep production, and in lesser demand as eastern surface mining declined in its share of total surface production. These relationships are consistent with the personnel requirements among the different model coal mines developed for this study (see Appendix A). The percentage of non-hourly workers represented by degreed engineers is greatest for continuous and longwall mines among the deep technologies, and for contour and small area mines (which characterize eastern production) among surface technologies. However, the eventual decline of engineers as a percentage of non-hourly workers reflects in part the saturation effects of continuous and conventional deep mines growing more slowly as conventional mines phase out.

Forecasting changes in the demand for scientists was more difficult as this could not be linked with any degree of significance to structural changes in the coal industry. Based on the Industry/Occupational Matrix (BLS #1, 1979) and discussions with several coal companies, scientists, almost all of whom work off-site, were estimated to comprise about 1.0 percent of non-production work force demand. This relationship was maintained in forecasting the future demand for scientists in the coal industry. As a result, the number of scientists is projected to increase slightly relative to the number of engineers, rising from less than a fourth to almost a third of the engineer employment total. Given the increasing propensity for companies to perform environmental work in-house and the greater relative employment of off-site personnel, this projected trend seems consistent with current industry practices.

1.3.14 Demand for Mining Technicians

The demand for qualified mining technicians, preferably those having two-year associate (A.S.) degrees is expected to grow quite rapidly as long as the coal industry itself is expanding. This demand exists primarily for skilled production workers (e.g., electricians, heavy equipment operators, welders, and various types of mechanics, especially for diesel equipment in surface mines), and to a lesser degree, for those in technical support positions (e.g., health and safety personnel, reclamation technicians, etc.). In the most probable employment future, employment of such technicians is expected to increase from less than one percent of total coal industry personnel in 1980, i.e., about 2,000 technicians, to over five percent or about 25,000 technicians by the year 2000. As was shown in Table 1-IV, the anticipated rapid growth in demand for mining technicians exists for all employment futures. In the Low Case for example, about 21,000 technicians are forecasted to be employed by 2000; an increase of 12 percent per year. This trend is expected to continue regardless of the future surface-underground production split, as greater mechanization is likely to occur in both surface and underground technologies. This mechanization is expected to increase the relative demand for mining technicians.

1.3.15 Support for Mining Technology Programs

Coal companies have been particularly active in establishing and supporting mining technology programs, especially two-year degree programs usually offered through community colleges.

In a telephone survey of schools offering such programs, the majority indicated that they received direct support in various ways from coal companies (e.g., institutional/scholarship funding, donating free equipment for classroom instruction, providing guest speakers, and providing trustees to ensure appropriate training).

Both industry and college officials have confirmed the overall success of such programs, many of which provide on-the-job work experience and rapid placement following graduation. However, the performance of graduates, both in school and on-the-job, varies greatly. Notably, according to all faculty and coal company personnel quetioned on this subject, CETA-funded students consistently have had higher-than-average drop-out rates during enrollment and higher-than-average quit rates shortly after employment. This type of experience was attributed by some university officials to the fact that CETA candidates tend to have had limited work or academic experience prior to enrollment. Thus, the goals of CETA funding to assist the disadvantaged do not necessarily result in funding the most promising prospective candidates. Nevertheless, the majority of students who complete two-year associate degree programs are well received by the coal industry, which hires about 95 percent of these graduates.

1.3.16 Potential Competition Between Four-Year and Two-Year Graduates

A key area of potential job competition between four-year B.S. degreed engineers and two-year A.S. degreed mining technicians is that of production or first-line supervision (i.e., section foremen in deep mines, pit foremen in surface mines).

In discussions with several coal companies, a maximum of about five percent of production supervisors were cited as having four-year engineering degrees of any type. Although most companies indicated a willingness to hire more B.S. degree engineers for such positions, they felt that most of these engineers were reluctant to stay within the production work force for more than a few years. Production supervision, therefore, is often viewed by B.S. degree engineers as part of the necessary experience required to advance to front office or other more traditional engineering or managerial functions.

Company interest in hiring more B.S. degreed engineers for supervisory and other state-certified positions stems in part from the waiver by most states of two out of the three years experience requirement for certified positions. This interest in hiring B.S. degreed engineers is mitigated by a tradition of promoting from within the production work force, as well as the reluctance of many B.S. degreed persons to spend much time directly in production. Moreover, several states now waive one year of experience for two-year mining technology graduates at approved schools. To the extent that two-year degreed technicians are willing to work their way up and remain in the production work force, many of them may obtain jobs that otherwise might be offered to B.S. degreed engineers.

2.0 COAL MINING MANPOWER OVERVIEW

In the next twenty years, it is expected that substantial changes will take place in the regional distribution of coal production, in the technologies used to produce this coal, and in the skills required in both the professional and non-professional coal mining work force. These factors, combined with an expected significant increase in total tonnage produced, can lead to situations in which mismatches between the available and the required work force occur. These mismatches can be expressed in terms of work force size, skill compositions, or both, and may take place as a regional or national labor shortage or surplus in the coal mining industry.

In order to place the analysis carried out in this study in proper perspective, it is useful to describe the current composition of the coal mining labor force and to discuss some of the significant influences which have affected this work force in recent years. This discussion also introduces some of the data which exists concerning labor in the coal industry and leads to a brief review of the use and limitations of these data in other coal industry manpower studies.

2.1 Labor Force Profile

In order to address the future adequacy of coal mining manpower, some understanding of how the work force evolved to date is essential. Significant changes in mining technology and in the demand for coal over the last few decades have caused equally significant qualitative and quantitative changes in the coal industry labor force. Advances in mechanized production have encouraged shifts from labor-intensive to capital-intensive mining methods in all types of mines, as well as an overall shift from underground to surface mining. The human impact of automation in coal mining was manifested by a decline of 70 percent in production personnel from 1950 to 1969, the low point among such workers this century. Figures 2-1 and 2-2 capture the essence of these trends in comparing coal production and employment* by mining sector. For example, underground mining employment has declined by 55 percent since 1950, while underground production has declined by only 25 percent over the same period. To some extent this reflects the shift toward extraction methods having higher capital productivity, mainly continuous mining and haulage systems. This trend has been even more pronounced in surface mining, where employment has declined by 40 percent while production has increased by over 200 percent from 1950 to 1976.

2.1.1 Skills Composition of the Work Force

While overall employment between 1950 and 1970 declined in both mining sectors, the skills composition of the work force has also been changing. A number of short-term pre-employment vocational training programs (e.g., the industry-financed Coloardo Mine Career

*Employment in both surface and underground mining includes all workers at coal mine sites who perform production activities, including working supervisors and on-site preparation plant employees.

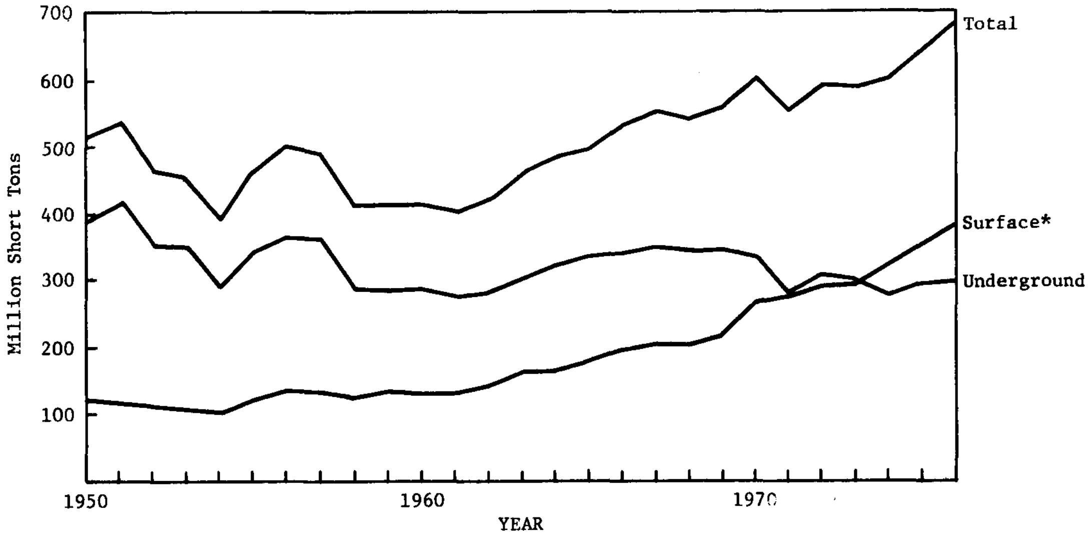
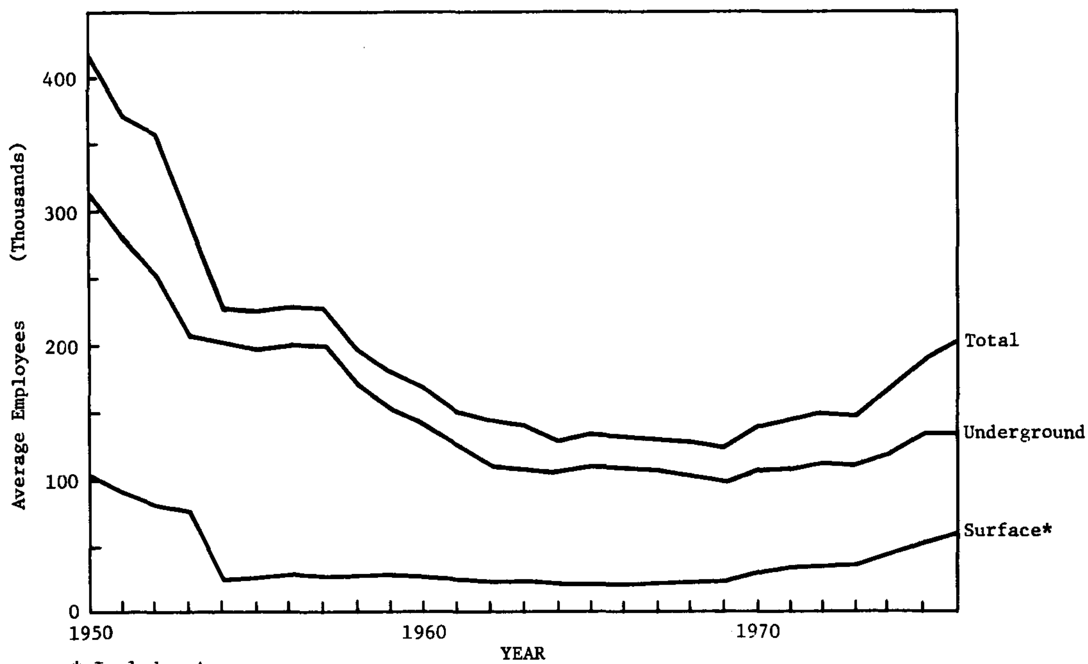


FIGURE 2-1
COAL PRODUCTION



* Includes Auger
Source: Minerals Yearbook

FIGURE 2-2
COAL INDUSTRY EMPLOYMENT

Center) have been established to provide coursework in health and safety as well as in major production skills such as heavy duty mechanics, equipment operation, and welding. Also, several newly-developed specific training programs have been developed in areas such as preventive maintenance and electrical systems troubleshooting. These programs, under joint BCOA/NCA* sponsorship, provide high-quality on-site training on a cost-per-student basis, making such programs equally affordable to small and large coal companies alike (Mining Engineering, August 1978). Moreover, mandatory minimum training requirements of the U.S. Mine Safety and Health Administration (MSHA) make today's miner more skilled than his predecessor in such areas as methane detection and overall mine safety. Finally, the last decade has seen the proliferation of mining technology programs, mainly through community colleges, many of which offer two-year and in a few cases, four-year degrees (see Appendix B for details). However, no official national data exist regarding the extent of formal training or education among coal industry production personnel.

To assess the nature of changing skills required in the coal mining industry, some aggregation among the industry's diverse occupations would be useful as a frame of reference. Although pay scales do provide some indication of skill level, wage differentials

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*Bituminous Coal Operators Association/National Coal Association.

for relative exposure to work hazards and seniority make such delineations less reliable. For the purpose of showing changes in the mix of production workers over time, we have developed two definitions to aggregate the numerous production worker job categories listed by the Bureau of Labor Statistics (BLS). These definitions are as follows:

- Skilled - A worker whose job requirements entail completion of some formal on-the-job apprenticeship program, fulfillment of MSHA approved training requirements for a "qualified person" with responsibilities for various health and safety testing procedures, and/or the practice of specialized skills which require some supervision or demonstration of ability for a limited period beyond the minimum training period (now 45 days for new miners under the BCOA/UMWA* contract).

- Semi-skilled - All other workers, including helpers, for whom no formal training program or supervision period is required beyond the minimum training period for new miners.

The above definitions were applied to the distribution of jobs among companies surveyed by the Bureau of Labor Statistics (BLS #2, 1962-1976).** The results, expressed in percentage terms (since the absolute numbers only represent a sample), are presented in Table 2-I. As may be seen, skilled labor has grown consistently, particularly in surface mining, since 1962. In both sectors, the

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*Bituminous Coal Operators Association/United Mine Workers of America.

**The BLS series, <u>Industry Wage Surveys</u> attempts to estimate average earnings and hours worked by selectively sampling a number of industry establishments. The 1976 Survey for bituminous coal mining included almost a third of all coal establishments with 10 or more workers, and includes over half of all coal production workers. See the glossary for a categorization of mining jobs by skill level.

TABLE 2-I

SKILL LEVELS AMONG BITUMINOUS COAL MINING PRODUCTION WORKERS BY PERCENT

	1962		1967		1976	
	Skilled	Semi-Skilled	Skilled	Semi-Skilled	Skilled	Semi-Skilled
Underground	53.1	46.9	54.9	45.1	57.5	42.5
Surface	56.1	43.9	60.6	39.4	73.1	26.9

*Based on MITRE categorization of representative sample from BLS Industry Wages Surveys for Bituminous Coal Mining, 1962, 1967 and 1976.

increased use of heavy mobile equipment (which is considered to require skilled operators), as opposed to equipment associated with hand picking, loading and related jobs, has contributed to the overall trend toward skilled labor. Another factor may be the use of larger size haulage trucks which has resulted in fewer truck drivers (semi-skilled) employed in relation to all other production employees at the establishments surveyed.

To view coal industry employment more broadly, Table 2-II presents a distribution of total industry employment for selected years since 1950. Separate data compiled by BLS and by BOM/EIA are presented for comparative purposes. Without assessing the relative accuracy of the two series, each may be useful to show certain trends. One of the most obvious trends seen in the BLS data is the increasing percentage of what it defines as non-production employees*, growing from 4.5 percent of the work force in 1950 to almost 18 percent by 1978. In Table 2-III, the percentage of the work force accounted for by production workers as defined by BLS is disaggregated by mine type and skill level. This table indicates that among total labor employed in 1976, surface mine production workers comprised 26.2 percent of total industry employment, the

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*The BLS defines production and related workers at mines and preparation plants to include working supervisors. This appears to be a somewhat narrower definition that that used by BOM-EIA in their series, which includes all employment at mines and preparation plants except office workers. MITRE provides its own disaggregation of coal industry employment later in this section to achieve consistency according to job function and pay status.

TABLE 2-II

NUMBER AND DISTRIBUTION OF PRODUCTION AND NON-PRODUCTION WORKERS

IN BITUMINOUS COAL AND LIGNITE MINING[(a)]

		1950	1960	1962	1967	1976	1978
BLS	Non-Production Workers						
	Number (10^3)	16.5	19.3	16.9	17.4	32.6	35.4
	Percent	4.5	11.5	12.1	13.2	14.7	17.8
	Production Workers[(b)]						
	Number (10^3)	351.4	149.2	123.1	114.6	188.8	163.1[d]
	Percent	95.5	88.5	87.9	86.8	85.3	82.2
	Total Industry Workers	367.9	168.5	140.0	132.0	221.4	198.5[d]
BOM-EIA	Production Workers[(c)] Number (10^3)	415.6	169.4	143.8	127.9	202.3	221.0

Sources: BLS# 3 , 1979; BOM, 1950-1976; EIA, 1978 (Preliminary)

(a) Years selected for comparison with BLS Industry Wage Survey data in Table 2-III (BLS # 1, 1962-1976).

(b) BLS production workers defined to include working supervisors.

(c) BOM-EIA production workers defined to all employment at mines and preparation plants except office workers.

(d) Annual averages from monthly observations based on establishment payrolls. 1978 decline due to personnel on strike for entire pay periods (months) and thus, omitted in monthly average employment.

TABLE 2-III
PRODUCTION WORKER DISTRIBUTION BY
MINE TYPE AND SKILL LEVEL*

	1950	1960	1962	1967	1976
Underground Production Workers					
Skilled	-	-	39.0	39.0	33.9
Semi-Skilled	-	-	34.3	31.9	25.2
Total	71.6	74.3	73.3	70.9	59.1
Surface Production Workers					
Skilled	-	-	8.2	9.6	19.1
Semi-Skilled	-	-	6.4	6.3	7.1
Total	23.9	14.2	14.6	15.9	26.2
Production Workers as percent of total work force	95.5	88.5	87.9	86.8	85.3

*Derived from BLS #1, 1962-1976 and BLS #3, 1979. All numbers in percent of total work force.

highest percentage ever, while underground mine production workers comprised 59.1 percent of industry employment, the smallest percentage ever. It is interesting to note that while surface mine production has grown from 24 to 57 percent of the nation's total between 1950 and 1976, surface production labor has declined by 40 percent in absolute numbers and only increased from 24 to 26 as a percent of total industry employment by 1976. These trends clearly manifest the relationship between historically large increases in surface productivity and production and relatively small increases in the demand for surface production labor. By contrast, underground production workers have experienced a decline of 45 percent in absolute numbers employed since 1950, as well as a decline in terms of the percentage of total workers employed (from 75 percent to 59 percent between 1950 and 1976).

For professional employment (defined as those jobs which require a minimum of a four-year college degree) no time series data are available for the coal industry. The best disaggregation of professional employment within this industry is that provided in the BLS Industry/Occupational Matrix based on the 1970 Census. For that year, the distribution of scientists and engineers is presented in Table 2-IV. As may be noted, mining engineers at that time comprised 53.5 percent of the professionals and 64 percent of all engineers, but still less than one percent of all employees in the coal industry that year.

TABLE 2-IV

DISTRIBUTION OF ENGINEERS AND SCIENTISTS IN COAL MINING
BASED ON 1970 CENSUS

Professional Category	Estimated Number	Percent of Professionals	Percent of Total Employment
Engineers			
Chemical	25	1.6	-
Civil	119	7.8	<0.1
Electrical	96	6.3	<0.1
Industrial	95	6.2	<0.1
Mechanical	86	5.6	<0.1
Mining	820	53.5	0.6
Other	24	1.5	<0.1
Total Engineers	1265	(82.5)	0.9
Life and Physical Scientists			
Chemists	214	14.0	0.1
Geologists	54	3.5	<0.1
Total Life and Physical Scientists	268	(17.5)	0.2
Total Engineers and Scientists	1533	100.0	1.1
Total Coal Mining Employment	144804*		

Source: BLS #1, 1979.

*Total employment numbers by BLS differ from those provided by BOM/EIA in Minerals Yearbook, reflecting different accounting and job categorization techniques.

Based on discussions with coal industry personnel, and our independent analysis of employment data, several trends pertaining to professionals in coal mining are evident. First, the demand for professionals in absolute terms is rising, especially the demand for engineers as a percent of the non-hourly work force. Using BLS, BOM and Census Bureau data, and making certain assumptions about the growth of the off-site work force (see Section 4.0), we estimated the changing distribution of engineers and scientists, including those employed as production supervisors, as percentages of what we are calling the non-hourly work force. For purposes of this study, the coal industry work force is defined as follows:

- Non-hourly (salaried) work force: Among employees at mine sites, all supervisors and technical support staff, including those involved in production, as well as all administrative (office and clerical) personnel. In addition, all off-site personnel (i.e., main and regional office personnel) are considered here as non-hourly workers.

- Hourly (union or union-equivalent) work force: All production workers, regardless of skill level, up to but excluding first level supervisors. In union mines, this would include all categories covered under hourly wage rate contracts.

Using these definitions, we estimated that from 1960 to 1977, the number of all engineers employed increased from about 3.5 percent to almost 6 percent of the non-hourly work force. The employment of scientists, on the other hand, has shown no discernible upward trend as a percentage of the non-hourly work force, and is estimated to have comprised about one percent of this coal industry labor segment. This difference between the two professional groups may be attributed in large part to two factors: (a) the growth of engineer employment as well as clerical staff (associated with increased paperwork and regulatory requirements) tended to dominate the growth of non-hourly workers; and (b) engineers rather than scientists are sought as production supervisors and thus, to some extent their numbers have increased along with those of production workers. Thus, the growth of scientists relative to others in the non-hourly work force was not estimated to be very significant. Nevertheless, the absolute growth in employment of engineers and scientists, apart from increased coal demand, is considered to be largely due to the growth of more sophisticated extraction techniques in use as well as the need to comply with various environmental, health and safety regulations.

The second perceptible trend among professionals is that mining engineers as a percent of all engineers employed has been slowly decreasing for some time. This trend has occurred in inverse relation to the growth of surface mining as a percent of total coal mining. Although this may be attributed in part to the relatively small number of mining engineers graduating each year, the primary reason for this trend is that other engineers (particularly civil engineers), have been hired instead. If surface mining as a percentage of the total continues to increase, the tendency to hire civil engineers in lieu of mining engineers for certain positions may accelerate engineering enrollment. Thus, graduates with baccalaureate degrees in mining engineering rose from a low of 95 in 1968 to 331 in 1976 (an increase of 250 percent), with future graduations expected to be significantly higher based on current enrollments.* A more extensive discussion of educational and training aspects of the coal mine labor force is provided in Appendix B.

2.1.2 Union Participation

For many years one of the major concerns in the coal industry has been that of labor force stability and unionization. The impact of the UMWA strike of 1977-78 was partially mitigated by non-UMWA coal production, which has increased in recent years with the expansion of western coal development. Table 2-V presents the percentage of production (and related) workers in mines with union contracts as estimated by the Bureau of Labor Statistics in three post World War II Industry Wage Surveys for Bituminous Coal Mining (BLS #2, 1962, 1967, 1976). For both the surface and underground sectors, union mine production appears to have slightly declined and then increased to levels higher than those existing in 1962. However, given the relative increase in surface production vis-a-vis underground production, a slightly higher percentage of total tonnage (25 vs. 22 percent) was being produced in non-union mines in 1976

*Unpublished graduation data and projections by Mineral Resources Committee of the National Association of State Universities and Land Grant Colleges.

TABLE 2-V

PERCENT OF PRODUCTION AND RELATED
WORKERS IN MINES WITH LABOR-MANAGEMENT CONTRACTS

	1962	1967	1976
Surface	60	54	62
Underground	87	84	92

SOURCE: BLS #2, 1962-76

than was the case in 1962.* Whether future trends will be toward large-scale collective bargaining or smaller company-wide agreements remains uncertain at this time.

2.1.3 Labor Compensation

Another aspect of the coal mine labor force involves the changing rate of compensation over the last few decades. Figure 2-3 compares changes in miner earnings with the selling price of coal from 1950 to 1977, in current and constant (1976) dollars. Over this period, real coal prices have risen by 68 percent to $19.26 per ton, while real earnings** have risen by 73 percent to $7.94 per hour for coal over that period. Nevertheless, at present, production workers in the bituminous coal industry are among the highest paid industrial workers in the country, as shown in Table 2-VI. Taking an average of the hourly earnings among the five other industries in this table, coal mine workers were earning an average of 35 percent more in hourly earnings than those in other industries as of 1978.

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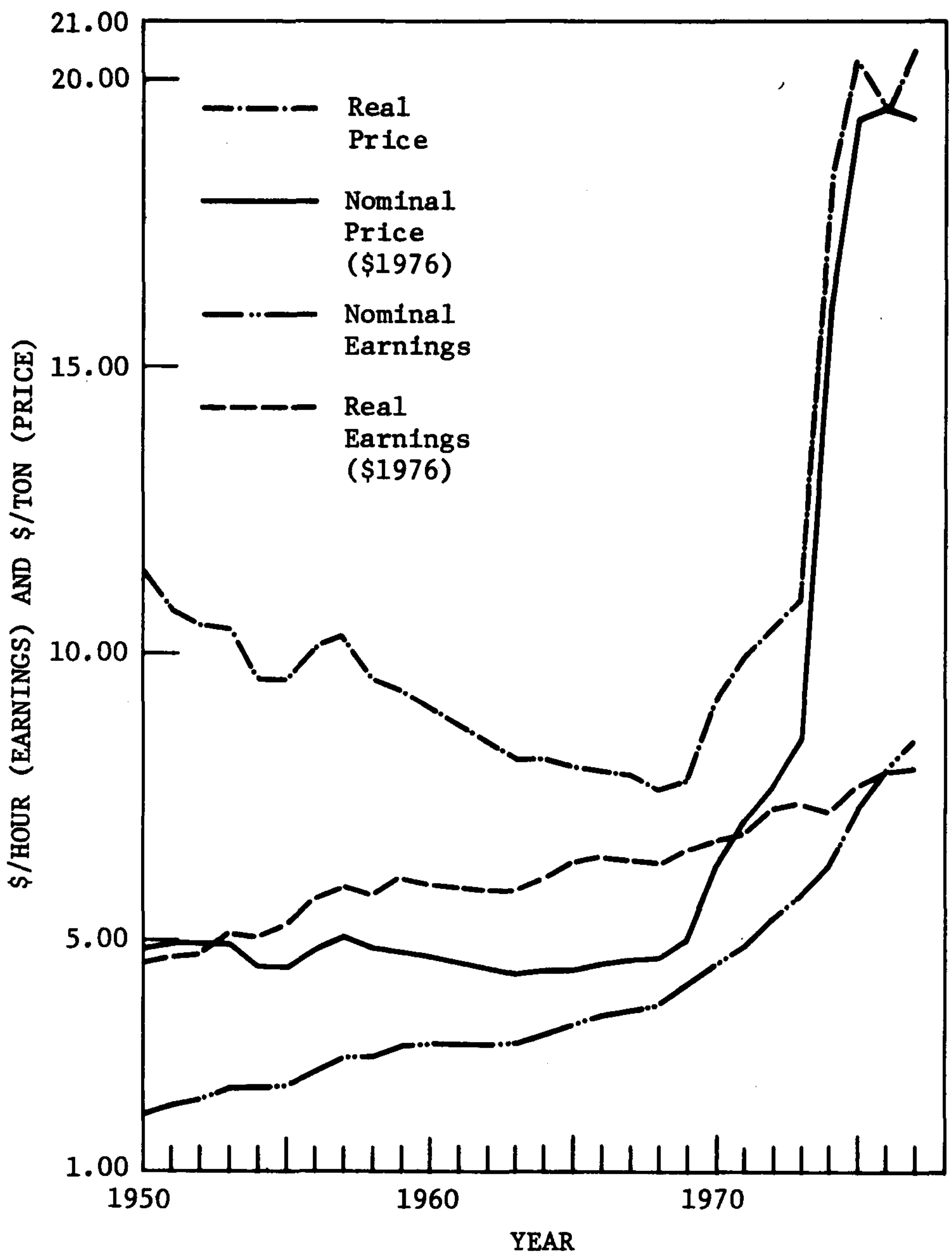
*In 1976, about 54 percent of U.S. bituminous coal and lignite production came from mines covered by the National Bituminous Wage Agreement between the Bituminous Coal Operators Association (BCOA) and the United Mine Workers of America (UMWA). About 4 percent of total 1976 production was covered under similar western surface agreements between UMWA and individual companies (personal communication with Mr. Charles Perkins, BCOA, January 22, 1979). The remaining union-produced coal in that year (approximately 17 percent of the national production total) is attributable to several smaller unions.

**Average hourly earnings represent a weighted average for all production workers from surface and underground bituminous coal mines. It includes premium pay for overtime and for work on weekends, holidays and late shifts. No estimation of fringe benefits is included in hourly earnings.



* Price is freight-on-board and excludes transportation costs

FIGURE 2-3
MINER EARNINGS VS. SELLING PRICE* OF COAL

TABLE 2-VI

AVERAGE HOURLY EARNINGS IN COAL AND OTHER INDUSTRIES

	Bituminous Coal	Chemicals	All Manufacturing	Automobiles	Textile Mills	Steel Industry
1948	$1.84	$1.34	$1.33	$1.61	$1.16	$1.59
1949	1.88	1.42	1.38	1.70	1.18	1.66
1950	1.94	1.50	1.44	1.78	1.23	1.70
1951	2.14	1.62	1.56	1.91	1.32	1.90
1952	2.22	1.69	1.65	2.05	1.34	2.00
1953	2.40	1.81	1.74	2.14	1.36	2.18
1954	2.40	1.89	1.78	2.20	1.36	2.22
1955	2.47	1.97	1.86	2.29	1.38	2.39
1956	2.72	2.09	1.95	2.35	1.44	2.54
1957	2.92	2.20	2.05	2.46	1.49	2.70
1958	2.93	2.29	2.11	2.55	1.49	2.88
1959	3.11	2.40	2.19	2.71	1.56	3.06
1960	3.14	2.50	2.26	2.81	1.61	3.04
1961	3.12	2.58	2.32	2.86	1.63	3.16
1962	3.12	2.65	2.39	2.99	1.68	3.25
1963	3.15	2.72	2.46	3.10	1.71	3.31
1964	3.30	2.80	2.53	3.21	1.79	3.36
1965	3.49	2.89	2.61	3.34	1.87	3.42
1966	3.66	2.99	2.72	3.44	1.96	3.53
1967	3.75	3.10	2.83	3.55	2.06	3.57
1968	3.86	3.26	3.01	3.90	2.21	3.76
1969	4.24	3.47	3.19	4.10	2.34	4.02
1970	4.58	3.69	3.36	4.22	2.45	4.16
1971	4.83	3.97	3.57	4.72	2.57	4.49
1972	5.32	4.26	3.82	5.13	2.75	5.08
1973	5.75	4.51	4.09	5.46	2.95	5.51
1974	6.26	4.88	4.42	5.87	3.20	6.27
1975	7.25	5.39	4.83	6.44	3.42	6.94
1976	7.78	5.91	5.22	7.09	3.69	7.59
1977	8.29	6.43	5.68	7.86	3.98	8.36
1978	9.57	7.01	6.17	8.51	4.29	9.41

Source: BLS #3, 1979.

Two other aspects of labor compensation are examined in Figures 2-4 and 2-5. In Figure 2-4, miner earnings and total labor costs both expressed in dollars per ton produced, are plotted along with the average selling price of coal, all in real (1976) dollars. All values are weighted to reflect the relative proportions of underground and surface man-hours worked and total production. Total labor costs were estimated using historical trends in earnings as a percent of the total, including aggregated estimates* of the following non-wage cost items:

- o holiday-vacation-sick leave
- o allowances for clothing, sickness and accidents
- o contributions to health and pension funds
- o social security-unemployment insurance
- o workmen's compensation and black lung benefits

As may be seen in Figure 2-4, the revenues from coal prices in excess of real labor costs remained relatively constant in absolute (non-percentage) terms through the late 1960's, fluctuating between $4.00 and $5.00 per ton. However, as of 1977, revenues in excess of real labor costs rose to almost $12.00 per ton. This amount would have been even greater had it not been for dramatic increases since

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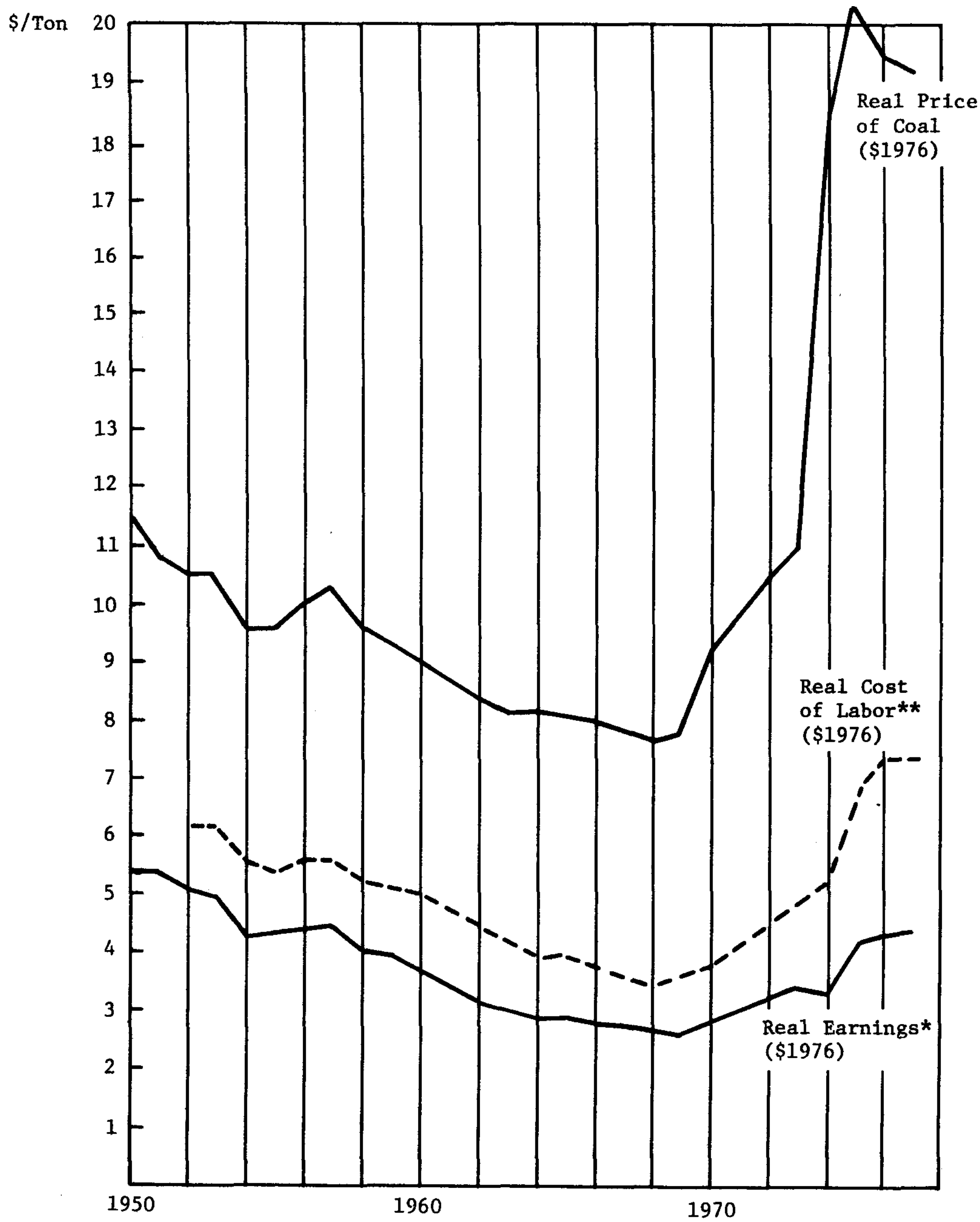
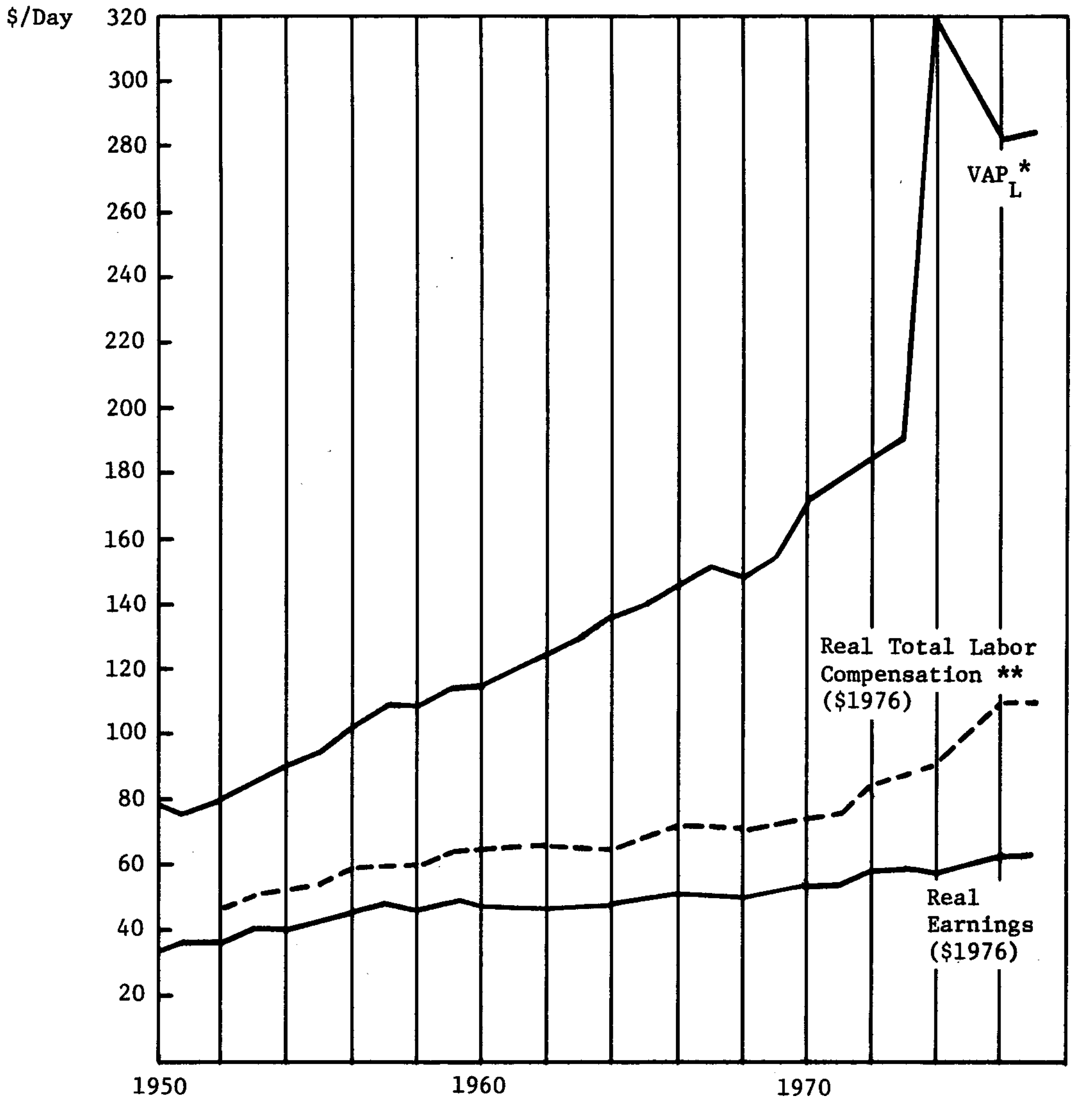
*Earnings as a percent of total labor costs by year are based on preliminary BCOA estimates (personal communication with Mr. Charles Perkins, January 11, 1979).



$$* \text{ Real Earnings} \times \frac{\text{hours}}{\text{day}} \times \frac{1}{\text{Average Product of Labor}} = \frac{\$}{\text{hour}} \times \frac{\text{hours}}{\text{day}} \times \frac{\text{days}}{\text{ton}} = \frac{\$}{\text{ton}}$$

** Real cost of labor adjusted for non-wage employment costs

FIGURE 2-4
REAL COST OF LABOR PER TON OF COAL



* VAP_L = Real Price of Coal x Average Product of Labor = $\frac{\$}{ton} \times \frac{tons}{man\text{-}day} = \frac{\$}{man\text{-}day}$

** Real total labor compensation is equivalent to real cost of labor except measured in terms of time worked.

FIGURE 2-5
VALUE OF AVERAGE PRODUCT OF LABOR (VAP_L)
VS. MINER EARNINGS

1971 in non-wage labor costs, particularly increases in contributions to health and pension funds and workmen's compensation/ occupational disease benefits. Using preliminary BCOA estimates of earnings as a percent of total labor costs for underground and surface miners, composite non-wage costs of miners were developed based on relative hours worked and coal production by both mining sectors for each year since 1952. From 1952 to 1977, although real earnings per ton produced actually declined in constant dollars, total labor costs per ton have risen by 18 percent. Despite a decline in coal prices over most of this period, gains in productivity reduced real labor costs until 1968. Since then, real labor costs per ton produced have almost doubled, as non-wage costs increased from 30 percent to 40 percent of total labor costs over the nine year period 1968-1977. In contrast, non-wage costs per ton were only seven percent of total labor costs in 1952.

Figure 2-5 presents these data in a different light, measuring real labor compensation with respect to labor's average contribution to coal company revenues. Unlike Figure 2-4, in which all values are expressed in dollars/ton produced, Figure 2-5 measures these values in terms of dollars/day, facilitating a time series comparison of changes in the true return to labor as a key factor of production. Here the economic concept of the value of average product of labor

(VAP_L)* is introduced. It provides an approximate measure of the average value of labor's product or output in terms of contributing to the total revenues of the coal industry each year. Unlike the real price of coal which declined until 1968 and then rose sharply, the VAP_L has risen almost continuously since 1950. A slight decline in the VAP_L may be noted in 1968 (due to a decline in real coal prices, rather than productivity); however, subsequent declines in productivity were more than offset by increased coal prices, thus resulting in a significantly greater value attached to labor's output throughout the 1970's. Figure 2-5 also indicates that real earnings increased by 73 percent while real total labor compensation increased by 138 percent over the last 25 years. Non-wage costs as a percent of total labor compensation per day have increased from about 18 percent in 1952 to almost 47 percent in 1977. The primary reason for non-wage costs being a somewhat lower percentage of total labor costs, when measured on a per-ton basis (40 percent in 1977 as indicated previously), is the decline in labor productivity since 1969.

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*VAP_L is a variation of the economic concept of value of marginal product (VMP). VMP refers to the contribution to total revenues of the last unit hired of the variable input factor, usually labor, and serves to determine the appropriate quantity to employ (i.e., a firm hires labor up to point where VMP = real wage rate in a competitive industry). VAP is equal to VMP only in cases where average product = marginal product, or where the industry employs factors in fixed proportions. Although this may not be the case between mining technologies, in the aggregate, VAP_L does provide an estimate of labor's contribution to total revenues which accrue to all coal operators.

Both Figures 2-4 and 2-5 show important trends regarding the relative cost of and the return to labor in the coal mining industry. In Figure 2-4, the gap between labor's total cost and coal prices has widened considerably since the oil embargo of 1973. Similarly, the gap between total labor compensation and the VAP_L also widened over this same period. However, no firm conclusions can be drawn from these data regarding the effect of changes in labor compensation on coal industry profits (i.e., measured as average annual return on investment to coal operators). Undoubtedly, non-labor costs of production have also increased considerably, especially since 1970, in terms of expenditures for health, safety and environmental controls as a percent of total production costs (although some portion of such capital expenditures are indirectly related to labor quantities and types).

To estimate the effect of changing labor compensation on industry profits, a weighted average annual return on investment among the nation's coal producers would, if obtainable,* provide some basis for determining a statistical correlation; however, increases in the average annual return on investment may be just as attributable to changes in "capital compensation" (i.e., the difference between the

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*One difficulty in estimating the average annual return on investment is that many leading coal companies are subsidiaries of integrated energy companies, with annual coal expenditures not always disaggregated from corporate totals. For a limited analysis in this area, see Tomimatsu, 1976.

value of the average product of capital and total capital expenditures, including operation and maintenance), by coal operators each year. Thus, a comparison between the relative contributions of, and return to, capital and labor, respectively, is necessary to accurately attribute changes in the industry's average return on investment to changes in the relative returns to each factor of production.

2.2 Limitations of Existing Studies

Numerous studies have been conducted which address, in varying degrees, the manpower supply/demand outlook for the coal industry over the next few decades. Often, the issue of manpower adequacy is addressed by studies within the context of the entire energy production sector of the economy. In other cases the issue is narrowly defined either in terms of changes in labor requirements for technical personnel (i.e., engineering and science) or in terms of changing skill requirements among the production work force. Often, labor adequacy studies have focused on specific manpower categories such as mining engineers or else on coal industry manpower as a single labor category. While many of these studies indicate the likelihood of some shortages, especially for professional manpower, large variations among study projections exist.

An example of such variations in projections may be illustrated in the case of mining engineers, the discipline considered to be most in demand by the coal mining industry. No universally accepted estimates of mining engineers employed exist, and in fact, the definition of an engineer of any kind has been subject to much dispute in the labor analysis community for some time. Given the need for such data in our analysis however, we employed the BLS Industry/Occupational Matrix* (BLS #1, 1979), a now discontinued series on engineer and scientist employment (BLS #4, 1973) and its current employment data by industry (BLS #7, 1979) to estimate that approximately 7,000 mining engineers were employed nationally in 1977.

Looking to the future, a 1978 survey conducted among a large segment of the American Mining Congress membership (Johnson, 1978) estimated that from 1978-1987, 4,012 new mining engineers would be sought by the responding companies (comprising all types of mining industries, including coal). To extrapolate this expected demand to cover companies not included in the survey, it was suggested that the respondents had represented 80 percent of the industry employers, but only 60 percent of the total number of mining engineers demanded, given the concentration of mining engineers among employees within small mining companies generally excluded from the survey.** Applying this logic to the survey results, this would result in about

*The BLS Industry/Occupational Matrix provides a mapping of occupations distributed among all major industries or sectors of the economy, including all levels of government. Occupational distributions are extrapolated from the 1970 Census into the future based on BLS assumptions about changing demand patterns by industries. Although the matrix is currently under revision to attain consistency with the new BLS long range employment forecasts, the relative distribution of occupations within an industry are expected to remain largely the same.

**Personal communication with Mr. John Johnson, Jr., Newmont Services Ltd., October 4, 1979.

6,700 new positions available by 1987. It should be noted, however, that at least half of these may be considered replacements for retirees, thus resulting in at most about 3300 new positions for mining engineers forecasted to be available. However, using the most recent BLS long range employment projections (BLS #2, 1979, and BLS #8, 1979) and its Industry/Occupational matrix, the number of new mining engineer positions (in excess of replacements) over the same period was estimated to be only around 1,400.

Specific forecasts within the context of broad energy manpower studies may differ even more drastically. One such example is a recent study by the Center for Advanced Computation at the University of Illinois (CAC, 1977). The study's maximum scenario forecast for total (not incremental) mining engineer employment in 1985 was only 6,500. One reason for this exceedingly low projection was that it started with a low base year value of 4,700 mining engineers employed in industry in 1974. In light of subsequent data made available by the BLS as cited above, most if not all of CAC's forecasted increase by 1985 has already occurred.

Another problem with developing specialized labor market data such as that pertaining to mining engineers is the potential for relying too heavily on surveys or questionnaires sponsored by either industry or educational institutions. For example, it may be in the interest of mining companies to make liberal estimates of their future needs for mining engineers, so as to foster an employer's market--which puts downward pressure on wages and fringe benefits. Similarly, it may be in the interest of mining schools to make conservative estimates of the future job market for mining engineers to discourage similar new or expanded programs in other schools which can compete for Federal funds and students. Thus, care must be taken in incorporating the viewpoints and estimates of all viable sources of information within a final methodology to ensure objectivity and balance in data utilization.

2.2.1 The Use of Productivity in Labor Forecasting

Central to most labor forecasting studies is the element of productivity, usually measured in physical units of labor input. In general, forecasts of labor demand in the coal mining industry measure productivity separately for deep and surface mines in tons per man-day or per man-hour. Productivity is then commonly used to derive demand in one of two basic ways. The first way is simply to assume that productivity will remain at the current year's level, allowing personnel requirements to be derived directly from scenarios or other assumptions regarding the average days worked per year and the tonnage levels to be produced. In a modified version of this, productivity is assumed to change at some rate (perhaps linearly) or is based on certain theoretical asssumptions. In this version, labor demand is derived directly from productivity. The second basic way in which demand is derived from productivity involves estimating productivity via regression analysis, either in absolute terms or in percentage rate of change per year, as a function of several independent variables. In such multiple regression analyses, the contribution to productivity changes associated with each independent variable may then be used to forecast future productivity based on future assumptions regarding independent variables. Thus, by assuming future values for variables such as average seam thickness, strip ratio, proportion mined by certain technologies, etc., one may forecast average productivity for deep and surface mines and then derive the demand for labor as described above. Although the use of regression analysis is far better than simply assuming constant productivity or forecasting that it will change in a non-empirical fashion, estimating future productivity via regression cannot by itself address the issue of future labor adequacy in terms of skill and educational requirements.

Over the last few years, several coal industry labor demand projections have been made which were based on the method of estimating labor productivity described above. The General Accounting Office (GAO) in 1977 projected the total new personnel requirements of the coal mining industry through the year 2000 (GAO, 1977). Its projections were derived from coal production estimates through 2000 provided by Edison Electric Institute (EEI) and by the Bureau of Mines (BOM). The GAO assumed constant deep and surface productivity rates after 1974, and then simply estimated projected coal tonnage over the study period, given a constant worker separation rate.

Using this technique, the EEI scenario required a total of only 232,100 miners by 2000 compared with 390,600 miners required to meet the BOM scenario. The difference between GAO projections based on EEI and BOM data has some value in assessing the potential impact on coal industry employment, nationally and regionally, of assuming different tonnage projections.

Past projections of future manpower needs have provided little insight into the relative needs for specific skills by major job category. One such need is that for off-site personnel. Such personnel have been estimated by MITRE to be about six percent of total industry personnel at present. This percentage is expected to increase along with the growth of environmental, health and safety regulations. Another problem associated with manpower projections made to date is the continued use of constant deep and surface productivity rates as were used in the GAO study. Figure 2-6 illustrates why this is a problem. Comparing the declining productivity shown in this figure with the rising cost of labor shown previously in Figure 2-4, one may see why the use of constant productivity poses serious problems in assessing future manpower needs. By assuming constant productivity in the future, potential changes in labor costs per ton are ignored, thus precluding any consideration of technology selection based on relative economic criteria. Thus, it appears likely that in the future a premium will be put on higher productivity technologies among those vying for selection in new mine

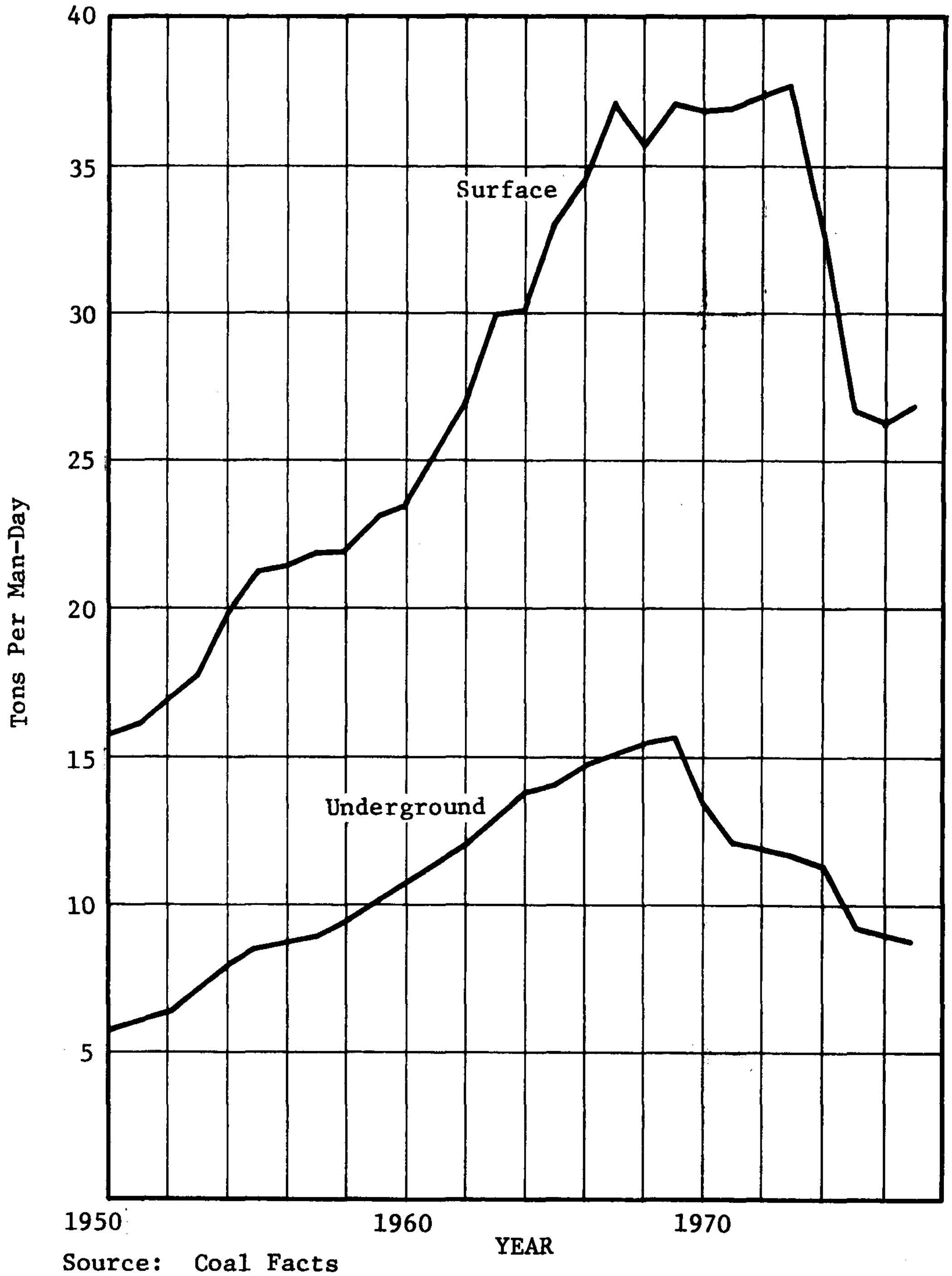

FIGURE 2-6
LABOR PRODUCTIVITY TRENDS

development. Only rapidly rising coal prices will mitigate the impact of higher wages on the value of marginal product (VMP)* of labor in new technology selection.

Any projections regarding the future demand for coal industry labor must make some assumptions regarding expected changes in real wages vis a vis expected changes in real coal prices. These considerations must be taken into account as they are major factors which influence the input decisions of the firm and hence future capital-labor ratios. However, a decline in the value of the marginal product of labor, by encouraging a reduction in the relative use of labor to capital or equipment, may actually contribute to the rapid penetration of advanced mining technologies and thus a higher productivity per man day. More recently, a study was conducted by John Short & Associates, Inc. (Short, 1979), to forecast employment and training in the coal mining industry. This study assumed constant deep and surface productivity by region (rather than state) from the 1977 levels, with a shift toward more productive western mines. In addition, the study used more sophisticated workforce separation rates based on historical intra- and inter-industry move rates during a period of coal expansion (presumed to continue) and the actual labor force age distribution to forecast deaths and retirements. Nevertheless, the accuracy of the study estimates depends on the likelihood of constant productivity in each region.

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*See Section 2.1.4 for definition of VMP.

Perhaps the first study to employ econometrics or multiple regression techniques to forecast deep and surface mine productivity separately for each state was the 1975 study performed by the Institute for Research on Human Resources at Pennsylvania State University (Pennsylvania State University, 1975). Like most of the other studies, it too used fixed levels of coal demand to project total coal industry production manpower aggregated among the producing states. Manpower supply was forecasted separately based on wage rates, available population, and civilian unemployment rates. However, manpower supply and demand were then simply compared under different scenario assumptions to see whether shortages might occur, with no feedbacks to address the impact of supply/demand balance on wages. The study's major drawback however, was that the time series data from which productivity was forecasted were based on the period 1948 to 1970, a time of rapidly rising productivity. Extrapolation of this trend into the future is highly questionable, given subsequent significant reductions in productivity during the 1970's. Also, as in the case of most studies using productivity as the key forecasting variable, both labor demand and supply are treated homogeneously or as a single labor category. Thus, little consideration is given to the increased demand for and supply of specific skilled and professional labor categories.

Since 1975, several coal mining productivity studies have used econometric methods either to explain the volatility of productivity in recent years, or to forecast labor demand. A 1979 study by Oak Ridge Associated Universities (Baker, 1979) was conducted to gain insight into the reasons for productivity fluctuations; the productivity estimates obtained however, were not used explicitly to forecast labor demand. In a current study (Conference Board, 1979), econometrics is being used to explain productivity changes as well as to forecast labor demand. This study represents a substantial improvement of the Penn State study in its use of key significant variables such as coal prices and explicit dummy variables for mine health and safety and reclamation laws. (It should be noted that the timing of the Penn State study severely limited its possible consideration of such legislative factors.) The Conference Board in its study does not address the issue of labor supply since this is not among its study objectives.

To summarize, federal concern over future manpower adequacy is a separate issue which heavily involves productivity but which also requires separate consideration of labor supply. Because labor tends to be considered as a single homogeneous variable in most studies, it has not been possible to associate available labor supplies with the mix of skills and educational requirements that underlie future labor demands and thus to pinpoint specific labor imbalances as they might occur in the future.

2.3 Considerations for Assessing the Future Adequacy of Coal Mining Manpower

As discussed in Section 2.2, previous studies have had two major limitations in assessing labor adequacy: (1) The lack of sufficient labor disaggregation to translate forecasts into shortages and surpluses by skill and educational levels to meet the various job functions which comprise labor demand, and (2) The lack of dynamic feedbacks which incorporate the two-way impacts of supply and demand balances by labor category, on appropriate equilibrium wages, and then the subsequent impacts on future labor supply and demand. To remedy the first limitation, it is necessary to assess labor adequacy by integrating forecasts of manpower supplies by skill and educational categories, with manpower demands by job or functional categories, as derived from national and regional coal production scenarios. Relative adequacy is then assessed via a mapping of manpower supply and demand categories. This should be done in terms of the availability of specific professional and skilled workers in order to meet functional job openings where minimum professional and skill levels are considered desirable.

To remedy the second limitation, it should be noted that labor supply should be estimated independently of labor demand for potential shortages or surpluses to be projected. Wherever possible, future labor supply should be forecasted as functions of those factors which entice prospective candidates into defined labor pools, especially for professional and technical personnel. However, real wage rates play a key role in explaining changes in both labor supply and demand. Thus, some mechanism is essential to simulate the two-way feedbacks which characterize the price-(i.e., wage)-quantity (i.e., labor supply and demand) relationships of the labor market. The model used in this study includes mechanisms which attempt to remedy both of the major limitations of previous studies, as well as to assess the impact of Federal policies on the future adequacy of coal mining manpower.

3.0 ANALYTICAL APPROACH

3.1 Overview

The major objective of this study is to assess the adequacy of manpower required by the coal mining industry through the year 2000. The primary analytical approach selected to meet this objective was the development of a hybrid system dynamics/econometric model of the coal mining industry with an emphasis on labor supply and demand. System dynamics offers several advantages over other modeling methods, the most important being its ability to capture complex feedback interactions in large systems. These interactions are responsible for secondary impacts that can add to or subtract from the primary impacts. Econometrics is the use of economic theory, empirical data and regression analysis to determine the relationships between economic variables. MITRE has employed both system dynamics and econometric techniques in the mining manpower model developed in this study.

The key characteristics of a system dynamics model are that it deals with time lagged (delayed) responses, feedback relationships, response distortions, and system constraints. Through the simultaneous solution of differential equations, a system dynamics model determines the values of all variables in the system for each solution period. The results of one solution period then become the inputs for the next solution period. In this manner, a system dynamics model attempts to simulate the continuous or dynamic behavior of a set of related elements within a system. A very simple but broad example of a coal production labor supply/demand system is illustrated in Figure 3-1. The system consists of seven elements interconnected in a causal-loop diagram. The circular nature of the diagram indicates that there is essentially no starting point in the system; i.e., that the system is continuously reacting. For example, we can begin with an increasing demand for coal. The positive sign at the end of the arrow leading from coal demand indicates a positive impact on the production of coal (i.e., an increase in production). This in turn leads to an immediate increase in the demand for labor (assuming that all other factors including labor productivity are constant). The broken arrow from labor demand to wages indicates a lagged response in wages. This lagged response may be attributable to the time intervals between union contract negotiations or for the information of greater labor demands to be translated to higher expectations in wages by the labor force. The increase in wages will translate to an increase in production costs which in turn is reflected in an increased price of coal. Simultaneously, an increase in wages will, after a time interval, attract additional people to coal mining, thereby increasing the mining labor supply pool. Continuing on the demand side of the diagram, an increase in the price of coal, assuming a demand elasticity of greater than zero, will decrease the demand for coal. This decrease in coal demand results in turn, in a decreased rate of coal production and a decreased labor demand thus illustrating the continuous nature of the cycle.

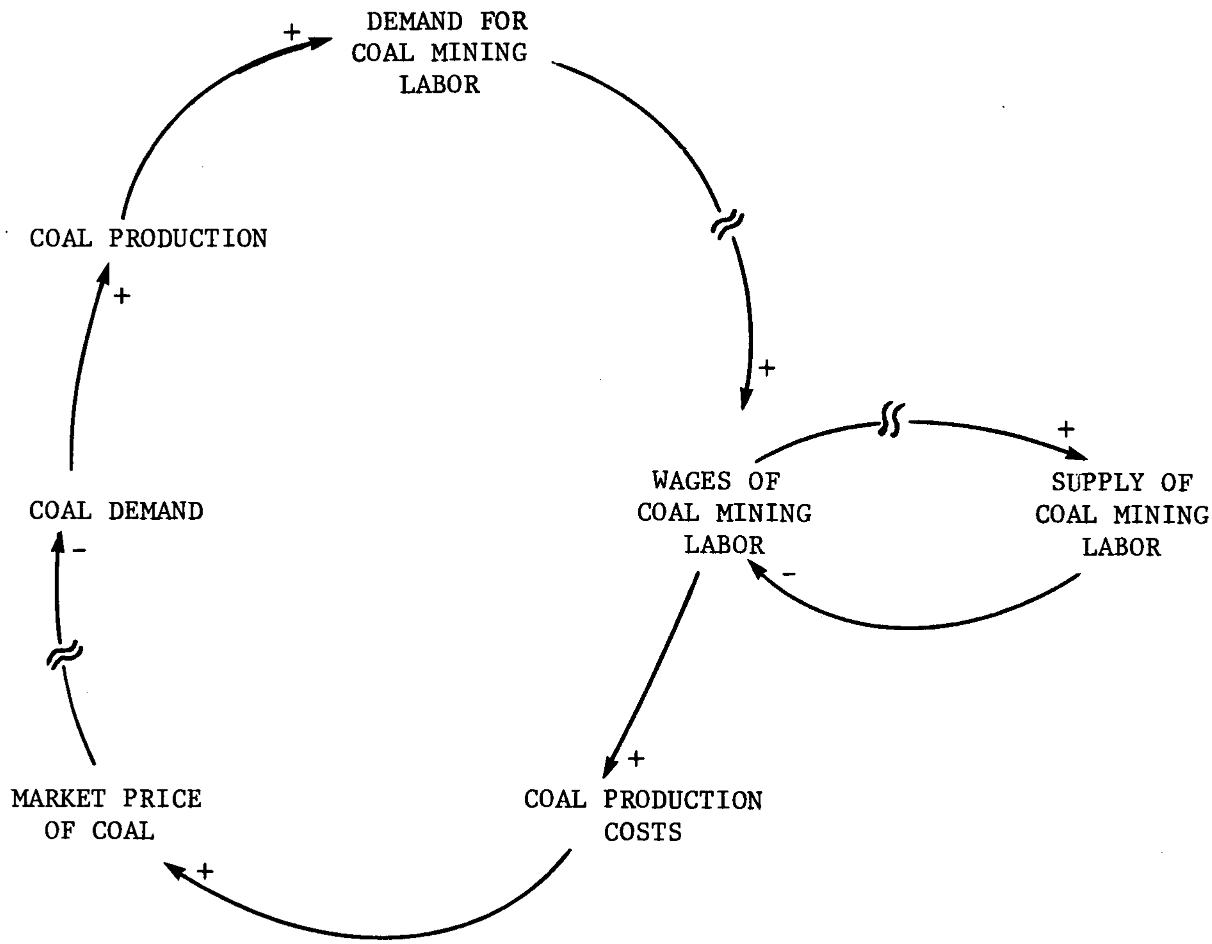

FIGURE 3-1
SIMPLE EXAMPLE OF A COAL MINING LABOR SUPPLY/DEMAND SYSTEM

In reality the coal mining labor supply/demand system is much more complex than the example presented in Figure 3-1. Several other factors simultaneously impact coal demand, labor wages, production costs, coal prices, and the response time between elements.

The MITRE coal mining manpower model incorporates the direct, indirect and synergistic impacts on coal mining labor supply and demand of key variables such as coal production, labor productivity, wages, mining technologies, resource characteristics, training requirements, and regulatory requirements. The boundaries of the system modeled by MITRE were determined after a careful study of the characteristics of the coal mining industry and the behavior of the labor supply categories that are drawn on by the mining industry. An extensive use of economic theory and engineering analysis were required to define the relationships in the model.

Four main aspects distinguish the system dynamics approach from other techniques that have been used to study coal mining labor supply and demand.* They are:

1) The formulation of a system dynamics model relies on the very basic relationships between elements of a system. In many cases these relationships are postulated based on system structure, physical laws, identities, engineering data, etc. As such, system dynamics does not rely solely on historical data.

2) A system dynamics model solves for the values of all variables simultaneously and provides insights concerning the behavior of the key elements in the system.

*See Section 2.2 for a discussion of previous coal mining labor supply/demand studies.

3) Since system dynamics models are not based entirely on historical data, comparison of the model results against historical data is an excellent means for model validation.

4) Finally, the flexibility inherent in system dynamics models allow for their application in the analysis of a broad spectrum of policy and other questions.

The MITRE mining manpower model, in addition to projecting annually, to the year 2000, labor supply and demand for the coal mining industry, projects annually several other industry economic and production variables. For example, the model projects labor productivity, production levels by type of mining technology, labor costs, mining technology growth rates, investment levels in new technologies and a host of other coal mining industry parameters. Because the MITRE model is a system dynamics model it continuously solves for all variables and can thus provide as output the projected values of all the variables.

The MITRE model is written in DYNAMO,* a computer language developed primarily for system dynamics models. The DYNAMO compiler allows the user to specify all the variables in the model that are desired as either printed or plotted output. This feature of a DYNAMO system dynamics model provides the analyst with considerable flexibility in utilizing a model.

The remaining sections in this chapter present the overall analytical approach of the MITRE model. In Section 4.0 the labor demand

*For a complete discussion of DYNAMO see the DYNAMO Users Manual (Pugh, 1976).

sector is discussed in detail while the labor supply and wage determination sectors are discussed in Section 5.0.

3.2 Development of the Coal Mining Labor Supply/Demand Model

The approach utilized to develop the MITRE coal mining manpower model can be outlined as follows:

1) Develop a good understanding of the coal mining labor supply/demand system;

2) Clearly define the boundaries of the system,

3) Collect time-series and cross-sectional data relevant to the system;

4) Analyze the available data and formulate quantitative relationships between the variables in the system;

5) Develop a logic framework for the system;

6) Incorporate the quantitative relationships into the logic framework;

7) Computerize the model logic; and

8) Analyze and validate the model results.

The following discussion briefly presents an overview of the analytical approach used in developing the MITRE coal mining manpower model.

3.3 Understanding the Coal Mining Labor Supply/Demand System

3.3.1 Coal Mining Labor Demand

Coal mining labor demand at the micro level is a derived demand. That is, given the level of coal output and labor productivity for a given mining technology,* the demand for labor is derived (see

*In Section 3.3.3 the coal mining technologies utilized in this study are defined.

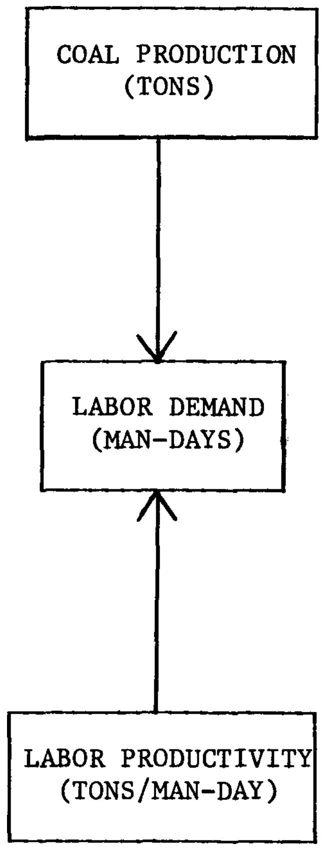

FIGURE 3-2
DERIVED DEMAND MODEL

Figure 3-2). The derived demand approach implicitly assumes a fixed proportions production function.* In the aggregate, for the coal mining industry, this assumption may be too restrictive. But, if the industry is disaggregated into specific technologies and the demand for labor determined for each technology, then the derived demand approach is valid. This approach does not preclude a change in the aggregate ratio of input factors as the relative price of the input factors change. A shift in the aggregate mix of mining technologies will change the aggregate ratio of input factors. Thus, a rise in the relative price of labor to capital can cause a shift to more capital intensive technologies resulting in a drop in the aggregate labor to capital input ratio (see Figure 3-3).

In a more general sense, the demand for labor depends on the total demand for coal and on the productivity of labor.** Coal mining labor productivity depends primarily on the level of capital, the skill level of labor, the characteristics of the resource and the working environment. Clearly the impact of some of these variables will have a greater influence on mining labor productivity than others. For example, labor productivity in continuous deep mines

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*A fixed proportions production function requires a fixed ratio of input factors per unit of output. Fixed proportion production functions are homogeneous of degree zero and exhibit constant returns to scale. A change in the relative price of input factors will not change the ratio of the input factors in the production process.

**$D_L = CP/APL$

where DL = demand for labor in man-days

CP = Coal production in tons

APL = Average product of labor in tons/man-day

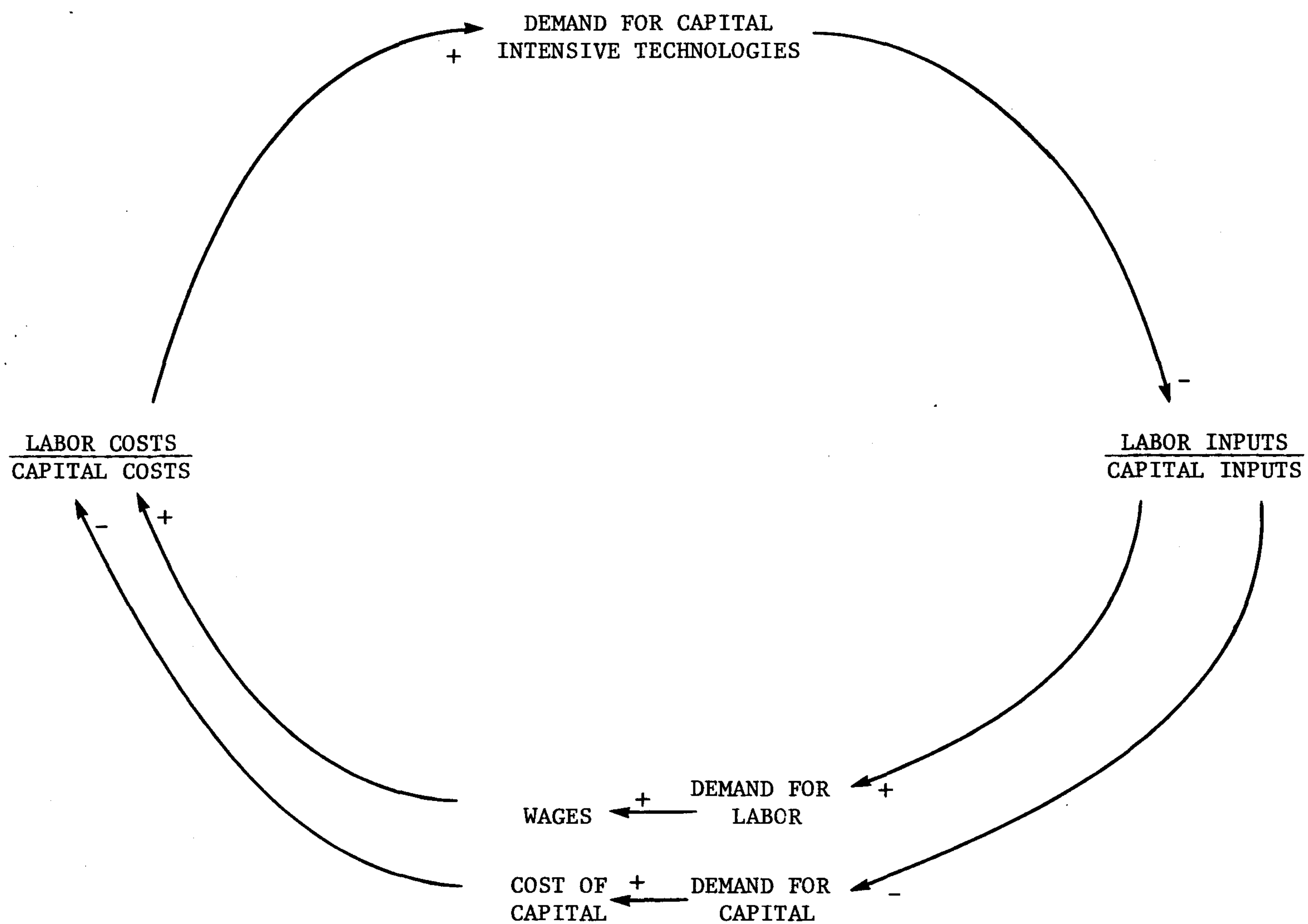

FIGURE 3-3
CAUSAL LOOP DIAGRAM FOR A SHIFT IN THE CAPITAL-LABOR INPUT RATIO

tends to be consistently higher than in conventional deep mines regardless of seam thickness because the continuous deep mines reflect a higher ratio of capital to labor than do conventional deep mines.

Labor skills vary between mining technologies. Some technologies, such as longwall mining, require more professionally trained and skilled labor than do conventional mining. Because labor skills are not completely substitutable, the demands for various categories of labor are an important consideration in the coal mining system. Five types of labor skills or functional job categories are considered in the model. These are:

1) Supervisors;
2) Technical support;
3) Administrative support;
4) Skilled production workers; and
5) Semi-skilled production workers

Descriptions of these demand categories along with a detailed discussion of the labor demand sector of the model is presented in Section 4.0.

3.3.2 Coal Mining Labor Supply

Unlike the demand for labor in coal mining, which is a derived demand, the supply of labor to coal mining is more globally influenced. Conditions throughout the economy have a significant impact on labor supply. For example, the non-coal mining (i.e., metals and non-metal mining) and construction industries have labor skill requirements that are similar to that of the coal mining industry. Thus, the employment levels of these industries significantly impact the labor supply/demand balance facing coal mining. Many labor requirements, especially production jobs, require little or no formal educational training. On-the-job experience or training is all that is necessary. As such, the potential labor supply for these production jobs is the able-bodied work force at large. Relatively high wages recently observed in the coal industry have attracted labor away from other, lower paying occupations and into coal mining. (Wall Street Journal, 1978). The rise in the relative starting salaries of mining engineer graduates to all other engineers has helped increase the number of B.S. degreed mining engineer graduates from below 200 in 1971 to above 600 in 1979.

The major variable impacting the supply of labor to coal is the relative wages in coal to non-coal industries. In the case of the professional labor categories, wages eventually influence the number of graduates and thus, with a significant time lag, the supply of professional labor. Similarly, the wages paid to production workers attract labor from the work force at large.

Estimates of the labor supply to coal mining developed in the manpower model are based on regression equations developed with time-series data for the following labor supply categories:

1) Mining engineers;

2) Other engineers;

3) Scientists applicable to mining;

4) Mining technicians;

5) Experienced miners; and

6) Work force at large.

The key variable in the supply equations for each category is relative wages. The regression equations are incorporated within the overall systems dynamics model such that the magnitudes of the variables, including wages, is determined within the model. A detailed discussion of the labor supply and wage determination sectors of the model is presented in Section 5.0.

3.3.3 Coal Mining Technologies

The type of mining technology utilized has a major impact on both the quantity and type of labor demanded. In general, underground mining requires a greater labor input per unit of output than does surface mining. More specifically, the type of underground or surface technology used directly influences the demand for specific types of labor (i.e., number of roof bolters, continuous mine operators, dragline operators, etc.). In the extreme it can be stated that no two mines are alike and that each coal mine requires a unique set of labor skills.

Labor requirements, capital costs and O&M costs will also vary as a function of seam thickness and depth, mine size, geographic location, regulatory requirements, mine age, union affiliation, and several other variables. It is, however, possible to define a set of representative or model mines which, in the aggregate, are a fair representation of the spectrum of coal mining technologies available. In this study, MITRE has defined thirteen model deep mines and six model surface mines. These are described in Appendix A of this volume. In the manpower model, mining technique, mine size, seam thickness and seam depth are varied across model mines while labor requirements and capital and O&M costs are varied through time (to reflect changes in regulatory requirements or in the real costs of capital) within each model mine. The model mines can be grouped into six major coal mining technologies. These are:

1) Conventional deep mining;
2) Continuous deep mining;
3) Longwall deep mining;
4) Contour surface mining;
5) Small area surface mining; and
6) Large area surface mining.

For the purposes of the MITRE mining manpower model, the cost and labor coefficients for model mines within a technology are algebraically combined to represent, for that technology, the national average mine size, seam thickness and seam depth. Figure 3-4 illustrates the procedure of determining cost and labor coefficients for the six technologies in the MITRE model.

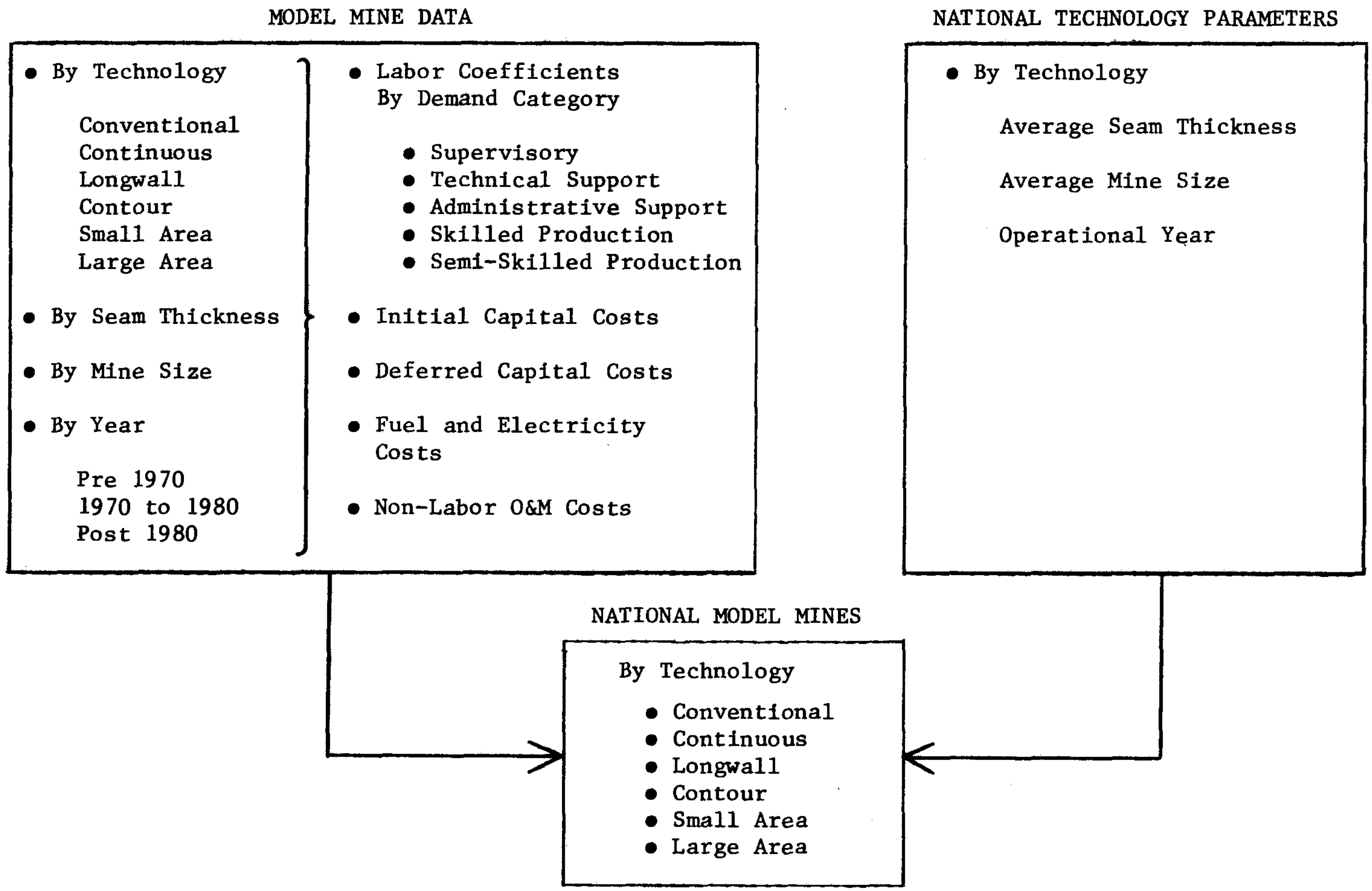

FIGURE 3-4
DETERMINATION OF COST AND LABOR COEFFICIENTS FOR NATIONAL MODEL MINES BY TECHNOLOGY

3.4 Defining the Coal Mining Labor Supply/Demand System

The boundaries of the coal mining labor supply/demand system modeled by MITRE are defined to include all major activities within coal mining that impact labor supply and demand. Activities of the non-coal mining sectors that directly or indirectly impact the coal mining labor system are considered as exogenous inputs to the system. For example, employment in the non-coal mining sectors of labor applicable to mining is an exogenous input in the MITRE model. Similarly, the national demand for coal and the average F.O.B. price of coal are also exogenous inputs which drive the model. Coal production by technology, however, is endogenously determined within the model as a function of the average F.O.B. price faced by the technology,* its production costs, and potential resource or technology constraints.

Figure 3-5 presents a simple illustration of the coal mining labor supply-demand system. The system is divided into three major sectors: a labor demand sector; a labor supply sector; and a wage determination sector.

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*The average F.O.B. price faced by each technology is based on the product of the national average price and a technology price differential. The technology price differential is a function of regional prices and regional production by technology. For example, large area surface mines which are predominantly located in Northern Great Plains have a price differential of less than one reflecting the low regional market price due to coal quality and transportation costs to market demand centers. A detailed discussion of price differentials is presented in Section 4.0.

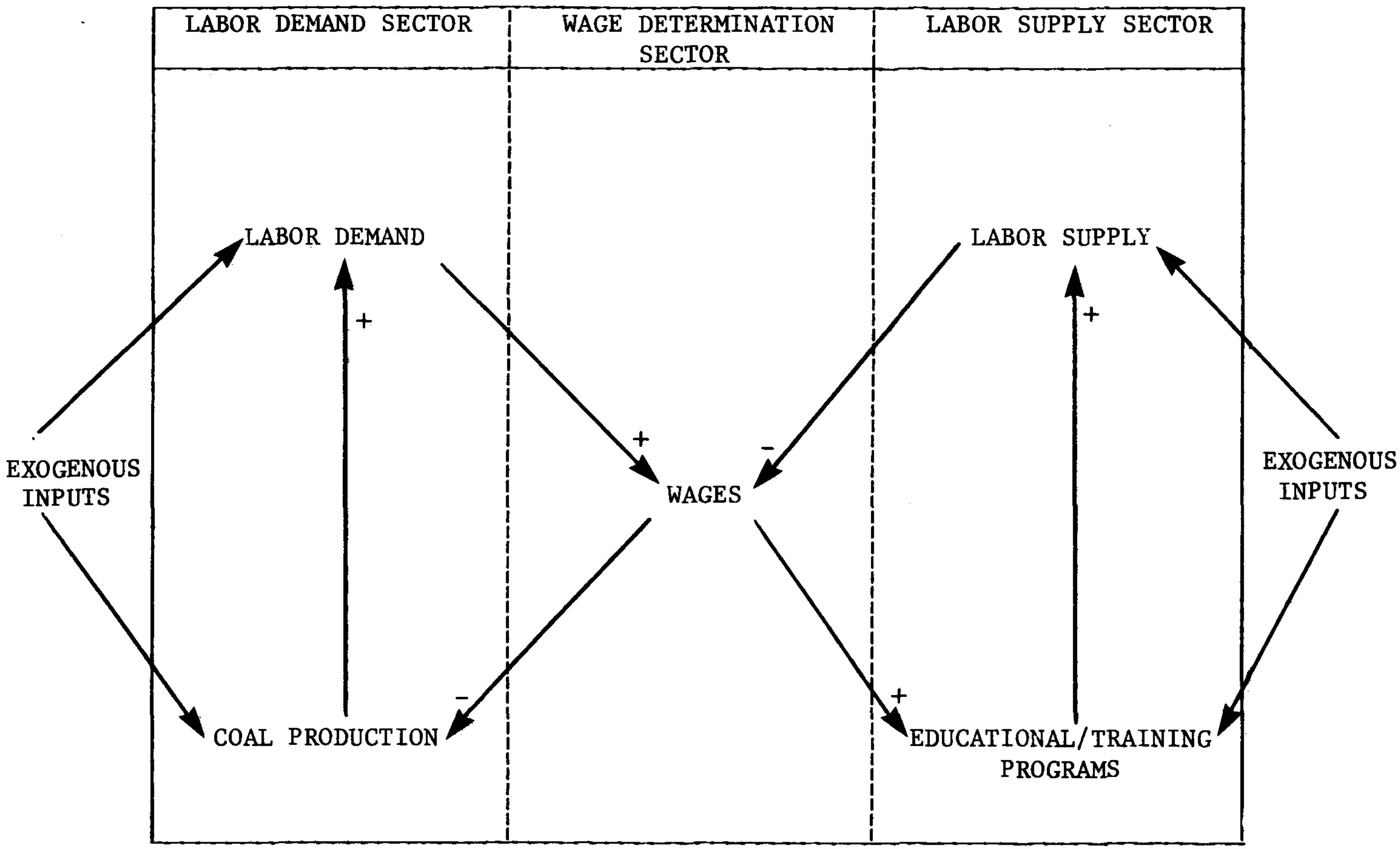


FIGURE 3-5
COAL MINING LABOR SUPPLY/DEMAND SYSTEM

3.4.1 Demand Sector

The primary purpose of the labor demand sector is to determine the annual on-site and off-site labor demands of the coal mining industry. An equally important determinant of the demand sector is the level of coal production by each of the six mining technologies defined in Section 3.3.3. The demand sector interacts with the wage sector to determine the labor costs in mining coal. Labor costs are a major cost component in coal mining and are a key variable in determining the long term shift in mining technologies. Several other industry parameters such as capacity construction and retirement rates, investments, labor productivity, etc., are determined in the demand sector. The details of this sector are discussed in Section 4.0.

3.4.2 Supply Sector

The labor supply sector determines the availability to the coal mining industry of appropriately trained labor. The supply sector interacts with outputs from the wage determination sector and exogenous inputs such as unemployment rates in the non-coal mining sectors to determine labor supply levels. A detailed discussion of the labor supply sector are presented in Section 5.0.

3.4.3 Wage Determination Sector

The wage determination sector has two key roles to play in the MITRE model. First, it maps the six labor supply categories onto the five labor demand categories. Second, it determines the equilibrium wages by both labor supply and demand categories. Since labor demand is based on functional job categories (i.e., job requirements, functions) while labor supply is based on skill or training, there is considerable overlap in the mapping of supply to demand. That is, a particular supply category can meet demands in several categories. For example, mining engineers can be supervisors as well as technical support personnel. Table 3-I illustrates the mapping possibilities of labor supply categories to demand categories. The letters and numbers in parentheses indicate the corresponding demand or supply mappings.

The wage determination sector, in the process of accomplishing the supply/demand mapping, determines the levels of employment in the coal industry by supply category. Thus, the level of employment of mining engineers, mining technicians, etc., is an additional output of the wage determination sector.

3.5 Coal Mining Manpower Model Framework

The MITRE coal mining manpower model's formal structure can be presented at several levels of detail. At the most general level, the model can be presented as a three sector labor supply-demand-wage model (Figure 3-5) as outlined in Section 3.4. At a more detailed level, the model can be broken down from the three major sectors into thirteen sub-models. This representation is shown in Figure 3-6. The interactions between sub-models are indicated in this figure and

TABLE 3-I

LABOR SUPPLY/DEMAND MAPPING

SUPPLY	DEMAND
1. Mining Engineers (A,B)	A. Supervisors (1,2,3,4,5)
2. Other Engineers Applicable to Mining (A,B)	B. Technical Support Personnel (1,2,3,4,5)
3. Scientist Applicable to Mining (A,B)	C. Administrative Personnel (6)
4. Technicians (A,B,D)	D. Skilled Production Workers (4,5)
5. Miners with Experience (A,B,D,E)	E. Semi-Skilled (5,6)
6. Work Force at Large (C,E)	

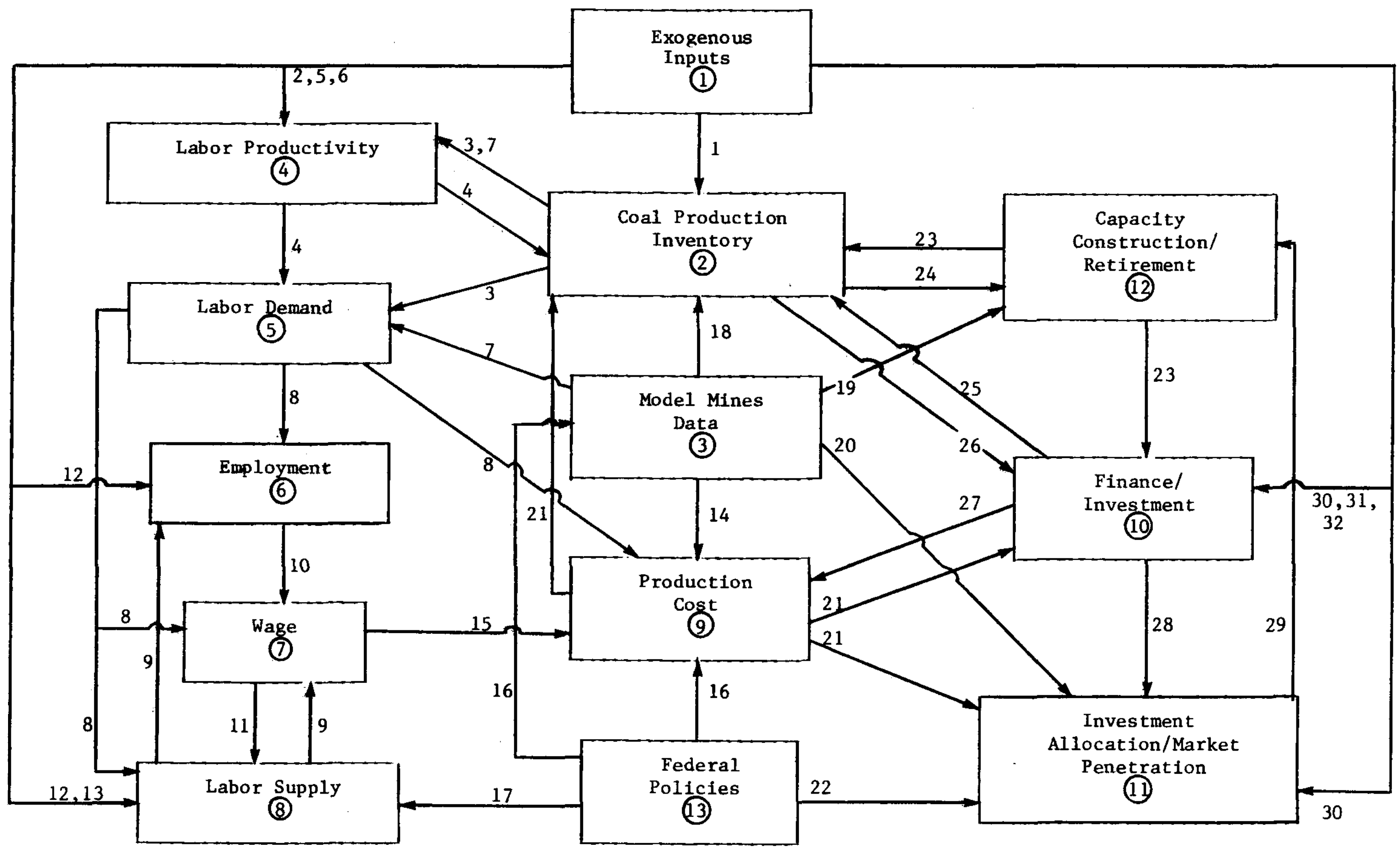


FIGURE 3-6
SUB-MODEL AND INFORMATION FLOWS IN THE MITRE COAL MINING MANPOWER MODEL

are listed in Table 3-II. A brief discussion of the purpose of each sub-model follows.

3.5.1 Exogenous Inputs Sub-Model

The exogenous inputs (EI) sub-model essentially incorporates the ICF scenario data on coal production and price, GNP, inflation, employment in non-coal mining sectors, and population cohorts that are used to drive the model. This sub-model allows the user to easily change any one of these inputs before running the entire model.

3.5.2 Coal Production Inventory Sub-Model

The coal production inventory (CPI) sub-model is designed to: 1) keep an account of the existing production capacity by mining technology; and 2) determine the average capacity utilization of each technology. The CPI sub-model interacts with the capacity construction retirement (CCR) sub-model to determine the addition or retirement of new capacity (i.e., it keeps track of physical assets by technology). The CPI sub-model also uses the calculated return on investment by technology, generated in the finance-investment (FI) sub-model, and production cost data to adjust the capacity utilization of each technology. If a technology is profitable it calculates a high capacity utilization. If a technology is marginally profitable or is operating at a small loss the capacity utilization is adjusted downward. For technologies facing large losses, the capacity utilization is set equal to zero. A detailed discussion of the analysis carried out in this sub-model is presented in Section 4.3.3.

TABLE 3-II

INFORMATION FLOWS BETWEEN SUB-MODELS

1. Total Annual Demand for Coal
2. National Average F.O.B. Price of Coal
3. Coal Production by Mining Technology
4. Labor Productivity by Technology
5. Mining Labor Accident Rate: Underground and Surface
6. Percent of Coal Cleaned: Underground and Surface
7. Model Mine Labor Coefficients
8. Labor Demand by Demand Category
9. Labor Supply by Supply Category
10. Labor Supply/Demand Imbalance by Labor Supply Category
11. Labor Wages by Supply Category
12. Employment in Non-Coal Mining Sectors and Real GNP
13. Population Cohorts
14. Model Mine Cost Coefficients
15. Labor Wages by Demand Category
16. Federal Regulatory Requirements
17. Federal Educational/Training Policies
18. Model Mine Production Capacities
19. Model Mine Construction/Retirement Data
20. Model Mine Capital and Labor Cost Data
21. Production Cost Data
22. Federal Policies Directly Impacting Resource or Technologies

TABLE 3-II (Concluded)

23. Capacity Construction/Retirement Rates by Technology
24. Capacity Utilization Factor by Technology
25. Annual ROI by Technology
26. Production and Capacity Utilization Data by Technology
27. Cost of Capital
28. Total Investment Funds Available for the Coal Mining Industry
29. New and Deferred Capital Investments
30. National Average F.O.B. Coal Price
31. Real Interest Rates
32. Annual Inflation Rate

Finally, the CPI sub-model uses labor productivity data to adjust the maximum potential production capacity of the existing physical assets. If, for example, labor productivity declines due to health and safety impacts, then the maximum potential capacity of the existing physical assets will also decline. If productivity increases, so will the maximum potential production capacity, all other factors being equal.

3.5.3 Model Mines Data Sub-Model

The model mines data (MMD) sub-model defines the cost and labor coefficients for each technology (i.e. continuous deep, longwall, small area, etc.). In this sub-model, specific model mines data, as presented in Appendix A, are aggregated to define the mining technologies such that the technologies exhibit national average characteristics. The MMD sub-model can also be used to modify the mining technologies cost and labor coefficients to reflect different assumptions of the impact of environmental and health and safety regulations.

3.5.4 Labor Productivity Sub-Model

The labor productivity (LP) sub-model uses regression equations to determine the national labor productivity for underground and surface mines. Labor productivities by technology are then derived based on estimated productivity differentials between technologies. This is further discussed in Section 4.3.2.

3.5.5 Labor Demand Sub-Model

The demand for labor by technology is determined in the labor demand (LD) sub-model. Labor demand is a function of the quantity of coal produced and the productivity of labor. Coal production by technology is obtained from the CPI sub-model while labor productivity is input from the LP sub-model. The total labor demand by technology is then disaggregated to labor demand by functional category. This disaggregation is based on the labor coefficients from the model mines sub-model.* The labor demands calculated in the LD submodel are then used in the employment and wage sub-models.

3.5.6 Employment Sub-Model

The interaction in the coal mining industry of labor demands with labor supply is accomplished in the employment sub-model. Labor demand is based on functional job categories (i.e., supervisors, technical support, skilled production workers, etc.) while labor supply is based on educational and experience categories (i.e., mining engineers, mining technicians, miners with experience, etc.). The employment sub-model translates the labor demands by functional categories into employment by educational and experience categories. This translation is based on a hierarchical system of hiring preferences by which personnel within those educational and experience

*This process assumes fixed proportions for the labor inputs in each technology. The rationale for assuming fixed proportion production functions for each technology is discussed in Section 3.3.1.

categories most in demand and which are available get employed first for new job openings in the relevant functional categories.* Exogenous inputs of employment in non-coal mining sectors of the economy are considered to determine the national total employment in each category. The results of the employment sub-model are a determination of supply/demand imbalances by educational and experience categories. These imbalances are used in the wage sub-model.

3.5.7 Wage Sub-Model

The wage sub-model utilizes regression equations to determine the annual average wage rate by educational and experience category. The resulting supply category wage rates are used to determine the average wage by demand category and are an input to the supply sub-model to determine the labor supply reactions in each category. Wage rates are also used as inputs to the production cost sub-model. Details of the wage sub-model are presented in Section 5.2.2.

3.5.8 Labor Supply Sub-Model

The labor supply (LS) sub-model determines the annual supply of labor by educational and experience categories. The categories are:

- Mining engineers
- Other mining related engineers (mechanical, civil, electrical and industrial)
- Earth scientists (geologists, agronomists, biologists, chemists, etc.)
- Mining technicians

*In Section 5.0 the supply-demand mapping is discussed in more detail.

- o Miners with experience, and
- o Work force at large

Additions to the labor supply pool for the first four categories are econometrically estimated with sequential adjustment for retirement and attrition. The supply of miners with experience is derived within the model, based solely on hiring, retiring, attrition and assumed unemployment rates (the latter geared to the rate of coal production growth which characterizes each scenario. Data concerning the potential work force at large is exogenously input from Bureau of Census data.

The major inputs to the LS sub-model are:

1) The number of job slots by category from the labor demand sub-model; and

2) The average earnings by category from the wage submodel.

3.5.9 Production Cost Sub-Model

The production cost (PC) sub-model calculates the average total cost, fixed cost, variable cost, labor cost and operation and maintenance cost for each technology. The major inputs to the PC sub-model are production rates, wage rates, labor requirements, capital investments, interest rates, depreciation, fuel and electricity costs and other operating and maintenance costs. The output of the PC sub-model is used to determine the return on investments (ROI) of each technology, the average capacity utilization of each technology and as an input to the investment allocation/market penetration sub-model.

3.5.10 Finance-Investment Sub-Model

The finance-investment (FI) sub-model is a key element in the dynamics of the coal mining manpower model. The sub-model determines: 1) the annual ROI of each technology; 2) the gross and net income from each technology; 3) the net income of the coal mining industry; 4) the internal and external funds available to the industry for investments in new capacity; and 5) the funds needed for investments based on projected coal demand growth. The data generated in the FI sub-model is used as inputs to the production cost sub-model, the coal production inventory sub-model and the investment allocation/market penetration sub-model. For example, the total dollars available for investments in new capacity are calculated in the FI sub-model. The current ROI of each of the existing technologies are also calculated in the FI sub-model and are used with production cost and price data in the coal production inventory sub-model to determine the capacity utilization factors of each existing technology. The FI sub-model also requires exogenous inputs of national average coal prices, the inflation rate and the real interest rate for its analysis.

3.5.11 Investment Allocation/Market Penetration Sub-Model

The investment allocation/market penetration (IAMP) sub-model simulates the allocation of investments between technologies and the market penetration of the technologies in the coal industry. The allocation of investments between technologies is based on the estimated relative marginal profits of each technology. A logit curve is used to estimate investment shares as a function of the relative marginal profits. Technological, resource and regulatory constraints on the market penetration of each technology are quantified in this sub-model in terms of additional risks on capital investments or of increased production and operation costs. These higher costs result in lower marginal profits.* Details of the IAMP sub-model are presented in Section 4.3.7.

3.5.12 Capacity Construction-Retirement Sub-Model

The capacity construction-retirement (CCR) sub-model translates the investments allocated to each technology into coal production capacity construction and retirement rates. The estimated lags between the investment decisions and physical production capacity are incorporated within the CCR sub-model. Retirement rates of production capacity are based on the estimated life of the physical assets and capacity utilization within each technology. The output of the CCR sub-model is used to keep track of physical assets in the production inventory sub-model and to adjust capital cost estimates (due to rapid technology growth rates) in the investment allocation sub-model.

3.5.13 Federal Policies Sub-Model

The Federal policies (FP) sub-model is designed to incorporate exogenously determined impacts of Federal policies on coal mining

*This statement implicitly assumes that the coal prices faced by each technology remain constant in a given time period.

labor supply, demand and production. Given the exogenously determined direct impacts of a policy, the FP sub-model allows the user to alter the appropriate labor supply equations or the labor demand and production cost coefficients. For example, a Federal scholarships program for mining engineers that increases the number of annual mining engineer graduates by a particular amount can be evaluated in the model to determine the impacts on the supply and wages of mining engineers in subsequent years. The impact on the supply and wages will have secondary impacts on demand for and employment of mining engineers and on coal production costs. Similarly, an environmental regulation that requires additional labor and which increases production cost will have secondary impacts in terms of market penetration, labor productivity, return on investments, labor demand, employment and wages. The FP sub-model, at present, provides the means by which Federal policies that directly impact labor supply or labor demand and production costs can be evaluated for their subsequent impacts on the entire coal mining labor supply/demand system.

4.0 LABOR DEMAND SECTOR

4.1 Objectives

The main objective of the labor demand sector in the MITRE coal mining manpower model is to project the demand for manpower in the coal mining industry over the next twenty years. The types of labor skills needed by the coal mining industry vary from trained engineers and scientists to skilled and semi-skilled production workers. A complete catalog of the more than sixty types of job functions that are needed in coal mining is presented in Appendix A. For the purpose of labor demand projections, MITRE has classified job functions into five major categories:

1) Supervisory personnel;
2) Technical support personnel;
3) Administrative personnel;
4) Skilled production workers; and
5) Semi-skilled production workers

The first three categories include job functions that are generally filled by salaried (i.e., non-hourly) employees.* The last two categories include job functions that are filled by hourly (i.e., union or union-equivalent) employees. The hourly employees include all production workers at the mine site up to but excluding first

*See Section 2.1.1 for a more detailed discussion of the skills composition and categorization of the labor force.

line supervisors.* The labor demand sector thus projects mining industry needs for the five major demand categories. Estimates of labor demand on a more disaggregated level (i.e., by specific job function) can be obtained exogenously based on the model projections.

Fulfilling the major objective of the labor demand sector requires that two supporting objectives be met: accurately projecting the production of coal from exogenously assumed demand, and forecasting labor productivity by technology. Labor productivity presently varies from below 10 tons per man-day for some underground technologies to well above 60 tons per man-day for some large western surface mining technologies. In addition to variations in labor productivity between technologies, the ratio of the types of labor (i.e., supervisory, technical support, etc.) required per ton of coal produced also varies extensively. Thus, the determination of the average productivity of labor and the production of coal by technology are key factors in the forecasting of labor demand.

4.2 Overview

The demand for labor in the coal mining industry is assumed to be a derived demand. That is, this demand results from the level of coal production (which is a function of coal demand) and the productivity of labor. The implicit assumptions of the industry aggregate

*The definition of skilled and semi-skilled workers is presented in section 2.1.1.

and technology specific production functions were discussed in Section 3.3. Essentially, the derived demand approach assumes a fixed proportions production function for each specific technology but does not restrict the industry aggregate production function to fixed proportions. In the MITRE mining manpower model specific technologies compete on the basis of relative marginal profits causing the mix of technologies within the industry to change in the direction of the more profitable technologies. Marginal profits are a function of price (P) and the marginal costs of inputs (MC). The market share function for a two technology case can be represented as:

$$MS_1 = f\ (M\pi_1 / M\pi_2) \tag{4-1}$$

where MS_1 = the market share of new investment for technology 1

$M\pi_1$ = the marginal profit of technology 1

$M\pi_2$ = the marginal profit of technology 2

And: $$M\pi_i = P - MC_i = P-(w_i+r_i) \tag{4-2}$$

where P = the market price of coal ($/ton)

MC_i = the marginal cost of production in technology i ($/ton)

w_i = the labor cost for production in technology i ($/ton)

r_i = the non-labor costs of production in technology i ($/ton)

Substituting in equation 4-1,

$$MS_1 = f\left(\frac{P-(w_1+r_1)}{P-(w_2+r_2)}\right) \tag{4-3}$$

Thus, in the MITRE mining manpower model the demand for input factors is, in the long-run, a function of the relative prices of the input factors.

Figure 4-1 presents a box diagram of the sub-models in the labor demand sector. The information links between sub-models, and the framework for the entire MITRE coal mining manpower model was presented in Section 3.5. Figure 4-1 shows the inputs to and outputs from the labor demand sector of the model. The generic structure and equations within each sub-model of the labor demand sector is presented in the remainder of this Section.

4.3 Generic Structure: Labor Demand Sector

4.3.1 Labor Demand Sub-Model

Total labor demand in the coal mining industry can be divided into on-site and off-site labor demands. A discussion of the model logic, assumptions and generic equations for each of these categories follows.

4.3.1.1 On-Site Labor Demand

The labor demand sub-model uses coal production levels, labor productivity and model mine labor coefficients as inputs to yield the labor demand as an output. These relationships are shown graphically in Figure 4-2. The generic equations can be written as follows:

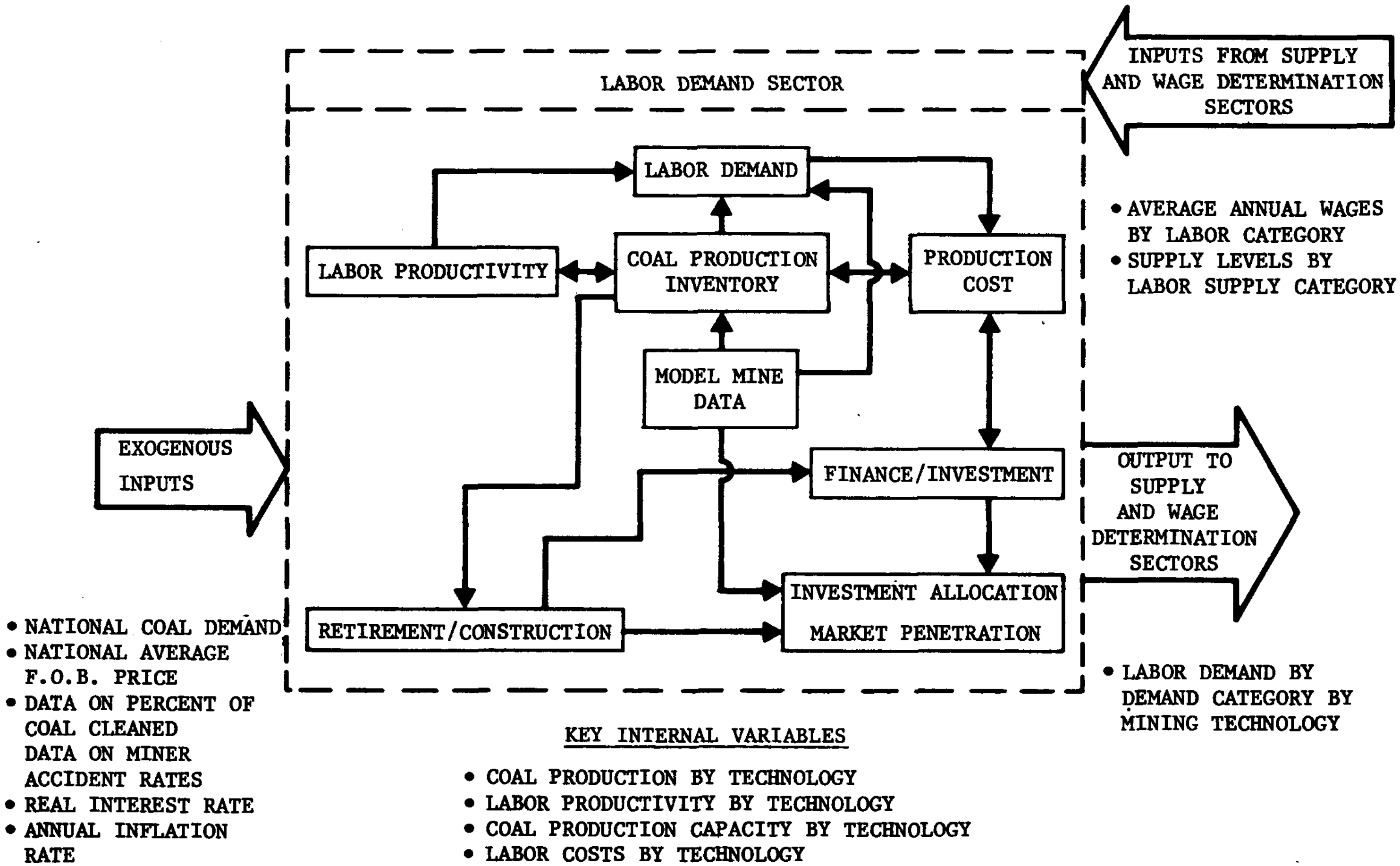
$$DLA = \left(\sum_{i=1}^{6} DLA_i \right) + DLPA \qquad (4\text{-}4)$$

$$DLA_i = (CP_i * LA_i)/PRM_i \qquad (4\text{-}5)$$

$$DLPA = DLP * FPPLA \qquad (4\text{-}6)$$

$$DLP = (TCP * PCTCL * .01)/APLPP \qquad (4\text{-}7)$$

$$PRM_i = APL_i/EAPL_i \qquad (4\text{-}8)$$



KEY INTERNAL VARIABLES

- COAL PRODUCTION BY TECHNOLOGY
- LABOR PRODUCTIVITY BY TECHNOLOGY
- COAL PRODUCTION CAPACITY BY TECHNOLOGY
- LABOR COSTS BY TECHNOLOGY
- NON-LABOR COSTS BY TECHNOLOGY
- PRODUCTION CAPACITY GROWTH RATES BY TECHNOLOGY

FIGURE 4-1
LABOR DEMAND SECTOR SUB-MODELS

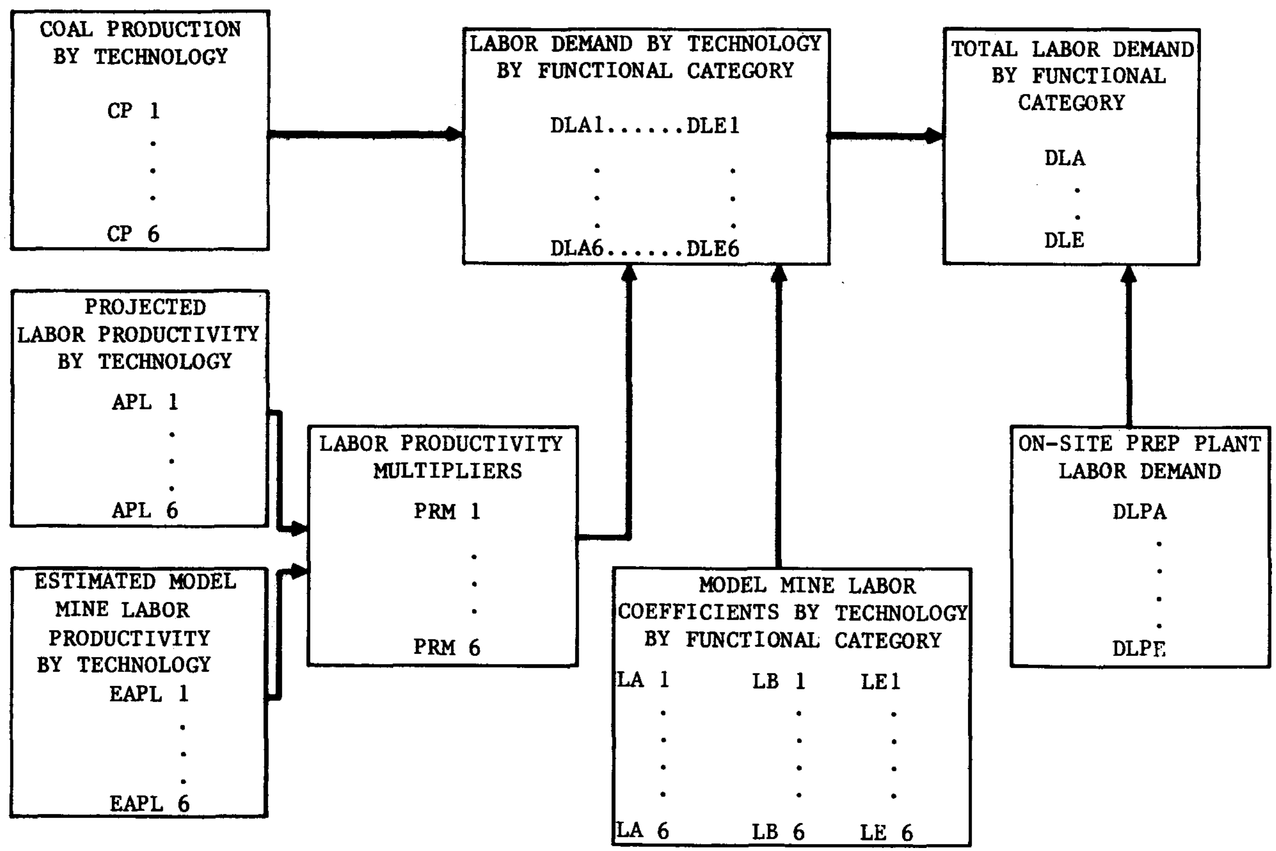

COAL PRODUCTION BY TECHNOLOGY
CP 1
CP 6
LABOR DEMAND BY TECHNOLOGY BY FUNCTIONAL CATEGORY
DLA1......DLE1
DLA6......DLE6
TOTAL LABOR DEMAND BY FUNCTIONAL CATEGORY
DLA
DLE
PROJECTED LABOR PRODUCTIVITY BY TECHNOLOGY
APL 1
APL 6
LABOR PRODUCTIVITY MULTIPLIERS
PRM 1
PRM 6
ON-SITE PREP PLANT LABOR DEMAND
DLPA
ESTIMATED MODEL MINE LABOR PRODUCTIVITY BY TECHNOLOGY
EAPL 1
EAPL 6
MODEL MINE LABOR COEFFICIENTS BY TECHNOLOGY BY FUNCTIONAL CATEGORY
LA 1
LB 1
LE1
LA 6
LB 6
LE 6

FIGURE 4-2

where DLA = total labor demand by functional category (man-days/year)

DLA_i = demand for labor by functional category by mining technology (man-days/year)

DLPA = demand for labor in on-site preparation plants by functional category (man-days/year)

CP_i = coal production by mining technology (tons/year)

LA_i = model mine labor coefficient by functional category by technology (man-days/year)

PRM_i = labor coefficient productivity multiplier by technology

DLP = total demand for on-site prep plant labor (man-days/year)

FPPLA = fraction of prep plant labor by functional labor category

TCP = total coal production (tons/year)

PCTCL = percent of total coal production that is cleaned on-site

APLPP = average productivity of on-site prep plant labor (tons/man-day)

APL_i = average productivity of labor by technology (tons/man-day)

$EAPL_i$ = model mine estimated average productivity of labor by technology (tons/man-day)

The labor coefficient productivity multiplier, PRM_i in equation 4-5, is used to adjust the model mine labor coefficients to reflect the difference between the estimated average product of labor (EAPL) in the model mines versus the actual average product of labor (APL) experienced in the technology. The model mine data is a design estimate of the inputs of labor per unit of production. It does not include the negative impacts of accidents, injuries, labor-management relationships, etc., on labor productivity. As such, the model mine average products of labor tend to be higher than historically observed average products of labor. The productivity multiplier, PRM, is used to adjust the model mine labor coefficients to reflect the related difference between the estimated (EAPL) and actual (APL) labor productivities. Equation 4-5 indicates that for a given technology the labor coefficients in all functional categories are adjusted by the same productivity multiplier. The assumption implicit in equation 4-5 is that each technology requires fixed proportions of its labor inputs.*

4.3.1.2 Off-Site Labor Demand

A sizable number of coal company employees are employed at division, regional or corporate headquarters. The relative numbers of such off-site employees vary considerably. Large coal producers tend to employ hundreds of personnel off site at various locations depending upon the concentration and types of mines located within discernable regions and the degree of decentralization of support desired. Typical off-site functions include water and air quality monitors and reclamation specialists. Although larger mines may be assigned some of these types of personnel on a full time basis, multi-mine companies usually provide these services to a number of mines from division or regional offices. Small companies, on the

*See Section 3.3 for a discussion of the rationale for assuming fixed proportions production functions by technology.

other hand, especially independent operators with one or two mines, often employ virtually all of their personnel on site. Another component of off-site labor is the degree of consulting support which companies choose to rely upon for mine design, for permit applications, and for EIS preparation.

As indicated previously in Table 2-II, the BLS has estimated non-production workers within the total workforce in its Employment and Earnings Series (BLS #3, 1979). However, non-production personnel include many categories of labor that perform work on site, such as non-production supervisors, most technical support staff and all office or administrative personnel.

To estimate off-site personnel requirements, a number of coal companies of different sizes, having varying regional and technology attributes, were surveyed. It was found that among the top 20 producers, off-site personnel varied from about 6 to 10 percent of total personnel. Among smaller companies, it was more difficult to estimate off-site workers, since many supervisors and technical support staff work from within an office building at a mine site. Nevertheless, most of these personnel should have been included in on site personnel as compiled by the Bureau of Mines/Energy Information Administration in the series from which labor productivity is estimated (BOM/EIA, 1950-1976).

Other small companies which did have corporate headquarters tended to minimize overhead costs and cited about four percent off site employment. For the purpose of this study, it was assumed that, given the present composition of the industry, off-site employees comprise about 5.5 percent of total industry employment. Moreover, it was determined that this has not changed significantly, at least since the 1960's. This is due to the fact that while absolute off-site labor requirements were far lower prior to the environmental, health and safety legislation beginning in 1970, productivity was also much higher than it has been since then. Thus, both off-site and on-site employment increased after 1970, tending to cancel each other out in terms of affecting relative employment at both places. This was confirmed in discussions with coal company officials, who indicated that at most, a slight increase may have occurred after 1970 in off-site labor as a percentage of total employment. Thus, for the period 1960-70, off-site employment was assumed to be at 4.5 percent of total employment.

For the three coal production cases the post-1970 assumption of 5.5 percent off-site employment was used in the analysis. The purpose of doing so was to assess the impact that changes in this variable would have on the demand for engineers, scientists and other non-hourly personnel.

4.3.2 Labor Productivity Sub-Model

The labor productivity sub-model uses regression equations to estimate underground and surface labor productivities nationally. The inputs to the sub-model are coal production by technology, national average coal price for underground and surface coal, underground and surface mine accident rates, and the percent of underground and surface coal receiving on-site preparation. Estimates of the average labor productivities by technology are then derived from the projected national labor productivities and from the model mines data. These relationships are shown graphically in Figure 4-3.

The regression model postulated to explain changes in coal mining labor productivity is:

$$APL_t = B_0 + B_1(\text{logn}(Price_t)) + B_2(Technology_t)$$
$$+ B_3(\%\ Cleaned_t) + B_4(Accidents_t) + u_t$$

where APL_t = the productivity of labor in period t.

A brief discussion of the rationale for the selected variables and functional form of the model is presented below.

$Price_t$: The average F.O.B. selling price of coal is assumed to impact labor productivity negatively by attracting marginal mines into operation when the real selling price increases. In the short term, if the real price of coal rises rapidly, economically marginal mines tend to enter the market to capitalize on potential profits. These marginal mines tend to have low labor productivities due to several factors including resource and capital characteristics. The price effect is assumed to be initially large and to eventually diminish suggesting the semi-log relationship with productivity.

$Technology_t$: Improvements in the aggregate technology are assumed to impact labor productivity positively. In underground mining this improvement in technology can be characterized by the shift from pick and shovel and conventional mining techniques to continuous and longwall mining techniques. In surface mining, the technology shift to larger buckets and draglines and the concomitant shift to large western surface mines represents the major technology improvements. The technology shift is assumed to exhibit a positive and linear relationship to labor productivity.

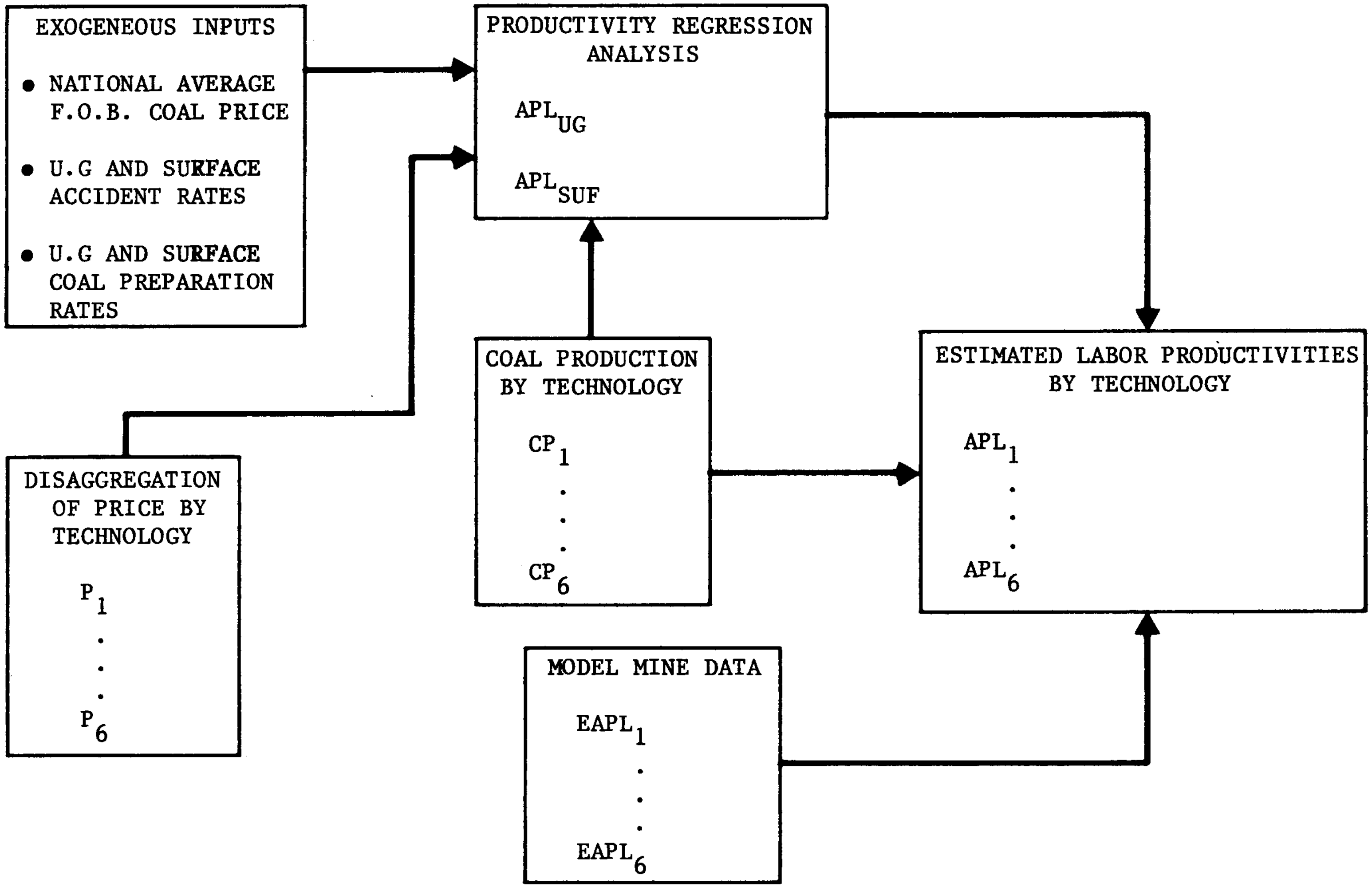


FIGURE 4-3
LABOR PRODUCTIVITY SUB MODEL

% $Cleaned_t$: The percent of coal mined that is mechanically cleaned on site is assumed to have a negative impact on coal mining labor productivity. The present measurement of mining labor productivity includes all non-office workers on site in the estimate of total man-hours worked. This includes on-site preparation plant workers. Thus, if the percent of coal that is mechanically cleaned were to increase, all other factors remaining constant, coal mine labor productivity would decline. One additional factor contributes to the negative impact of this variable. The present definition of the coal production data used to measure mining labor productivity is the sum of cleaned tonnage (i.e., raw coal less refuse) and raw coal that is not mechanically cleaned. Thus, if the percent of coal that is mechanically cleaned increases while raw production remains constant, under the present definition the total production of coal will decrease, all other factors remaining constant.*

$Accidents_t$: The annual total accident rate in coal mining is assumed to have a negative impact on labor productivity. The accident rate is defined as the sum of the fatal and non-fatal disabling injuries per million man-hours of mining. A linear relationship is assumed.

The results of regression analysis for the national underground and surface labor productivities are presented below:

$$\underset{}{APLUG} = \underset{(8.94)}{36.8954} - \underset{(-12.52)}{8.71101^*}\ UGACPX + \underset{(15.80)}{0.143499^*}\ PCON \qquad (4\text{-}9)^{**}$$

$$- \underset{(-1.34)}{0.033771^*}\ UGPCL - \underset{(-4.96)}{0.156642^*}\ UGACR$$

$$\bar{R}^2 = 0.9736$$
$$D\text{-}W = 1.2639$$

$$APLSU = \underset{(5.43)}{122.020} - \underset{(-7.73)}{31.8094^*}\ SUACPX + \underset{(2.30)}{0.470223^*}\ PSUW \qquad (4\text{-}10)^{**}$$

*Clyde Boykins of D.O.E.'s Energy Information Administration indicates EIA's recognition of this definitional problem (Boykins, 1979).

**The numbers in parentheses indicate the t-statistic of the estimated coefficient. A t-statistic greater than ±2.08 indicates that the coefficients are significant at the .025 level.

$- 0.669317^* SUPCL - 1.03697^* SUACR$
$(-7.65) \qquad (-3.73)$

$\overline{R}^2 = 0.8374$
D-W = 2.0928

where APLUG = national underground labor productivity (tons/man-day)

APLSU = national surface labor productivity (tons/man-day)

UGACPX = logn (UGACP)

UGACP = the average F.O.B. price of underground coal ($/ton)

SUACPX = logn (SUACP)

SUACP = the average F.O.B. price of surface coal ($/ton)

PCON = the percent of underground production mined by mechanized methods (includes continuous and longwall mining)

PSUW = the percent of surface production mined in the west

UGPCL = the percent of underground production that receives on-site primary cleaning

SUPCL = the percent of surface production that receives on-site primary cleaning

UGACR = the annual accident rate per million man-hours in underground mines.*

SUACR = the annual accident rate per million man-hours in surface mines.*

Coal production, labor productivity and price data were obtained from Bureau of Mines (Minerals Yearbook, series 1950-1970) and the Department of Energy. Health and safety data was obtained from Mine Health and Safety Administration publications.

The coefficients from the estimated productivity regression equations were incorporated within the framework of the MITRE mining

*The accident rate is defined as the sum of fatal and non-fatal disabling injuries.

manpower model. The annual values for the price and technology variables are determined endogenously in the MITRE model while the cleaned coal and accident rate variables are exogenously specified. The MITRE model, thus, projects labor productivity within the dynamics of the entire coal mining system.

Labor productivities by technology are derived by utilizing the estimated national underground and surface productivities, the labor productivity ratios between technologies estimated in the model mines data, and the levels of coal production by each technology. The algorithm utilized to derive the productivities by technology ensures that their weighted sum equals the national productivity estimates.*

4.3.3 Coal Production Inventory Sub-Model

The coal production inventory (CPI) sub-model uses national coal demand, national average F.O.B. coal prices, production cost data, and production capacity construction and retirement rates as inputs to yield estimates of:

1) coal production by technology;

2) production capacity/physical assets by technology; and

3) average utilization of capacity by technology.

The generic equations in the sub-model can be written as follows:

*The weights used are based on the man-hours employed by a technology within the underground or surface mining category divided by the total man- hours employed in either the underground or surface mining category.

$\text{Weight}_i = \text{man-hours}_i/\sum \text{Man-hours}$;

$$TCP = \sum_i CP_i \quad (4\text{-}11)$$

$$CP_i = AVPC_i * ICUF \quad (4\text{-}12)$$

$$ICUF = MIN\ (DTPC, 1) \quad (4\text{-}13)$$

$$DTPC = CD/TAVPC \quad (4\text{-}14)$$

$$TAVPC = \sum_i AVPC_i \quad (4\text{-}15)$$

$$AVPC_i = ACPC_i * CUF_i \quad (4\text{-}16)$$

$$ACPC_i = DNPC_i * MPRF * PRM_i \quad (4\text{-}17)$$

$$PRM_i = APL_i / EAPL_i \quad (4\text{-}18)$$

$$DNPC_{i,t} = DNPC_{i,t-1} + DT*(PCCR_i - PCRR_i) \quad (4\text{-}19)$$

$$CUF_i = f\ (P_i,\ APC_i,\ EROI) \quad (4\text{-}20)$$

where TCP = total coal production (tons/year)

CP_i = coal production by technology (tons/year)

ICUF = industry capacity utilization factor

DTPC = ratio of coal demand to production capacity

CD = national coal demand (tons/year)

TAVPC = total available production capacity in the industry (tons/year)

$AVPC_i$ = available production capacity by technology (tons/year)

$ACPC_i$ = actual coal production capacity by technology (tons/year)

MPRF = maximum production capacity factor

PRM_i = productivity multiplier by technology

$DNPC_i$ = model mine designed production capacity by technology (tons/year)

$PCCR_i$ = designed production capacity construction rate (tons/year/year)

$PCRR_i$ = designed production capacity retirement rate (tons/year/year)

CUF_i = technology capacity utilization factor

P_i = market price of coal facing the technology ($/ton)

APC_i = average production cost by technology ($/ton)

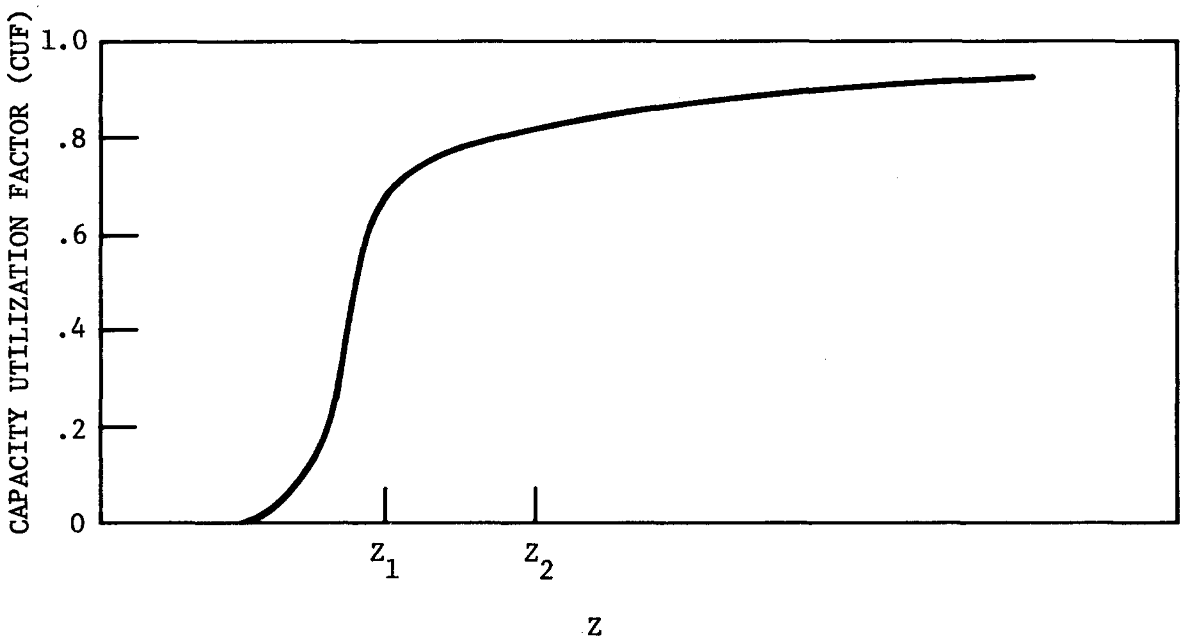
EROI = expected return on investment

The generic equations presented above illustrate the core of the CPI sub-model. In equation 4-19 the designed level of production capacity (DNPC)* is determined based on production capacity construction and retirement rates. In equation 4-17 the designed level of production capacity is translated into the actual or theoretical maximum production capacity (ACPC) after accounting for the impacts of labor productivity and the model mines assumptions. The productivity multiplier (PRM) was discussed earlier in section 4.3.1. It converts the physical assets to production capacity as a function of the estimated labor productivity. The term MPRF (maximum production capacity factor) in equation 4-17 accounts for the 80 percent capacity utilization factor assumption in the model mines data. Thus an investment in one unit of design capacity will yield 1.25 units of maximum production capacity, all other factors being equal.

*The designed production capacity is based on the model mines data. It therefore assumes the model mines estimated labor productivity and a capacity utilization factor of 0.8 (80%).

The available production capacity (AVPC), determined in equation 4-16, is the capacity that is made available by the industry given the economics of the industry. The capacity utilization factor (CUF), which varies between 0.0 and 1.0 and which determines AVPC, is a function of the price of coal, production costs, and the producer's expected returns on investment. The relationship between the CUF and these variables is derived from the economic theory of the behavior of a competitive firm which suggests that a rational producer will not operate when the ratio of price to average variable costs is less than one (P/AVC<1). At this point the producer is unable to recover variable costs and thus loses more by operating than by not operating. Alternately, the producer is willing to operate at a normal CUF* when the market price is equal to the sum of average variable costs, fixed costs and expected profits (P=AVC+FC+EROI). The producer is theoretically indifferent at the point where price over average variable costs is equal to one (P/AVC=1). Figure 4-4 graphically presents the CUF function incorporated in the MITRE mining manpower model. It indicates that near the point where price equals average variable costs there is a steep rise in the CUF. The second point of interest is that when the price allows the producer to recover his costs and realize his expected profits he moves to the normal CUF (0.8). When the producer is realizing greater than

*Normal CUF is assumed to be equivalent to the designed CUF which is 0.8.



AT Z_1: P = AVC

AT Z_2: P = AVC + FC + EROI

FIGURE 4-4
CAPACITY UTILIZATION FACTOR

expected profits he will push his productive capacity towards its maximum as indicated by the right hand portion of the curve.

Equations 4-11 through 4-15 allow for coal production to meet but not exceed coal demand. That is, given that the total available production capacity (TAVPC) exceeds the total coal demand (CD), the model assumes that production will meet demand. However, if TAVPC is less than CD, production will fall short of demand. Production capacity surpluses or shortages are taken into consideration in the finance/investment sub-model when projecting the new capacity needed.

4.3.4 Retirement-Construction Sub-Model

The retirement-construction (RC) sub-model translates financial investments in new capacity and physical retirements of existing assets into production capacity construction and retirement rates. These construction and retirement rates are used to determine the production capacity levels in the CPI sub-model discussed in Section 4.3.3. Figure 4-5 presents a simple diagram of the RC sub-model. The generic equations in this sub-model are:

$$PCCR_i = DELAY2P(CON_i, AFCT_i, CUC_i) \quad (4\text{-}21)$$

$$PCRR_i = DNPC_i * ARF_i \quad (4\text{-}22)$$

$$CON_i = INVN_i / ACCT_i \quad (4\text{-}23)$$

$$ARF_i = f\ (GR_i) \quad (4\text{-}24)$$

where:

$PCCR_i$ = the production capacity construction rate by technology (tons/year/year)

$PCRR_i$ = the production capacity retirement rate by technology (tons/year/year)

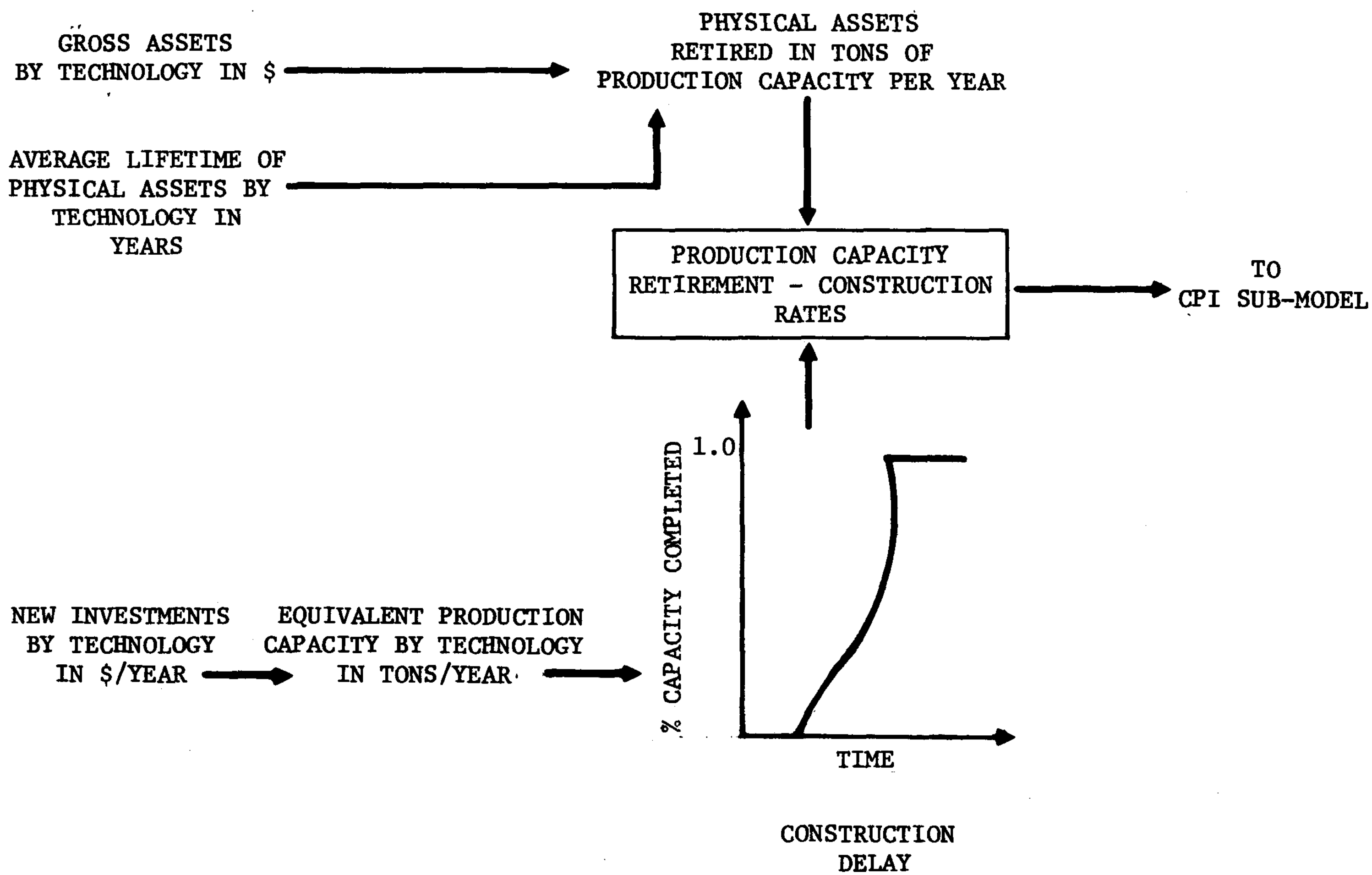


FIGURE 4-5
RETIREMENT-CONSTRUCTION SUB-MODEL

CON_i = investment in construction by technology in terms of physical capacity (tons/year)

ARF_i = asset retirement factor by technology

$AFCT_i$ = average facility construction time by technology

CUC_i = capacity under construction by technology (tons/year)

$INVN_i$ = investments in new capacity by technology ($/year)

$ACCT_i$ = average initial capital costs ($/year)

GR_i = growth rate of assets by technology

The "DELAY2P" term in equation 4-21 is a DYNAMO function which delays the investments in new capacity (CON) by the average facility construction time (AFCT). The asset retirement factor (ARF) used in equation 4-22 is a function of the growth rate of the physical assets in each technology. The fraction of assets to be annually retired in a technology experiencing a constant growth rate (GR), with an average lifetime of assets (AFL) is:

$$ARF_i = GR_i/e^{GRi*AFLi}-1 \qquad (4\text{-}25)*$$

In the MITRE model the growth rate (GR) is estimated using a DYNAMO averaging function over the average lifetime of the assets.

4.3.5 Production Costs Sub-Model

The production costs (PC) sub-model is an accounting sub-model that estimates the principal components of production costs by technology. These components: total costs, average variable costs, average labor costs, and fixed costs are used in the coal production

*For the complete derivation of equation 4-25 see (Masevice, 1978).

inventory (CPI), finance investment (FI), and investment allocation sub-models. The major inputs to the PC sub-model are endogenously determined within the MITRE model and thus changes in production costs due to changes in wages, labor productivity, capacity utilization, or regulatory requirements* are reflected in the annual determinations of production costs.

The generic equations in the PC sub-model are:**

$$TCST_i = (CP_i * AVC_i) + FC_i \tag{4-26}$$

$$AVC_i = ALC_i + EOMC_i \tag{4-27}$$

$$FC_i = IOD_i + DEP_i \tag{4-28}$$

$$ALC_i = \sum_j W_j / APL_{ij} \tag{4-29}$$

$$EOMC_i = FEC_i + NLOMC_i \tag{4-30}$$

$$IOD_i = DEBT_i * SNIR \tag{4-31}$$

$$DEP_i = GA_i / BLC_i \tag{4-32}$$

$$DEBT_i = NA_i * DF_i \tag{4-33}$$

$$EQ_i = NA_i * EF_i \tag{4-34}$$

$$GA_{i,t} = GA_{i,t-1} + DT * (RINV_i - GARR_i - VLI_i) \tag{4-35}$$

$$NA_i = GA_i * (1 - ADF_i) \tag{4-36}$$

$$DF_i = DER_i * EF_i \tag{4-37}$$

$$RINV_i = INV_i \tag{4-38}$$

$$GARR_i = GA_i * ARF_i \tag{4-39}$$

$$VLI_i = GA_i * INFR \tag{4-40}$$

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*Changes in regulatory requirements as they impact labor and capital requirements in each technology are incorporated in the model mines data. It is through the model mines data that the regulatory requirements enter the MITRE model to impact production costs, labor productivity, investment allocations, etc.

**The PC sub-model is designed based on the generic production cost equations in the FOSSIL 79 model (Dartmouth, 1979).

where:

$TCST_i$ = annual total production costs by technology ($/year)

CP_i = annual coal production by technology (tons/year)

AVC_i = average variable costs by technology ($/ton)

FC_i = annual fixed costs by technology ($/year)

ALC_i = average labor costs by technology ($/ton)

$EOMC_i$ = average non-labor operation and maintenance costs by technology ($/ton)

W_j = average wage rate by labor demand category ($/man-day)

APL_{ij} = average productivity of labor by labor demand category and technology (tons/man-day)

FEC_i = average fuel and electricity costs by technology ($/ton)

$NLOMC_i$ = non labor O and M costs less FEC_i by technology ($/ton)

IOD_i = estimated annual interest paid on debt by technology ($/year)

DEP_i = estimated annual depreciation by technology ($/year)

$DEBT_i$ = estimated level of debt by technology ($)

EQ_i = estimated level of equity by technology ($)

SNIR = averaged nominal interest rate per year

GA_i = level of gross assets by technology ($)

NA_i = level of net assets by technology ($)

BLC_i = estimated average book life of capital in years

DF_i = estimated debt fraction by technology

EF_i = estimated equity fraction by technology

$RINV_i$ = annual rate of new investments by technology ($/year)

$GARR_i$ = annual retirement rate of gross assets ($/year)

ARFi = asset retirement rate by technology

VLI_i = value of gross assets lost due to inflation ($/year)

INFR = annual inflation rate

The total costs of production, determined in equation 4-26, is used to determine total revenues by technology in the finance investment sub-model. The average cost data determined in the PC sub-model is used in determining the capacity utilization factor (CUF) discussed in section 4.3.3 and investment allocations discussed in section 4.3.7.

4.3.6 Finance-Investment Sub-Model

The finance-investment (FI) sub-model performs four major functions:

1) It estimates the revenues, income and ROI by technology and for the industry as an aggregate;

2) It estimates the funds available for investments for the industry as an aggregate;

3) It estimates the funds needed for capital investments to meet projected growth in coal demand; and

4) It determines the amount of funds invested in new and deferred capital.

A brief discussion of the model logic and generic equations for each of these major functions is presented below.

4.3.6.1 Revenues, Income and ROI

Data on production costs, coal production and coal price are used as inputs to the FI sub-model to estimate revenues, income and

ROI by technology and for the industry as an aggregate. The financial data, generated in the FI sub-model, are then used in a feedback loop to the CPI and PC sub-models. The generic equations used in this portion of the FI sub-model are presented below.*

$$TREV_i = CP_i*ACP_i \quad (4\text{-}41)$$

$$GRIN_i = TREV_i - TCST_i \quad (4\text{-}42)$$

$$NTIN_i = GRIN_i*(1-INTR) + NPC_i*INTCR \quad (4\text{-}43)$$

$$NPC_i = PCCR_i*ACCT_i \quad (4\text{-}44)$$

$$ROI_i = (NTIN_i + IOD_i)/TINV_i \quad (4\text{-}45)$$

$$TINV_i = DEBT_i + EQ_i \quad (4\text{-}46)$$

where:

$TREV_i$ = annual total revenues by technology ($/year)

CP_i = annual coal production by technology (tons/year)

ACP_i = average coal price "facing" each technology ($/ton)

$GRIN_i$ = annual gross income by technology ($/year)

$TCST_i$ = annual total production costs by technology ($/year)

$NTIN_i$ = annual net income by technology ($/year)

INTR = effective industry tax rate

INTCR = investment tax credit rate

NPC_i = value of investments in new production capacity by technology ($/year)

*The financial equations used in this sub-model assumes each mining technology exists like a firm. Income, investments and profits are calculated under these assumptions. Within the coal industry it is recognized that a firm may operate more than one technology. However, when viewing technologies in the aggregate it is assumed that the behavior of operators with respect to technologies can be approximated by treating the technologies like firms.

$PCCR_i$ = production capacity construction rate by technology (tons/year/year)

$ACCT_i$ = average production capacity capital cost by technology ($/ton/year)

ROI_i = annual return on investments by technology

$TINV_i$ = total investments by technology ($)

Equation 4-41 indicates that total annual revenues are based on the quantity of coal produced by a technology (CP_i) and the F.O.B. price "facing" the technology (ACP_i). In the MITRE model, ACP_i is based on an estimated price differential between technologies. These price differentials are derived from an implicit recognition of regional price differentials and technology distributions among regions. For example, the average F.O.B. price facing large area surface mines is weighted predominantly by the regional prices in the western regions because the technology is generally applicable only in these areas.

The equation used to determine ACP_i is:

$$ACP_i = \sum_k \frac{CP_{ik}}{TCP_i} * ACP_k \qquad (4\text{-}47)$$

where:

CP_{ik} = coal production by technology i in region k

TCP_i = total coal production by technology i

ACP_k = average F.O.B. coal price in region k

Equation 4-47 shows that the average F.O.B. coal price by technology (ACP_i) can be derived by weighting the regional prices (ACP_k) by the percentage of the technology's coal production in each region (CP_{ik}/TCP_i). In the MITRE model a set of technology price differentials, derived from equation 4-47, are used to develop the technology prices.

Equation 4-43 estimates the income after taxes within each technology. An effective industry tax rate of 0.35 based on data from the National Income and Product Accounts (BEA, 1979) is applied to all technologies. An investment tax credit for the industry of 0.07 is assumed based on data in the FOSSIL 79 model (Dartmouth, 1978). The tax credit allows for a reduction in income tax expenses as a percentage of the depreciable assets that the industry acquires in a specific year, and therefore serves to increase net income as a percentage of the new assets which become available.

Aggregate coal industry financial parameters are calculated by summing over technologies. The aggregate industry parameters are used to estimate the funds available to the industry for investments in new capital. A brief discussion of how funds available are determined is presented below.

4.3.6.2 Investment Funds Available

The funds available section of the FI sub-model serves to estimate the total funds available to the industry for investment in new and deferred capital. The funds available can be divided into internally generated funds and external funds attracted to the industry.

The generic equations employed in this section of the FI sub-model are presented below:*

$$TFA = INFU + EXFU \quad (4\text{-}48)$$

$$INFU = ANTIN - DIVD - DRP + DEP \quad (4\text{-}49)$$

$$EXFU = TGA*EXFF \quad (4\text{-}50)$$

$$ANTIN = \sum_i NTIN_i \quad (4\text{-}51)$$

$$DIVD = f\ (IROI/ROIE,\ ANTIN) \quad (4\text{-}52)$$

$$DRP = \sum_i DRP_i \quad (4\text{-}53)$$

$$DEP = \sum_i DEP_i \quad (4\text{-}54)$$

$$TGA = \sum_i GA_i \quad (4\text{-}55)$$

$$EXFF = f\ (IROIX) \quad (4\text{-}56)$$

$$IROIX = SMOOTH\ (IROI/ROIE,\ 5) \quad (4\text{-}57)$$

Where:

TFA = annual total funds available ($/year)

INFU = annual internally generated funds ($/year)

EXFU = annual externally attracted funds ($/year)

ANTIN = annual aggregate net industry income ($/year)

DIVD = annual industry dividend payouts ($/year)

DRP = annual industry total debt repayment ($/year)

DEP = annual industry total depreciations ($/year)

TGA = total industry gross assets ($)

EXFF = external funds factor

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*The equations used to determine funds available are largely based on the generic equations used in the FOSSIL 79 source of funds sub-sector (Dartmouth, 1979). The equation for external funds has been modified.

IROI = aggregate industry return on investments

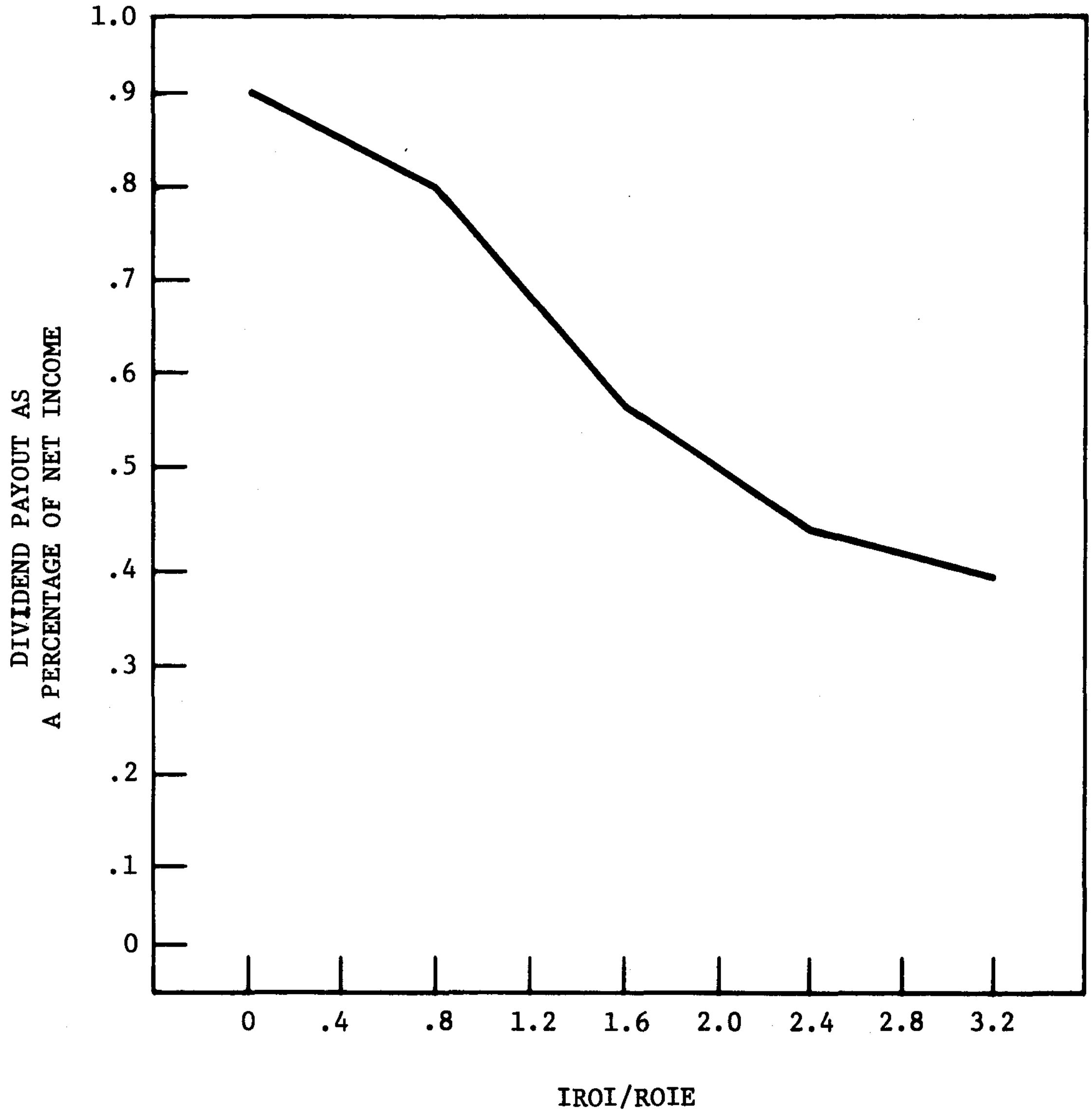
ROIE = industry expected return on investments

IROIX = five year average return on investments index

The internal funds available (equation 4-49) are defined as the sum of net income and non-cash charges (depreciations) less dividend payouts end debt repayments. The dividend payouts are calculated as a percentage of the industry's net income; the percentage varying as a function of the industry's actual return on investment divided by its expected return on investment. The expected return on investment (ROIE) is assumed to be the sum of a normal or real ROI of 5 percent plus a five year average inflation rate. Figure 4-6 illustrates the functional relationship given in equation 4-52. The annual debt repayment is based on the industry's debt level divided by the average debt life of 10 years (Dartmouth, 1979). The external funds attracted to industry are a function of the gross assets of the industry and its five year average return on investments index (IROI/ROIE). This relationship, shown in Figure 4-7, was developed based on a qualitative assessment of industry data and through discussions with industry officials.

4.3.6.3 Investment Funds Needed

The FI sub-model also determines the investment funds desired to meet expected future demand for coal production capacity. The funds needed are calculated by forecasting the amount of new physical assets which must be on-line to meet future demand and adding to it



SOURCE: (Dartmouth, 1979)

FIGURE 4-6
DIVIDEND PAYOUT AS A PERCENTAGE OF NET INCOME

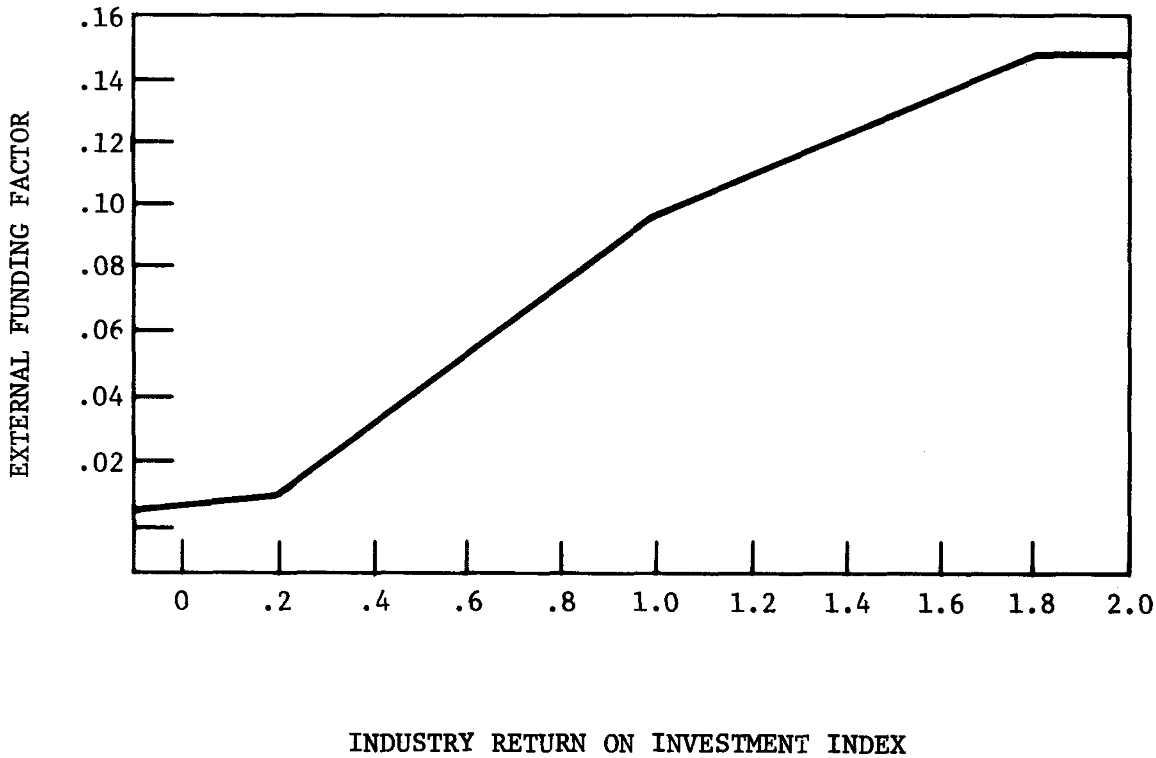


FIGURE 4-7
EXTERNAL FUNDING FACTOR VERSUS INDUSTRY RETURN ON INVESTMENT INDEX

the annual deferred capital investments needed to maintain existing capacities. The new physical assets or production capacity needed are determined by taking the value of the projected physical assets that must be on-line to meet future demand and comparing it with the present value of physical assets, allowing for retirements and the completion of new construction that is underway or planned. The annual deferred capital investments are a function of the existing physical assets and the mix of mining technologies that make up those physical assets.

The generic equations used to determine the investment funds needed are presented below:

$$TFN = (NPCN*EACC) + DCI \tag{4-58}$$

$$NPCN = FCD - FPC \tag{4-59}$$

$$FCD = CD*EXP(SDGR*AFCT) \tag{4-60}$$

$$FPC = TAVPC*(EXP(-NRR*AFCT)) + ECUC \tag{4-61}$$

$$DCI = \sum_i DCI_i \tag{4-62}$$

$$ECUC = \sum_i CUC_i*PRM_i \tag{4-63}$$

$$SDGR = MAX(SMOOTH(DGR, AFCT)\ 0.04) \tag{4-64}$$

$$DGR = LOGN(CD/CD_{t-3})/3 \tag{4-65}$$

where:

TFN = total investment funds needed ($/year)

NPCN = new production capacity needed (tons/year/year)

EACC = estimated average capital costs of new production capacity ($/ton/year)

DCI = annual deferred capital investments ($/year)

FCD = expected future coal demand (tons/year)

FPC = expected future production capacity with no new investments (tons/year)

ECUC = estimated production capacity presently under construction (tons/year)

SDGR = expected annual demand growth rate (%/year)

AFCT = average facility construction time (years)

NRR = normal production capacity retirement

TAVPC = total existing production capacity (tons/year)

CD = present coal demand (tons/year)

DGR = demand growth rate (%/year)

Future coal demand and production capacity are projected for a time period equivalent to the average facility construction time (AFCT), because it takes AFCT years from the time investment decisions are made until production capacity is achieved. AFCT, which varies between 2 and 5 years, is a function of the analysis period and the existing mix of mining technologies.* Projections of future coal demand are based on an exponential growth over AFCT years. The expected demand growth rate (SDGR) is determined as a function of averaged demand growth in the past AFCT years. The model assumes a minimum expected demand growth of four percent. Similarly, projections of production capacity are based on an exponential decline over AFCT years of existing capacity at a normal retirement rate (NRR) of

*AFCT varies by time period due to assumptions of the impacts of regulatory requirements on construction delays. AFCT also varies by technology because of the different physical aspects of opening new mines inherent in each technology.

five percent* plus the sum of production capacity in the construction pipeline. Figure 4-8 illustrates graphically the determination of the new production capacity needed.

4.3.6.4 Total Funds Invested

The FI sub-model determines the annual total funds invested in new and deferred capital. The funds invested by the industry are determined to be the minimum of either the funds available or the funds needed. Funds invested in new technologies are the difference between the total funds invested and the funds needed for deferred capital. The generic equations used to determine the funds invested in the FI sub-model are presented below

$$TFI = MIN(TFA, TFN) \qquad (4\text{-}66)$$

$$INVN = MAX(TFI\text{-}DCI, 0) \qquad (4\text{-}67)$$

where:

TFI = the total annual funds invested by the industry ($/year)

INVN = the total annual funds invested in new capital ($/year)

The total annual funds invested in new capital (INVN) determined in equation 4-67 is used as an input to the investment allocation (IA) sub-model discussed below.

4.3.7 Investment Allocation/Market Penetration Sub-Model

The investment allocation/market penetration sub-model (IA) determines the distribution of investments for new capital among competing technologies. The distribution is based on a logit function

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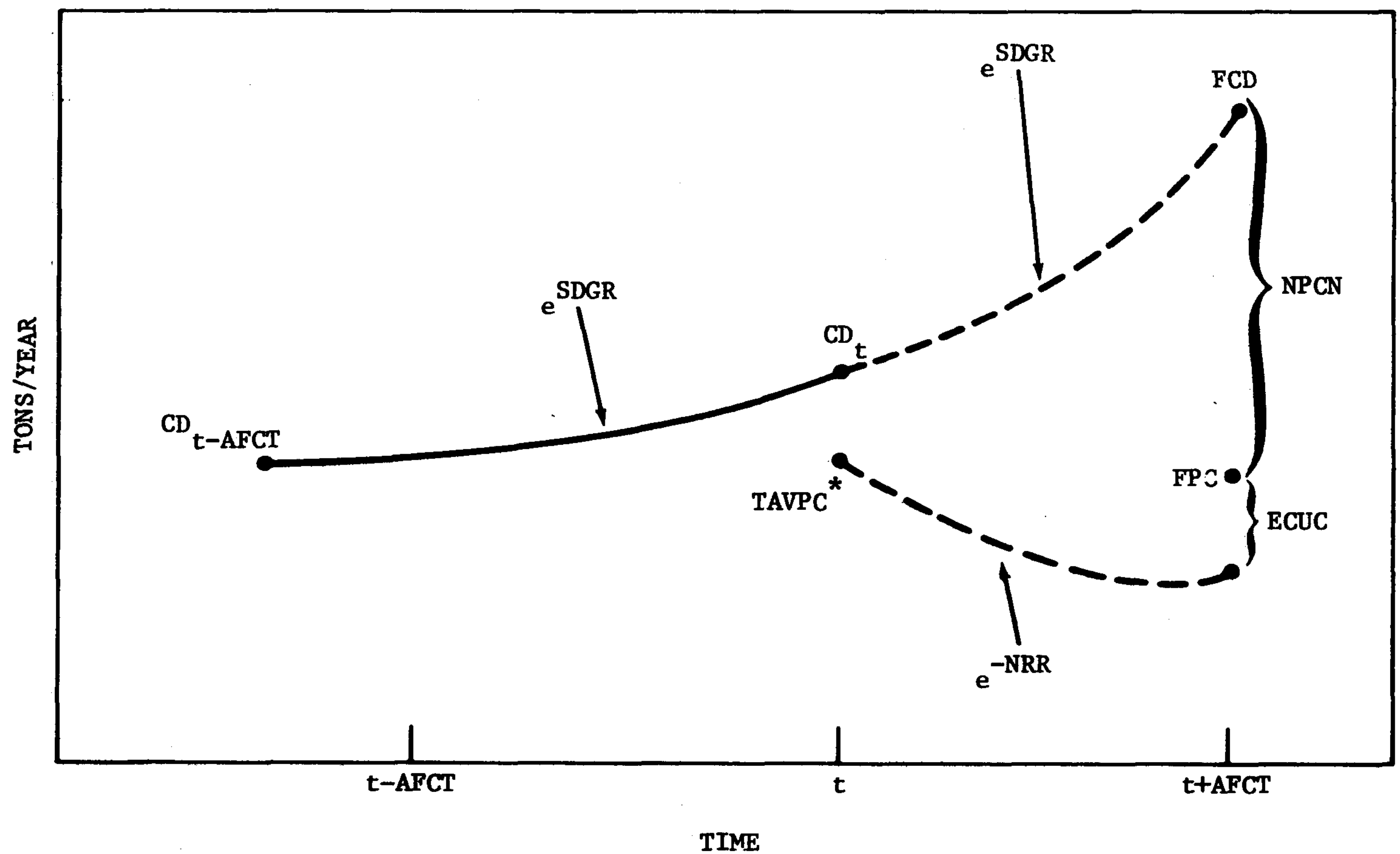
*NRR = .05 implies an effective facility life of 20 years.



*The location of TAVPC can be either above, below or equal to CD_t

FIGURE 4-8
DETERMINATION OF NEW PRODUCTION CAPACITY NEEDED (NPCN)

of the relative marginal profits of each technology. The logit function generates an "S"-shaped distribution around technology alternatives. Figure 4-9 illustrates the logit function for a two technology case. As the marginal profit of technology 1 increases relative to technology 2, its share of investments first increases rapidly and then gradually approaches the maximum. The logit function has been used in previous market share studies (Dartmouth, 1979) and is desirable because it does not provide a "knife edge" solution but rather a smooth distribution of new investments among technologies.

The shape of the logit curve is dependent on the power (γ) to which the marginal profits are raised. For a value of γ=0 the function yields equal investments in all technologies regardless of relative marginal profits. In Figure 4-9 this would be represented by a horizontal line of IS=0.5. For $\gamma=\infty$, the function becomes a step function such that when the profit ratio is less than one the investment shares in technology 1 are zero and when the profit ratio is greater than one the investment shares in technology 2 are zero. Thus, the case where $\gamma=\infty$ yields the knife edge solution that would be characteristic of a two technology optimization model.

The generic equations used in the IA sub-model are:

$$INVN_i = TINVN*(AW_i/TAW) \qquad (4\text{-}68)$$

$$AW_i = MP_i^{\gamma} \qquad (4\text{-}69)$$

$$TAW = \sum_i AW_i \qquad (4\text{-}70)$$

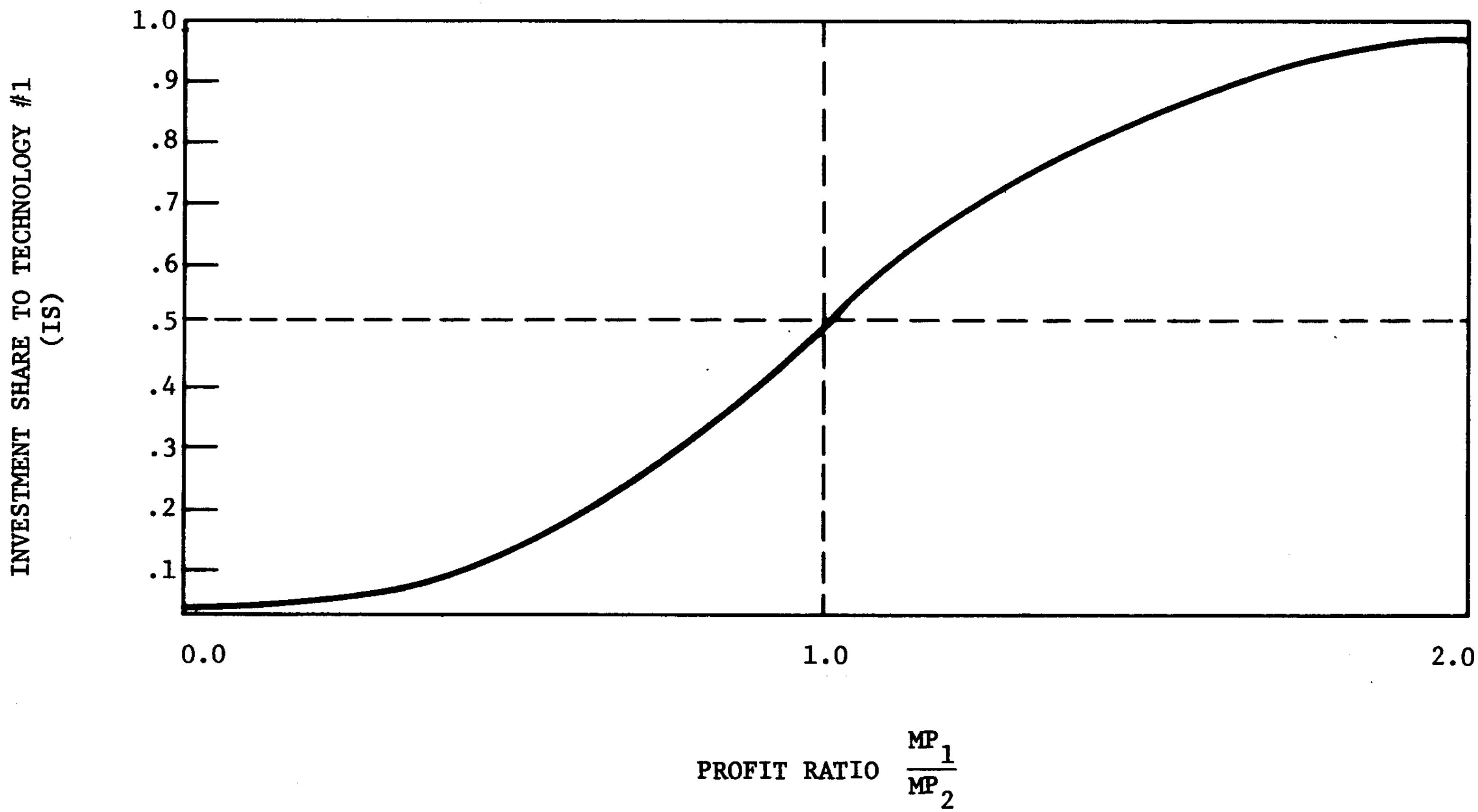


FIGURE 4-9
ILLUSTRATIVE INVESTMENT ALLOCATION FUNCTION

$$MP_i = ACP_i - MCST_i \quad (4\text{-}71)$$

$$MCST_i = MCCT_i + MOMC_i + MLCT_i \quad (4\text{-}72)$$

$$MCCT_i = ACC_i * GRM_i * (1+RSKF_i) \quad (4\text{-}73)$$

where:

$INVN_i$ = investments in new capital by technology ($/year)

AW_i = investment allocation weight by technology

TAW = total of investment allocation weights

MP_i = marginal profit by technology ($/ton)

$MCST_i$ = marginal cost by technology ($/ton)

$MCCT_i$ = marginal capital cost by technology ($/ton)

ACP_i = average coal price "facing" each technology ($/ton)

$MOMC_i$ = marginal O&M costs by technology ($/ton)

$MLCT_i$ = marginal labor costs by technology ($/ton)

ACC_i = average capital cost by technology ($/ton)

GRM_i = growth rate multiplier by technology

$RSKF_i$ = capital investment risk factor by technology

Equation 4-69 and 4-70 indicate that the marginal profits are used to establish investment allocation weights (AW_i) for each technology. The allocation weights are computed by raising the marginal profits of each technology to the power γ. The value of γ utilized in the MITRE model was based on historical observations of the relative market shares gained by each technology and the estimated marginal profits for these technologies. A value of $\gamma = 3.0$ was utilized in the model. A sensitivity analysis on the value of γ

was performed during the development of the model. The results indicated that the output of the model was not very sensitive to values of γ that were $\pm$ 25 percent.

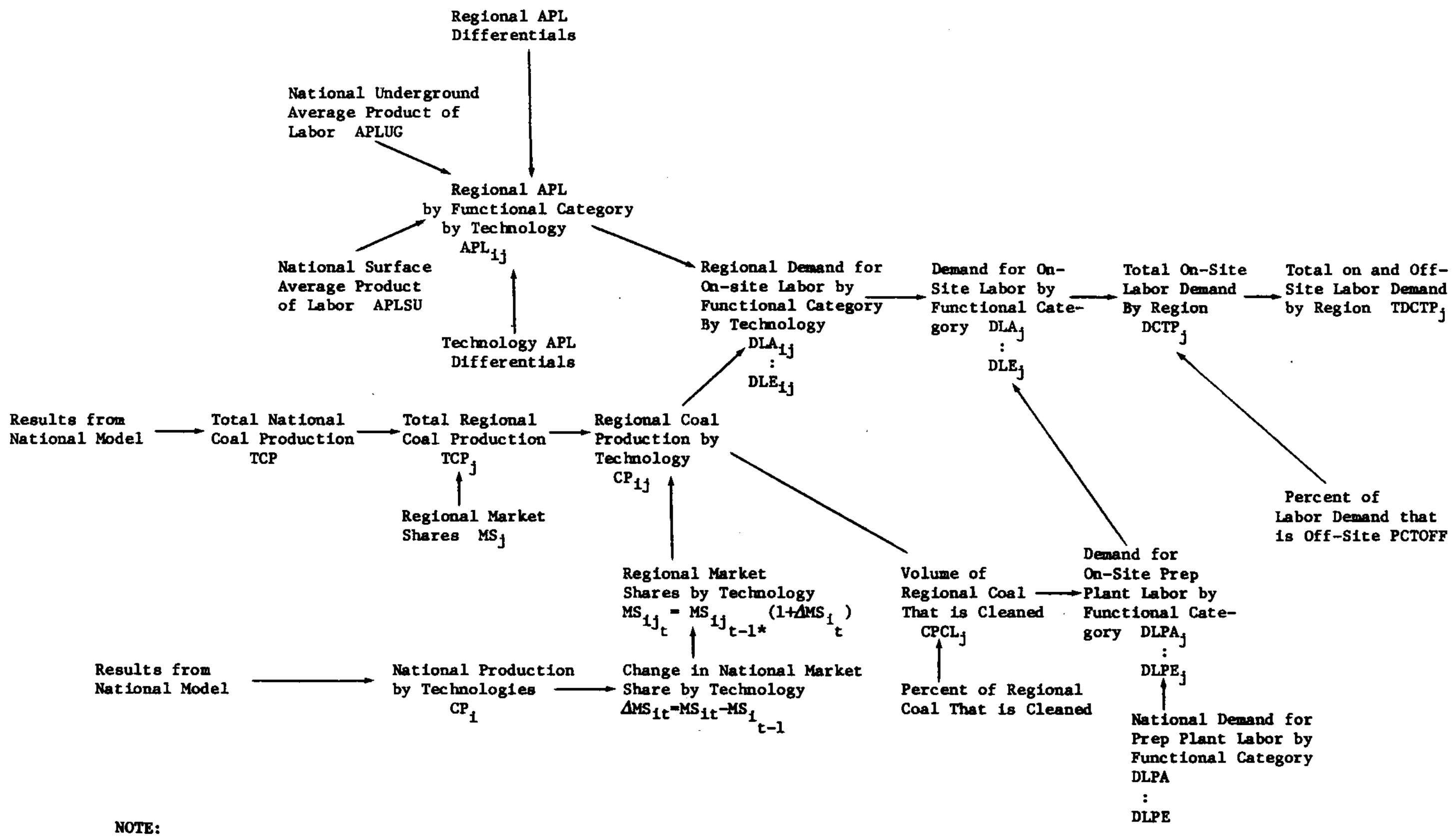
Marginal capital costs by technology were based on the average capital costs determined in the model mines data and a growth rate and investment risk factor. The growth rate multiplier (GRM) serves to dampen unrealistically high growth rates of a particular technology. The multiplier works by raising the capital costs of a technology when its growth rate places high demands on the secondary industries (i.e., equipment manufacturers) that support the technology. The data for GRM were derived qualitatively by MITRE based on discussions with industry analysts. A risk factor on capital investments was utilized to account for the greater uncertainty of investments in new technologies. In the MITRE model the risk factor was set equal to zero for all technologies except longwall mining. In the case of longwall mining the risk factor was set equal to 1.0 in 1960 and allowed to decline to 0.10 by 2000. In the case of longwall mining the allocation weight (AW) was also constrained to equal zero prior to 1962 because longwall equipment was not commercially available in the U.S. prior to that year.

4.4 Regionalization Methodology

The national coal production and labor demand results are disaggregated regionally based on a methodology incorporating regional growth rates and regional labor productivity differentials.

The regional growth rates are based on historical data for the period prior to 1980 and on the ICF scenario data (see Table 6-I) for post-1980. Regional labor productivity differentials are based on data from the Conference Board's regional productivity study (Conference Board, 1979). A summary diagram of the regionalization methodology is presented in Figure 4-10. A brief discussion of the key assumptions is given below.

The objective of the regionalization methodology is to estimate regional labor demand and coal production within the constraints of the projected national labor demand, coal production, and technology growth rates. It must be emphasized that this methodology is not a regional model but an estimate of the regional disaggregation of the national model results. Total regional labor demand is the sum of on-site and off-site labor demand. The percentage of labor demand that is off-site is assumed exogenously (see Section 4.3.1). Regional on-site labor demand is determined as the sum of all on-site labor including preparation plant labor. Two key factors are necessary to determine the regional on-site labor: regional coal production by technology; and regional labor productivity by technology. The regional coal production is estimated by taking the products of total coal production from the national model and the coal production scenario estimates of the percentage of the national production originating in each region. The regional production by technologies are then based on the assumption that technology growth



NOTE:
Subscript i = technology
j = region
t = time period

FIGURE 4-10
SUMMARY DIAGRAM OF REGIONALIZATION METHODOLOGY

rates within a region are similar to the national technology growth rates. Because of the importance of this assumption, technology growth rates were exogenously input to the model for the historical period (up to 1980) and allowed to assume the growth rates determined by the model only after 1980.

Regional labor productivity was determined based on regional productivity differentials and the national estimates of labor productivity incorporated in the MITRE model. The regional productivity differentials for both deep and surface mining were developed based on historical data up through 1980 and by utilizing a recent Conference Board study for the post-1980 period. Technology productivity differentials similar to those used in the national model were then used to estimate the regional productivities by technologies. These regional estimates are only first order approximations of the regional labor productivities. However, their use in this regional disaggregation methodology yielded reasonably accurate results of regional labor demand in the historical period 1960-1978 which was replicated by the model.

5.0 LABOR SUPPLY AND WAGE DETERMINATION SECTORS

5.1 Objectives

The objectives of the labor supply and wage determination sectors of the coal extraction model are to forecast the available supplies of labor over the next 20 years by educational and experience categories pertaining to the coal industry, and to forecast the average wages paid to those supply categories in each year of that period. As discussed in Section 3.0, the supply and wage sectors of the model have been developed primarily through the use of econometric or multiple regression techniques. The period of observation and overall consistency of the time series data used in these sectors fluctuated widely among variables. Nevertheless, these data were relatively more consistent than those required in the labor demand sector. Therefore, using regression analysis in these sectors allowed the use of empirical data where available to develop a limited number of key relationships, while still maintaining the dynamic feedbacks between sectors that lend themselves to historical verification.

One of the main objectives of the labor supply sector was to forecast future graduation rates for general educational categories using historical relationships. These categories are:*

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*Based on discussions with industry and university personnel, it was felt that B.S. degree engineers could be divided into two categories - mining and other engineers - to effectively comprise the supply pool from which new coal industry engineers are drawn. Advanced degree mining engineers are forecasted separately from B.S. degree graduates in order to indicate the relative availability of future

- mining and mineral engineers (B.S. and advanced degrees as two separate categories)
- other engineers applicable to mining (B.S. degrees in mechanical, civil, industrial and electrical engineering as a single category)
- scientists applicable to mining (M.S. and Ph.D. degrees in general chemistry and biology, agronomy, geology, wildlife ecology, range management, and forestry as a single category)
- mining technicians (two-year associate degree graduates as a single category)

Available supplies of each labor category were developed by adding yearly graduation rates to base year labor supplies and then subtracting yearly separation rates, the latter estimated from previous graduation rates added to the available supply pool and averaged for each 10 year period. However, to estimate and forecast labor supplies and equilibrium wages for each labor category, employment and labor demand data by educational and experience category also had to be developed. Such data were necessary to establish the labor supply base upon which additions (i.e., graduations) and separations (i.e., deaths, disabilities and retirements) were to be calculated.

Finally, one of the key objectives of this study has been to forecast supply/demand imbalances over time, and the potential need for Federal funding to alleviate any such imbalances. Since wages in

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teachers. Professional scientists, unlike engineers, are often required to have an advanced degree, and they have been forecasted as such. Two year technicians are separated out from others in technical schools, because four-year engineering technicians are considered equivalent to B.S. degreed engineers by H.E.W. Division of Education Statistics. Graduates with less than two-year degrees are regarded as not having enough education to waive time off the miner certification requirement for supervisory positions imposed by many states.

competitive labor markets should reflect the relative availability of labor supply and demand, the wage determination sector attempts to measure the impact of changing supply/demand imbalances on market wages paid to each supply category in a given year.* Then, average wages paid by job or functional category are derived from market wages paid to engineers employed in mining, allowing for fixed variations to reflect relative responsibilities between job categories (i.e., supervisors are assumed to earn about 15 percent on the average more than technical support staff). In terms of initial estimation, however, wage rates are derived for the following labor supply categories:

- o mining and mineral engineers
- o other engineers applicable to mining
- o scientists applicable to mining
- o coal mine hourly production workers

Thus, from these four base supply wage estimations, all labor demand wages are calculated using logic similar to that described above. The rest of this section is devoted to explaining in more detail the generic relationships involved in each sector. To illustrate an application of the model logic, the example of mining engineer graduations and wage estimation is developed in Section 5.3.

*Labor supply wages are those averaged among persons with similar educational or training backgrounds such as mining engineers and other engineers applicable to mining. Labor demand wages are those averaged among persons performing similar functions, such as supervisors, technical support staff, skilled production workers, etc.

5.2 Labor Supply and Wage Determination Sector Logic

5.2.1 Generic Relationships - Labor Supply Sector

The generic relationships modeled in the labor supply sector involve the impact of key factors which influence people to become part of a discernable labor supply segment. For professional labor categories such as engineers and scientists, economic theory and past studies strongly suggest that salaries and job opportunities are two of the main factors which entice people into the formal education programs necessary to enter such labor supply pools (Fleisher, 1970) (Friedman, 1979). Salaries and job opportunities may be estimated either in absolute terms or relative to those of a competitive supply category based on appropriate theoretical considerations. However, in some cases, a proxy variable such as the growth in real gross national product per person may be used to capture the effect of increasing technical job demands where time series data for the latter are either inconsistently observed, or theoretically uncertain in terms of a competitive labor supply category.

Other factors such as personal taste, working conditions, family traditions, etc. may also be of considerable importance in influencing individuals to enter a specific academic program. However, these other factors are virtually impossible to aggregate in any meaningful way across a potential supply pool, and thus can be of little use in regression analysis.

To derive professional labor supplies from the 1960 base year, effective separation rates* for each labor category were applied based on the average working career in the given position and on average historical growth rates for the supply category in question derived from the Census Bureau data (Census #1, 1975). For each of the professional labor categories (mining engineers, other engineers and scientists), a 30 year working career as an engineer or scientist was assumed. Many of these personnel eventually become administrators and managers, which effectively removes them from the supply pool of personnel available to perform typical engineering and scientific work. The effective separation rate applied to each category was estimated for 10 year intervals by the following equation:

$$r = \frac{g}{e^{gL}-1}$$

Where:

r = effective separation rate

g = average annual growth rate estimated at 10 year intervals

L = average working career within category (assumed to be 30 years)

For non-professional labor categories, such as coal mine hourly production workers, the growth in supply is more difficult to measure.

*The effective separation rate of mining technicians, on the other hand, was taken at a constant rate of 1.0 percent per year, about half the rate of professionals. This was used because deaths and retirements would not enter into its estimation, given that the growth of technician supply is dated only from about 1970.

This is due mainly to the absence of a formal education or training program over which a definitive lag period must occur before entrance to a given supply pool occurs. Although a miner is required to receive certain MSHA approved training prior to actual work performance, this usually occurs after a company's decision to hire him, making him essentially an on-the-job trainee. Thus, to first become part of the labor supply pool for miners, some prior decision on the part of the employer is necessary to extend the job offer. Thus the supply pool of potential coal miners (i.e., those who would like to work as a miner but lack an initial job opening) is impossible to observe. Therefore, for purposes of this study the supply of coal miners is defined as:

$$SUCPW = \frac{ECHP}{1-UM}$$

Where:

SUCPW = supply of coal mine hourly production workers

ECHP* = Employment in coal industry of hourly production workers (ECCPA-ECHPE)

ECCPA = Employment in coal industry of all non-degreed on-site personnel, experienced and inexperienced, except administrative or office workers

ECNPE = Employment in coal industry of all non-degreed personal employed as supervisors and technical support staff

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*For regression purposes, ECHP was estimated by separating out non-degreed supervisors and technical support staff from historical data for the total production work force as provided by BOM/EIA, 1950-1977.

UM = Unemployment rate in mining (this is used as a surrogate for unemployment in the coal industry, as the latter unemployment data are not available over a sufficient time series; the coal industry represents slightly over half of mining employment and thus historical trends between the two measures are quite close)

Within the model, the supply of all hourly production workers consists of both experienced and inexperienced workers. Experienced workers are defined as all workers having been employed for one period (i.e., one year equals one period in the model) in the coal industry, including non-hourly personnel categories (i.e., supervisory, technical support and administrative). Thus, hourly production workers with one year's experience is a subset of the experienced worker supply category. Inexperienced workers are defined as all workers employed less than one year, and also include non-hourly employees. Thus, while all hourly production workers are considered as part of either the experienced or inexperienced labor supply pools, these pools also include non-hourly personnel as well.

Table 5-I presents the primary inputs and outputs which comprise the model's labor supply sector. The exogenous inputs in the first column represent those values which are taken historically but which are subject to variation in the sensitivity analysis. The inputs derived from other model sectors, shown in column two, are actually calculated each year within the model; however, they represent "inputs" to the labor supply sector in the sense that they are solved for

TABLE 5-I

PRIMARY INPUTS AND OUTPUTS OF LABOR SUPPLY SECTOR

Exogenous Inputs	Inputs Derived From Other Model Sectors	Outputs - Available Supplies Of:
- Real gross national product	- Mean and starting wage rates by labor supply category[a]	- Mining engineers (two categories - B.S. and advanced degree)
- Historical separation rates by labor supply category		- Other engineers applicable to mining (B.S. degree)
- Total civilian labor force	- Employment levels by labor supply category[b]	
- Mining engineers employed in non-coal mining sectors		- Scientists applicable to mining (advanced degree)
- Unemployment rates (nationally and in mining sector)		- Mining technicians (two-year graduates)
		- Experienced coal industry personnel[c]
		- Inexperienced coal industry personnel[c]

[a]Derived annually within wage determination sector

[b]Derived annually within labor demand sector

[c]Both personnel categories have explicit subset for hourly production workers

within the other two model sectors (i.e., labor demand and wage determination) and are then used as independent variables in the labor supply regression equations.

5.2.2 Generic Relationships - Wage Determination Sector

The wage determination sector is relatively straightforward as compared with the labor supply and demand sectors. The analytical basis for this sector is the estimation of four equations which solve for the average annual wages in each of the following labor supply categories:

- o mining and mineral engineers
- o other engineers applicable to mining
- o scientists applicable to mining
- o coal mine hourly production workers

As discussed briefly in Section 5.1, all other wages are derived from these four equations. For example, the average wages of supervisors and technical support staff are set respectively at 15 percent above and equal to the average salaries of mining engineers. These percentages were based on discussions with coal industry personnel and a comparison of coal industry wages with those paid, on the average, to mining engineers in other industries and in government. Many supervisors, in particular those employed at corporate headquarters, are no longer considered employed as engineers. It is therefore likely that such supervisors are excluded in the historical wage data on engineers employed in mining developed by the Engineers Joint Council (EJC #1, 1953-1978).

In the case of mining technicians, these personnel are also compensated according to the function they perform, rather than as technician graduates per se. It is assumed that many if not most technicians enter the coal mine work force as skilled hourly production workers, since a large number of mining technology students are either on temporary leave from existing jobs with coal companies, or else perform field work as part of the curriculum. In either case, such technicians would be entering the work force upon graduation and are compensated based on their function as skilled coal miners.*

Each of the four wage equations actually solves for the percentage rate of change in annual wages (expressed in nominal or current dollars) as a function of three variables: the percentage rate of change in the demand/supply ratio for that labor category, the percentage rate of change for the consumer price index (CPI), and a trend variable.** These variables were selected in order to take into consideration cost of living changes as reflected in the CPI as a major factor in annual current dollar wage increases.

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*For the purposes of this study, average earnings among hourly production workers which were compiled by the BLS (BLS #3, 1979) have been disaggregated into wages paid to skilled and semi-skilled workers, based on the distribution of such workers defined in Section 2.0 and apportioned according to BLS Industry Wage Surveys (BLS #2, 1962-76). It is estimated that, on average, skilled workers earn 10 percent more than semi-skilled workers.

**The trend variable was statistically significant in all four equations, and theoretically represents the trend toward higher real incomes when the CPI is held constant.

In measuring demand/supply balances by labor category for use in the four wage equations, some discussion is necessary regarding key definitions. The labor forecasting literature is replete with the problems of defining an engineer and scientist (NSF, 1975), (EJC #2, 1976). Even the BLS admits that using their occupational definition of engineers, between one-third and one-half of its estimated engineering manpower supply is comprised of non-graduates (EJC #2, 1976). Because of definitional inconsistencies, uncertainty is cast on any empirical measures of employment among engineers and scientists, as well as on the levels of supply and demand from which employment is theoretically derived.

In 1975, the National Science Foundation (NSF) performed a major study in which it redefined the population of engineers and scientists originally estimated from the 1970 Census. As discussed in Section 2.0, many positions labelled "engineer" and to a lesser extent "scientist" are filled by people other than degreed engineers and scientists. The NSF recognized this, and in redefining these populations, it categorized respondents based on factors including education, experience and professional identification. The NSF's redefined populations of engineers and scientists were then based on meeting two out of three criteria, including formal education, self-identification (as an engineer or scientist) and employer/occupational identification.*

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*Personal communication with Dr. James Brown, Study Director, Demographic Study Group, National Science Foundation, June 29, 1979.

In the NSF postcensal survey of engineers and scientists listed in the 1970 census, data were provided regarding employment by the degree level and discipline. Adjusting these totals to incorporate probable employment levels from the appropriate categories of 1971 graduates, degreed personnel employed in each category were estimated as percentages of the NSF engineer and scientist totals, as redefined. It was found that in 1970, degreed engineers of all types (not disaggregated) comprised about 75 percent of the redefined engineer population total, while degreed scientists applicable to mining comprised about 105 percent of the redefined scientist population total. This reflected the fact that many more scientists are employed in positions as engineers than vice versa. Given the marked trend toward advanced degree credentials required for many if not most professional scientists, it was decided that degreed engineers of all types and advanced degreed scientists were the supply pools most important to model. For scientists, advanced degree holders represented about 70 percent of the redefined scientist population.

The appropriate percentages (i.e., 75 and 70, respectively) of degreed engineers and scientists were applied to total employment for those engineering and science disciplines applicable to mining in 1960. This provided the model with initial base year labor supply pools to which subsequent graduations would add and from which separations would subtract. Taking empirically derived employment totals of engineers and scientists applicable to mining (which includes many on-the-job trainees),* and dividing them, respectively, by the above supplies of degreed personnel, one obtains a measure of the demand/supply balance for such labor categories. These measures were then applied in the regression equations for other engineers and scientists to estimate the impact of demand/supply balances on the respective wages.

Table 5-II presents the primary inputs and outputs which comprise the model's wage determination sector. The distinction between exogenous inputs and model derived inputs is the same as that described in Section 5.2.1. It should be noted that the unemployment rate in mining was not computed in the model but was varied based on the applicable scenario. This was due to mathematical problems associated with the measurement of the supply of hourly production workers apart from demand. Specifically, the supply of hourly production workers was derived by assuming appropriate unemployment rates rather than estimating such rates because their estimation at the same time as the estimation of wages (partly based on the same unemployment rates) resulted in simultaneous equation bias. In each of the three scenarios, the unemployment rate in mining is assumed to decline to a level

*MITRE derived its time series estimates of employment among engineer and science disciplines applicable to mining from the now discontinued BLS series on engineers and scientist employment in industry (BLS #4, 1973), as well as the BLS Industry/Occupational Matrix (BLS #2, 1979) and the 1970 Census. The BLS monthly series Current Population Survey (BLS #5, 1960-1979) was reviewed and rejected for this purpose due to its extremely small sample size, and its extreme fluctuations within employment for certain labor categories such as mining engineering.

TABLE 5-II

PRIMARY INPUTS AND OUTPUTS OF WAGE DETERMINATION SECTOR

Exogenous Inputs	Inputs Derived From Other Model Sectors	Outputs
- Annual inflation rate	- Labor supplies by supply categories[a]	- Market wage rates by labor supply categories
- Unemployment rate in mining	- Labor demands by demand category[b]	- Market wage rates by labor demand categories
	- Mapping of supply and demand[c] categories	- Demand/supply balance (based on mapping) by supply category

[a]Derived annually within labor supply sector

[b]Derived annually within labor demand sector

[c]Fixed system of preference hiring to meet labor demands by available labor supplies

of about 3.0 percent. This allows for a limited amount of frictional unemployment, based on the assumption of relatively steady growth overall in the coal industry over the study period. The rate of decline varies by scenario to reflect relative growth rates of coal production.

The main aspect of feedback among the three sectors is the mapping between labor supply categories by education and experience with labor demand categories by function or job category performed. The mechanism by which this mapping occurs is a hierarchical system of hiring preferences by which personnel within those educational and experience supply categories most in demand by the coal industry and which are available get first preference for any new openings by job functions. Hiring rates, in turn, affect the demand/supply balance for each labor supply category. This provides the necessary wage feedbacks for each labor supply and demand category. This process may become clearer by considering one example in some detail.

5.3 Example: Supply and Wage Estimation of Mining Engineers

The estimation of labor supply and market wages for mining engineers typifies the logic used throughout both model sectors. Figure 5-1 illustrates this logic in a DYNAMO causal loop diagram. As discussed previously, arrows indicate causal impacts of one variable or another, with plus or minus indicating a positive or negative impact. Two exogenous inputs to this portion of the labor supply and

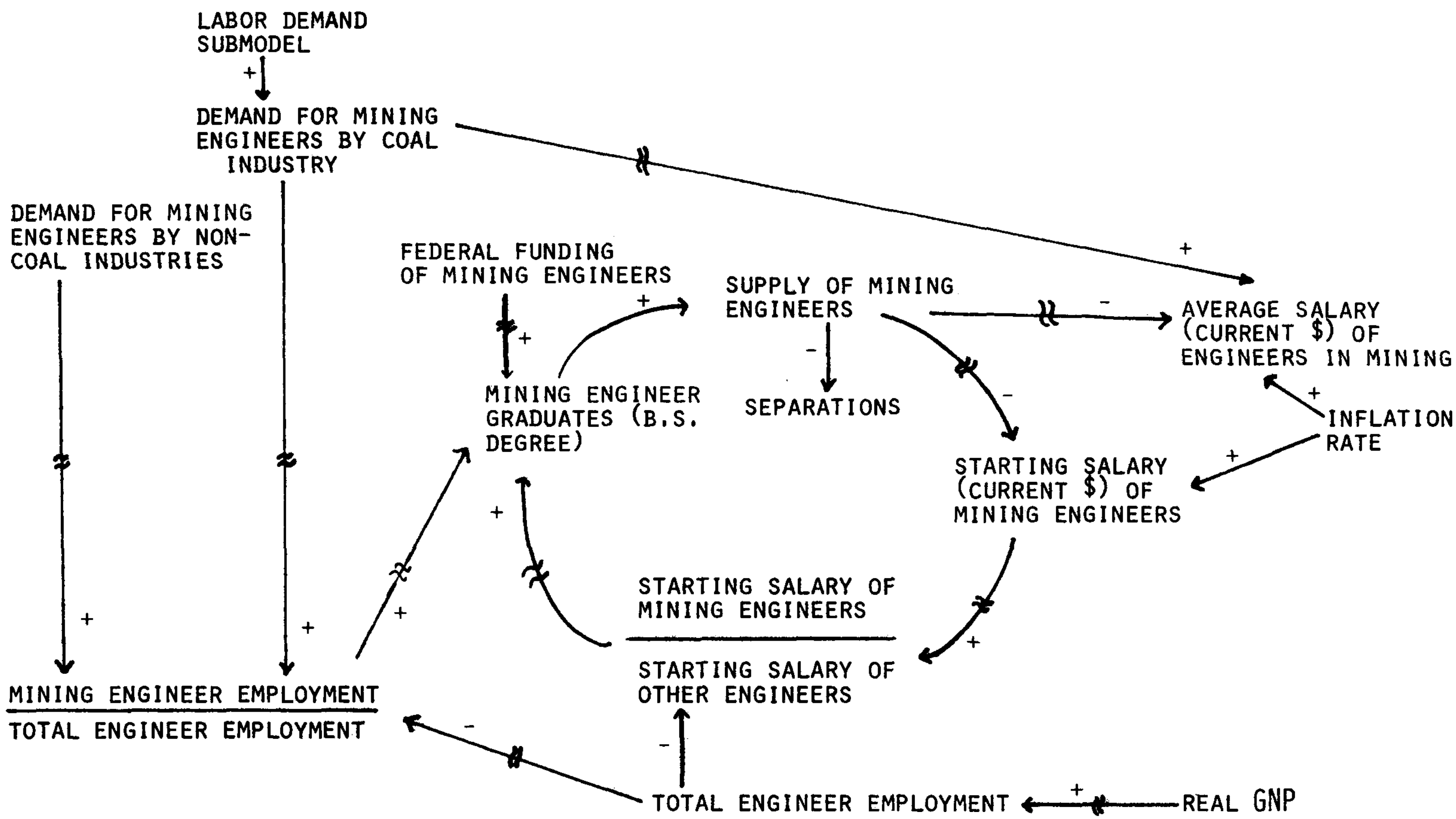

FIGURE 5-1
LABOR SUPPLY AND WAGE DETERMINATION SECTOR

wage sectors are the demand for mining engineers in non-coal industries, and real Gross National Product. In addition, the labor demand sector exerts its influence on the supply and wage sectors via its derived demand for mining engineers in the coal mining industry.

The key equation to be estimated is that of the graduation rate of B.S. degree mining engineers. Theoretically, job availabilities, starting salaries, opportunities for advancement, personal tastes, working environment, family tradition and scholarship funding are all factors which should influence prospective candidates.* Empirical data, however, were only available for the first two factors, although the future level of Federal funding under the State Mining and Mineral Resources and Research Institute (SMMRRI) program is considered to be a potentially significant variable. Both the need for and the impact of such funding on future graduation rates are estimated in the sensitivity analysis performed in this study. A detailed discussion of trends associated with mining engineering is given in Appendix B.

If the impact of starting salaries (in constant dollars) and job availabilities (in employment levels) on B.S. degree mining engineer graduates is measured through regression analysis, an inadequate explanatory relationship is obtained. A major reason for this is the inverse relationship between declining real starting salaries of

*A recent survey among mining engineering students indicates that challenging work and opportunity for advancement were of greatest importance in their attraction to the discipline, followed by steady employment and high pay (Dresher, 1978).

mining engineers throughout most of the 1970s and the graduation rate of mining engineers, which was experiencing a major resurgence over the same period. This relationship is clearly opposite what is suggested by a simplistic economic theory. Instead, a more appropriate theory suggests that salaries and job opportunities in mining engineering relative to those available in other engineering disciplines may exert greater influence on prospective students. Hence, the starting salary ratio and the engineer employment ratio (of mining relative to other engineers) were applied as regressors to explain changes in the graduation rate.

Finally, a major shift in coal industry employment occurred in the early 1970s. Implementation of the Federal Coal Mine Health and Safety Act (CMHSA) in 1970 and the Arab oil embargo in 1973-4 are considered two events which dramatically reversed the post-World War II decline in coal industry employment. The Federal CMHSA may be regarded as having given new impetus to the technology needs of the coal mining industry, placing greater emphasis on a healthier and safer working environment. The oil embargo may be seen as having extended this impetus by creating a shift in the demand for coal, and, presumably, in its derived demand for employment. Together, these events provide an argument for testing the influence of greater expected demand in terms of future employment opportunities for B.S. graduates beginning about 1975, assuming a four-year lag period before graduation with a B.S. degree.

A number of regression equations were estimated using these variables in different functional forms, with and without a dummy variable to capture the post-1974 impact of these events on the demand for mining engineers. Based on the quality of results and the absence of theoretical justification for using any non-linear form, a linear estimation of the graduation rate for B.S. degree mining engineers (GRME) was used. Results of this estimation, both with and without a dummy variable, are presented in Table 5-III. The second equation in this table, employing a dummy variable beginning in 1975, provides greater explanatory power regarding the graduation rates of mining engineers than does the first equation. As used, the second equation implies a significant incremental change in the relationship of mining engineer graduates as a function of the engineer employment ratio (EER). This relationship is discussed in Appendix B and illustrated in Figure B-2.

It should be noted that the demand/supply ratio for mining engineers (DSRME) should also indirectly impact the graduation rate, primarily through wages. Given the inclusion of DSRME as a regressor in the wage equation for mining engineers, its explicit inclusion alongside the starting salary ratio (SSR) in estimating GRME would result in a high level of collinearity. However, theory suggests that if the demand/supply ratio falls too low, the incremental effect of employment expectations captured by the dummy variable after 1975 should diminish. In keeping with the composite nature of this model,

Table 5-III

Regression Results for Estimating B.S. Degree Graduation Rate in Mining Engineering (GRME)

	Variable	Coefficient Value	t Statistic
Equation #1	C	-1742.81	-8.00
$\overline{R}^2$ = 0.795			
DW = 0.992	SSR_{t-4}	1724.28	7.819
σ = 55.6			
N = 23	EER_{t-4}	41705.7	2.744
Equation #2	C	-1386.01	-10.258
$\overline{R}^2$ = 0.932	SSR_{t-4}	1410.49	10.346
DW = 1.059			
σ = 32.1	EER_{t-4}	35819.7	4.062
N = 23	$D*EER_{t-4}$	37837.8	6.409

GRME = B.S. degree graduations of mining and mineral engineers
C = Constant
SSR = Starting salary ratio (of mining engineers to other engineers)
EER = Engineer employment ratio (of mining engineer to all engineers)
DW = Durbin-Watson statistic
σ = Standard error of regression
N = Number of observations

a table function is used in which the incremental impact of employment expectations (embodied within the dummy variable) is adjusted based on the degree of the demand/supply inbalance for mining engineers (embodied within DSRME).

Thus:

(1) EEXPF = 0 when DSRME < 1.0 (no shortage)

(2) EEXPF = 1 when DSRME > 1.8 (the average level of demand/supply ratio since 1970)

(3) 0 < EEXPF < 1 (linearly interpolated)

when 1.0 < DSRME < 1.8

where EEXPF = employment expectation factor, applied to dummy variable

In essence, this technique accomplishes the following:

- It allows for incorporation of the non-linear effect of EER on GRME (which was proven statistically significant after 1975) but in a modulated way, unlike the pure econometric approach which requires the rigid use of one or zero with a dummy variable

- It avoids having to arbitrarily decide whether or not the employment expectation factor captured by the dummy variable should be treated as permanent or temporary, allowing future demand/supply imbalances to determine the degree of its effect

Finally, applying the coefficients of the second equation in Table 5-III in the causal loop shown in Figure 5-1, B.S. degree mining engineer graduations are derived for each year. In those scenarios where the impact of Federal funding is assessed, additional students are assumed to graduate based on the 1979 constant dollar average undergraduate scholarship of $850/year,with a maximum attraction rate of 50 percent (i.e., up to 50 percent of students on scholarships are assumed to be enrolled specifically in mining engineering because of the scholarship). Thus, for every 850/.5 x 4 years = \$6800 (\$5450 in 1976 dollars), up to one additional B.S. degree graduate may be matriculated.

Following the logic of Figure 5-1, mining engineer graduates each year flow into the level of mining engineer supply, which was initialized in 1960 by the same technique described earlier for hourly production workers. This initialization was performed using the following equation:

$$SUME_{60} = \frac{ETME_{60}}{1-UM_{60}}$$

Where:

$SUME_{60}$ = supply of mining engineers in 1960

$ETME_{60}$ = employment total of mining engineers in 1960

UM_{60} = unemployment rate in 1960

However, in this case, UM was only used to establish an initial condition, after which supply and demand are estimated independently. Following 1960, supply and demand are estimated using the following equations:

$$SUME_t = SUME_{t-1} + GRME_t - SRME_t$$

$$TDME_t = DCME_t + NCDME_t$$

$$NCDME_t = DOIME_t + DUNME_t + DTSME_t + DCCME_t$$

Where:

GRME = graduation rate of B.S. degree mining engineers

SRME = separation rate of mining engineers

TDME = total demand for mining engineers nationally

DCME = demand in coal industry for mining engineers (derived from labor demand rates)

NCDME = Total non-coal industry demand for mining engineers (includes demands in universities, technical schools, consulting firms and other industries or DOIME)

DOIME = demand in other industries for mining engineers (includes demand in metal mining, non-metal mining, petroleum and natural gas, construction, manufacturing, transportation, wholesale, finance and government - all exogenous)

DUNME = demand in universities for mining engineers (derived from labor demand sector based on a desired faculty-student ratio of 20 to 1 among staff available for teaching, i.e., excluding full time equivalent research faculty)

DTSME = demand in technical schools for mining engineers (derived from labor demand sector based on desired faculty ratio of 20 to 1)

DCCME = demand in consulting firms for mining engineers to support coal industry (derived from labor demand sector based on five percent of investment funds for consulting support, with demand for mining engineer direct labor a function of surface/underground split)

Next, average wages in current dollars for mining engineers* was estimated in double log format (as wage changes usually are based

*Historical wage data were derived from the series: Professional Income of Engineers (EJC #1, 1953-1978). Wage data actually apply to all engineers employed in the mining industry rather than specifically by degree. However, over the historical period, mining engineers comprised a considerable majority of engineers employed in all mining sectors, accounting for about 60 percent of all engineers in the sector as of the 1970 Census. Furthermore, according to industry spokesmen, this differential is narrow to begin with (usually 5 to 10 percent greater for mining engineers at first). It then tends to narrow if not disappear over time as job achievement and similar responsibilities tend to exert greater influence on average wages of engineers in mining. In using the historical data, therefore, the average wage of engineers in mining is assumed equal to the average wage of mining engineers.

on percentages) as a function of the demand/supply ratio for mining engineers nationally and the consumer price index, each lagged one period. Results of this estimation, both with and without a trend variable are presented in Table 5-IV. As may be seen, the significance of the trend variable implies that it should be left in the final equation. This variable separates out the impact on wages of the overall trend (Tr) toward higher nominal wages among mining engineers, apart from the impacts of changes in living costs (CPI) or in the labor demand/supply balance of mining engineers (DSRME).

Finally, increasing average salaries of mining engineers has a positive impact on starting salaries. Estimating changes in starting salaries as a percentage of average salaries of mining engineers is impossible to measure directly from the published data, which only relate salaries based on years experience since earning a B.S. degree. However, with minor fluctuations, starting salaries for mining engineers since the early 1950s have averaged about 60 percent of the salaries earned by mining engineers with 20 years of experience*.

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*Published data were unavailable regarding the age distribution of engineers employed in mining (much less mining engineers by discipline), or for the true arithmetic mean wages paid to engineers employed in mining. Given median wage data based on years employed since receiving a B.S. engineering degree (EJC #1, 1953-1978), such median data for those persons with 20 years experience were used in this study as historical "average" wages for mining engineers and as "average" wages for other engineers.

Table 5-IV

Regression Results for Estimating Current Dollar Annual Wages for Mining Engineers (WRME)

	Variable	Coefficient Value	t Statistic
Equation #1			
$\bar{R}^2$ = 0.949	C	4.45688	5.088
DW = 0.546			
σ = 0.0769	ln $DSRME_{t-1}$	0.90161	2.091
N = 17			
	ln CPI_{t-1}	1.10733	6.001
Equation #2	C	7.4371	9.367
$\bar{R}^2$ = 0.979	ln $DSRME_{t-1}$	0.34929	1.236
DW = 1.021			
σ = 0.0464	ln CPI_{t-1}	0.29181	1.484
N = 17			
	Tr	0.04492	5.035

WRME = Annual current dollar wage rate of mining engineers
C = Constant
DSRME = Demand/supply ratio of mining engineers
CPI = Consumer price index
Tr = Trend variable (i.e., year 1=1, year 2=2, etc.)
σ = Standard error of regression
N = Number of observations

Hence, a constant ratio of 60 percent is used to derive starting salaries from the average salaries of mining engineers which are estimated each year in the wage determination sector.*

Following the link between average salaries of engineers in mining and the starting salary of mining engineers, the causal loop system closes, with the continuous estimation of supply and wage levels of mining engineers based on all of the factors discussed above. We emphasize that the annual wage levels derived in this example represent market wages applicable to a given labor supply category (mining engineers). Throughout the wage sector, wages are combined in various ways, based on hiring practices and industry preferences, to arrive at wages paid by function or demand category. This distinction is significant in that any shortage of labor must be based on some unsatisfied demand for labor services that are characterized by common educational, experience, or skill backgrounds. Thus, labor imbalances result from the mapping of labor supply and demand categories discussed earlier. It makes little sense to identify a shortage of production supervisors per se, since promotion

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*Based on similar logic in using EJC data the starting wage for all engineers was assumed to be about 52 percent of "average" wages for those with 20 years of experience. Since historical data for average wages of other engineers applicable to mining does not exist, such wages were assumed to be the same as wages paid to all engineers. This assumption appears quite reasonable in light of the fact that the "other engineer" disciplines (i.e., mechanical, civil, industrial and electrical) regularly comprise over two thirds of the graduates and based on independent verification using College Placement Council data (CPC, 1960-1979), the starting wages of "other engineers" deviated less than five percent from those of all engineers.

from within the work force can always ensure the mere filling of an available supervisory position. However, a derived demand for degreed mining engineers as some percentage of the non-hourly work force can, when measured against supply, be translated into a time specific shortage of available mining engineers. Therefore, only through an appropriate mapping of labor supply and demand categories can potential shortages or surpluses by education, experience, or skill type be adequately identified.

The detailed example regarding mining engineers was intended to illustrate how the model logic and available empirical data were utilized within the labor supply and wage determination sectors to estimate regression coefficients. By combining these sectors with the derived demand and engineer design/investment decision components of the labor demand sector, a composite system dynamics/econometric model is obtained.

6.0 MODEL ASSUMPTIONS

6.1 Coal Demand and Selling Price Estimates

The primary objectives of this study were to assess supply/demand adequacy by coal mining labor category under various conditions, and to evaluate the need for Federal educational and training programs to ensure a sufficient manpower supply. In developing a model capable of addresssing these objectives, consideration was first given to the probable range of future coal demands through 2000. Following a review of numerous coal-specific and general energy models, (MITRE, 1979), three initial coal demand cases were developed to bracket this probable range over the next two decades. These coal demand cases were based on three scenarios which have been used in several recent studies prepared for Federal agencies. Tables 6-I and 6-II present the regional coal demand and selling prices assumed in the three cases. The underlying demand scenario assumptions were specified by DOE (ICF #1, 1978) for the purpose of testing the impact of key economic and regulatory factors on regional coal production trends. It should be noted that the five coal supply regions presented in Tables 6-I and 6-II are the ones used for the MITRE mining manpower model. Since DOE's projections only went through 1990, subsequent projections were derived by using a later study, (ICF #2, 1978). In that study, only the medium scenario was projected through 1995, with a number of different SO_2 standards affecting the regional allocations of an essentially constant national

TABLE 6-I

REGIONAL COAL DEMAND CASES (10^6 TONS)*

Supply Region	1977 (actual)	1985 Low	1985 Medium (Base)	1985 High	1990 Low	1990 Medium (Base)	1990 High	2000 Low	2000 Medium (Base)	2000 High
Northern Appalachia	173.0	208.6	213.0	223.4	194.0	225.3	253.3	291.3	338.2	380.2
Southern Appalachia	216.7	218.3	226.6	231.1	202.2	220.0	225.4	303.7	330.3	338.5
Interior-Gulf	163.2	249.3	272.7	282.0	336.1	402.2	441.0	515.2	604.1	662.4
Northern Great Plains Northwest	91.4	249.3	331.9	378.6	298.5	555.2	803.8	437.8	833.8	1207.1
Rocky Mountains	43.4	64.6	72.1	73.1	83.6	118.3	133.0	125.5	177.6	199.6
	687.7	990.1	1116.3	1188.2	1114.4	1521.0	1856.5	1673.5	2284.0	2787.8

*All cases for 1985 and 1990 are taken directly from the three scenarios of the same name developed by ICF, Inc., in _The Demand for Western Coal and Its Sensitivity to Key Uncertainties_. All cases are projected to 2000, using the annual growth rate of the medium scenario from 1990 to 1995 as presented in ICF, Inc., _Further Effects of Alternative New Source Performance Standards for New Coal-Fired Power Plants_. The five coal supply regions represent aggregations of the 11 PIES regions used by ICF, Inc. which in turn are aggregations of the 23 U.S. BOM Coal Mining Districts. These five regions are presently employed by the Energy Information Administration in its Bituminous Coal and Lignite Distribution Series.

TABLE 6-II

REGIONAL AVERAGE F.O.B. SELLING PRICES BY COAL DEMAND CASE ($1976/TON)

Supply Region	1977 (Actual)	1985 Low	1985 Medium (Base)	1985 High	1990 Low	1990 Medium (Base)	1990 High	2000 Low	2000 Medium (Base)	2000 High
Northern Appalachia	22.73	18.28	20.36	22.02	21.61	24.31	26.60	24.73	27.84	30.54
Southern Appalachia	24.88	23.96	25.98	28.49	26.92	29.06	31.36	32.64	35.17	38.09
Interior/Gulf	15.32	15.44	15.55	17.08	17.78	19.39	20.72	21.85	24.03	26.56
Northern Great Plains/ Northwest	6.64	9.04	10.44	10.93	9.39	9.73	9.88	12.02	12.50	12.75
Rocky Mountain	13.81	18.05	19.72	21.16	16.56	17.75	19.09	22.87	25.23	27.77

production total. As the annual growth rate of this scenario changed sharply after 1990, the annual rate between 1990-95 was applied to total production in all three scenarios over the period 1990-2000. Thus, the regional market shares <u>within</u> each case based on the corresponding scenario remain constant after 1990, while the absolute production differences <u>between</u> cases widen over the same period. This approach was considered more realistic and, hence, preferable to extrapolating individual regional growth rates, which create improbable situations in some cases (e.g., a 16 percent annual growth rate in the Northern Great Plains-Northwest region in the high case leading to 3.6 billion tons per year in that region alone by 2000).

The purpose of using three initial production cases is to provide a probable range of coal production estimates associated with various assumptions which influence the relative demands, nationally and regionally, for bituminous coal and lignite production.

The coal demand cases presented in Tables 6-I and 6-II were used for two purposes in the MITRE mining manpower model. The national totals (i.e., the sum of the regional totals) were used as exogenous inputs to specify the total coal demand in the model. Given this demand, the MITRE model thus determines the market shares captured by each of the six competing mining technologies.* The regional demand and selling price data were used to determine the percentage of the national production originating within each region and subsequently

*Conventional, continuous, longwall, contour, small area, large area.

used to disaggregate regionally the MITRE model national results. A discussion of this disaggregation procedure is presented in Section 4.4.

In further developing the exogenous inputs used in the three cases described above, other data sources were used, supplemented by discussions with officials in industry, labor unions, universities and government. Key among the other exogenous inputs used were:

- o Model coal mines - 13 deep and six surface mines with representative geologic conditions and input (i.e., capital and labor) requirements
- o General economic parameters - real GNP growth, unemployment rates, inflation rates, civilian labor force, employment of mining engineers in non-coal industries

As discussed briefly in section 4.0, the model mine data were expanded by MITRE through detailed discussions with industry, union and government officials from work initially performed for the Department of Energy by S. Katell (Katell, 1976, and 1978). A more detailed description of the model mines, including a disaggregation of capital and labor input factors, is provided in Appendix A.

6.2 GNP Growth Rates

In performing much of the regression analysis described in Section 5.0, historical data for general nationwide economic parameters were employed. However, to forecast labor supply and wages based on the results of regression analysis, independent variables such as lagged labor demands, real GNP and inflation must either be solved for within the overall model or provided exogenously. A decision was made to assume such economic parameters exogenously to avoid having to model the entire U.S. economy. The main source from which the exogenous variables were derived was the Bureau of Labor Statistics long range projections of employment and output by industry through 1990 (BLS #6, 1978, and BLS #7, 1979). Although the BLS has published its projections only through 1990, work has been underway to carry the projections through 2000, using the same underlying assumptions. To maintain continuity, unpublished data were obtained from BLS in which real GNP, inflation and unemployment rates through 2000 were projected.*.

In order to relate the two main sources of exogenous input data, it was necessary to merge the ICF coal production scenario assumptions with the BLS long range projections of employment and industry output. The ICF scenarios only assumed explicit growth rates in energy prices and consumption, such as in electricity demand, but these were not linked directly to any forecasts of GNP. The BLS long range base projection, on the other hand, assumes explicit growth rates in real product or output for each economic sector, such as that of electric utilities. By comparing growth rates in electricity demand first with real GNP and then with that of the electric utility sector output, some assocations between ICF and BLS forecasts and

*Personal communication with Mr. Norman Sanders, Office of Economic Growth, Bureau of Labor Statistics, June 6, 1979.

assumptions can be drawn. These comparisons are shown in Table 6-III.

In terms of the ratio of the average annual growth of electricity consumption to that of the average annual growth of real GNP, major changes have occurred. By measuring this ratio separately for the pre-and post-oil embargo periods, one sees a greater decline in electricity consumption growth relative to real GNP growth, resulting in a ratio change from 2.10 between 1950 and 1973 to 1.79 between 1973 and 1977. It is felt that the growth of electricity demand relative to real GNP will further decline in the future, as electricity demand growth continues to slow and as the economy further becomes oriented toward the production of services rather than goods. Thus, even though the ICF high electric growth scenario provides a ratio of electric consumption to real GNP growth that is closer to that of the 1973-77 period (1.40) than does the medium scenario (1.16), it was felt that the medium scenario more closely approximates the overall assumptions of the BLS long range projections.*

*The BLS long range projection for coal production assumed an average annual rate of real output growth at 4.5 percent. This compares with the ICF annual growth rates for coal output at 3.8, 6.3 and 7.9 percent, respectively, for the low, medium and high scenarios. Thus, since the BLS projection fell between the low and medium scenarios in terms of coal production growth, but closer to the high scenario in terms of the historical ratio of electricity output to real GNP, and given the uncertain nature of these relationships in the future, for the purposes of this study we applied the BLS assumptions to the medium scenario.

TABLE 6-III

AVERAGE ANNUAL GROWTH RATES OF ELECTRICITY CONSUMPTION, ELECTRIC UTILITY OUTPUT, AND GNP

			Electricity Consumption		Real Gross Output by Electric Utility Industry	Real GNP
Historical[a]	1950-73		7.8		6.53[b]	3.71
	1973-77		3.43		-0.27	1.92
Forecasted			ICF		BLS	
		Low	Medium	High		
	1975-1985	4.0	4.8	5.8	5.14	4.14
	1985-1990	3.5	4.0	4.5	5.07	3.22

Sources: EEI, 1978; ICF #1, 1979; BLS #8, 1979.

[a]Generated by electric utility industry

[b]Based on gross output of electric, gas and sanitary services sectors

Next, to develop appropriate real GNP growth rates for the low and high scenarios, we employed the ratio of electricity growth rates among the ICF scenarios for each period to gross output of the electric utility sector in the BLS projection. This was done as follows:

$$\frac{\text{Electric utility gross output growth}}{\text{Electric demand growth}} = \frac{X}{\text{(electric demand growth in ICF high and low scenarios)}}$$

where X = electric utility sector gross output growth applied to the High and Low cases.

For example, applying this formula to the High Case for the period 1975-1985, electric utility gross output growth is estimated as follows:

$$\frac{5.14}{4.8} = \frac{X}{5.8} \quad ; \quad X = 6.21$$

Taking this electric utility gross output growth for each period and for each case we were then able to infer real GNP growth rates. Again, for the period 1975-85 in the high case:

$$\frac{4.14 \text{ (BLS assumed real GNP growth)}}{5.14 \text{ (BLS assumed electric utility output growth)}} = \frac{X}{6.21}$$

X = 5.0 = real GNP growth rate assumed in high case over period 1975-1985

In developing the three cases from the coal production scenarios and the BLS projections through 2000, we assumed that real GNP growth over the period 1990-2000 was the same among all cases. The reason for this is similar to that used in assuming constant rates for regional coal production growth among all cases over the same period; that is, applying a constant growth rate to the different 1990 electric utility output levels reduces the absolute variations in output among cases which would otherwise occur by 2000. Table 6-IV presents the real GNP growth rates and levels by period in each of the three manpower model cases. As shown in this table, the difference in real GNP between the high and low scenarios by 2000 derived in this manner already results in over 20 percent variation, or almost $700 billion in 1976 dollars.

6.3 Unemployment Rates

Of the remaining economic parameters, only unemployment rates and non-coal industry employment are assumed to vary from the BLS base projection among the three manpower model cases. As the BLS explains, its unemployment rates reflect policy objectives based on a gradual achievement of a stable noninflationary long run unemployment rate of 4.5 percent by 1990. Although economists are not fully in agreement as to what such a non-inflationary, or "natural" rate of unemployment might be, most concur that it is within the range of four to six percent. Based on the commonly held assumption of some short term tradeoff between real GNP growth and unemployment rates (Gordon, 1979), the three scenarios are assumed to achieve this natural rate at different times, based on their real growth rates.

Similarly, there is likely to be some natural rate of unemployment in the mining sector. This rate has traditionally been

TABLE 6-IV

REAL GNP GROWTH RATES AND LEVELS*
BY MANPOWER MODEL CASES

	LOW	MEDIUM (BASE)	HIGH
1975 Level	1609.8	1609.8	1609.8
1975-1985 Growth Rate	3.44	4.14	5.0
1985 Level	2257.7	2414.3	2622.2
1985-1990 Growth Rate	2.82	3.22	3.62
1990 Level	2594.5	2828.6	3132.4
1990-2000 Growth Rate	2.52	2.52	2.52
2000 Level	3327.7	3626.8	4017.6

*All growth rates in average annual percent. All levels in \$1976 x 10^9.

influenced heavily by coal industry employment trends. In 1977 coal industry employment comprised almost 30 percent of total sector employment and over 50 percent when excluding the petroleum and natural gas subsectors. As discussed in section 5.0, the unavailability of published historical data concerning coal industry unemployment required the use of data on mining sector unemployment in order to derive hourly production labor supply. Based on the unemployment rate observed in mining during the oil embargo years 1973-74 of 2.9 percent (and unpublished BLS data available for the coal industry during those years of under 2.5 percent), the stable, non-inflationary rate of unemployment in mining may be assumed to be slightly higher, perhaps on the order of three percent. As with the national (U.S.) natural rate of unemployment, each case is assumed to reach the same natural rate of unemployment in mining based on relatively steady growth in coal production overall, but with its achievement at different times based on relative coal production growth rates. Table 6-V presents historical and assumed future unemployment rates nationally and in the mining sector for the three manpower model cases.

Although it is recognized that regional unemployment rates in mining are far more meaningful than national ones in terms of potential labor shortages, due to the highly localized nature of the coal mining industry, only county unemployment rates could be considered to be meaningful. Moreover, the remoteness from population centers of most mining operations and the nature of the work

TABLE 6-V

HISTORICAL AND ASSUMED FUTURE UNEMPLOYMENT RATES, NATIONALLY AND IN MINING

		UNEMPLOYMENT RATE-NATIONAL			UNEMPLOYMENT RATE IN MINING		
Historical	1950		5.3			6.7	
	1955		4.4			9.0	
	1960		5.5			9.5	
	1965		4.5			5.3	
	1970		4.9			3.1	
	1975		8.5			4.0	
		Low Case	Medium Case	High Case	Low Case	Medium Case	High Case
Future	1980	6.2	5.5	5.3	4.0	4.0	3.8
	1985	5.6	4.7	4.5	3.5	3.0	3.0
	1990	5.0	4.5	4.5	3.0	3.0	3.0
	2000	4.5	4.5	4.5	3.0	3.0	3.0

involved have resulted in comparatively high wages paid to attract hourly production workers from distant locations as well as nearby alternative employment opportunities (Wall Street Journal, 1978), (Business Week, 1979). Without considering future employment demands and wages from all industries within the coal producing counties of a given region, it is difficult to estimate probable levels on immigration among potential production workers who may then be drawn from the work force at large. The regional analyses provided in Section 1.0 address this issue by estimating coal industry employment by case, as a percentage of the estimated civilian work force within each region's coal producing counties. Drawing civilian labor availability within these counties from Census Bureau estimates, this provides a rough measure of the pressure expected to be placed on other industry labor forces within these counties in the absence of in-migration. Nevertheless, the national unemployment rates in mining assumed in Table 6-V do provide a way of approximating the existing labor force, based on relative coal industry growth, among people who have already have some experience in mining. Furthermore, such unemployment rates are necessary to estimate the demand/supply balance for hourly production workers which is an independent variable used to derive miners wages as discussed in section 5.0.

6.4 Non-Coal Industry Employment of Mining Engineers

The last exogenous input to the model which varies by case is that of non-coal industry employment of mining engineers*. This includes mining engineers employed everywhere in the economy except those employed in universities and technical schools, as consultant support to the coal industry and those employed directly by the coal industry. (These excluded categories are all solved for via derived demand within the labor demand sector.)

Since the coal industry has historically accounted for only about a fifth of all mining engineers employed nationally, the future adequacy of mining engineers is heavily dependent on the level of demand outside of the coal industry, especially in the metal and nonmetal mining sectors. Labor demand uncertainties in these sectors appear to be at least as great as those facing the coal industry. The approach taken in this study was to derive, for each of the three cases, non-coal industry demands for mining engineers from BLS projections in each industry (BLS #7, 1979) and expected changes in mining engineers as percentages of total employment in each sector according to the Industry/Occupational Matrix (BLS #1, 1979).

The Census-derived Industry/Occupational Matrix, although undergoing revision at this time, does provide absolute numbers of

*Non-coal industry employment of other engineers and scientists is included within national employment totals derived via regression analysis. Coal industry employment in these categories is so small relative to their totals that it is easily exceeded by the standard error of the regressions.

employees by supply category working within numerous subsectors of the economy. For example, mining engineers as a percentage of total metal mining in 1970 and forecasted through 1985 is used in our non-coal industry forecasts, even though the absolute employment levels presented in the current version of the matrix are undergoing revision. Thus, BLS forecasts of total employment by industry through 1990 were applied to the percentages of total employment that were forecasted to be accounted for by mining engineers in the current matrix. In this manner total potential employment of mining engineers in non-coal industries was derived through 1990.

It should be noted that these expected employment totals for mining engineers are considered as labor demands within the model. These demands are met when the supply of mining engineers is sufficient but constitute a shortage when left unmet (presumably filled by on-the-job trainees) based on each industry's proportion of total mining engineer employment in the previous year.

To forecast mining engineers employed in non-coal industries after 1990, two techniques were employed:

- For non-mining industries, the ratio of total employment to real GNP in 1990 was assumed applicable in 2000. Thus, applying the same percentage employment of mining engineers by industry in 1985 according to the Industry/Occupational matrix we derived the absolute number of mining engineers in demand through 2000.

- For the metal and non-metal mining and crude petroleum and natural gas industries, the annual growth rates of real output from 1985-90 were applied through 2000. Next, assuming a constant level of gross output originating (value added) in each of these industries per employee (a measure of productivity*), total employment levels by industry were derived through 2000. Applying the same percentage employment of mining engineers by industry in 1985 as above we then derived the absolute number of mining engineers in demand through 2000.

The levels of mining engineers demanded by non-coal mining industries within the economy (including the anthracite industry) for the medium or Base Case are presented in Table 6-VI. Table 6-VII then presents the cumulative level of mining engineers demanded by all non-coal mining industries in the three initial cases. It is important to note that the assumptions which were used to derive the employment demands by the non-coal mining and petroleum/natural gas industries are among the key variables tested in the sensitivity analysis discussed in detail in Section 7.0. The BLS projections for the metal and non-metal mining and petroleum and natural gas industries each show small overall declines in employment from 1985 to 1990. Thus, even with slightly increasing concentrations of mining engineers within each industry, employment totals for them grow quite slowly after 1985. MITRE assumed that the total employment declines

*Constant productivity is assumed here for two reasons: First, it provides a basis for testing the sensitivity of non-coal mining industry demands for mining engineers to changes in productivity; and, by not continuing the rate of productivity growth forecasted by BLS through 1990, we avoid an absolute decline in the level of mining engineers employed in these industries after 1990. For such a decline not to occur while continued productivity increases, one would have to assume further increases in mining engineers as a percentage of total employment in these industries, which has been already projected by the BLS to increase substantially since the last empirical data (the 1970 Census).

TABLE 6-VI

BASE CASE DISAGGRFGATION OF EXOGENOUS MINING ENGINEER DEMAND IN NON-COAL INDUSTRIES[a]

	Metal Mining	Non-Metal Mining	Petroleum & Natural Gas Extraction	Anthracite[a] Coal Mining	Construction	Manufacturing (including petroleum refining)	Transportation	Wholesale	Finance	Professional[b] Services To Non-Coal Mining	Government - All Levels	Demands by Non-Coal Industries (including Government)	Total[c] Mining Engineers Demanded
Historical Employment													
1970	1500	520	500	(20)	80	310	30	80	20	250 (490)	600	3910	(5100)
Forecasted Demand													
1980	2400	590	990	10	100	280	20	130	30	290	640	5480	N/A
1985	2670	700	1050	10	110	300	20	140	40	330	680	6050	N/A
2000	3010	850	1100	10	120	320	20	140	40	440	700	6750	N/A

[a]Anthracite industry demand separated out based on same proportion of mining engineer demand to total work force as in bitumimous coal and lignite industries.

[b]This includes consulting support to non-coal mining industries. Census employment estimate of 490 in 1970 includes consulting support to coal industry as well, but this was separated out as function of coal investment.

[c]Total exceeds non-coal industry demand by sum of demands for mining engineers in bituminous coal and lignite mining, universities, techical/ vocational schools, and consulting support to the coal industry. 1970 total demand shown for comparison based on empirical data and not derived within model.

TABLE 6-VII

EXOGENOUS MINING ENGINEER
DEMAND IN NON-COAL
MINING INDUSTRIES
BY CASE

YEAR	LOW CASE	BASE (MEDIUM) CASE	HIGH CASE
1980	5400	5480	5530
1985	5630	6050	6530
1990	5500	6000	6640
2000	6150	6750	6710

in these industries would be gradually reversed after 1990, based on proportional allocation of new employment to existing sectors of the economy. In contrast, several sensitivity analyses were carried out to test the impacts of changes in assumptions made about non-coal industry demand for mining engineers. Included among them are the results of a long range planning survey among the majority of mining companies which provide a probable upper bound on mining engineer demand barring major unforeseen events (see Analysis #4 in Section 7.0.)

7.0 PARAMETERS FOR SENSITIVITY ANALYSIS

It should be noted that the three coal production cases presented in the previous Section were developed by merging together and extrapolating from the ICF scenarios and the BLS long range projections. Of necessity, this required the incorporation of numerous assumptions which individually may be tested for their impact on labor supply/demand imbalances. Rather than accepting or rejecting each assumption separately, an attempt was made to assess the sensitivity of the analytical results obtained from the model to changes in these assumptions, individually and in meaningful combinations. In this way, both those sets of conditions under which manpower shortages are likely to occur and conditions under which the need for Federal funding may be at its greatest are identified.

In the remainder of this Section, each sensitivity analysis is briefly described in terms of how its assumptions differ from those of the initial cases and what potential changes in labor supply or demand are expected as a result of thse difference in assumptions. Many of the sensitivity analyses are designed to specify conditions under which certain labor demands increase, particularly for mining engineers, as the three initial cases indicate that no such labor shortages are likely (see Section 1.0). All modifications of assumptions apply to the Base Case unless otherwise specified.

7.1 Analysis #1: Constant Productivity

One of the key assumptions required in projecting mining engineer demand in non-coal mining industries is that of productivity, i.e., real gross output (in constant dollars) per employee. Rather than using the BLS projected increases in productivity through 1990 for each of the three non-coal industries which comprise the mining sector*, we instead assume constant productivity at the 1978 levels through 2000. Left unchanged are the BLS projected increases from 1970-85 of mining engineers as percentages of total employment in each industry.** The result of this assumption of constant productivity was to increase the exogenous mining engineer demand among the three industries, and therefore increase the total exogenous demand for mining engineers. This demand rose by 2,000 within the three industries alone, from 4,960 in the base case to 7,540, an increase of over 50 percent. Total exogenous demand for mining engineers rises by almost 40 percent to 9,340 by 2000.

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*Metal mining, non-metal mining and quarring, and crude petroleum and natural gas extraction.

**These percentage increases are as follows: 1.6 to 2.3 in metal mining; 0.5 to 0.8 in non-metal mining and quarrying; and 0.18 to 0.21 in crude petroleum and natural gas (BLS #1, 1979). It should be stressed that these percentages refer to positions which are considered engineering rather than purely managerial or sales oriented. The 30 year career life as an engineer assumed in the separation rate equation embodies the concept of advancement in which many degreed mining engineers are no longer considered engineers but managers, executives, etc.

7.2 Analysis #2: High Non-Coal Mining Engineer Demand

One of the primary reasons for performing this study was to assess the demand for mining engineers by the coal industry independent of that demand by other industries. To establish a probable upper bound on the level of future mining engineer demand in the non-coal mining industries, the results of a recent comprehensive mining company survey were used (Johnson, 1978). The 1977 Mineral Industry Manpower Survey conducted by the American Mining Congress (AMC), covered 87 companies engaged in all types of metal and non-metal mining, including coal, but excluding petroleum and natural gas extraction.* While the respondents represented less than a majority of AMC membership, they represent approximately 80 percent of the employers and perhaps 60 percent of the mining engineers likely to be demanded, based on the disproportionate exclusion of small companies having greater relative preference for mining engineers.** The survey indicated that over the period 1978-87, about 4,000 new mining engineers would be demanded by the mining industry, 2,100 of which would be in non-coal mining. Since coal industry demand is derived within the manpower model, we incorporated only those positions forecast for the non-coal (i.e., metal and non-metal) industries.

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*The BLS industry classification system includes petroleum and natural gas extraction in its mining sector, but more narrowly defined as in this survey, the mining industry excludes petroleum and natural gas extraction.

**Personal communication with Mr. John Johnson, Jr., Director - Industrial Relations, Newmont Services Ltd., October 4, 1979.

This amounted to a demand for between 325 and 400 new mining engineers per year from 1978 through 1987. However, a critical consideration in deriving an exogenous demand for personnel is the distinction between new and replacement positions, based on expected separations. Given the age distribution within the mining industries, it was suggested that over 50 percent and perhaps as high as 80 percent would be replacement positions over this 10 year period. Since an effective separation rate equation was incorporated within the supply sector for mining engineers based on previous graduation rates, it was necessary only to input exogenously the demand for new positions. To be conservative in the separation assumption, and again to establish a probable upper bound on the demand for mining engineers in non-coal mining, we therefore assumed 200 new positions demanded per year up to 1985, and 250 new positions per year thereafter. As a result, total exogenous demand among all non-coal industries is assumed to rise to 10,950 by 2000, more than a 60 percent increase over the base case. Equally important, demand growth in this analysis is relatively steady, avoiding the assumption of reduced employment in non-coal mining from 1985-90 made initially by BLS and incorporated within the three initial model cases. Thus, the potential for future dislocations in the market for mining engineers due to such demand fluctuations are likely to be minimized in this analysis.

7.3 Analysis #3: Gradual Off-Site Employment Increase

In this analysis, a modification is made to the assumption in section 4.0 regarding the extent of offsite employment demands in the coal mining industry. If industry trends toward larger coal companies continue, especially the entrance of oil company subsidiaries, the percentage of total industry employment located offsite, as in corporate or regional headquarters, may be expected to increase. The reasons underlying this assumption are numerous. Most of them involve greater financial and thus, human resources available to larger companies, different management philosophies, and more comprehensive staffing to perform much of the permitting, monitoring, and related environmental, health and safety work in-house. The base case assumption of maintaining off-site employment at a constant 5.5 percent of the total work force after 1970 was based largely on a key assumption which was borne out in discussions with certain coal company officials. That is, declines in productivity after 1970 tended to cancel out, in percentage terms, the additional absolute demands for off-site employment stemming from the post-1970 growth of regulatory requirements. Whether these counterbalancing forces continue depends on several future uncertainties. Key among these are productivity trends, surface and underground production mix, the extent of new regulatory requirements, the ability of small independent operators to compete while absorbing greater per ton regulatory costs, and the inclination of various operators to perform environmental, health and safety work themselves.

To incorporate the potential impact of some combination of these considerations, off-site employment was gradually increased to almost double its present level relative to on-site employment. Thus, off-site employment is assumed to grow from approximately 5.5 percent of total industry employment at present to a full ten percent by 1990. This will affect demands for engineers and scientists of all types where these demands are derived directly as functions of non-hourly employment (which encompasses all off-site employment as a major subset). This analysis, therefore, may be expected to have a positive impact on labor demands within all non-hourly positions, and especially on the absolute numbers of professionals desired based on the supply/ demand mapping to fill these positions.

7.4 Analysis #4: Combination of Assumptions in Analysis #2 and #3

This analysis simply combines the assumptions described in Analyses #'s 2 and 3 above, regarding increased demand for mining engineers in non-coal industries and increased off-site employment demand in general. Under this analysis the potential for shortages of mining engineers, other engineers and scientists applicable to mining is expected to increase.

7.5 Analysis #5: Assumptions in Analysis #4 and Federally Funded Scholarships

Analysis #5 assumes the same market conditions as does Analysis #4, but also assumes an active role for Federal scholarship funding. The main vehicle for this funding is the State Mining and Mineral Resources and Research Institutes (SMMRRI) program, established under the Surface Mining Control and Reclamation Act of 1977. Under Title III, Section 302 of the Act, research and scholarship funding are authorized to "provide opportunity for training individuals as mineral engineers and scientists."

The initially appropriated level for scholarship funding was $160,000 to cover a three year period at each of the 22 SMMRRI. During the 1979-80 academic year, over $1 million of these scholarship funds were allocated by the 22 recipient institutes. Of these funds, about 21 percent were allocated for undergraduates, 65 percent for graduate fellowships, and 14 percent for postdoctoral fellowships. However, of the approximately $220,000 allocated to B.S. degree candidates, only 21 percent or $47,175 was awarded to 55 students in mining and mineral engineering, which as a category comprise about 60 percent of all engineers employed by the coal industry. Moreover, this $41,175 allocated to B.S. degree candidates represented only 18 percent of all scholarship funding (see Table B-13 in Appendix B for a full disaggregation of scholarship funding).

Key among the purposes of this analysis are the identification of those conditions under which scholarship funding may be needed, and of the impact that certain levels of funding may have on alleviating potential future shortages of professional personnel. In identifying a potential shortage of mining engineers under the market conditions assumed here (see section 1.0 for details), three other observations were made regarding how the impact of Federal funding could be assessed:

- The average funding level per B.S. degree mining engineering candidate among all schools was \$850 per year (\$680 in \$1976). This would remain the average funding level in constant dollars used to attract future candidates.

- The proportion of funding allocated to undergraduates as a group or to mining engineers as a discipline falls within university discretion, and therefore may be considered as variables which can change in response to market forces. The annual sum of scholarship funding, assuming Federal policy continues at the current level for at least the existing 22 SMMRRI is:

$$\frac{\$160{,}000}{3 \text{ years}} \times 22 \text{ schools} = \frac{\$1{,}173{,}333}{\text{year}} \; \frac{(\$939{,}840}{\text{year}} \text{ in } \$1976)$$

- Based on discussions with numerous university officials, between 25 and 50 percent of undergraduate students who receive scholarship funding probably are enrolled or employed elsewhere. To define a maximum possible impact of Federal funding, we assume the following:

$$\frac{\dfrac{\$850}{\text{student}} \times \dfrac{1}{.5 \text{ (attraction factor)}}}{\text{year}} = \frac{\$1700}{\left(\dfrac{\text{student}}{\text{year}}\right)} = \text{funding cost (to attract each additional student)}$$

It is assumed that attrition from the program cancels additional expenditures by reducing funding requirements over the last few years of a four year scholarship by an amount equivalent to the funds lost on dropouts. Based on the potential magnitude of the shortage forecasted under Analysis #4, a doubling of the percentage now allocated to mining engineer students among all B.S. degree candidates was assumed . Thus, within the present allocation to undergraduate students but concentrating 42 percent instead of 21 percent of scholarship funding on mining engineers, the maximum number of expected graduates which may be attributable to Federal funding is estimated as follows:

$$\frac{\frac{\$1,173,333}{\text{year}} \times .21 \times .42}{\$1,700} \approx 60$$

where .21 is the ratio of undergraduates to total funding, .42 is the ratio of B.S. mining engineers on scholarship to total B.S. candidates on scholarship, $1,173,333 is the level of current Federal scholarship programs at the SMMRRI, and $1,700 is the computed funding needed to attract an additional student. The same results could be obtained by doubling the percentage allocation to all undergraduates and keeping constant the original 21 percent allocation within undergraduate funding to B.S. degree mining engineers.

The mechanics of incorporating this assumption within the model simply involves adding 60 students per year to those attracted solely by market forces based on the equation for GRME presented in section 5.0. The initial entrance to the labor supply of these additional graduates is assumed to begin in 1983, allowing four years for matriculation.

7.6 Analysis #6: Strict Enviornmental, Health and Safety Regulations

This analysis tests the impacts of charges in the labor coefficients that are incorporated in the model mines data used in the MITRE model. The labor coefficients incorporated in the model mines data were estimated based on several factors including type of mining technology, average mine size, average seam thickness and regulatory requirements. Particular attention was given to changes in the labor coefficients as a result of changes in regulatory requirements such as those resulting from the 1969 Mine Health and Safety Act and the 1978 Surface Mining Act. The labor coefficients were thus varied through time to account for regulatory changes. In the base case, the labor coefficients for the post FY80 period incorporate estimates, made by MITRE, of the impacts of environmental and health and safety regulations on labor requirements. In Analysis #6, the post-1980 labor coefficients in each model mine were increased to assess the sensitivity of labor demand impacts on labor. The labor coefficients were increased by 2.5 percent to 20 percent depending on the labor category and mining techniques. A summary of the changes used in Analysis #6 is presented in Table 7-I.

7.7 Analysis #7: Combination of Assumption in Analysis #3 and #6 and High Coal Demand

This analysis combines the assumptions of analyses #6 and #3 with the High (rather than Base) Case. Specifically, it includes: the changed manpower and capital requirements for the model mines assumed under a stricter set of environmnental, health and safety regulations as discussed in Analysis #6; the higher off-site manpower demands and the higher demands for mining engineers in non-coal industries already combined in Analysis #3; and the High Case assumptions regarding greater coal demand, real GNP and related factors. Thus, Analysis #7 provides the maximum manpower demands of

TABLE 7-I

PERCENT CHANGE IN LABOR COEFFICIENTS USED IN ANALYSIS #6

	SUPERVISORY PERSONNEL	TECH SUPPORT PERSONNEL	ADMINISTRATIVE PERSONNEL	SKILLED PRODUCTION WORKERS	SEMI-SKILLED PRODUCTION WORKERS
UNDERGROUND MINING TECHNOLOGIES	+2.5%	+10.0%	+2.5%	+5.0%	+5.0%
SURFACE MINING TECHNOLOGIES	+5.0%	+20.0%	+5.0%	+10.0%	+10.0%

all types and, hence, the maximum likelihood for shortages, especially for mining engineers.

7.8 Analysis #8: Combination of Analysis #7 Assumptions and High Level of Scholarship Funding

Analysis #8 assumes the same market conditions as does Analysis #7, but, as with Analysis #5, also assumes an active role for Federal scholarship funding. The only difference in the application of Federal funding here vis a vis that applied in Analysis #5, is that in this case, the greater potential for a mining engineer shortage is likely to require a different allocation of Federal funding. Using logic similar to that employed in Analysis #5, but increasing the concentration of Funds allocated to undergraduate mining engineers from 21 percent to 75 percent, the maximum number of expected graduates attributable to Federal funding is estimated as follows:

$$\frac{\$1{,}173{,}333 \times .21 \times .75}{\$1{,}700} \approx 110$$

As indicated in Analysis #5, the same results could be obtained by some other allocation of funding among degree levels and funding among disciplines (e.g., 40 percent to undergraduates in general and 40 percent to B.S. mining engineers in particular). Alternatively, of course, the same result could be attained simply through more funding. Here too, the initial entrance to the labor supply of additional mining engineer graduates as a result of increased funding is assumed to begin in 1983.

7.9 Analysis #9: Combination of Analysis #3 and Higher Rate of Eastern Coal Production

In Analysis #9 the average F.O.B. selling price* facing the small and large area surface mines (which are located predominantly in the Interior/Gulf and Northern Great Plains Regions) is reduced to assess potential shifts in technology and labor demand. The reduction in price is based on the assumption that transportation premiums for Western and Interior/Gulf coals assumed in the base case** may potentially be higher. If transportation premiums increase, the average F.O.B. selling price of these coals will have to decrease in order to be competitive at the demand centers. Analysis #9 incorporates a gradual decline (from 1980 to 2000) of 10 percent in the average F.O.B. selling price facing the small and large area mines. The purpose of this analysis is to determine the sensitivity of the growth rates and market shares of each technology and the shifts in the types of labor demand as a function of the relative price and therefore relative profitability associated with each technology.

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*The derivation of the F.O.B. selling price facing a technology is discussed in Section 4.3.6.

**Base case transportation premiums are implicitly incorporated in the coal demand scenario data.

8.0 MODEL VALIDITY

Defining the concept of "validity" for the systems dynamics labor supply/demand model developed in this study is not straightforward. In assessing the validity of another energy-oriented systems dynamics model (FOSSIL 1), it has been pointed out (Masevice, 1978) that:

- Validation of a model is a subtle, complicated process for which no absolute measure of model quality exists.
- Models must be assessed on a relative scale that judges their ability to provide useful knowledge and insights into social system behavior.
- It is more relevant to think of the process of model validation as a process of assessing model utility or usefulness. A model is constructed for a specific, well-defined purpose. It is only with respect to its purpose that a model can be considered valid or invalid, useful or not useful.
- The thrust of the validation process must be twofold. First, the behavior of the assumed model structure must be compared with that of the real world system. Second, the model structure must be examined with respect to the decision-making details of the actual system it is trying to represent.

The approach taken in validating the coal mining manpower model is based on the last of these points. The historical behavior of the real world system can be used as a criterion against which to measure model behavior. The model's ability to re-create historical trends and to provide estimates of major variables should be such that the model user has confidence in its ability to forecast future trends and variables.

Even if, however, the model is excellent in reproducing historical trends, this does not guarantee that it is a good predictor of the future. For this reason, the ability of the model to provide believable forecasts under a variety of extreme conditions should also be tested. This was done in the sensitivity analysis described in Section 1.0 where returns on investment for large area surface mines were increased in the model to very high levels and where the model then forecasted a large increase in market capture for these mines. Also, extreme labor demand conditions were created by allowing a very high demand for mining engineers in the model for both the coal and non-coal mining industries. This resulted in model forecasts of a shortage of mining engineers through the 1980's. By changing both model inputs as well as the assumptions embedded in the model's logic, the resulting model behavior i.e., its output, can be observed as a function of these changes. One can then compare this behavior with that expected of the actual system and can if necessary, trace this behavior back to the causal relationships in the model's logic to see if the model can replicate the cause and effect relations evidenced in the real world.

The ability of the model to reproduce historical trends in the coal extraction industry for the period 1960-1978 is considered to be crucial to developing confidence in the model's structural relationships and thus in the validity of these relationships in forecasting future trends. It has been pointed out in Section 3.0 that the nature of the model is such that using 1960 base year data, it iteratively computes the values of variables for subsequent years, given the causal relationships in its logic. The model makes relatively little use of time-series data in estimating these variables for the 1961-1978 time period. If this were the case, it would not be a test of model validity to reproduce history in its output. Since the coal mining manpower model minimizes the use of time series data, its ability to reproduce historical behavior represents a rigorous test of its validity.

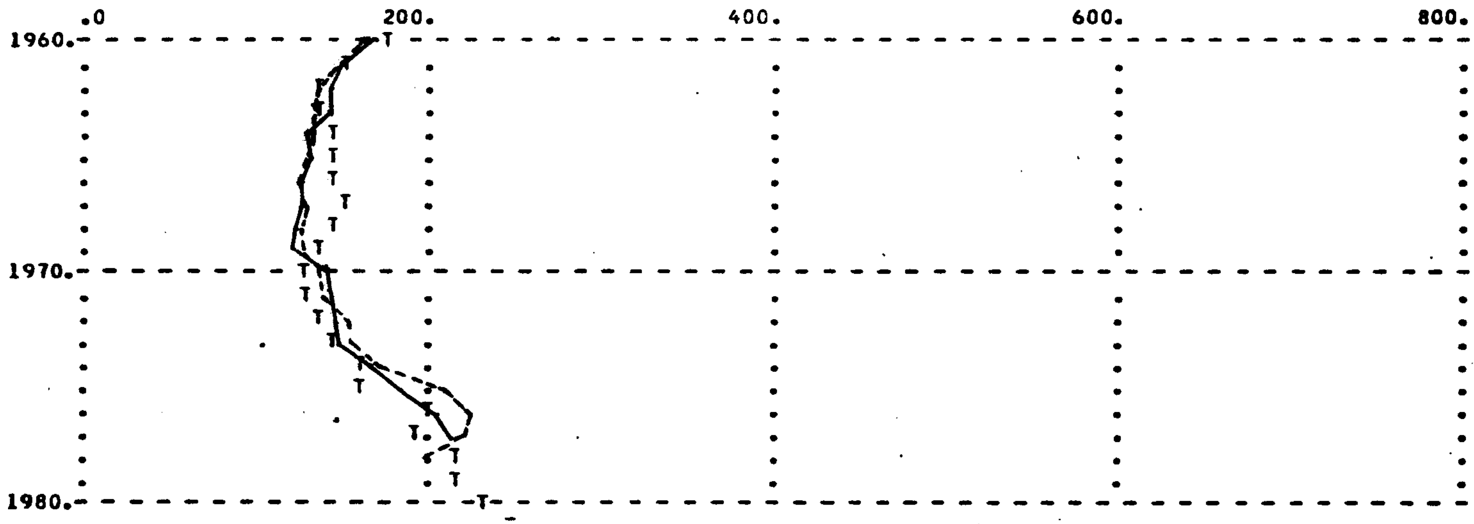
In the remainder of this section, model output is compared with historical trends for a variety of industry parameters for which such historical data are available. These outputs include total industry employment, underground and surface labor productivity, total coal production, underground production, surface production, the number of B.S. mining engineering graduates, salaries for mining engineers and wages paid to production workers.

It should be emphasized that the significance of the model's outputs lie not in their exact matching of historical data for each year represented, but in reasonably approximating these data (i.e., to be within ± 15 percent of reality). More importantly, the model should have the ability to reproduce major historical trends in its output by accurately reflecting the impact that significant changes in input parameters have on the coal production system.

8.1 Total Industry Employment

Figure 8-1 provides plots of the model's estimates of total employment in the coal industry and actual employment taken from two sources. As with the plots given in section 1.0, time is shown on

NUMBER EMPLOYED IN THOUSANDS



———: U.S. BOM/EIA, Bituminous coal and lignite distribution. Includes all employed at mine site except office workers.

-----: U.S. DOL/BLS, Employment and Earnings, United States, 1919-78. All employed at mine site.

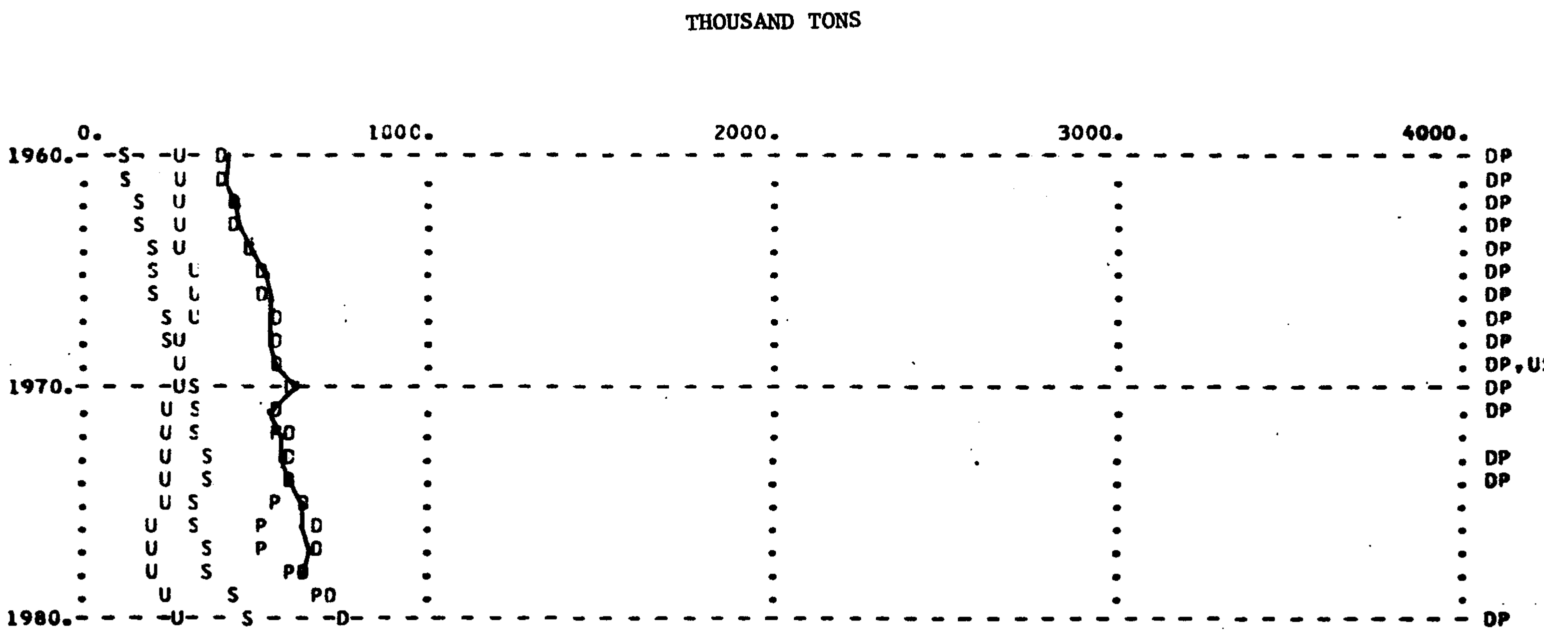
T: Model estimate

FIGURE 8-1
TOTAL INDUSTRY EMPLOYMENT

the vertical axis, increasing from top to bottom and the quantities plotted appear on the horizontal axis, increasing from left to right. The model captures the declining employment in the early 1960's, the unchanging level of employment for the rest of the 1960's and the employment increases which have taken place throughout the 1970's. Maximum differences between model estimates and reported figures are about 15 percent. It should be noted that the "actual" employment data given in Figure 8-1 are themselves inconsistent, this fact illustrating the problem of attempting to exactly reproduce in a model a quantity which in reality, is difficult to measure. The employment totals taken from BOM/EIA include all on-site employment other than office workers while the totals given by DOL/BLS include all of those employed at the mine site including office workers. Even though the latter figures should be higher than the former, for some years they are lower, indicating inconsistencies in the reporting of employment.

8.2 Coal Production

Total coal production, in thousand tons, is shown in Figure 8-2. The solid line indicates actual production while the letter "P" indicates the model's estimate of production. For those years where production equals demand the letter "D" is used instead for the model's estimate. It is apparent that for most years the model's estimates of production are very close to what had occurred with a slight overestimation of production in the mid-1970's. In this figure, it may also be seen that the model reproduced the excess of demand



P = Coal produced (model)
D = Coal demanded (model)
S = Surface production
U = Deep production

FIGURE 8-2
TOTAL COAL PRODUCTION

above what was produced in the mid-1970's following the 1973-74 oil embargo and also captured the crossover from predominantly underground to predominately surface production.

While the model reproduces the decline in undergound coal production, it underestimates this production by as much as 25 percent. This is illustrated in Figure 8-3 and is due to two factors: First, more new underground mines were built in the 1960's and early 1970's than were forecast by the model because the deep mining segment of coal industry at that time was accepting a lower return on investment than it had historically received and was operating under near-loss conditions. Second, older deep mines were kept in operation for longer time periods than the model allowed, again because of the low R.O.I. for new deep mines. Consequently, production from these mines exceeded the model's forecast. By 1978, the model's estimates were only 8 percent lower than actual production.

Finally, the model's estimates of surface production for the time period 1960-1978 are shown in Figure 8-4. The upward trend in this production is reproduced with the model estimates being within $\pm$ 15 percent of actual production.

8.3 Labor Productivity

The productivity of labor in coal mining has varied greatly since 1960, reflecting among other things, a changing technology mix, changes in the regional distribution of coal, labor unrest, and the impacts of state and Federal mine health, safety and environmental

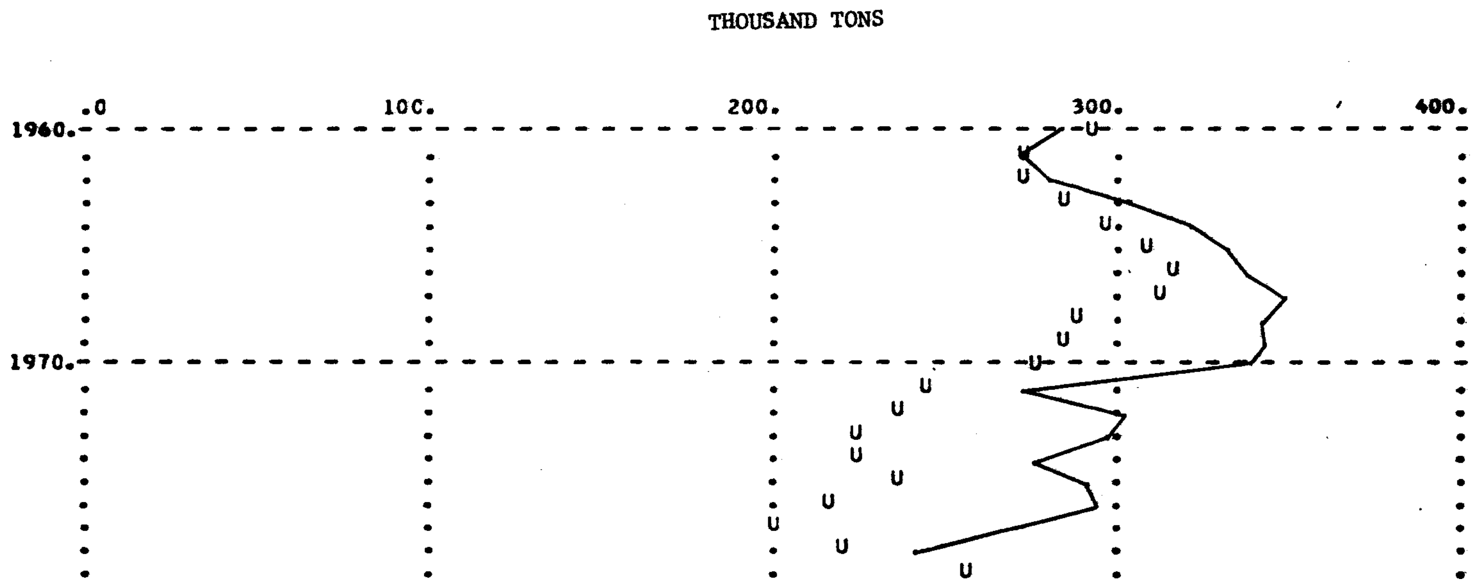


FIGURE 8-3
UNDERGROUND COAL PRODUCTION

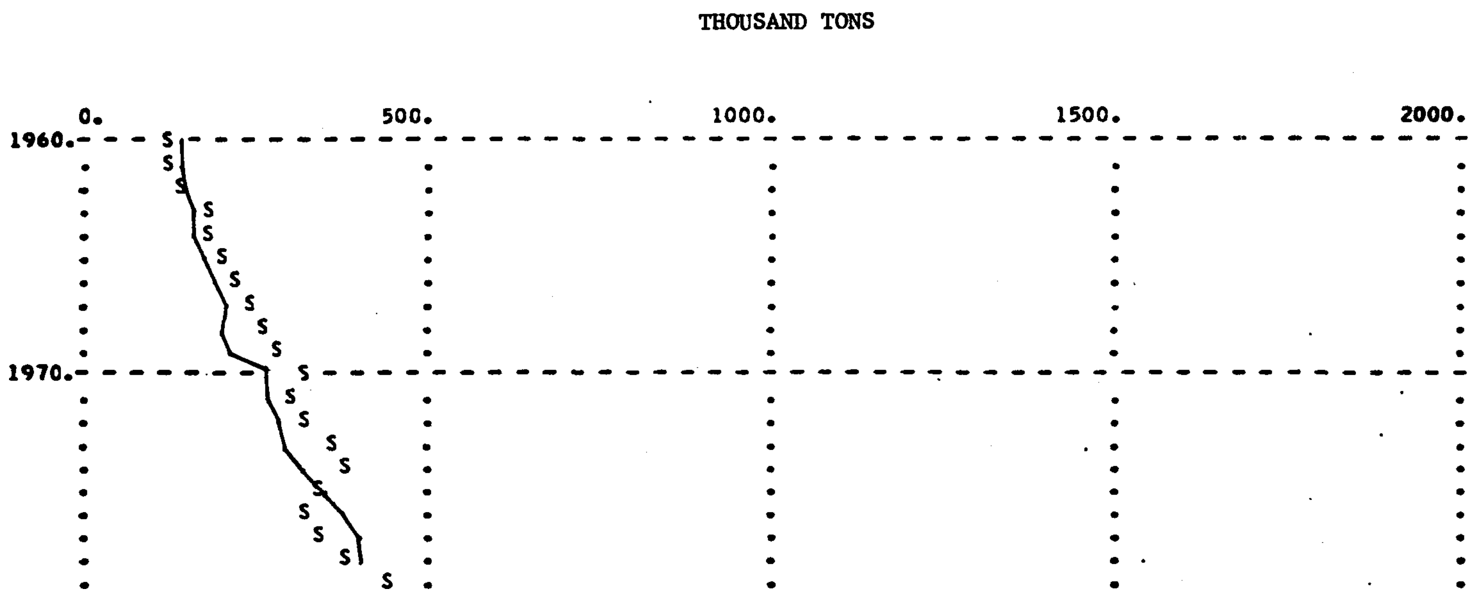


FIGURE 8-4
SURFACE COAL PRODUCTION

laws, in Figure 8-5, labor productivity for both deep and surface mines are compared with model estimates. The model reproduces the rise and fall of productivity in deep mines, including the steady decrease following enactment of the Federal Mine Health and Safety Act of 1969. The model also reflects the sharp rise in surface mining productivity throughout the 1960's followed by an equally sharp decline in the early 1970's as various state surface mining reclamation laws took effect. While the model overestimates the size of the decline by about 30 percent in the mid-1970's, by 1978 the difference between estimated and actual productivity is only slightly greater than one ton per man day.

8.4 Wages and Salaries

As both the demand for coal and the average skill levels of production workers have increased, so have production worker wages. This is illustrated in Figure 8-6 which shows model estimates of these wages (in 1976 dollars) using the "$" symbol and actual wages using the solid line. It can be observed that over the entire period the model has closely matched the actual changes in these wages, which have increased by about 70 percent in real dollar terms.

Also shown in Figure 8-6 are the model estimates of the supply and demand for production workers. It can be seen that the supply surplus which existed through the 1960's is reproduced, followed by the excess of demand over supply in the mid-1970's and then in turn, the re-emergence of a supply surplus in the late 1970's as coal markets softened.

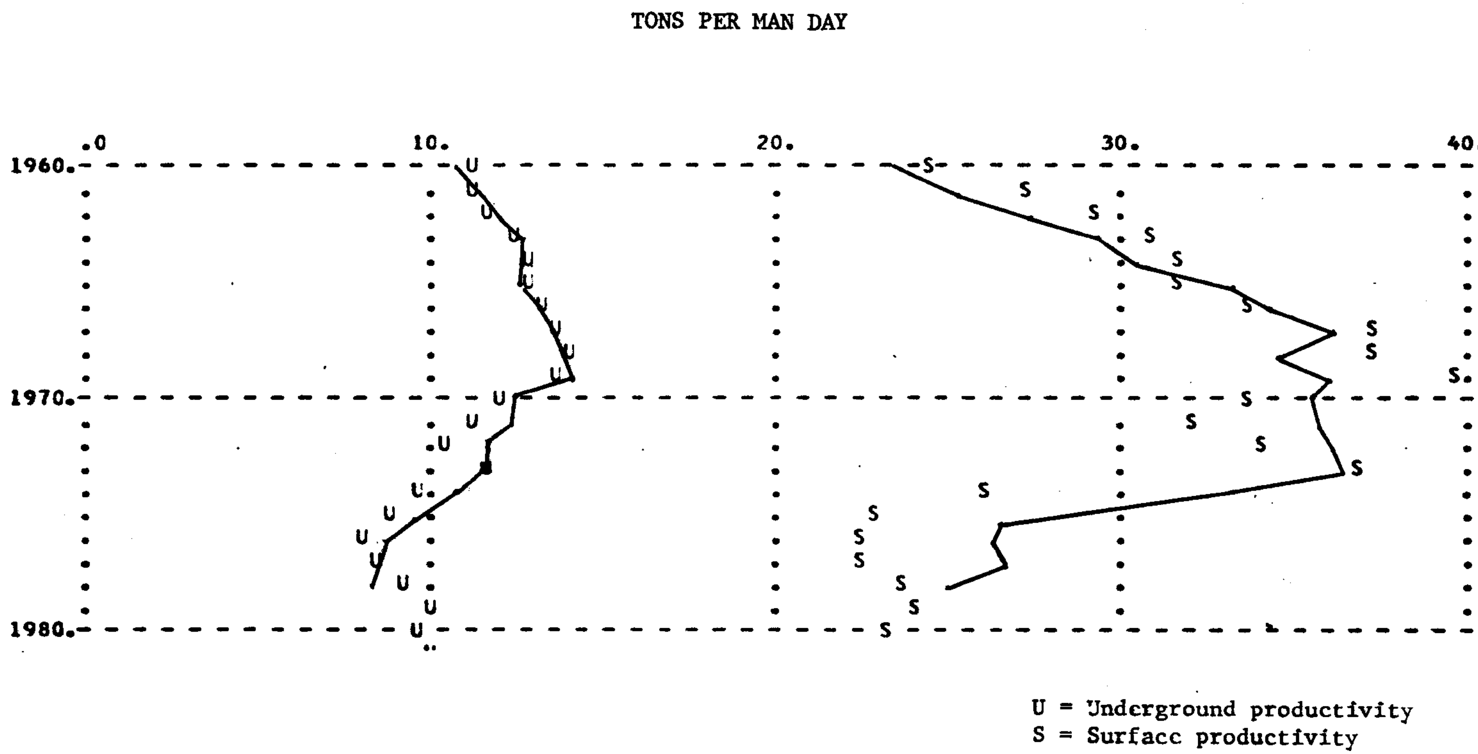
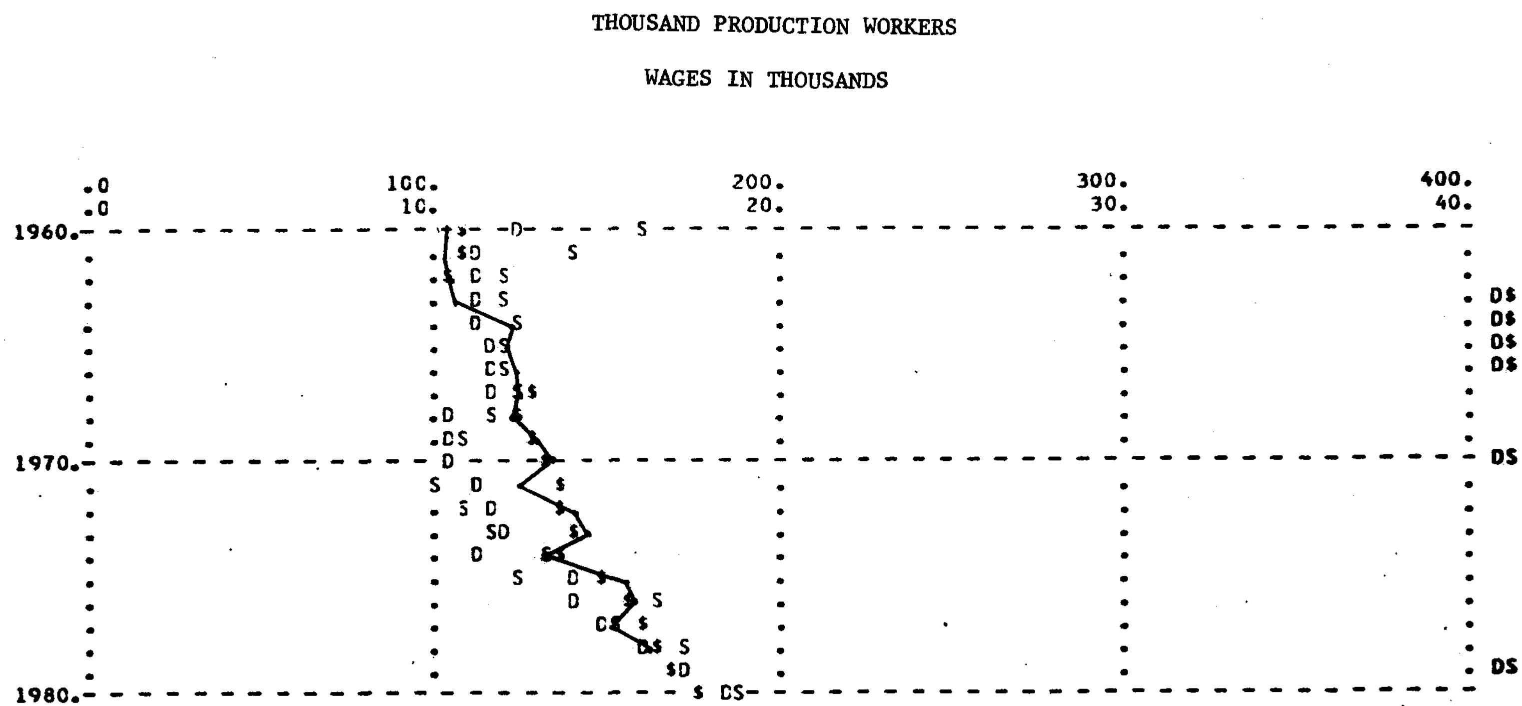


FIGURE 8-5
LABOR PRODUCTIVITY



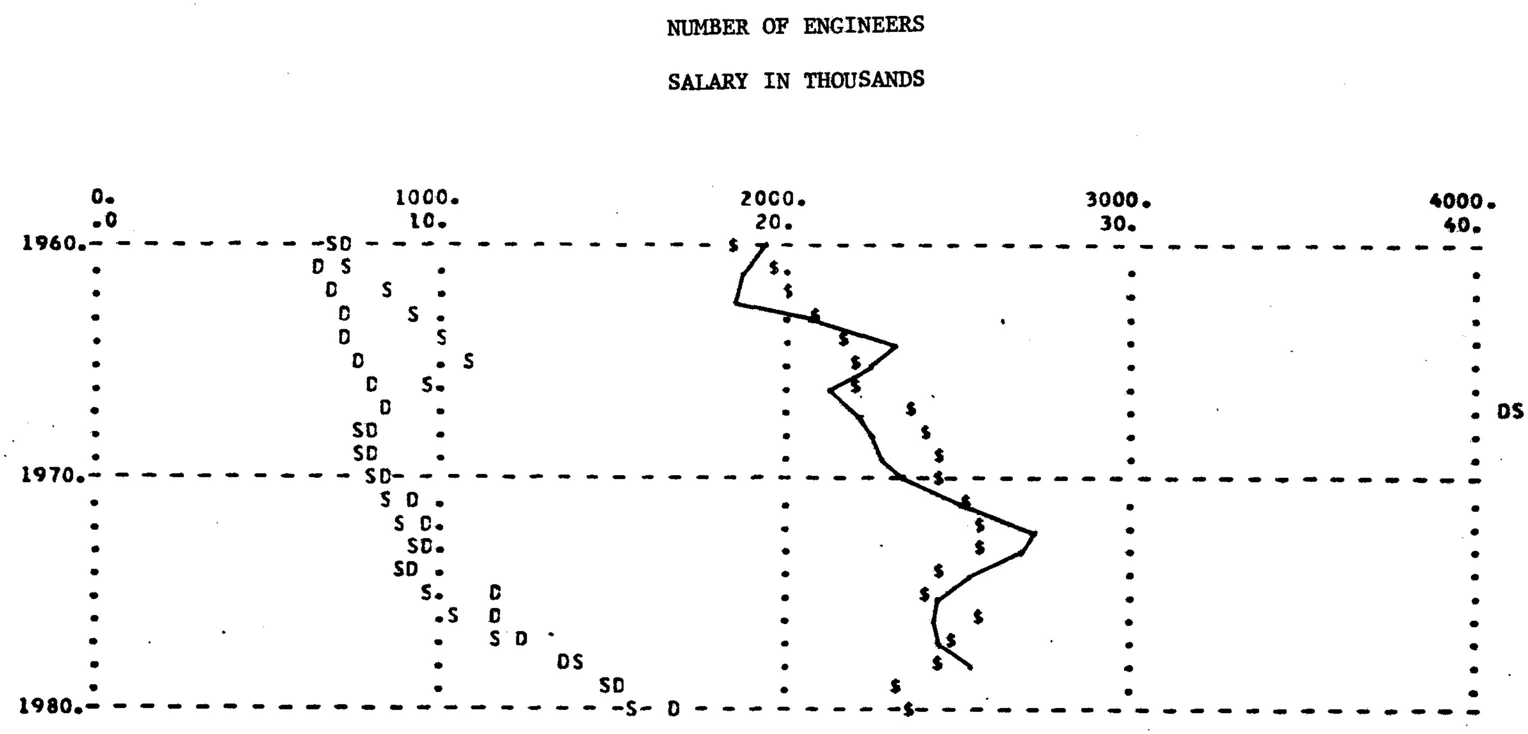
$ = Wages in thousand dollars per year (1976 dollars)
D = Demand for production workers
S = Supply of production workers

FIGURE 8-6
WAGE RATES FOR COAL PRODUCTION WORKERS

Trends in salaries for mining engineers are also reproduced by the model as shown in Figure 8-7. The model's salary estimates, as shown by the "$" symbol, (given in 1976 dollars) deviate from actual salaries, as shown by the solid line, by no more than 7 percent over the 18 year period reproduced. Figure 8-7 also gives the model's estimates of the supply/demand status of mining engineers over this time period. In the model, a supply surplus in the 1960's gives way to an excess of demand over supply by the early 1970's, this latter situation persisting through the late 1970's. This approximates actual trends in mining engineer supply and demand over this period.

8.5 Mining Engineer Graduates

In response to higher salaries and perceptions of increased job opportunities, enrollments in B.S. degree mining engineering programs at universities offering such programs have greatly increased. The number of graduates of such programs have also increased, from about 150 per year in the mid-1960's to over 600 per year in the late 1970's. This trend is shown in Figure 8-8 where actual historical graduations are given by the "H" symbol. Also in this figure, the model's estimates of graduations are given by the "C" symbol. These estimates are close to the historical figures for the early 1960's, drop considerably below actual graduations in 1964 and 1965, and then increase, as do actual graduations through the 1970's. While for some years, (1972, 1975, and 1976) the model overestimates graduations, in years subsequent to these, the graduations closely match



$ = Salary in thousand dollars per year (1976 dollars)
S = Supply of mining engineers
D = Demand for mining engineers

FIGURE 8-7
ANNUAL MINING ENGINEER SALARIES

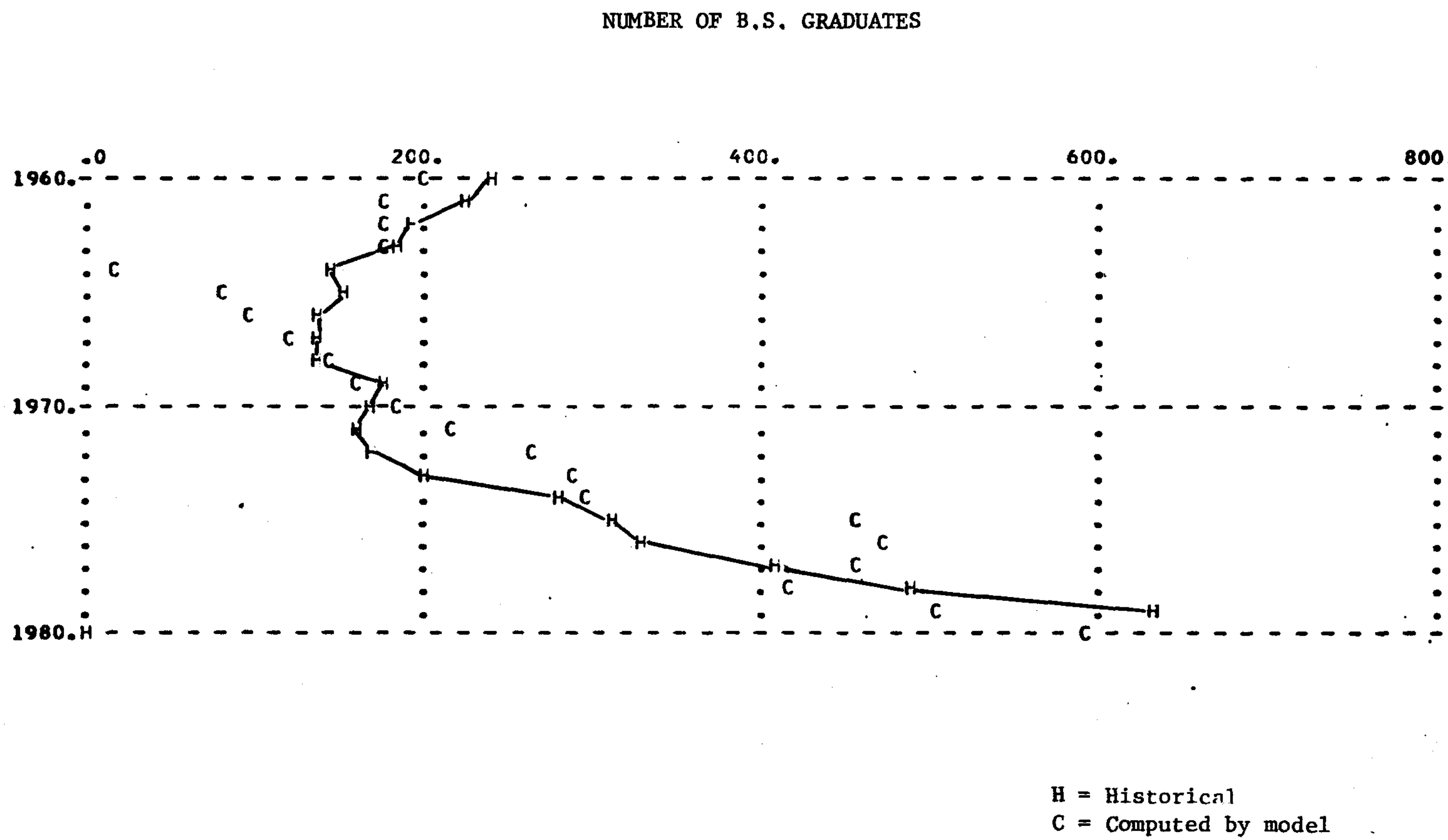


FIGURE 8-8
B.S. DEGREED MINING ENGINEER GRADUATES

those estimated by the model. What is significant is not the fact that the model does or does not absolutely match history, but that it realistically portrays significant trends in graduations and indeed in all major variables which were modeled.

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APPENDIX A

MODEL MINES

The MITRE Mining Manpower Model calculates coal production and the resulting labor requirements for six mining technologies: underground conventional, underground continuous, longwall, contour strip, small area strip, and large area strip mines. Labor and capital requirements for each mining technology are based on model mine data developed from Bureau of Mines sources and modified with the assistance of a MITRE consultant, Mr. Sidney Katell (Katell #1, 1978; #2, 1979; and Duda #1 and #2, 1976). The model mines used for each of the six technologies are our match of the mine size, seam thickness and strip ratios of his model mines to general regional geologic conditions.

Tables A-I and A-II contain estimated capital costs and labor requirements for 1980 for the underground and surface model mines in the data base. These tables contain the estimated capital costs (in 1976 dollars) and labor requirements for each mine type based on engineering design performance and personnel allocations at that time. Coal output levels from these mines assume optimal capacity utilization, with maximum labor productivity attainable implicit from the design specifications. Actual labor employed among these model mines was derived from regression estimates of labor productivity over time which, in turn, provided the means for estimating approximate capacity utilization (see Section 4.3 for details).

Capital costs for conventional and continuous underground model mines are based on model mine data provided by Katell. The deferred

TABLE A-I

MODEL UNDERGROUND COAL MINES*

FACTORS OF PRODUCTION	LABOR (man-day/year)					CAPITAL (costs in $1976 x 10^3, 30-year mine life)			
	Salaried			Hourly					
MINES	Supervisory	Tech. Support	Administrative	Skilled	Semi-Skilled	Initial Capital Investment	Annual Deffered Capital Investment	Annual Fuel & Electricity	Other Non-labor Operating Costs**
A. Room & Pillar Conventional 48" seam 0.5 MMTPY capacity	4,320	3,360	1,920	22,270	18,030	29,200	580	295	1,320
B. Room & Pillar Conventional 72" seam 0.5 MMTPY capacity	3,840	3,360	1,920	20,070	16,490	22,900	569	295	1,125
C. Room & Pillar Conventional 48" seam 1.0 MMTPY capacity	7,440	4,800	2,160	36,580	28,800	44,700	883	530	2,620
D. Room & Pillar Conventional 72" seam 1.0 MMTPY capacity	6,720	4,800	2,160	34,820	27,260	40,000	866	530	2,250
E. Room & Pillar Conventional 84" seam 1.0 MMTPY capacity	6,480	4,560	2,160	33,940	26,600	40,000	861	530	2,060
F. Room & Pillar Continuous 48" seam 0.5 MMTPY capacity	4,320	3,360	1,920	19,800	15,000	28,820	556	295	1,300
G. Room & Pillar Continuous 72" seam 0.5 MMTPY capacity	3,840	3,360	1,920	17,000	12,960	22,600	556	295	1,100
H. Room & Pillar Continuous 48" seam 1.0 MMTPY capacity	7,440	4,800	2,160	32,832	24,850	42,100	835	530	2,450
I. Room & Pillar Continous 72" seam 1.0 MMTPY capacity	6,720	4,800	2,160	29,100	22,060	33,100	835	530	2,100
J. Room & Pillar Continuous 84" seam 1.0 MMTPY capacity	6,480	4,560	2,160	27,550	20,450	32,900	835	530	1,900
K. Longwall 48" seam 1.0 MMTPY capacity	6,720	3,120	1,920	26,270	17,510	47,100	1,330	360	1,900
L. Longwall 72" seam 1.5 MMTPY capacity	6,720	3,600	2,400	30,360	20,240	57,800	1,700	300	2,900
M. Longwall 84" seam 1.5 MMTPY capacity	6,720	3,600	2,400	28,240	17,340	54,500	1,750	300	2,900

*All costs in 1976 dollars
**Royalties, licenses and bonds excluded. See Table A-4

TABLE A-II

MODEL SURFACE COAL MINES*

MINES \ FACTORS OF PRODUCTION	LABOR (man-day/year)					CAPITAL (costs in $1976 x 10^3, 20-year mine life)			
	Salaried			Hourly					
	Supervisory	Tech. Support	Administrative	Skilled	Semi-Skilled	Initial Capital Investment	Annual Deferred Capital Investment	Annual Fuel & Electricity	Other Non-labor Operating Costs**
A. Contour Strip 75'/6'=12.5 strip ratio 0.15 MMTPY capacity	360	960	480	6,933	3,462	8,520	216	134	102
B. Contour Strip 50'/6'=8.33 strip ratio 0.15 MMTPY capacity	360	960	480	5,080	2,770	6,720	175	130	97
C. Area Strip-large Truck-shovel 100'/57'=1.75 strip ratio 5.0 MMTPY capacity	2,160	1,680	1,920	29,600	13,900	40,400	1,440	1,325	1,630
D. Area Strip-large Dragline 100'/57'=1.75 strip ratio 5.0 MMTPY capacity	2,160	1,680	1,920	22,900	10,800	42,200	1,190	775	1.560
E. Area Strip-small 70'/5'=14.0 strip ratio 0.5 MMTPY capacity	1,920	1,200	2,160	8,800	4,400	17,000	500	235	244
F. Area Strip-small 105'/5'=21.0 strip ratio 0.5 MMTPY capacity	1,920	1,200	2,160	14,760	6,540	21,900	579	293	305

* All costs in 1976 dollars

** Royalties, licenses and bonds excluded. See Table A-4 capital cost shown assumes a thirty-year mine life. The capital costs shown for longwall mines are developed by increasing Katell's costs to include a third longwall section and an additional continuous mining machine. The O & M costs furnished by Katell are used for all underground mines. The fuel and power costs reflect an electricity cost of $0.025 per KWH and a fuel cost of $0.30 per gallon in 1975.

Data on surface mine costs were also provided by Katell. These data included 5 million tons per year western mines using draglines and were modified to give an additional model mine using stripping shovels and trucks.*

As indicated, the regression estimates of productivity provide the basis for forecasting labor demand and, hence, employment by job or functional category. The model mine labor requirements were used primarily to establish the relationships among major on-site labor categories, specifically those of supervisors, technical support staff, administrative staff, and hourly production (union or union-equivalent) personnel. Hourly production personnel were then disaggregated into skilled and semi-skilled miners based on BLS Industry Wage Surveys (BLS#2, 1962-1976) and unpublished data on the distribution of UMWA employees by job classification and mine type. The numbers in Tables A-I and A-II include those adjustments. Table

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*Cost data from Flour Utah, 1977 and Finch, 1979 were used in estimaing costs of modified mines.

A-III presents a listing of those job functions which correspond to the five labor demand categories.

In Table A-IV, additional costs per ton of coal produced are given. The costs for royalties, contracted reclamation, licenses and bonds are as provided by Katell.

In the coal mining manpower model, the costs of royalties rise to $2.00 per ton in 1990. The value of $2.00 per ton was used in the final regulatory analysis of the Surface Mine Mining Control and Reclamation Act of 1977 (SMCRA) by the Department of Interior (DOI, 1977). This act established a fund for reclaiming abandoned mine lands. The fund is financed by the following fees (GAO, 1977):

- deep-mined coal: the smaller of $.15/ton or 10% of coal value at mine gate
- surface-mined bituminous and sub-bituminous coal: $.35/ton
- lignite: the smaller of $.10/ton or 2% of coal value at mine gate

If future regulations require underground mine owners to control subsidence, an additional reclamation cost of $1.50/ton is estimated plus an additional cost of $0.06/ton for control of acid mine drainage (GAO, 1977). In the model, these reclamation costs are added to reclamation fund costs in 1985 and subsequent years for continuous and conventional mines. Only the acid mine drainage cost is added to longwall reclamation fund costs in 1985 and subsequent years, as subsidence control costs are incorporated within the mine's total capital cost. Annual taxes and insurance are calculated at two percent of the initial capital investment.

TABLE A-III

ON-SITE MINE LABOR CATEGORIES*

	Supervisors	Technical Support Staff	Administrative Staff
Salaried and Adminis- trative Personnel	Superintendent	Chief mine engineer	Office manager
	General mine foreman (U)	Draftsman	Timekeeper/bookkeeper
	Assistant mine foreman (U)	Surveyor	Purchasing supervisor
	Section foreman (U)	Safety director	Warehouseman
	Maintenance superintendent	Safety inspector	General office personnel
	General shop foreman	Dust sampler (U)	
	Mine maintenance foreman		
	General pit foreman (S)		
	Pit foreman (S)		

	Skilled	Semi-Skilled	
Hourly Production Personnel	Auger-machine operator (S)	Bit sharpener (U)	Trimmer (U)
	Blacksmith (U)	Boom-conveyor operator (U)	Truck driver
	Bonders-wireman (U)	Brakeman (U)	
	Bulldozer operator (S)	Bratticeman (U)	
	Carpenter, maintenance (U)	Cager, bottom (U)	
	Continuous-mining-machine operator (U)	Car dropper (U)	
	Cutting-machine operator (U)	Car dumper (U)	
	Dragline operator (S)	Car repairman (U)	
	Driller, machine	Continuous-mining-machine operators' helper (U)	
	Electrician, maintenance	Conveyor belt cleaner (U)	
	Engineer, stationary (U)	Cutting-machine operators' helper (U)	
	Hoistman (U)	Dinkey operator (U)	
	Loading-machine operator (U)	Driller, hand (U)	
	Longwall-miner operator (U)	Electricians' helper, maintenance	
	Machinist, maintenance (S)	Groundman (S)	
	Mechanic, maintenance	Lampman (U)	
	Motorman	Loader, hand (U)	
	Power-shovel operator-coal (S)	Mechanics' helper, maintenance	
	Power(stripping)shovel operator-overburden (S)	Miner, pick (U)	
	Roof bolter (U)	Oiler/greaser	
	Shot firer	Pumpman	
	Welder, maintenance	Shovel operator helper (S)	
		Shuttle-car operator (U)	
		Slate picker	
		Timberman	
		Tipple operator	
		Trackman (U)	

* S designates surface mines only; U designates underground mines only; blank means applicable to all mine types

TABLE A-IV

ADDITIONAL MINE COSTS[(a)]

MODEL MINE	ROYALTY[(b)]	RECLAMATION FUND OF 1977	LICENSES AND BONDS	CONTRACTED[(c)] RECLAMATION
UNDERGROUND MINES	0.20	0.15	0.10	—
CONTOUR STRIP (100 MTPY)	1.00	0.35	0.05	0.10
SMALL AREA MINE (500 MTPY)	0.85	0.35	0.02	0.08
LARGE MINE AREA (5 MMTPY)	0.36[(d)]	0.35	—	0.02

(a) In 1976 dollars per ton produced.
(b) Increased to $2.00 per ton in 1990.
(c) Mulching, liming, fertilizing and seeding.
(d) Includes royalty, strip license and rent.

Table A-V relates the six mining technologies to the model mine data in Tables A-I and A-II. The following information was used to determine the composition of the technologies in this table.

For the conventional and continuous technologies, the mix of model mines is based on data from BOM (1967) and the Keystone Coal Manual for 1978 (McGraw-Hill, 1978). In 1965, seam thickness was 5.3 feet for coal mined in underground mines. Fifty-two percent of 1977 underground production was from mines producing 500,000 tons per year or more.

The longwall mix of 48" and 72" seam model mines gives an average seam thickness of 67 inches. This average seam thickness was obtained from the 1978 DOE census of longwall mines weighted by the 1977 productions of those mines as reported in the 1978 Keystone Manual.

For surface mines, the U.S. Bureau of Mines gives strip ratios of 50.3'/4.23' = 11.9/1 for eastern mines and 47.6'/17.48' = 2.73/1 for western mines. The fraction of model mine types making up each surface technology was provided by Katell.

During the modeled years 1960-2000, the costs of labor requirements of the regional model mines will change. To model these changes, model mine cost and personnel data are input as tables. The tables contain data values at five year increments from 1960 to 2000. The model linearly interpolates between data points to obtain costs for non-tabled years.

TABLE A-V

COMPOSITION OF MINING TECHNOLOGY DATA

MINING TECHNOLOGY	MODEL MINES*
Underground Conventional	.7(0.5MMTPY 63" Seam Conventional) + .3(1.0MMTPY 63" Seam Conventional)
Underground Continuous	.7(0.5MMTPY 63" Seam Continuous) + .3(1.0MMTPY 63" Seam Continuous)
Underground Longwall	.21(1.0MMTPY 48" Seam Longwall) + .79(1.5MMTPY 72" Seam Longwall)
Surface Contour	.8(0.15MMTPY Contour 75'/6'Strip Ratio) + .2(0.5MMTPY Area Mine 70'/5'Strip Ratio)
Surface Large Area	.2(0.5MMTPY Area Mine 70'/5'Strip Ratio) + .8(5.0MMTPY Truck-Shovel Mine 100'/57'Strip Ratio
Surface Small Area	.8(0.5MMTPY Area Mine 70'/5'Strip Ratio) + .2(5.0MMTPY Dragline Mine 100'/57'Strip Ratio)

* Data for 63" Seam Mines for Conventional and Continuous Mines = (5/8)*(72" Seam Data) + (3/8)*(48" Seam Data).

For the underground model mines, labor requirements for the years 1960 through 1980 reflect changes in the labor force due to the Coal Mining Health and Safety Act of 1969, the UMWA 1974 contract requiring helpers on face equipment, and increases in professional labor due to Health and Safety and reclamation regulations. The total labor requirements for 1975 for each model mine are as provided by Katell. The labor requirements for 1970 were obtained by subtracting the following from the 1975 numbers: operator's helpers for continuous and conventional cutting machines, one-half of the roof bolters and their helpers, two front-end loader operators, two lab technicians and two members of the engineering staff. The requirements in 1980 reflect increases due to the Surface Mining Control and Reclamation Act of 1977 (SMCRA, 1977). One supervisor, one engineer and one skilled technician are added to the administrative staff. One skilled and one semiskilled worker are added for construction of sedimentation ponds, upgrading roads, covering acid and toxic materials, etc. It is assumed that existing construction equipment would be used for these tasks.

The costs and labor requirements for the model surface mines reflect the changes in reclamation requirements. The data for 1970 and earlier reflect minimum reclamation. In the early 1970s states enacted reclaimation laws and surface mining costs increased. The 1975 data include the costs and personnel required for reclamation of the surface mined land. The data for 1980 and beyond include our estimates of the effects of regulations of the Surface Mining Control and Reclamation Act of 1977.

Each of the six mining technologies in the MITRE mining manpower model is a linear combination of two representative model mines, as shown in Table A-V. This combination can model the effects of technology improvements in new mines on overall regional labor requirements or can be used to represent a mix of geological variables. The fraction of each mine comprising the regional model mine is an input table with values at five-year increments. Table A-VI contains the data used in the computer model to represent underground conventional mines.

TABLE A-VI

DATA FOR UNDERGROUND AND CONTINUOUS MINES USED IN MITRE MODEL

```
***********************************************************************
*                          MODEL MINE DATA                            *
*                              7/18/79                                *
***********************************************************************
NOTE      GENERAL DATA APPLICABLE TO NATIONAL MODEL MINES
T    TACTUA=2.0/4.0  AVG UNDERGROUND CONV MINE CONSTRUCTION TIME 1970/80
T    TACTUC=2.0/4.0  AVG UNDERGROUND CONT MINE CONSTRUCTION TIME 1970/80
T    TACTUE=4.0/5.5  AVG LONGWALL MINE CONSTRUCTION TIME 1970/80
T    TACTSA=2.0/3.0  AVG EAST SURFACE MINE CONSTRUCTION TIME 1970/80
T    TACTSC=3.0/5.0  AVG WEST SURFACE MINE CONSTRUCTION TIME 1970/80
T    TIFCAU=1.0/1.207/1.457/       U.G. CAPITAL INFLATION FROM 1980-2000
T    TIFCAS=1.0/1.127/1.271/       SUF. CAPITAL INFLATION FROM 1980-2000
T    TIFFUU=1.0/1.162/1.350/       U.G. FUEL COST INFLATION FROM 1980-2000
T    TIFFUS=1.0/1.162/1.350/       SUF. FUEL COST INFLATION FROM 1980-2000
T    TIFOMU=1.0/1.207/1.457/       U.G. O&M COST INFLATION FROM 1980-2000
T    TIFOMS=1.0/1.127/1.271/       SUF. O&M COST INFLATION FROM 1980-2000
***********************************************************************
NOTE      SPECIFIC DATA FOR EACH MODEL MINE TYPE
NOTE      TABLE TUMX CONTAINS 9 TABLES, EACH 1 LINE LONG
NOTE      YEAR   1960/1965/1970/1975/1980/1985/1990/1995/2000/
NOTE      LINE 1   MINE SITE SUPERVISORY LABOR (MANDAYS PER YEAR)
NOTE      LINE 2   MINE SITE TECHNICAL SUPPORT LABOR (MANDAYS PER YEAR)
NOTE      LINE 3   MINE SITE ADMINISTRATIVE LABOR (MANDAYS PER YEAR)
NOTE      LINE 4   SKILLED PRODUCTION LABOR (MANDAYS PER YEAR)
NOTE      LINE 5   SEMI-SKILLED PRODUCTION LABOR (MANDAYS PER YEAR)
NOTE      LINE 6   ANNUAL INITIAL CAPITAL COST ($1976 PER TON OF COAL)
NOTE      LINE 7   ANNUAL DEFERRED CAPITAL COST ($1976 PER TON OF COAL)
NOTE      LINE 8   FUEL & ELEC. COSTS PER TON OF COAL PRODUCED ($1976)
NOTE      LINE 9   NON-LABOR O&M COSTS PER TON OF COAL PRODUCED ($1976)
***********************************************************************
*                   UNDERGROUND MODEL MINE TYPE A                     *
***********************************************************************
NOTE      ***MODEL UNDERGROUND MINE A  (0.5 MMTPY 63" SEAM CONVENTIONAL)
NOTE      PART OF NATIONAL MODEL MINE #1
NOTE             TABLE TUMX VALUES FOR 63" SEAM MINE =.375*(VALUES FOR
NOTE             48" MINE) + .625*(VALUES FOR 72" MODEL MINE)
C    MLIFUA=30                                   DESIGN LIFETIME (YEARS)
C    SMCRUA=0.15  SMCRA RECLAIMATION FUND COST PER TON OF COAL MINED
C    SUBAUA=1.56  ESTIMATED ($/T) FOR SUBSIDANCE & ACID DRAINAGE CONTROL
C    EDCPUA=500000.      DESIGN COAL PRODUCTION (TONS PER YEAR)
T    TROYUA=0.10/0.10/0.10/0.30/0.30/1.20/2.10/2.10/2.10  ROYALTIES & LIC
NOTE                          FOR SOUTHERN APPALACHIA
NOTE      1960./1965./1970./1975./1980./1985./1990./1995./2000./   YEAR
NOTE
T    TUMA=3600./3600./4080./4080./4080./4080./4080./4080./4080./
X         2160./2160./2640./3120./3360./3360./3360./3360./3360./
X         1680./1680./1680./1680./1920./1920./1920./1920./1920./
X         18152/18521/18379/20428/24782/25637/25637/25637/25637/
X         19665/17096/15038/16714/17946/17091/17091/17091/17091/
X         01.20/01.19/01.21/01.59/01.69/01.69/01.69/01.69/01.69/
X         0.817/0.811/0.827/01.08/01.15/01.15/01.15/01.15/01.15/
X         00.32/00.29/00.25/00.52/00.59/00.59/00.59/00.59/00.59/
X         01.60/01.59/01.62/02.12/02.25/02.25/02.25/02.25/02.25
***********************************************************************
*                   UNDERGROUND MODEL MINE TYPE B                     *
***********************************************************************
NOTE      ***MODEL UNDERGROUND MINE B  (1.0 MMTPY 63" SEAM CONVENTIONAL*
NOTE      PART OF  REGIONAL MODEL MINE #1, SOUTHERN APPALACHIA
NOTE             TABLE TUMX VALUES FOR 63" SEAM MINE =.375*(VALUES FOR
NOTE             48" MINE) + .625*(VALUES FOR 72" MODEL MINE)
T    TFRN1=.3/.3/.3/.3/.3/.3/.3/.3/.3        B IS THIS FRACTION OF MINE #1
C    MLIFUB=30                                   DESIGN LIFETIME (YEARS)
C    SMCRUB=0.15  SMCRA RECLAIMATION FUND  COST PER TON OF COAL MINED
C    SUBAUB=1.56  ESTIMATED ($/T) FOR SUBSIDANCE & ACID DRAINAGE CONTROL
C    EDCPUB=1000000.      DESIGN COAL PRODUCTION (TONS PER YEAR)
T    TROYUB=0.10/0.10/0.10/0.30/0.30/1.20/2.10/2.10/2.10  ROYALTIES & LIC
NOTE                          FOR SOUTHERN APPALACHIA
NOTE      1960./1965./1970./1975./1980./1985./1990./1995./2000./   YEAR
NOTE
T    TUMB=6750./6750./7180./7180./7420./7420./7420./7420./7420./
X         1920./1920./3360./4320./4800./4800./4800./4800./4800./
X         1920./1920./1920./1920./2160./2160./2160./2160./2160./
X         31944/31746/32731/35651/37180/38462/38462/38462/38462/
X         34606/29304/28319/28011/26923/25641/25641/25641/25641/
X         0.934/0.927/0.945/1.237/1.134/1.134/1.134/1.134/1.134/
X         0.615/0.611/0.627/0.815/0.866/0.866/0.866/0.866/0.866/
X         00.29/00.26/00.23/00.47/00.53/00.53/00.53/00.53/00.53/
X         01.60/01.59/01.62/02.12/02.25/02.25/02.25/02.25/02.25
***********************************************************************
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APPENDIX B

PROFESSIONAL AND TECHNICAL LABOR SUPPLY

B.1 Introduction

The professional and technical support needs of the coal mining industry have grown markedly during the 1970's. However, the supply of trained engineers, scientists and technicians available to meet these needs has been the subject of much uncertainty. While the demand for professionals, especially engineers, has grown relative to demand for production workers ever since World War II, a decline in overall industry employment through the late 1960s has limited the absolute number of new professional job openings up to that point. Hence, for the 20 year period up until the late 1960s, total employment for professionals such as mining engineers virtually stagnated, while graduations fell by about two-thirds.

Since 1970, however, three factors have served to alter the status quo: passage of the Federal Coal Mine Health and Safety Act (CMHSA) in 1969, passage or strengthening of environmental legislation, especially many state reclamation laws (culminating in the Federal Law of 1977), and the oil embargo of 1973-74. Passage of CMHSA was an expression of Federal concern for miners' well-being which elevated both the demand for skilled and professional workers by coal companies as well as the perception among new work force entrants that future health and safety conditions in coal mines should be substantially improved. As such, this law altered both the relative and absolute demand for educated and trained or skilled personnel for functions such as improved mine design (i.e., ventilation and roof control), workplace air quality monitoring, and overall safer operation of more sophisticated mining equipment. Similarly, the air, water and land reclamation movements in several leading coal states during the late 1960s and early 1970s also increased the demand for educated and skilled personnel. Such functions as water quality monitoring, slope and refuse stabilization, revegetation, protection of wildlife habitats, and planning for ultimate land utilization enhanced the demand for and ultimately the supply of engineers and scientists to perform these tasks. Finally, the oil embargo of 1973-74 provided the greatest impetus for educated and skilled personnel through its sudden elevation of total coal demand. As of the late 1970's, enrollments in programs most directly affected by the coal industry, such as mining and mineral engineering and two year mining technology programs, have literally skyrocketed.

The purpose of this appendix is to describe in some detail the major professional and technical education and training programs which apply to the coal mining industry. Each section of this appendix describes one or more related disciplines and discusses the academic and employment characteristics of these disciplines. Finally, the last section provides an overview of educational support programs sponsored by government and industry for fields applicable to both coal mining and the mining industry as a whole.

B.2 Mining and Mineral Engineers

Mining and mineral engineers comprise the greatest percentage of engineers employed by the mining industry for the location, extraction, and preparation of minerals and fuels. According to the 1970 Census and the BLS Industry/Occupational Matrix, less than one percent of all coal industry employees were formally trained as engineers, with mining engineers comprising about 64 percent of this total (i.e., 820 mining engineers). Since then, the BLS has estimated this amount to have almost doubled, (BLS #1, 1979), although mining engineers have declined slightly as a percent of all engineers employed in the coal industry (presently estimated by MITRE to be about 60 percent of all engineers). In relative terms this decline is expected to continue, due in large part to the proportionate growth of surface vis a vis deep mines. The Census also estimated that the coal industry only accounted for less than 20 percent of total mining engineering employment as of 1970; however, this is expected to increase as coal expands relative to other mining industries.

Coal companies employ mining engineers to design mines, supervise various mining operations, and devise methods for the transportation of coal. Some engineers are responsible for the efficient, economic and safe operation of mines while others work along with geologists and other professionals in exploration. With the recent increasing emphasis on environmental protection, mining engineers have also begun working on water pollution, air pollution, and reclamation problems associated with mining.

Primary employers of mining engineers include the coal, copper, iron and ferroalloy, other hardrock, and aggregates (sand and gravel) mining industries. Other mining engineers work for the petroleum extraction industry (often retrained to become petroleum engineers), equipment firms, colleges and universities, government agencies, financial institutions, and construction industry, or as consultants.

B.2.1 Educational Overview

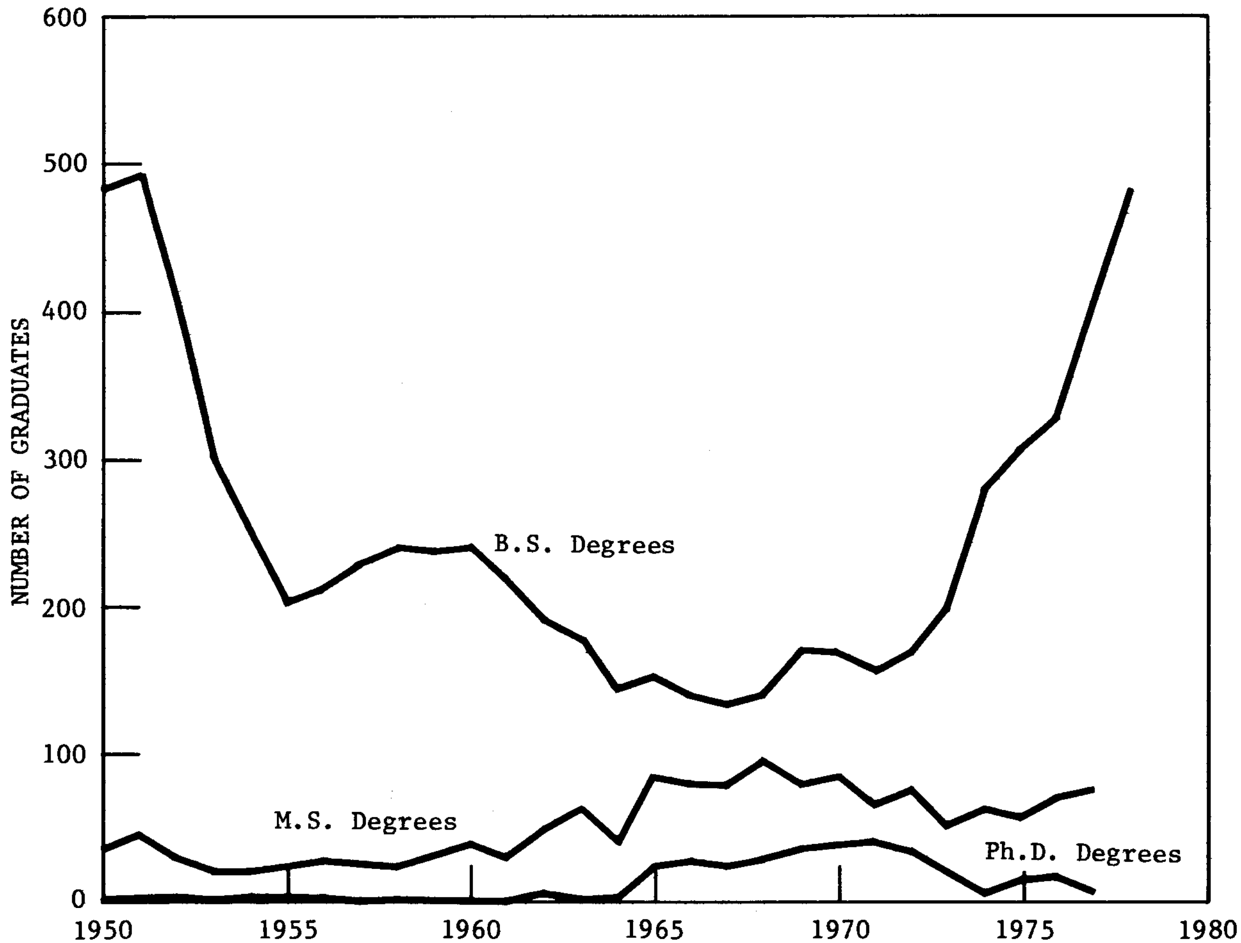
B.2.1.1 General

The function of the mining engineer is to apply knowledge of pertinent scientific theory and technology to problems presented in meeting the demand for minerals, while satisfying environmental, health, and safety requirements. The mining engineering student studies the principles and techniques of mineral exploration and underground and surface mining operations. Courses taken include rock mechanics, mine and plant design, mine ventilation, surveying, industrial hygiene, mine safety, mineral law, mineral economics, mine operation, geology, mineral processing, systems analysis, operations research, and ecological and environmental planning.

Mineral engineering curricula include courses similar to those in mining engineering. There are, however, more geological engineering, minerals processing, and metallurgy courses taught by those universities which offer mineral engineering degrees than by those which offer mining engineering degrees.

B.2.1.2 Historical Trends

The supply of new mining engineers entering the labor force each year since World War II appears somewhat like a valley, with the trough occurring in 1967. Figure B-1 shows the number of mining/ mineral engineering degrees awarded at each level over the period since 1950, with Table B-I presenting the yearly values. As may be seen, B.S. degree graduates rose gradually at first following the 1967 low of 134, but then rose more sharply beginning in 1973-74, four years after passage of the Coal Mine Health and Safety Act. Similarly, graduations in the academic year 1978-79, estimated at about 630, reflect the impact of the oil embargo four years prior and its subsequent impact on industry employment, salaries, and school enrollments. Somewhat curiously, advanced degrees, and Ph.D.'s in particular show a sharp rise between 1965-74, coinciding with the lowest period in bachelor degree graduations. It is possible that this seeming anomaly reflects, in part, a trend toward advanced degrees during the Vietnam War as well as the general stagnation in employment among all mining industries over this period. Nevertheless, questionable consistency in HEW's categorization of degrees cannot be ruled out as a contributory factor. For example, in certain years mineral dressing is grouped together with mining and mineral engineering while in other years it is not.



Sources: Graduates: HEW and MITRE Survey

FIGURE B-1
DEGREES AWARDED IN MINING/MINERAL ENGINEERING

TABLE B-I

MINING/MINERAL ENGINEERING GRADUATES

YEAR	BS(4-or 5-year)	MS	PhD	TOTAL
1948-49*	361	27	2	390
1949-50*	483	36	1	520
1950-51*	493	45	2	540
1951-52*	412	30	3	445
1952-53*	304	22	1	327
1953-54*	254	22	3	279
1954-55*	204	24	2	230
1955-56*	213	29	3	245
1956-57*	231	27	0	258
1957-58*	240	24	2	266
1958-59*	239	32	2	273
1959-60*	242	41	3	286
1960-61*	220	33	2	255
1961-62*	193	50	6	249
1962-63*	180	65	3	248
1963-64**	144	43	4	191
1964-65**	152	86	25	263
1965-66**	138	80	27	245
1966-67**	134	80	25	239
1967-68**	139	96	28	263
1968-69**	172	81	38	291
1969-70**	170	87	39	296
1970-71**	158	66	43	267
1971-72**	169	76	36	281
1972-73**	201	53	22	276
1973-74**	279	64	7	350
1974-75**	308	59	15	382
1975-76**	331	70	18	419
1976-77**	404	77	7	488
1977-78**	509	92	16	617
1978-79***	631	N.A.	N.A.	N.A.

* Source: U.S. Department of Health, Education and Welfare, Engineering Enrollments and Degrees, series.

** Source: U.S. Department of Health, Education and Welfare, Earned Degrees Conferred, series.

*** Source: MITRE survey

In trying to explain the fluctuations in graduation rates, one must address those factors which attract people into various degree programs. A MITRE telephone survey of mining engineering departments, confirmed that job availability and salaries were among the leading factors motivating students to become mining engineers (along with non-quantifiable factors such as family tradition and outdoor life). Table B-II presents recent trends in salaries and employment of mining/mineral engineers in addition to those of all engineers. It should be noted that national employment data for engineers as a discipline have been subject to much dispute and interpretation in recent years (see NSF, 1972).* Due to classification problems and the discontinuation of certain historical series, employment data of engineers had to be derived from several sources. As may be seen, by the late 1960s, the growth in employment and especially starting salaries of mining engineers (actually engineers employed by the mining industry) was substantially greater than that

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*The 1970 Census estimate of mining engineers by discipline employed nationally comprised about 82 percent of all engineers employed in the mining industry that year, the latter estimate derived from the more comprehensive industry employment survey conducted by the BLS for 20 years and discontinued in 1970. (BLS #4, 1971). This same distribution was found to have occurred previously according to the 1960 Census (after separating out petroleum engineers from mining engineers as they were then combined). Hence, the employment series through 1970 on mining engineers is based on the assumption of constant ratio of mining engineers employed nationally over all engineers employed in the mining industry. Employment estimates after 1970 for mining and all engineers were adjusted from the BLS Industry-Occupational Matrix and the Census Bureau's Current Population Survey to be definitionally consistent with the earlier BLS series.

TABLE B-II
ESTIMATED EMPLOYMENT AND SALARY TRENDS OF
MINING AND ALL ENGINEERS

YEAR	MINING/MINERAL ENGINEERS EMPLOYMENT	MINING/MINERAL ENGINEERS REAL MEDIAN SALARY - $1976* 20 Years Since B.S. Degree	MINING/MINERAL ENGINEERS REAL MEDIAN SALARY - $1976* Starting	ALL ENGINEERS EMPLOYMENT	ALL ENGINEERS REAL MEDIAN SALARY - $1976 20 Years Since B.S. Degree	ALL ENGINEERS REAL MEDIAN SALARY - $1976 Starting
1950	3,700	-	-	408,000	-	-
1951	3,800	-	-	451,000	-	-
1952	3,900	-	-	508,000	-	-
1953	4,000	13,670	9,220	555,000	16,500	9,120
1954	3,900	14,410	10,040	580,000	17,260	10,060
1955	3,700	15,330	10,300	603,000	19,000	10,440
1956	3,800	16,000	10,700	646,000	20,530	10,950
1957	3,900	16,370	10,860	708,000	20,730	11,210
1958	4,200	16,880	11,080	729,000	21,270	11,530
1959	4,200	18,080	11,520	767,000	22,170	11,920
1960	4,100	19,220	11,870	801,000	23,160	12,210
1961	4,100	19,960	12,040	833,000	23,520	12,640
1962	4,100	18,680	12,190	873,000	23,900	13,040
1963	4,100	20,740	12,930	922,000	24,730	13,340
1964	4,200	23,020	13,640	946,000	25,500	13,620
1965	4,200	22,320	14,100	970,000	26,040	14,230
1966	4,400	21,150	14,390	1,000,000	26,100	14,660
1967	4,600	22,080	15,090	1,038,000	26,620	15,140
1968	4,800	22,480	15,540	1,063,000	26,670	15,380
1969	5,100	22,930	16,040	1,085,000	26,370	15,450

TABLE B-II (Concluded)

1970	5,100	23,260	16,350	1,099,000	26,090	15,390
1971	5,600	25,070	16,270	1,049,000	26,000	15,320
1972	5,900	27,280	16,330	985,000	26,370	15,370
1973	5,900	26,900	16,690	992,000	26,010	15,080
1974	6,100	25,390	16,210	1,051,000	24,930	14,140
1975	6,300	24,370	15,690	1,035,000	24,650	14,100
1976	6,400	24,100	15,650	1,071,000	25,800	14,400
1977	6,900	24,460	15,890	1,140,000	26,480	14,270
1978	-	24,840	15,890	-	26,710	13,970

Employment data derived based on BLS # 4, 1973 and Census, CPS Series.

Salary data taken from EJC, 1978.

* Salary data for mining/mineral engineers actually apply to engineers directly employed in the mining industry, the vast majority of whom are mining/mineral engineers.

of all engineers over the same period. This may be seen more clearly in Figure B-2. Here, the engineer graduation ratio (EGR), the engineer employment ratio (EER), and the starting salary ratio (SSR) are all plotted over time since 1950. The positive correlation of EGR with both EER and SSR over this period illustrates the impact of the latter two variables in explaining changes in the former. Between the two independent or explanatory variables, it appears that EER, representing relative employment opportunities, exerts a strong influence on EGR and, hence, mining engineer graduates.

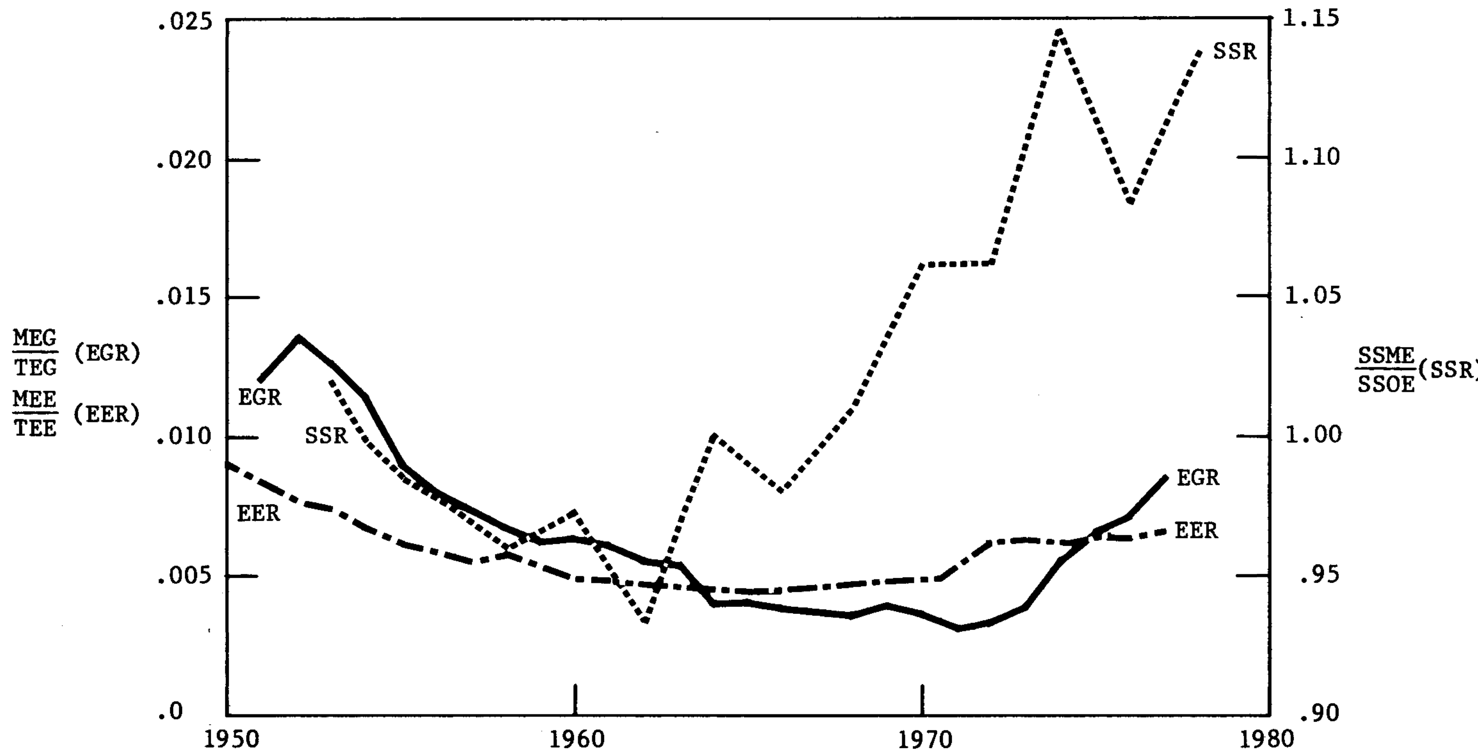
B.2.2 Educational Programs

B.2.2.1 Current Status

Twenty-four colleges and universities offer undergraduate programs in mining in the United States. Sixteen are currently accredited by the Engineers Council for Professional Development (ECPD) for mining engineering and two for minerals engineering.* These 24 programs produced 631 bachelor's degree graduates from about 3,400 students enrolled in the 1978-1979 school year.** Table B-III shows the numbers of students enrolled on a regional basis, for each

*Hereafter, the term mining engineer will include mineral engineering programs.

**Source: MITRE telephone survey. All universities with mining/mineral engineering curricula were contacted by telephone in order to obtain current data.



MEG - Mining Engineering Graduation - B.S. Degree

TEG - Total Engineering Graduations - B.S. Degree

EGR - Engineering Graduation Ratio

MEE - Mining Engineers Employed

TEE - Total Engineers Employed

EER - Engineer Employed Ratio

SSME - Starting Salary of Mining Engineers

SSOE - Starting Salary of Other Engineers

SSR - Starting Salary Ratio

FIGURE B-2
ENGINEER GRADUATION. ENGINEER EMPLOYMENT AND

TABLE B-III
MINING/MINERALS ENGINEERING PROGRAMS
STUDENT POPULATION*

UNIVERSITY	BS GRADUATES (1978-79)	UNDERGRADUATES ENROLLED (1978-79)	MOTIVATION OF STUDENTS TO ENROLL IN PROGRAM
REGION 1	(220)	(1042)	
Columbia U.	7	12	Job availability, salary
Michigan Tech.	40	143	Job availability, salary, tradition, national need, funds, variety
Ohio State U.	0 (New Program)	N/Available	Job availability, salary, variety
Pennsylvania State U.	75	450	Job availability, locality, tradition
U. of Pittsburgh	41	135	Job availability, salary, tradition
West Virginia U.	57**	280	Job availability, locality, tradition
REGION 2	(108)	(563)	
U. of Alabama	26	150	Job availability, salary, national need
U. of Kentucky	23**	120	Job availability, salary, national need, funds
Virginia Polytechnic Inst.	34	204	Job availability, locality, variety
West Virginia U.	25**	120	Job availability, locality, tradition
REGION 3	(135)	(829)	
U. of Arizona	23	142	Job availability, salary, tradition
U. of California, Berkeley	0 (New Program)	N/Available	Job availability, national need
Colorado School of Mines	63	326	Job availability, salary
New Mexico Inst. of Mining and Tech.	12	140	Locality, tradition, national need
U. of Nevada, Reno	10	60	Salary, funds, variety
U. of Utah	27	160	Tradition, outdoor life, funds
REGION 4	(80)	(526)	
U. of Alaska	5	100	Tradition, outdoor life, funds
U. of Idaho	24	89	Job availability, salary, national need, outdoor life
U. of Minnesota	15	100	No specific reasons given
Montana Coll. of Mineral Science & Tech.	24	150	Job availability, funds
South Dakota School of Mines & Tech.	12	87	Salary, variety
REGION 5	(88)	(416)	
Southern Illinois U., Carbondale	0 (New Program)	20 (1979-80)	Locality
U. of Missouri, Rolla	40	194	Job availability, salary, tradition
U. of Wisconsin, Madison	11	45	Job availability, outdoor life
U. of Wisconsin, Platteville	27	130	Job availability
U. of Kentucky	10**	40	Job availability, salary, national need, funds

*Source: MITRE survey
**Kentucky and West Virginia are split to obtain regional totals

of the programs. This table also lists possible factors which motivate students to enroll in mining engineering programs. Since Kentucky and West Virginia are each split between two regions, allocation of their enrollments were based on student origins as cited by the respective schools.

The chief attractions of a mining engineering degree, as cited by survey participants, are job availability (cited by 71 percent) and good salaries (50 percent). Some students come from a mining tradition, i.e., they are influenced by friends or family employed in coal mining (cited by 25 percent). The availability of scholarship funds or other assistance was also cited by 25 percent of the survey participants as being a positive influence on a student's choice of a mining engineering curriculum. The same percentage cited national energy needs or environmental concern as a motivating factor. Other possible reasons for pursuing a mining engineering degree were given as job variety and/or satisfaction; the influence of the mining industry on the local economic picture, and the attractions of the outdoor life.

The above results are similar to those of a survey published in 1978 by the University of Arizona and the American Mining Congress (Dresher, 1978). Of 923 mining engineers responding to this survey, 51 percent learned about the field from friends or relatives in the industry. "The remainder were largely influenced by the mining school or college of the university which they are now attending." Other students were attracted by the news media, high schools, or the mining industry. In terms of career choice, 90 percent were strongly influenced by "good employment opportunities," defined as challenging work and opportunities for advancement. Far fewer students listed steady employment, high pay, contributing to mankind's needs, and supervising people as career objectives.

B.2.2.2 Faculty Statistics

Table B-IV presents the number of faculty in each of the 24 schools offering mining/mineral engineering programs for the 1978-79 academic year. This table also gives student/faculty ratios for the 1973-74 and the 1978-79 academic years.

As expected, available student/faculty statistics shown in Table B-IV are not consistent from one university to another. Difficulties exist in counting both students and faculty. Most universities do not enroll students in mining engineering until the sophomore or junior year, since all engineering students may take the same courses during the first year or two. Faculty counting is even more complicated, because there are both full-time and part-time faculty members. Also, teaching responsibilities are often discharged by graduate students or adjunct faculty members. Finally, both faculty and students may be administratively included in other disciplines, most commonly civil engineering.

TABLE B-IV

MINING/MINERAL ENGINEERING PROGRAMS
FACULTY STATISTICS*

UNIVERSITY	NUMBER OF FACULTY 1978-79	NUMBER OF STUDENTS/INSTRUCTOR 1978-79	NUMBER OF STUDENTS/INSTRUCTOR 1973-74	1979-80 FACULTY OPENINGS
REGION 1				
Columbia U.	6	2 (Jrs. & Srs.)	--	2
Michigan Tech.	4	30	10-15	2
Ohio State U.	--	--	0 (New Program)	1
Pennsylvania State U.	28	15	15	2
U. of Pittsburgh	7**	10	3-4	2
		25-30	(New Program)	
West Virginia U.	9**	25-30	20-25	2-3
REGION 2				
U. of Alabama	5	30	--	2
U. of Kentucky	4**	30	--	2
Virginia Polytechnic Inst.	11**	20	--	2
REGION 3				
U. of Arizona	11	27	--	1
U. of California, Berkeley	3**	10-14	--	0
Colorado School of Mines	10	30	32	0
New Mexico Inst. of Mining and Tech.	6	15-25	20	0
U. of Nevada, Reno	4	18	18	1
U. of Utah	5	30	--	1-3

TABLE B-IV (Concluded)

REGION 4				
U. of Alaska	6**	10	--	0
U. of Idaho	5**	18	--	2
U. of Minnesota	6	15-20	--	1
Montana Coll. of Mineral Science & Tech.	3	50	29	1
South Dakota School of Mines & Tech.	5	23	32	1
REGION 5				
Southern Illinois U., Carbondale	4**	5	--	2
U. of Missouri, Rolla	8**	30	25	2
U. of Wisconsin, Madison	4	10	8	0
U. of Wisconsin, Platteville	3**	15	--	0

*Source: MITRE survey
**Source: Society of Mining Engineers, SME-AIME Guide to Minerals Schools, 1978-79.

Allowing for the disparate data resulting from the above factors, available statistics on student enrollment and student/faculty ratios can be used to draw some general conclusions. Mining engineering student/faculty ratios can be split into three size categories. First, ten of the universities currently have 15 or fewer students per faculty member, a low ratio. Of these, three (Berkeley, Ohio State, and Southern Illinois) have new programs in mining engineering and data are tentative or not available, and four (Alaska, Minnesota, and two in Wisconsin) are not located near major coal mining areas. The low student/faculty ratio given for Columbia, i.e., two, is atypical because only juniors and seniors are counted and the ratio is obtained by dividing those by the number of faculty teaching mining courses. Penn State's ratio was also derived by dividing the number of students by the number of faculty teaching mining courses; the full-time equivalent ratio given was much higher. Pittsburgh also has a relatively new program and, in addition, enrollment is controlled by requiring a certain grade point average for admission.

Second, at the opposite end of the size scale, nine universities have a high student/faculty ratio; greater than 25 students per professor. The fact that eight of these are seeking additional faculty members indicates that this ratio is felt to be too high. Finally, the remaining five universities (Idaho, Nevada, New Mexico Tech, South Dakota Tech, and VPI) have more manageable ratios of between 15 and 25 students per faculty member.

In terms of evaluating the <u>effective</u> faculty student ratio, it is more meaningful to use the concept of faculty available to teach mining courses, given certain obligations to conduct research. During the late 1950's and throughout the 1960s, approximately 75 percent of the full-time equivalent (FTE) faculty were involved in research* in areas such as health and safety, productivity analysis, environmental concerns and related matters. Since the oil embargo of 1973-74, however, this research fraction has declined to about 35 percent, as research obligations were reduced to avoid expanding class sizes too much. As of last year, enrollments skyrocketed to a level of 3400 with only about 160 instructors, resulting in absolute faculty/student ratio averages of about 21 to 1; however, assuming 35 percent of FTE faculty engaged in research, this leaves about 104 instructors for teaching, resulting in an effective faculty/student ratio of almost 33 to 1. At present the effective ratio is closer to 40 to 1 in many mining schools* as enrollments continue to grow while about 30 faculty positions remain vacant, underscoring the difficulty in attracting faculty relative to B.S. degree candidates.

One obvious problem in attracting mining engineers to teaching careers is the discrepancy between university and industry salaries, and the low financial reward for investing in education beyond the B.S. degree. Faculty salaries average $21,000 per academic year

*Personal communication with Dean T. Planje, University of Missouri-Rolla, School of Mines and Metallurgy, September 19, 1979.

(nine months) for an assistant professor with no teaching experience* while starting salaries for those with B.S. degrees in mining engineering averaged $18,000 in 1978 (CPC, 1978). Problems in attracting faculty are not however, always financial. Even if funds were available, the high salaries needed to attract mining engineering personnel can cause dissatisfaction among other faculty, or may be forbidden by single or multiple salary structures. Tenure questions have also been problems in recent years, due to declining enrollment in colleges as a whole.

B.2.2.3 Coal Industry Employment of BS Graduates

The number of BS graduates in mining/mineral engineering that were employed by the coal industry in 1978-79 is given in Table B-V. This table also shows the regional employment distribution of these graduates for the five coal mining regions used in this study.

The coal industry employment statistics shown in Table B-V were obtained from two sources: college career placement offices and mining engineering departments. Placement offices generally provided current statistics, while most data from departments are estimates based on current trends in employment.

Of a total of 631 mining engineering bachelor's degree graduates in the 1978-79 academic year, 379 (60 percent) are now employed by the coal industry. This is both a substantial numerical and a

*Source: MITRE telephone survey.

Table B-V

MINING/MINERAL ENGINEERING PROGRAMS
Coal Industry Employment*

UNIVERSITY	Number of Mining Engineering BS Graduates (1978-79)	(1972-73)**	Number of BS Graduates Hired By Coal Companies (1978-79	(1972-73)	Regional Destination of BS Graduates Hired By Coal Companies (1978-79) 1	2	3	4	5
REGION 1	(220)		(162)						
Columbia U.	7		3		3				
Michigan Tech.	40		5		4		1		
Ohio State U.	0		-						
Pennsylvania State U.	75		68		54	14			
U. of Pittsburgh	41		34		26	3	2		3
West Virginia U.	57***	16	52	14	52				
REGION 2	(108)		(105)						
U. of Alabama	26		26			26			
U. of Kentucky	23***		25			15			10
Virginia Polytechnic Inst.	34	7	32	6	3	24	2	1	2
West Virginia U.	25***		22			22			
REGION 3	(135)		(55)						
U. of Arizona	23	12	5	1		1	1		3
U. of California, Berkeley	0		-						
Colorado School of Mines	63	42	32	4	3		15	7	7
New Mexico Inst. of Mining and Tech.	12		1			1			
U. of Nevada, Reno	10		2				1	1	
U. of Utah	27	8	15	3		13	1	1	1
REGION 4	(80)		(29)						
U. of Alaska	5	5	0	0					
U. of Idaho	24	3	12	1	1		3	6	2
U. of Minnesota	15		3		1			2	
Montana Coll. of Mineral Science & Tech.	24	8				1	4	3	
South Dakota School of Mines & Tech.	12	6					3	3	
REGION 5	(88)		(28)						
Southern Illinois U., Carbondale	0		-						
U. of Missouri, Rolla	40	14	4	8				2	2
U. of Wisconsin, Madison	11		2						2
U. of Wisconsin, Platteville	27	10	14	2		1		2	11
U. of Kentucky	10***		8						8
	631	131	379	39	147	108	45	28	51

* Source: MITRE survey
**Source: Planje Survey
***Kentucky and West Virginia graduates split to obtain regional totals

percentage increase over 1972-73, the last pre-oil embargo year, when 33 percent, or 39 mining engineers, entered the coal industry.

Regional data show substantial variation in the numbers of graduates entering the coal mining industry. Most (86 percent) eastern (Regions 1 and 2) graduates enter coal mining. The percentage of midwestern and western graduates (Regions, 3, 4, and 5) employed by coal mining companies is only 37 percent of the total number of BS graduates from these regions. This is partially due to the fact that metal, uranium, and hardrock mining companies are recruiting heavily at colleges west of the Mississippi; this is confirmed by college personnel. Also, while the number of job offers to each mining engineering graduate have remained constant or improved over the past few years, the number of offers from coal companies has decreased since 1978. This may reflect current uncertaintites as to future demands for western coal. Additionally, the highly motivating family and local economic traditions which attract students to mining careers in coal are most prevalent in the eastern U.S.

Regional hires by coal companies for 1978-79 mining engineering BS graduates show that 67 percent are employed in the Northern and Southern Appalachian regions. This may be explained by the preponderance of labor-intensive underground mines in the eastern United States.

The regional employment of graduates shows little interregional mobility, with 77 percent obtaining employment in the region where they obtained degrees. Of those not employed in these regions, most of the remaining graduates were hired in adjoining regions.

B.2.2.4 Sources of Financial Support

The two types of financial support which were investigated are direct support to students in the form of fellowships and scholarships and indirect support in the form of research funds. The chief sources of funding are Federal and state governments and industry. A few colleges, however, derive significant funds from endowments.

Most undergraduate mining engineering students receive some sort of financial support. Table B-VI shows the percentage of students receiving financial support and the sources of that support for each university offering mining engineering degrees. Nationally, about 40 percent of the mining engineering students receive some sort of direct financial assistance. An additional 20 percent or more participate in co-op or work-study programs to help defray educational expenses.

The minerals industry represents the major source of financial support for mining engineering undergraduates at 18 universities. Three schools (Berkeley, Columbia, and Utah) provide a majority of their scholarship money from endowment funds. At Ohio State and Southern Illinois, the programs are too new for information about sources of funding to exist. One university (Kentucky) is atypical, in that the state provides almost all of the mining engineering scholarships.

TABLE B-VI

MINING/MINERALS ENGINEERING PROGRAMS
UNDERGRADUATE FINANCIAL SUPPORT*

UNIVERSITY	% OF UNDERGRADUATES SUPPORTED BY SCHOLARHSIPS	MAJOR SOURCES OF SUPPORT
REGION 1		
Columbia U.	80%	Private (endowment), State
Michigan Tech.	50-75%	Industry, Federal
Ohio State U.	New Program	--
Pennsylvania State U.	10%	Industry
U. of Pittsburgh	>50%	Industry, State
West Virginia U.	20%	Industry
REGION 2		
U. of Alabama	40%	Industry
U. of Kentucky	~100%	State, Industry, Federal
Virginia Polytechnic Inst.	25%	Industry
REGION 3		
U. of Arizona	20%	Industry, University
U. of California, Berkeley	New Program	Private (endowment)
Colorado School of Mines	20%	Industry, Federal
New Mexico Inst. of Mining and Tech.	70%	Industry, State
U. of Nevada, Reno	75%	Industry
U. of Utah	100%	Private (endowment)
REGION 4		
U. of Alaska	33-50%	Industry, Federal
U. of Idaho	60-80%	Industry, Private (endowment), Federal
U. of Minnesota	30-50%	Industry
Montana Coll. of Mineral Science & Tech.	40-50%	Industry
South Dakota School of Mines & Tech.	>35%	Industry

TABLE B-VI (Concluded)

REGION 5		
Southern Illinois U., Carbondale	New Program	--
U. of Missouri, Rolla	25%	Industry, Private, Federal
U. of Wisconsin, Madison	>50%	Industry, State, University
U. of Wisconsin, Platteville	~100%	Industry, Federal

* Source: MITRE survey

The second type of financial support investigated is funding for coal research, as shown in Table B-VII. Since research funding is not a major component of undergraduate support, this topic was covered in very general terms. A wide range of types and sizes of research programs exist. Nine schools receive funding for coal research on the order of $1.0 to $1.5 million per year for a variety of projects, commonly including coal liquefaction and gasification research. Four institutions receive less than $500,000 per year in coal research contracts and five indicated that they are doing "little" coal research. Data on research dollars were not obtained at five schools.

Available information shows that more than $14 million was spent on coal research at the 24 universities during the 1978-79 academic year. About one-half of this funding came from Federal agencies, principally, the Departments of Interior and Energy. Four states (Kentucky, Alabama, West Virginia, and New Mexico) are spending more than $500,000 per year on coal research at the universities in these states. Industry spends comparatively little; less than $2 million per year at all 24 institutions.

B.2.3 Projected Program Capacity

Enrollment capacity for mining/minerals engineering undergraduate students, as shown in Table B-VIII, is expected to be about 4,900

TABLE B-VII

MINING/MINERALS ENGINEERING PROGRAMS
FUNDING FOR COAL RESEARCH*

UNIVERSITY	1978-79 COAL RESEARCH	SPONSORS FEDERAL	STATE	INDUSTRY
REGION 1				
Columbia U.	Little			100% (1977-78)
Michigan Tech.	Little	100%		
Ohio State U.	Not available			
Pennsylvania State U.	$1-1.5 million	80%	10%	10%
U. of Pittsburgh	Little	100%		
West Virginia U.	$1.4 million	40%	40%	20%
REGION 2				
U. of Alabama	$1-1.5 million	25%	75%	
U. of Kentucky	$500,000	50%	50%	
Virginia Polytechnic Inst.	$300-400,000	75%	12.5%	12.5%
REGION 3				
U. of Arizona	$1 million	80%		20%
U. of California, Berkeley	Not available			
Colorado School of Mines	$1 million	90%		10%
New Mexico Inst. of Mining and Tech.	$1-1.5 million	60%	40%	
U. of Nevada, Reno	Little			
U. of Utah	$1 million	92%	8%	
REGION 4				
U. of Alaska	Not available	67%	33%	
U. of Idaho	Not available	50%		50%
U. of Minnesota	Not available	40%	30%	30%
Montana Coll. of Mineral Science & Tech.	$80,000	86%		14%
South Dakota School of Mines & Tech.	$100,000	100%		
REGION 5				
Southern Illinois U., Carbondale	$1 million	17%	21%	62%
U. of Missouri, Rolla	$1.5 million	67%		33%
U. of Wisconsin, Madison	$50-75,000	50%		50%
U. of Wisconsin, Platteville	Little	100%		

* Source: MITRE survey

TABLE B-VIII

MINING/MINERAL ENGINEERING PROGRAMS
ENROLLMENT CAPACITY*

UNIVERSITY	ENROLLMENT 1978-79	CAPACITY 1983-84	CONSTRAINTS ON ENROLLMENT
REGION 1	(1060)	(1410)	
Columbia U.	25	25	Student demand
Michigan Tech.	200	200	Faculty
Ohio State U.	New Program	200	Faculty, funds, student demand
Pennsylvania State U.	420	450	Faculty
U. of Pittsburgh	135	150	Facilities, qualified students (grade point average)
West Virginia U.	280**	385	Faculty, facilities
REGION 2	(640)	(810)	
U. of Alabama	150	200	Faculty, funds
U. of Kentucky	120**	165	Faculty, space
Virginia Polytechnic Inst.	250	280	Faculty space, facilities
West Virginia U.	120**	165	
REGION 3	(890)	(1110)	
U. of Arizona	150	150	Facilities, total university enrollment
U. of California, Berkeley	New Program	75-80	Faculty, total university enrollment
Colorado School of Mines	350	400	Faculty, space, funds, total university enrollment
New Mexico Inst. of Mining and Tech.	150	150	Faculty
U. of Nevada, Reno	80	150	Space
U. of Utah	160	180	Faculty, space
REGION 4	(590)	(800)	
U. of Alaska	100	100	None
U. of Idaho	150	150	Faculty, funds, space, total university enrollment
U. of Minnesota	100	150	Student demand
Montana Coll. of Mineral Science & Tech.	150	300	Faculty
South Dakota School of Mines & Tech.	90	100	Facilities
REGION 5	(490)	(730)	
Southern Illinois U., Carbondale	New Program	150	Faculty
U. of Missouri, Rolla	200	275	Faculty
U. of Wisconsin, Madison	100	100	Student demand
U. of Wsiconsin, Platteville	40**	55	

*Source: MITRE survey
**Kentucky and West Virginia split to obtain regional totals

by 1985, an increase of about 33 percent over 1978-79 capacity. The increase will result primarily from new space and new or reinstituted programs and is limited by a number of factors, including faculty, space and facilities, funds, student demand, and administrative constraints, such as limits on total university enrollment.

The major impediment to increasing the number of undergraduates is a lack of qualified faculty members. This was cited as a constraint at 15 of the 24 universities contacted and was mentioned by some as being a national problem. The current shortage of professors (and research-oriented graduate students) at some schools, when combined with an increasing industry demand for bachelor's degree mining engineers, is resulting in an insufficient number of undergraduates remaining to take advanced degrees. Consequently, new faculty members are not being trained in sufficient numbers to meet anticipated future needs. The current shortage of faculty has been somewhat ameliorated by the recruiting of foreign personnel, but this is not considered to be a long-term solution. Possible solutions include increasing average fellowship funding for graduate students and increased funding for basic research, with concurrent publicity, to attract and retain faculty.

A second constraint on increasing enrollment is a lack of space or facilities. This was stated as a problem at 10 of the universities. Six of these are either in the process of adding new physical capacity or are expecting to begin to do so within five years. Only one mention was made of the need for capital in conjunction with a space constraint.

Other types of enrollment constraints were total university enrollment limits, grade-point-average admissions limitations, and a lack of student interest.

B.2.4 Program Needs

Current educational program needs mentioned by mining engineering faculty and administrative personnel are similar to the constraints on expansion addressed earlier. Lack of faculty, funding, and student interest in mining engineering were the major problem areas currently facing those attempting to build an enlarged national mining engineering educational program having a solid faculty and research foundation. It was the consensus of opinion that a strong educational program is and will be required to meet present and projected professional manpower needs associated with an increased demand for coal and/or other minerals.

The recent drastic increase in the number of mining engineering students enrolled at some schools has exerted a heavy strain on teaching resources and will require a corresponding faculty increase to restore a reasonable teaching/research balance. In order to assure an adequate supply of qualified faculty members, there is a need for research-oriented graduate students. The problem, in this case, does not appear to be a lack of research funding, but of qualified students. Several university officials stated that research positions are available with no students to fill them.

Industry also has a need for high-level research personnel, i.e., mining engineers with advanced degrees, at least as consultant support on an as-needed basis, if not as full-time employees. Federal legislation, such as the Surface Mining Control and Reclamation Act and the Occupational Health and Safety Act, require improved technology and methods. These, in turn, require research, both at universities and in industry.

Another problem facing mining engineering education is a lack of properly-directed funding, both for scholarships/fellowships and for research. Scholarship/fellowship funding, as currently structured, presents two problems. First, the funding level per student is small and does not provide a sufficient incentive to enter a mining engineering program and, for those who are enrolled, to remain past the undergraduate level. Second, programs have not allowed continuity of funding, that is, a university has not been able to commit funds for a student's entire educational career.

It appears that the number of students enrolling in mining engineering programs has been constrained by the lack of information at the high-school level about the desirability of such a career. A need exists to publicize attractions, such as: job availability, good pay, a variety of work, and the satisfaction of working toward a solution of national energy/environmental problems.

Finally, there exists a national lack of "appreciation for the mining industry's contributions to our economy and society" (Planje, 1978). Funding is needed to implement methods for stimulating awareness of the contributions, problems, and opportunities of mining and minerals industries and disseminating information to more people, particularly in high schools. A need also exists for modern mining texts and reference books. The fact that these needs were addressed by the Committee on Mineral Science and Technology of the National Academies of Science and Engineering in the 1960s shows a lack of progress in meeting the needs of mining engineering education. The State Mining and Mineral Resources and Research Institute's programs, fortunately, show promise in this direction by providing increased support for research and faculty positions, more scholarship funds, and publicizing the personnel needs of the mining industry.

B.3 Mining Technicians

B.3.1 Educational Overview

A two- or four-year degree in mining technology gives a student a broad educational and technical background which will enable the graduate to maximize his opportunities for advancement in the coal mining industry. These programs are intended to meet the increasing demands for skilled workers and production supervisors who should be familiar with the theoretical concepts and practical applications of modern mining technology.

In contrast, non-degree and certificate programs provide participants with the basic understanding and technical skills necessary to perform as a production worker. Because of federal regulations, workers must have at least one course for inexperienced miner training before working in the mines. The individual states set their own guidelines as to the emphasis which is placed on each part of the training.

There are at least 30 community and junior colleges and 45 vocational-technical schools in the U.S. offering programs in coal mining technology. Because there is no complete listing of these institutions, it is difficult to obtain an exact total. A number of sources were combined to develop these totals (DOE, 1979; HEW, 1977; Hamilton, 1978; Doggette, 1976).

Figure B-3 shows the positive relationship between the starting wages of coal miners (BLS#3, 1979) and mining technician graduates (EJC #3, 1977). This figure also shows the relationship between the average starting salary and the graduations of all two-year degree engineer and science technicians. In this figure, while the real starting salary among all technicians should be associated with the graduations of all engineering and science technicians, the real starting salary of coal miners should be associated with the graduations of mining technicians, given that the majority of mining technicians are employed by the coal industry. As may be noted, while the gap widens between coal miners' salaries and that of all

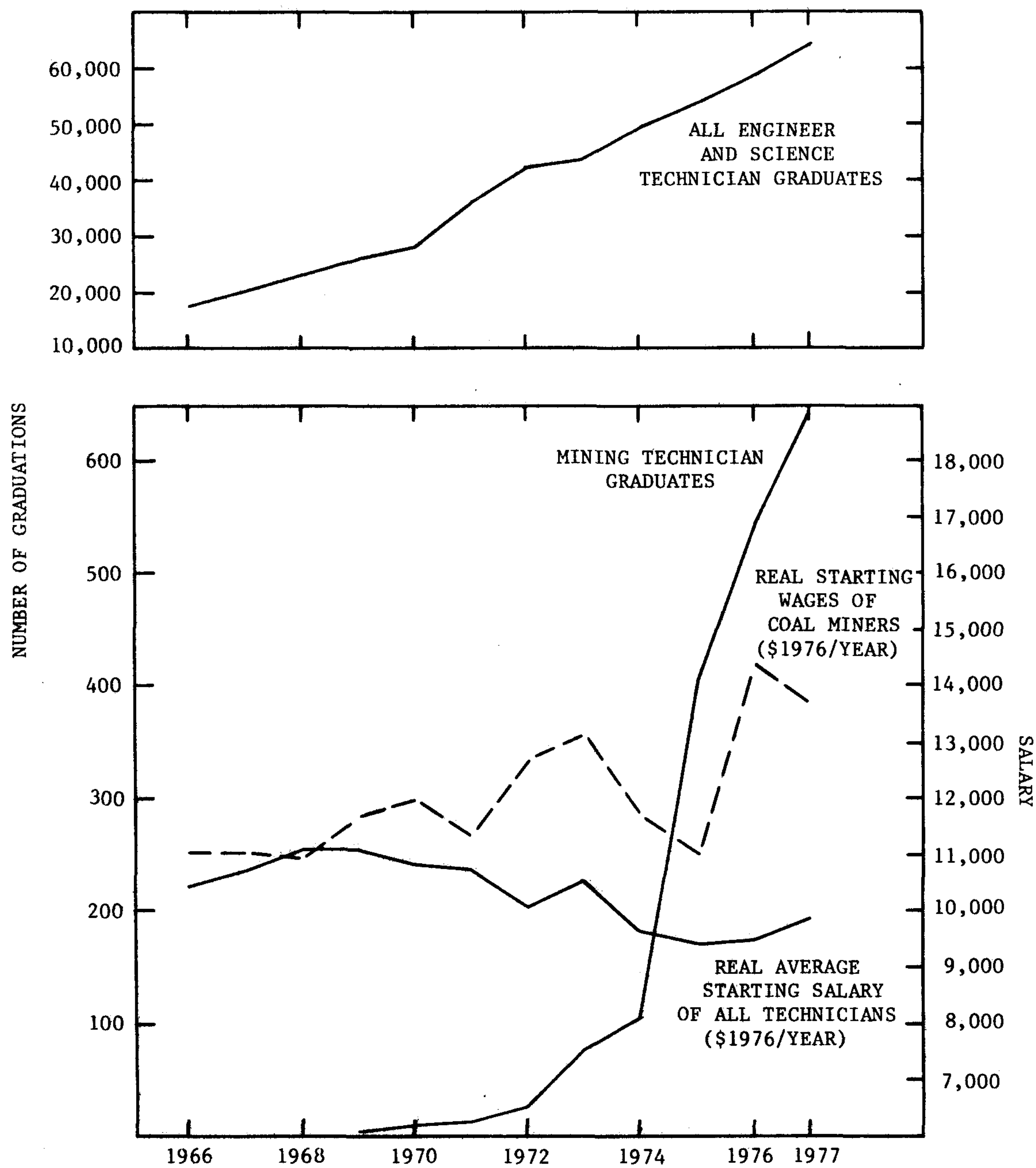


FIGURE B-3
STARTING SALARIES AND GRADUATIONS OF MINING TECHNICIANS AND ALL ENGINEER AND SCIENCE TECHNICIANS

technicians, the growth curve of mining technicians rises at a much faster rate than that of all engineering and science technicians.

Figure B-4 shows the historical trends in mining program enrollments. Four different types of programs are currently offered; non-degree, one-year certificate, and two- and four-year degrees in mining technology. These data were derived in part from the report of the Coal Task Force on Education and Training (DOE/EP, 1979). In the late 1960s and early 1970s, enrollments in the non-degree, one-year certificate and the two-year degree enrollments were all about the same. Since 1973, enrollments in the non-degree and the two-year degree programs have increased at a greater rate than have one-year certificate or four-year degree enrollments. Table B-IX presents the 1978-79 regional enrollment by type of program.

B.3.2 Current Educational Programs

Two types of educational institutions exist with regard to mining training. Two- or four-year degrees are offered in community and junior colleges and in a few universities. Non-degree and certificate programs are offered for the most part at vocational-technical centers and at career centers. Some community and junior colleges also offer short courses in mining training. These institutions generally emphasize two areas of training; managerial and technical. Approximately 61 percent of the colleges stress the management aspect, while 88 percent of the technical schools emphasize the technical element of training. Since the colleges predominantly offer

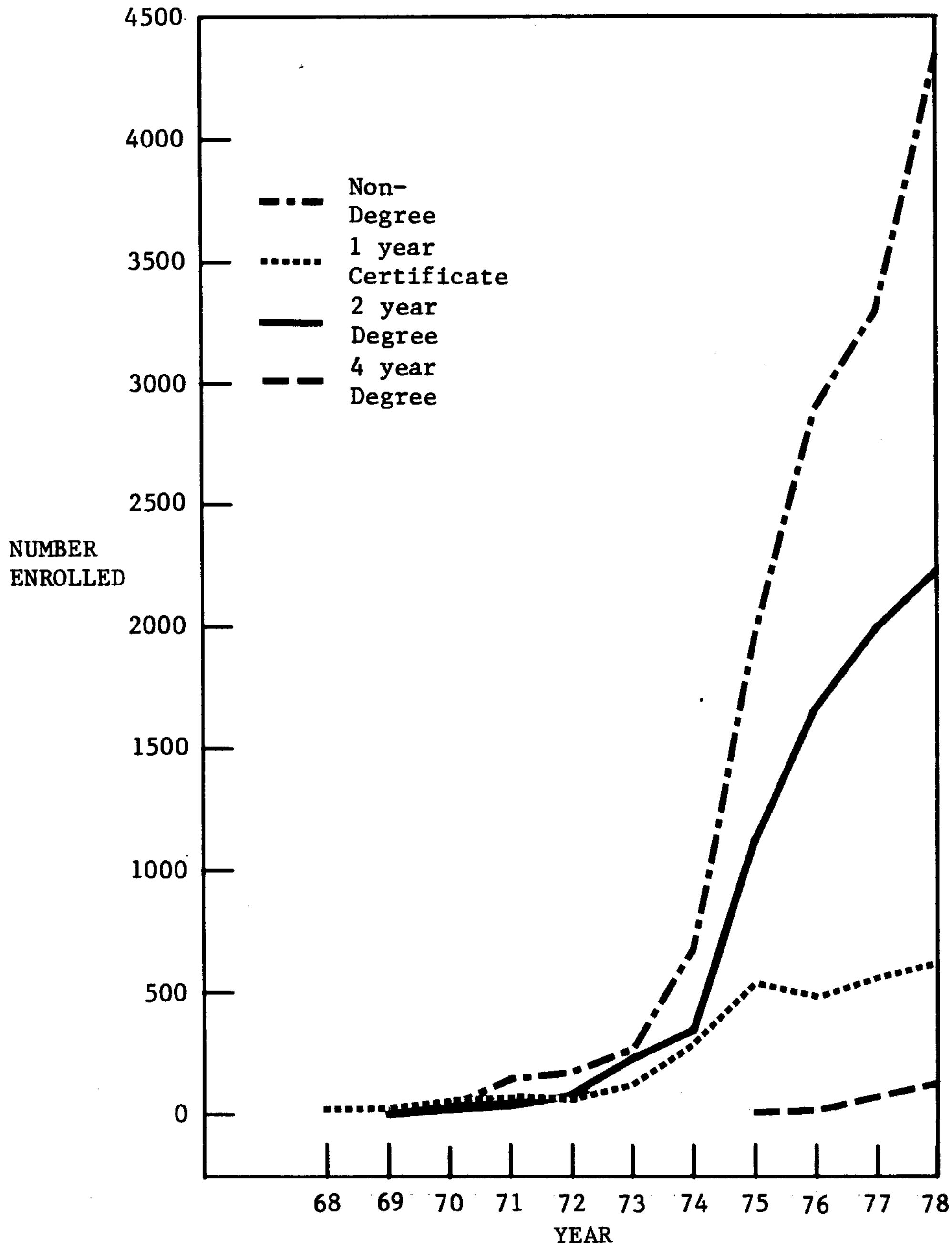


FIGURE B-4
MINING TECHNOLOGY PROGRAM ENROLLMENTS

TABLE B-IX

1978 ENROLLMENT IN MINING TECHNOLOGY PROGRAMS

REGION	NON DEGREE	1-YEAR CERTIFICATE	2-YEAR DEGREE	4-YEAR DEGREE	TOTAL
Northern Appalachia	110	-	380	33	523
Southern Appalachia	2667	468	1007	38	4180
Rocky Mountain	1270	120	42	-	1432
Great Plains	-	25	50	-	75
Interior and Gulf	327	6	762	213	1308
Total	4374	619	2241	284	7518

SOURCES: DOE/EP, 1979, and MITRE telephone survey, 1979.

formal degrees this would explain their emphasis on management training. Similarly, because the vocational centers are concerned with short, non-degree courses, their primary interest lies in developing technical skills.

B.3.2.1 Major Programs Offered

The programs offered through the institutions described above fall under three categories: underground training, surface training, and a combination of both. Underground training is offered in 51.3 percent of the schools, surface training in 17.9 percent, and the remaining 30.8 percent of the schools offer a combination of both. The underground training is offered for the most part at schools in the east, the surface training in the west, and both underground and surface training in the central part of the U.S.

There is a wide variety of course offerings in the two- and four-year degree programs and degree requirements are split between technical training and the physical sciences such as chemistry, geology, psychology, etc. Typical courses are Introduction to Mining, Mine Ventilation, Surveying, Laws and Regulations, Safety and Health, etc.*

B.3.2.2 Faculty Statistics

Student-faculty ratios vary between vocational-technical schools and colleges and universities. The average student-faculty ratio

*These courses are just a few examples of those offered. Although course names vary from school to school, the basic principles taught are similar.

among the technical schools surveyed is approximately 20:1, while the average ratio for colleges and universities is approximately 22:1. These ratios range from a low of 7:1 to a high of 40:1.

B.3.2.3 Coal Industry Employment

Vocational-technical schools, and colleges and universities contribute a large number of graduates to the coal mining industry. Approximately 93.5 percent of the graduates from degree programs were placed in coal mining and another 4.2 percent of the graduates were placed in related industries such as copper and uranium mining. This leaves 2.3 percent not employed in mining. Most of these graduates have taken jobs elsewhere or continued their education.

In the non-degree programs, 82.7 percent of the students were placed in the coal mining industry. Students entering related industries comprised 6.4 percent, and 10.8 percent were not placed. Some of these students not employed in mining have entered fields such as trucking or the armed services. Others were unwilling to work and chose to remain unemployed. Very little inter-regional mobility has been found among graduates of mining technology programs. Those graduates that are placed in the industry tend to be employed in the same region where they received their educational training. One justification given for this is that many of the students that begin technology programs in an area already have contacts or are employed in the mining industry in that area. Another means of finding employment after graduation are cooperative programs which enable students to either work in the mines and gain practical experience while in school or to alternate between working and studying. This enables students to gain knowledge and employment experience, and to become familiar with mine management. A high percentage of the students in non-degree programs already have jobs in the industry when they begin their educational training.

Two-year degree technicians are not qualified, in most cases, to fill more formal engineering positions. Even though many of these students have some training for first level supervisory or line foreman positions, they usually do not have a broad enough educational background for technical engineering positions, such as mine design, health and safety planning or permit application preparation.

There are 25 states which require certification or registration of mine and section foremen positions. Of these, 21 states require certification of mine foremen, and 16 states require certification of section foremen. These are just two examples of the approximately 10 to 15 positions which may require some sort of certification depending on each individual state.

B.3.2.4 <u>Sources of Financial Support</u>

Many sources of financial support exist for various mining technology programs. Some of these sources include individual states, the G.I. Bill, the Comprehensive Education & Training Act (CETA), the Mine Safety & Health Administration (MSHA), and the mining industry itself.

The coal mining industry is one of the major supporters of mining technology programs. They contribute a large amount of money towards scholarships, program funds, and financial support for faculty, in addition to providing adjunct faculty to the training institutions. In many cases, management personnel sit on advisory boards to assist in the development of training courses. Some of the coal companies also donate equipment to schools, enabling students to develop hands-on training in the use of various types of equipment.

One source of funding at the mining technology level is CETA funds. These funds are distributed to 455 prime sponsors through 10 regional offices. A prime sponsor is a unit of government or a combination of units of government with a population totaling 100,000 or more. Prime sponsors send their grant plans to their regional office and the funds are distributed by formula allocation according to recommendations made by regional office staff, Federal representatives, etc. Because of the many prime sponsors, the diversity of programs funded, and the lack of documentation, it is difficult to determine the amount of CETA funding in mining technology programs. Due in part to the nature of the CETA program (i.e., to provide training opportunitites to those with limited skills and employment experience), a higher than average dropout rate and a lower than average job retention rate among those who graduate have been cited by several faculty and industry personnel as among the problems associated with the CETA program.

A few unique cases exist of funding two-year degree programs from funds normally used for four-year degree programs. One of these is the Wyoming Community College System. Sheridan College in Wyoming receives Office of Surface Mining (OSM) funds which go toward scholarships for their 2-year Mining Programs. One program offered is an A.S. Degree in Mining Engineering which is intended to be a preparatory program for those wishing to continue to a B.S. in Mining Engineering. Another is an A.A.S. in Mining Technology.

Many states fund their community and junior colleges, but Kentucky is unique in the degree of funding involved. The community college system in this state includes six schools with two-year mining technology programs. Kentucky spends approximately $500 thousand in supporting students in two-year mining technology programs and also supports vocational technical schools through the Department of Mines and Minerals.

B.3.3 Projected Program Capacity

Schools offering mining technology degrees for the most part do not foresee any problem with overcrowding. Many of these schools have the capability to double or even triple their enrollment. Because technical schools do not require instructors to have a Ph.D. to teach in these schools, they are not constrained from expanding due to the shortage of professors with a Ph.D. in Mining Engineering.

B.4 Other Engineers in Coal Mining

While mining engineers comprise the greatest percentage of engineers employed by the coal mining industry, large numbers of other engineers are also employed. Civil, industrial, mechanical, and electrical engineers are those other disciplines sought most frequently. They often may be used by the mining industry as a substitute for a mining engineer; e.g., replacing the industry-specified skills of a mining engineer with the education-specific skills of, for example, a civil engineer, some of whose training is directly applicable to mining. In other cases, an engineer may be hired for non-mining-specific jobs; e.g., an industrial engineer may be employed to analyze material flows or mining productivity. Figure B-5 illustrates trends over the last few decades in bachelor degree graduations of these four disciplines.

Based on conversations with numerous coal and other metal and non-metal mining companies as well as several consulting firms, civil engineering is increasingly becoming a competitor with mining engineering as the degree of choice. Although mining engineers often command a premium from mining companies of up to 10 percentor more in salaries than other engineers, the trend toward surface production of coal as well as large-scale open pit mining of copper and other minerals is resulting in a greater percentage of civil engineers among all engineers employed. Since surface mining involves earth moving, run-off control, soil stabilization and construction industry skills which characterize civil engineering (rather than a stricter emphasis on rock mechanics, ventilation and other undergound concerns), a shift away from a predominance of mining engineers in

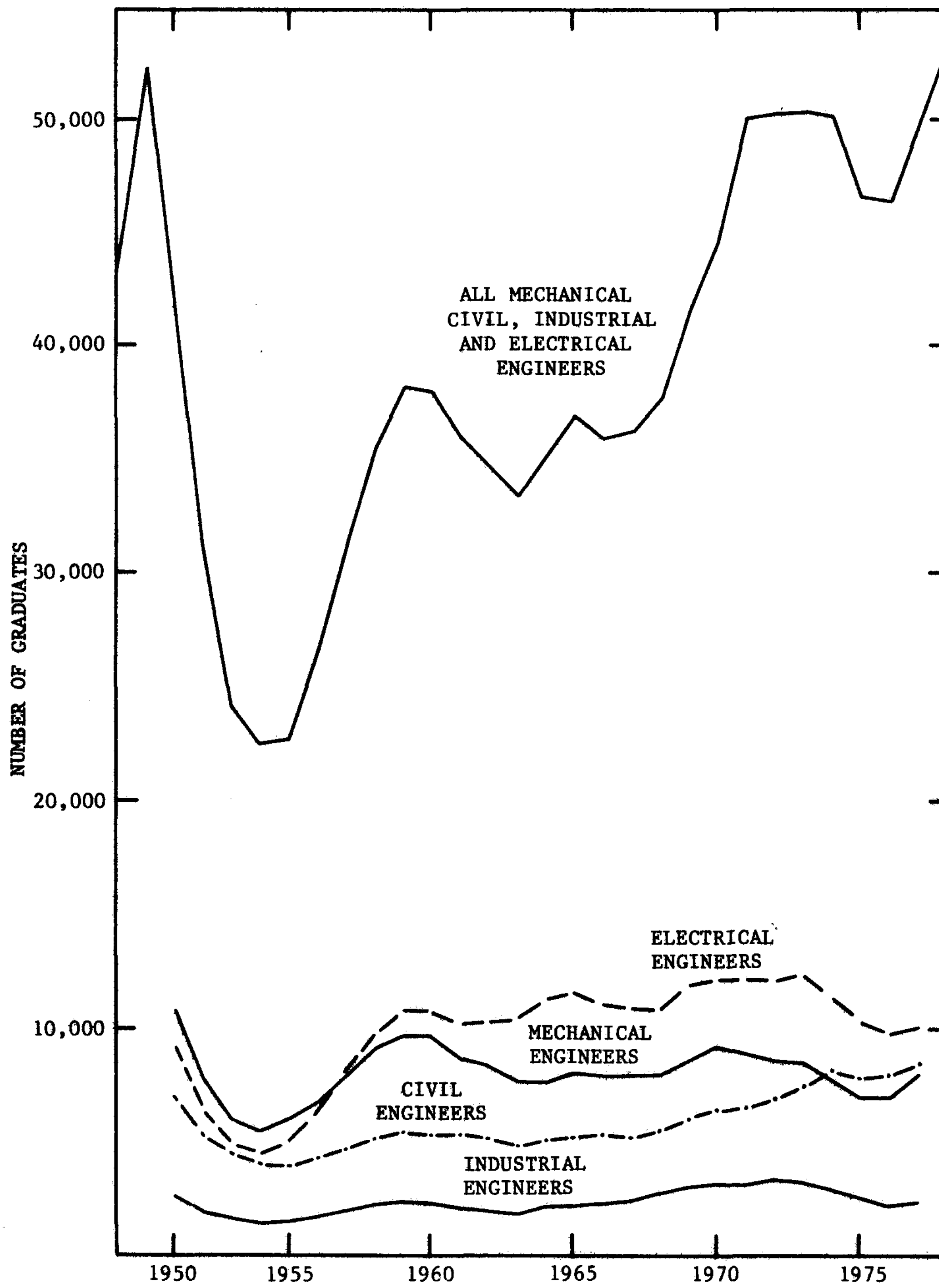


FIGURE B-5
BACHELOR'S DEGREE ENGINEERING GRADUATES
APPLICABLE TO MINING

surface mining may be inevitable. Nevertheless, there remains a strong desire to have at least one or more formally trained mining engineers at most mine sites. Active recruitment of engineers of various types, especially to fill first line supervisory positions (i.e., section foreman in deep mines, pit foremen in surface mines), is now being conducted by most coal and other mining companies.

Other minerals-related engineering disciplines are metallurgical, geological, and geophysical engineering. These engineers are predominantly in demand for metals mining and non-coal fuel (uranium and petroleum) industries.

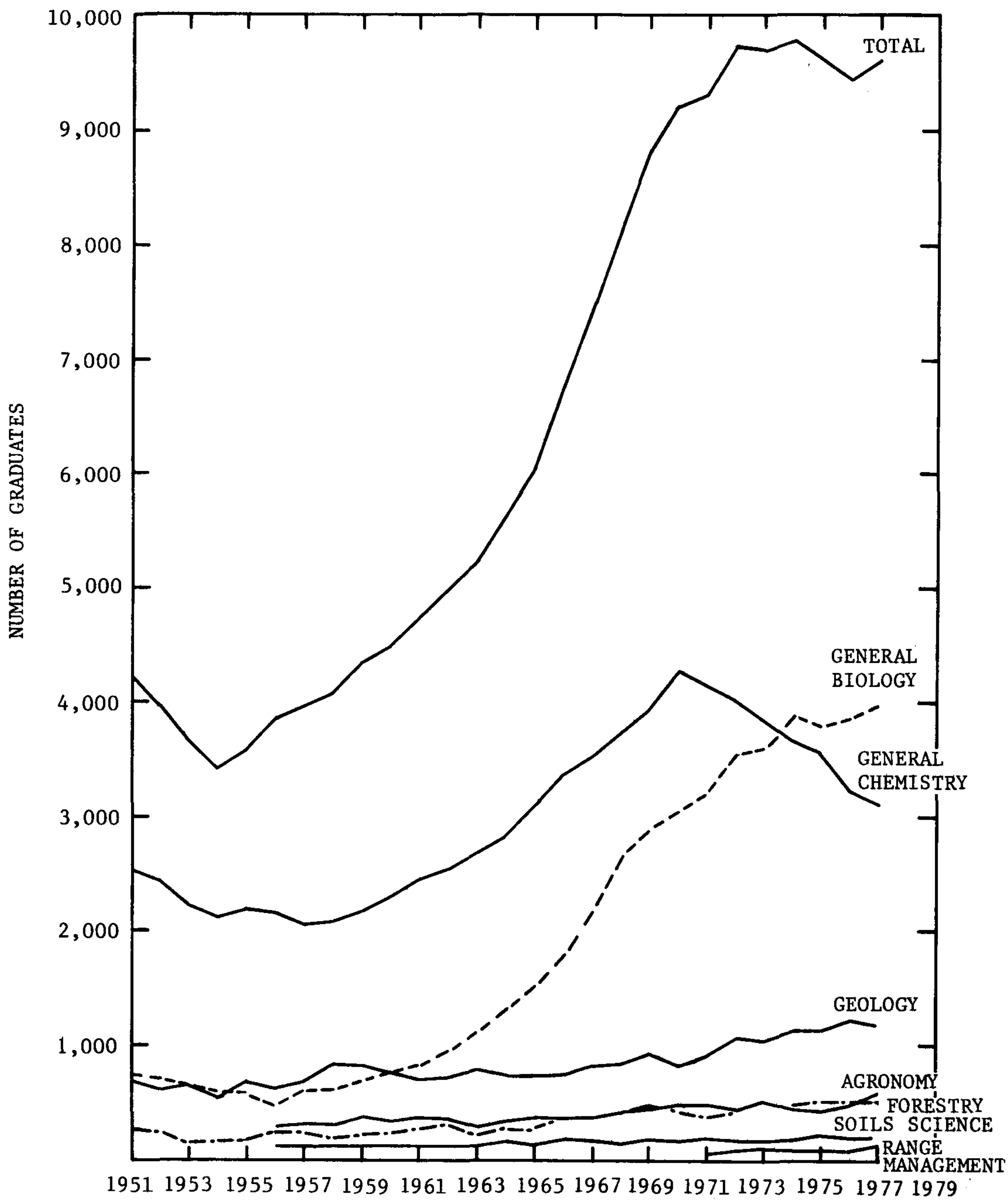
The projected supply of non-mining engineers to meet demand in the coal mining industry appears to be sufficient. Over 2,000 bachelor's degrees were conferred in industrial engineering in 1976-77, five times the 404 mining engineering graduates in that year (HEW, 1977). The numbers of mechanical (over 7,500 B.S. graduates), civil (approximately 8,400 B.S. graduates), and electrical (about 10,000 B.S. degrees) engineering graduates were far greater. Given the limited requirements for non-mining engineers by the coal industry and the industry's relative competitiveness in terms of salaries, it is unlikely that a shortage of other engineers would affect the coal industry apart from an engineer shortage affecting the nation as a whole. In recent years, the supply and demand outlook for mainstream engineering disciplines such as the above-mentioned ones has appeared relatively well-balanced.

B.5 Scientists in Coal Mining

The coal industry also employs a number of life and physical scientists who perform functions related to environmental protection and land reclamation. According to the 1970 Census and the BLS Industry/Occupational Matrix, such scientists comprised less than one-fifth of one percent of the total coal mine work force (about 270 scientists). Since then, as in the case of engineers, the number of scientists employed by the coal industry is estimated to have about doubled.

The science degrees most often sought by the coal industry include geology, agronomy, forestry, soils science, range management, general biology and general chemistry. Figure B-6 illustrates the numbers of advanced degree graduates in the above disciplines over the last 20 years. Unlike engineering in which bachelors' degrees were considered sufficient for professional entry levels, there is a greater emphasis on advanced degrees (i.e., masters and doctorates) in the sciences as a requirement for employment both within and outside of the coal industry. This is especially true for those involved in sensitive efforts such as preparing surface mine permits and reclamation plan preparation.

Among the regional differences in types of scientists demanded and supplied, geologists, soil scientists and chemists are in somewhat greater demand in the more humid regions of the east and the midwest than in the west. This is the case mainly because of the



SOURCE: EARNED DEGREES CONFERRED, HEW

FIGURE B-6
ADVANCED DEGREE SCIENCE GRADUATES APPLICABLE TO MINING

problems of runoff control, soil stabilization and acid mine drainage neutralization in the east and midwest. In the west, however, the problems of groundwater contamination, revegetation potential, wildlife preservation, and water conservation in general are of relatively greater importance than they are in the east. Thus, in addition to geologists, foresters, and range or wildlife ecologists are among the degrees most actively sought after. The types of science programs offered in schools in various regions reflect the indigenous problems faced by the coal companies operating in these regions.

Full time employment of scientists at individual mine sites is far less common than for engineers. Most scientists who perform runoff control monitoring and related environmental work do so from division or regional offices of companies with several coal mines. Depending upon the mine size and scope of the land reclamation effort, some companies assign full time reclamation foremen at individual sites, with support from elsewhere in the company provided according to a schedule for reclamation activities. The desire to employ scientists in-house for such functions is generally greater among larger companies which can better utilize a full-time environmental support staff. However, at least some use of engineering and science consultant support services, especially for baseline data gathering and monitoring efforts, is common among coal companies of all sizes and in all regions. The degree to which such support may continue in the future is as much based on the growth of regulatory requirements as it is on any consolidation of coal production by company size.

B.6 Mining Engineering Educational Support Programs

Many programs provide educational support for mining engineering students. This report addresses those which are currently in effect and which provide direct support to mining engineering students at more than one university. These include Federal programs such as the State Mining and Mineral Resources and Research Institutions (SMMRRI) and the Domestic Mining and Mineral Fuel Conservation Fellowships (DMMFC); industry programs such as the Minerals Industry Education Fund (MIEF), and other programs such as state-sponsored fellowship/ scholarship programs and endowments. These programs are summarized in Table B-X. In this Appendix, emphasis is placed on the SMMRRI program because it is the only Federal aid program which provides direct support to undergraduate mining engineering students.

B.6.1 State Mining and Mineral Resources and Research Institutes

B.6.1.1 Program Description

The SMMRRI program was authorized under the Surface Mining Control and Reclamation Act of 1977 to be administered from the Office of Surface Mining Reclamation and Enforcement (OSM) in the U.S. Department of the Interior. The Act intended to:

> "stimulate, sponsor, provide for and/or supplement present programs for the conduct of research investigations, experiments, and demonstrations, in the exploration, extraction, processing, development, and production of minerals

TABLE B-X

MAJOR MINING/MINERAL ENGINEERING EDUCATION SUPPORT PROGRAMS

--FEDERAL--

PROGRAM (DEPARTMENT)	ENABLING LEGISLATION	PERIOD OF FUNDING	FUNDING LEVELS	NUMBER OF STUDENTS SUPPORTED	RECIPIENT OF FUNDS	EDUCATIONAL LEVEL/ DISCIPLINE	ALLOWABLE USES OF FUNDS
State Mining and Mineral Resources and Research Institutes (DOI)	Surface Mining Control and Reclamation Act of 1977,	FY1978 through FY1985	FY1978: $5.4 million FY1979: $2.74 million An additional $2.7 million will be awarded for research in FY1979	FY1979: 262 undergraduates, 140 graduate students 13 postdoctoral	Institutions: For institutional allocations, scholarships/fellowships and research.	Undergraduates, graduates, and postdoctoral researchers in mining and mineral resources and allied fields	Institutional allotments: All but land or buildings. Scholarship/fellowships: For support of recipients. All funds: Can be used at other institutions in the same state.
Domestic Mining and Mineral Fuel Conservation Fellowships (HEW)	Higher Education Act of 1965 as amended, Title IX	FY1975 through FY1980	FY1975: $1.5 million FY1976: $3.0 million FY1977-FY1980: $4.5 million per year	FY1975: 181 FY1976: 375 FY1977: 500 FY1978: ~576 FY1979: ~540 FY1980: ~457	Institutions: For graduate student fellowships	Graduate students in mining, mineral, and mineral fuel conservation.	Stipends for student support. Allowance to educational institution to cover tuition and fees.

--INDUSTRIAL--

PROGRAM	SPONSOR	DATE OF INCEPTION	FUNDING LEVEL	NUMBER OF STUDENTS SUPPORTED	SELECTOR(S) OF RECIPIENTS	EDUCATIONAL LEVEL/ DISCIPLINE	COMMENTS
Minerals Industry Education Fund	Minerals Industry Education Foundation	1972	~$175,000/year	200-225/year	Institutions	Undergraduates in mining and metallurgical engineering	At 12 selected universities
Society of Mining Engineers (SME) of AIME Coal Division Scholarships	SME-AIME Coal Division	1950	~$13,000/year	≤24/year	Coal Division Scholarship Selection Committee	Student at school emphasizing coal. Student has chosen a career in mining engineering with emphasis on coal.	
SME-AIME Local Section Scholarships	Various organizations	Variable	Varies	Varies	Varies	Student expenses	Students chosen on basis of scholastic record and interests
Woman's Auxiliary Scholarship Loans	Woman's Auxiliary to the AIME (WAAIME)	1917	$55-62,000/year	166 in FY1978	WAAIME National Scholarship Loan Fund Committee	Student expenses -- 1/2 of each award to be repaid.	

and the training of mineral engineers and scientists in the field of mining, minerals resources, and technology, and the establishment of an appropriate research and training center in various States."

The objectives of the program as given by OSM are:

(a) To support research and training in mining and mineral resources problems related to the mission of the Department of the Interior.

(b) To contribute to a comprehensive nationwide program of mining and mineral research having due regard for the protection and conservation of the environment.

(c) To support specific mineral research and demonstration projects of industry-wide application.

(d) To assist the states in carrying on the work of competent and qualified mining and mineral resources research institutes.

(e) To provide scholarships, graduate fellowships and postdoctoral fellowships in mining and mineral resources, and allied fields such as mining engineering, civil engineering, soil conservation, hydrology, geology, chemistry, ecology, wildlife biology, land use planning, and resources management.

Institute funding has been divided into three parts: institutional allotments, research grants, and scholarship/fellowship funds. The institutional allotment was $110,000/university for the 1978-79 school year. Each Institute also received $160,000 for a 3-year period to be used for undergraduate scholarships and graduate and postdoctoral fellowships. Research grant funding has not yet been awarded.

Eligibility for the program was set by the Act and has been determined by the Secretary of the Interior. If more than one school in a state is qualified, then the Governor decides which will be designated an Institute.

B.6.1.2 Institutes Supported

Twenty Institutes were originally authorized, two have been added and eight more are currently proposed by DOI. The 22 existing during the 1978-79 academic year are shown in Table B-XI, along with the disciplines supported with SMMRRI funds. It should be noted that the SMMRRI program is state-based, i.e., some Institute funds may be spent at schools and colleges other than those at which the Institutes are located. For example, SMMRRI funds support mining students at Prairie View A&M, part of the Texas A&M system, although the Institute is located at the University of Texas at Austin.

Most of the Institutes (18) support mining engineering students. Metallurgical and geological/geophysical engineering programs are each supported at 12 Institutes. Other major disciplines are mineral processing (at 8 Institutes), petroleum and natural gas engineering (at 7 Institutes), and mineral economics (at 6 Institutes). SMMRRI funds also support students in a wide variety of additional specialties.

B.6.1.3 Institutional Allotments

Each Institute received a $110,000 allotment during the 1978-79 academic year. These funds have been used for a variety of purposes.

- o Salaries: to pay new professors', visiting professors, and summer salaries.

TABLE B-XI

SMMRRI INSTITUTES AND DISCIPLINES*

UNIVERSITY	DISCIPLINES SUPPORTED
U. of Alabama	Mining Engineering, Mineral Processing
U. of Alaska	Mining, Geological Engineering
U. of Arizona	Mining, Metallurgical, Geological, Chemical Engineering, Mineral Processing, Fuel Science
U. of California, Berkeley	Mining, Metallurgical Engineering, Other
Colorado School of Mines	Mining, Metallurgical Engineering, Mineral Economics, Other
U. of Idaho	Mining, Metallurgical, Geological Engineering
Southern Illinois U., Carbondale	Mining, Geological Engineering, Other
U. of Kentucky	Mining Engineering, Other
Massachusetts Inst. of Tech.	Mineral, Civil, Metallurgical, Chemical Engineering
Michigan Tech.	Mining, Geological, Geophysical Engineering, Mineral Processing
U. of Minnesota	Mineral, Metallurgical Engineering, Mineral Processing
U. of Mississippi	Petroleum, Geological Engineering, Mineral Economics, Fuel Science, Mineral Sciences, Mineral Law
U. of Missouri, Rolla	Mining, Metallurgical, Ceramic Processing, Petroleum, Geological Engineering
Montana Coll. of Mineral Sci. & Tech.	Mining, Metallurgical, Petroleum, Geological, Geophysical Engineering, Mineral Processing, Other
New Mexico Inst. of Mining & Tech	Mining, Petroleum, Geologcial, Metallurgical Engineering, Other
Ohio State U.	Mining, Metallurgical, Geological, Ceramic Processing, Chemical Engineering
U. of Oklahoma	Geological, Petroleum, Civil Engineering

TABLE B-XI (Concluded)

Pennsylvania State U.	Mining, Metallurgical, Ceramic Processing, Petroleum Engineering, Mineral Processing, Mineral Economics, Fuel Science
U. of Texas, Austin	Mining, Petroleum Engineering, Fuel Science, Other
U. of Utah	Mining, Metallurgical, Geological Engineering, Mineral Processing, Mineral Economics
West Virginia U.	Mining Engineering, Mineral Economics, Other
U. of Wyoming	Mining, Petroleum Engineering, Mineral Processing, Mineral Economics

*Sources: OSM Data and MITRE Telephone Survey

- Administrative costs: to pay salaries for administrative personnel such as the Institute Director, Assistant Director, and secretarial support. Additional uses classified as administrative include new course design and/or development, library materials, faculty travel, publication costs, supplies, support for seminar programs, and operational expenses.

- Research: to sponsor low-cost or otherwise unfunded research projects to enable researchers to obtain other funding by sponsoring proposal preparation or new initiatives.

- Equipment: to fund major equipment purchases.

- Technicians: to pay salaries for support personnel such as technicians, mechanics, equipment operatives, etc.

Since the decision on how to spend institutional allotments rests with individual Institutes, varying amounts have been spent for each of the above purposes.

B.6.1.4 Scholarships and Fellowships

The SMMRRI program provides each Institute with $160,000 to be spent over a 3-year period. These funds are to be used for undergraduate scholarships, graduate fellowships, and postdoctoral fellowships in mining and mineral resources and closely allied fields. Projections of the numbers of students to be supported and funds to be spent by each Institute for the 1979-80 academic year are shown in Table B-XII. Of the students supported, 63 percent are undergraduates, with an average scholarship of about $850. One hundred forty graduate fellowships, averaging $5,000, are being awarded. The Institutes are supporting 13 postdoctoral fellows at an average cost of $11,918. Scholarship/fellowship expenditures for 1979-80 will be over $1 million, averaging about $49,000 per Institute.

TABLE B-XII
SMMRRI STUDENT SUPPORT (1979-80)*

UNIVERSITY	UNDERGRADUATE SCHOLARSHIPS	GRADUATE FELLOWSHIPS	POST-DOCTORAL FELLOWSHIPS
U. of Alabama	0	3 ($15,600)	0
U. of Alaska	18 ($12,000)	3 ($15,000)	0
U. of Arizona	10 ($10,000)	2 ($ 7,075)	1 ($ 4,938)
U. of California, Berkeley	3 ($ 4,500)	4 ($25,280)	2 ($34,000)
Colorado School of Mines	17 ($16,400)	18 ($61,200)	0
U. of Idaho	0	0 (2 from institutional allotment)	0
Southern Illinois U., Carbondale	0 (10 projected in 1980-81)	0	2 (N/Av)
U. of Kentucky	14 ($18,200)	9 ($46,944)	0
Massachusetts Inst. of Tech.	7 ($ 4,550)	2 (N/Av)	0
Michigan Tech.	10 ($ 7,500)	6 ($24,000)	3 ($39,000)
U. of Minnesota	0	2 ($16,500)	1 ($18,000)
U. of Mississippi	38 ($28,500)	17 ($57,500)	0
U. of Missouri, Rolla	26 ($16,250)	12 ($61,200)	0
Montana Coll. of Mineral Sci, & Tech.	58 ($69,600)	4 ($19,920)	0
New Mexico Inst. of Mining & Tech.	12 ($ 6,000)	4 ($40,000)	1 ($24,000)
Ohio State U.	18 ($ 9,000)	5 ($40,000)	0
U. of Oklahoma	0 (some projected in Spring 1980)	0	0
Pennsylvania State U.	0	9 ($48,000)	0

TABLE B-XII (Concluded)

U. of Texas, Austin	8 ($ 8,000)	10 ($ 42,000)	0
U. of Utah	7 ($ 4,200)	15 ($ 62,400)	2 ($ 26,000)
West Virginia U.	0	12 ($110,414)	1 ($ 9,000)
U. of Wyoming	16 ($ 6,350)	3 ($ 7,000)	0
TOTAL	262 ($221,050)	140 ($700,033)	13 ($154,938)

*Source: OSM data and MITRE telephone survey. These are preliminary figures. Final will not be available from OSM until after submission of final reports in October, 1979.

It should be noted that more students are expected to be supported in 1980-81 than in 1979-80 because the arrival of funds at some Institutes was too late to allow for recruitment for the 1979-80 academic year.

The numbers of students by discipline to be supported by SMMRRI are shown in Table B-XIII. The largest number of students (55 undergraduates [UG], 29 graduates[G], and 3 postdoctorals [PD]) are in the mining engineering discipline, followed by petroleum and natural gas engineering (52 UG, 4 G, 1 PD); geological and geophysical engineering (33 UG, 15 G, 1 PD); metallurgical engineering and extractive metallurgy (24 UG, 18 G, 2 PD); ceramic processing engineering (14 UG, 4 G); mineral processing (10 UG, 12 G, 3 PD); mineral economics (1 UG, 15G, 1 PD); and fuel science (5 UG, 6 G). The "other" category is used to cover disciplines such as chemical engineering with few students supported and those such as mineral law which are only offered at one or two universities.

B.6.1.5 Program Benefits and Problems

Benefits of the SMMRRI program that were cited by survey participants are listed in Table B-XIV. These benefits include:

- o Increased scholarship availability. More student financial assistance is available at the undergraduate level. A particular benefit is that scholarships can be awarded on the basis of merit, without a requirement for the demonstration of financial need.

- o Increased publicity. The SMMRI program and other programs which support mining disciplines help to publicize the mining industry's need for personnel.

TABLE B-XIII

SMMRRI SCHOLARSHIPS/FELLOWSHIPS (1979-80)*

DISCIPLINE	UNDERGRADUATE		GRADUATE		POSTDOCTORAL	
	NUMBER	COST	NUMBER	COST	NUMBER	COST
Mining Engineering	55 (21%)	$ 47,175 (21%)	29 (21%)	$165,668 (24%)	3 (23%)	$ 43,000 (28%)
Petroleum and Natural Gas Engineering	52 (20%)	$ 45,525 (21%)	4 (3%)	$ 19,700 (3%)	1 (8%)	$ 24,000 (15%)
Geological and Geophysical Engineering	33 (13%)	$ 28,125 (13%)	15 (11%)	$ 59,780 (9%)	1 (8%)	$ 13,000 (8%)
Metallurgical Engineering and Extractive Metallurgy	24 (9%)	$ 17,975 (8%)	18 (13%)	$100,575 (14%)	2 (15%)	$ 30,000 (19%)
Ceramic Processing Engineering	14 (5%)	$ 8,250 (4%)	4 (3%)	$ 23,200 (3%)	0	--
Mineral Processing	10 (4%)	$ 8,050 (4%)	12 (9%)	$ 54,180 (8%)	3 (23%)	$ 35,938 (23%)
Mineral Economics	1 (0.5%)	$ 1,000 (0.5%)	15 (11%)	$ 61,100 (9%)	1 (8%)	$ 9,000 (6%)
Fuel Science	5 (2%)	$ 4,500 (2%)	6 (4%)	$ 25,700 (4%)	0	--
Other	68 (26%)	$ 60,450 (27%)	37 (26%)	$190,130 (27%)	2 (15%)	N/Av
TOTAL	262	$221,050	140	$700,033	13	$154,938

*Source: Office of Surface Mining and MITRE telephone survey. Preliminary figures only.

TABLE B-XIV
MAJOR IMPACTS OF SMMRRI ON UNDERGRADUATE ENROLLMENTS*

U. of Alabama	More scholarships
U. of Alaska	Limited impact on undergraduates; increased publicity for mining
U. of Arizona	Little impact on undergraduates; possible improved visibility for mining
U. of California, Berkeley	More scholarships; possible increased (visiting, etc.) faculty support
Colorado School of Mines	More scholarships/fellowships
U. of Idaho	More scholarships; increased research; increased publicity for mining
Southern Illinois U., Carbondale	Little impact on undergraduates; possible improved faculty
U. of Kentucky	More scholarships; more faculty members
Massachusetts Inst. of Tech.	Increased research
Michigan Tech.	More scholarships; more faculty members
U. of Minnesota	More faculty support; increased publicity for mining
U. of Mississippi	More student support based on merit
U. of Missouri, Rolla	More scholarships; more publicity for mining
Montana Coll. of Mineral Sci, & Tech.	More scholarships; increased publicity for mining
New Mexico Inst. of Mining & Tech.	Limited impact on undergraduates
Ohio State U.	More publicity for mining
U. of Oklahoma	More scholarships; increased research; increased faculty
Pennsylvania State U.	More publicity for mining and national needs

TABLE B-XIV (Concluded)

U. of Texas, Austin	More scholarships; more publicity for mining
U. of Utah	More scholarships; more faculty support
West Virginia U.	Little impact at undergraduate level
U. of Wyoming	More Scholarships

*Source: MITRE telephone survey

- Increased support for faculty. Faculty support is in the form of new positions, summer salaries, and visiting faculty to alleviate heavy teaching loads.

- Increased research support. Additional research made possible by the SMMRRI program can have several types of benefits. A strong research program has appeal to some students. Graduate assistants, hired to help with research, can also assume a portion of a university's teaching requirements. A good research program can help instructors to keep abreast of developments in their field and broaden faculty interests, thus increasing faculty reputations and appeal to students.

- Funding flexibility. The institutional allotment mechanism allows a good deal of flexibility, allowing an Institute to expend funds to strengthen portions of the mining program. The scholarship/fellowship funds can also be used for undergraduates, graduates, or postdoctoral fellows, wherever they are most needed.

- Funding continuity. The program allows a multi-year commitment to finance a student's entire research program.

- Research consolidation. An overall research program can be developed for the mineral industry. The technologies of many disciplines, e.g., reclamation, biology (acid mine drainage), etc., can be brought together for the benefit of the mining industry.

Problems of the SMMRRI program that were cited concerned the number and kind of institutions to be funded and an insufficiency of funds. Questions as to the number of Institutes have arisen because of different interpretations of the program's purpose. Some of those contacted feel that the interpretation is too strict, concentrating on coal mining, particularly on surface mining of coal, and that more Institutes should be admitted on the basis of environmental protection and conservation. Others feel that the interpretation is too broad, and that the program should be restricted to schools with mining engineering programs.

The amount of funding per Institute was cited as another problem. Some Institute personnel feel that institutional allotments should be increased to the authorized amounts of $200,000 in FY1978, $300,000 in FY1979, and $400,000 per year thereafter. They also believe that additional funds are needed for scholarships and fellowships.

B.6.2 Domestic Mining and Mineral Fuel Conservation Fellowships

B.6.2.1 Description

The Domestic Mining and Mineral Fuel Conservation Fellowship (DMMFC) program was authorized under Title IX, Part D of the amended Higher Education Act of 1965. Funded through the H.E.W. Office of Education, the fellowships help full-time graduate students who are in need of funds to pursue advanced degrees in disciplines involving oil, gas, coal, oil shale, and uranium. Fellows are urged to develop and improve methods of discovering, extracting, recovering, and conserving minerals and mineral fuels.

Under this program, fellows receive a stipend and an allowance is paid to the educational institution to cover the cost of tuition and fees. Although the focus of the program is on the master's degree level, doctoral dissertation fellowships are also available. Procedures for award are as follows: "Students who already possess a baccalaureate degree apply directly to a participating college or university. The school then nominates eligible students to the U.S. Commissioner of Education, who awards the fellowships. A student is eligible to receive up to 36 months of support as a fellow with an additional 12 months possible. (HEW/OE, 1977)

The DMMFC program has been authorized since the 1975-76 academic year. Authorization terminates in the 1980-81 academic year and the program, as such, is not expected to be renewed.

Available information concerning the numbers of students supported by this program is shown in Table B-XV. It should be noted that, as in the SMMRRI program, the DMMFC fellowships are awarded to both mining engineering students and others. During the 1978-79 year, 112 out of an estimated 576 fellows were mining engineering students.*

B.6.3 Minerals Industry Education Fund Scholarships

The Minerals Industry Education Fund (MIEF), sponsored by the Minerals Industry Education Foundation, is financed by contributions from non-ferrous mining companies, equipment manufacturers, and construction companies. The program began in 1972 and had as its objective increased enrollments of mining and metallurgical engineering students at the undergraduate level. The fund provides scholarship funds for these students, particularly in their first two years. The attrition rate among undergraduate engineering students is recognized and deemed an acceptable risk and, in fact, only 60 percent of the scholarship recipients receive undergraduate degrees.

The MIEF supports from 200 to 225 mining and metallurgical engineering students each year at 12 universities. The number of

*Source: MITRE survey.

TABLE B-XV

DOMESTIC MINING AND MINERAL FUEL CONSERVATION FELLOWSHIPS*

Academic Year	Number of Institutions	Number of Fellows	Total Funding
1975-76	40	181	$1.5 million
1976-77	48	375	$3.0 million
1977-78	52	500	$4.5 million
1978-79	55	576 **	$4.5 million
1979-80	51	540 **	$4.5 million
1980-81	N/Av.	457 **	$4.5 million **

* Office of Eduction, HEW

** HEW estimate

students per school ranges from 8 to 25. The amount of each scholarship ranges from $250 to $3,000 per year. Recipients are selected by their university on the basis of merit and usually rank in the top one-third to one-fifth of their high school classes. While most scholarships are for one to two years, some are available for four years.

In addition to scholarship funds, which total about $150,000 per year, the Foundation also provides recruiting funds to the selected universities. Each school receives $2,000 per year to use for recruiting undergraduates.

As previously mentioned, the MIEF is intended to increase the number of mining and metallurgical engineering students by attracting freshmen to the field. This is accomplished by filling the gap between high school and the upperclass years, for which adequate financial assistance exists, by providing scholarships to freshmen and sophomores. Foundation sponsors feel that the effort has been successful.

B.6.4 Society of Mining Engineers of AIME Coal Division Scholarships

The Coal Division of the Society of Mining Engineers (SME) of AIME offers up to 24 scholarships of up to $650 per year to "deserving college-university students who have chosen as a career path the field of mining engineering with an emphasis on coal. Candidates are selected by the Coal Division Scholarship Selection Committee on the basis of need, scholastic record and interests". These scholarships are offered only to students attending selected universities (Alabama, Kentucky, Missouri-Rolla, Penn State, VPI, West Virginia) emphasizing coal in their mining engineering programs.

B.6.5 SME-AIME Local Section Scholarships

More than 100 scholarships, ranging from $50 to $1,000 per year are available through local SME-AIME sections. Eligible disciplines include geology, mining, mineral processing, mining technology, and engineering. Recipients are selected based on their scholastic record and interests. Financial need requirements, applicable years of study, field of study, eligible schools or universities, and other eligibility requirements vary from section to section.

B.6.6 Woman's Auxiliary to the AIME Scholarship Loans

The Scholarship Loan Fund of the Woman's Auxiliary to the AIME provides scholarship loans to students of Engineering Science oriented toward the mineral industry (mining, metallurgy, geology, petroleum, mineral science, geological oceanography, mineral economics, civil engineering--mining option, and materials science or engineering--metallurgy). The Fund supported 166 students during the 1978-79 academic year. The amount of each scholarship loan is negotiable and one-half of each award is to be repaid to the Fund. Applicants must be enrolled in an ECPD-accredited degree course. Application is made through local sections and final selection is made by the Scholarship Fund Committee.

B.6.7 Other Programs

The previous Sections have addressed scholarship programs which support mining engineering (and other) students in more than one state or at more than one university. Other programs exist that are more restricted, e.g., state scholarship and university endowment programs. Kentucky, for example, spent over $400,000 in 1978-79 on mining education and training. Funds are supplied by the Kentucky Department of Energy through the Center for Energy Development and support students in mining engineering, mining technology, and reclamation technology. Single-university sources of financial support are usually in the form of endowment funds. Several university personnel mentioned these as significant sources of support for mining engineering students.

APPENDIX C

PRODUCTION AND TECHNOLOGY CONSTRAINTS

C.1 Introduction

The MITRE Mining Manpower Model calculates annual manpower requirements for five coal producing regions of the U.S. for the years 1960 through 2000. Estimated costs and labor requirements of regional model mines are inputs to the model. As the labor requirements of the model mines change with time, the labor demand, skills mix and labor costs per ton of coal will change in the model. As model mine costs change, the investment/finance submodel will change the allocation of new mine capacity among mining technologies.

The following mining technologies are represented in the MITRE manpower model:

underground mines--conventional, continuous, longwall
surface mines--contour, area

Data for the model mines for each region were presented in Appendix A. However, certain constraints are reflected in the model mine data discussed below.

C.2 Constraints on Coal Production

C.2.1 Demand for Coal

Historically, the coal industry has had excess production capacity. Coal production has been constrained by the demand for coal and its price. In the MITRE model the annual required regional coal production and the coal price are exogonous scenario inputs. These inputs will be used by the finance and investment submodel to calculate the annual regional coal production capacity.

C.2.2 Transportation

If coal production is to be expanded significantly, improved rail and barge facilities will be required to transport coal to consumers (GAO, 1977). The annual production required in each region and coal prices (scenario inputs) should reflect transportation constraints.

C.2.3 Availability of Capital

The development of new mines can be limited by the availability of capital. In the MITRE Manpower Model, this constraint is modeled in the finance investment submodel where the external capital available for new mines is calculated from the internal funds available and the debt-equity ratio. The debt-equity ratio is an input fraction of the current industry rate of return on investment.

C.2.4 Secondary Industries

Except for a surge in equipment orders following the first oil embargo in 1973, equipment manufacturers have historically had excess production capacity. With the possible exception of large draglines, the future capacity of mining equipment manufacturers is not viewed as a serious constraint by most authors (OTA, 1979; GAO, 1977). The introduction of new technology, such as longwall mining tends to be limited by factors other than equipment production. These include capital costs, incompatibility with existing mine design, geologic factors, and a general conservatism on the part of mine owners.

During the 1970's the costs of mining equipment and energy increased more rapidly than the general inflation rate. In the MITRE manpower model an equipment cost inflation factor is applied to capital costs and maintenance costs. The price index for construction equipment will be used to determine this factor for years prior to 1979. A separate inflation factor will be applied to energy costs. This factor will be proportional to the price of coal, which should reflect future changes in energy prices.

C.2.5 Technological Change

Improvements in coal mining technology can alter capital costs, improve productivity and change the skills mix of mining labor. The major technology improvement in area surface mining has been the increased size of draglines and shovels. However this growth in equipment size appears to have leveled off (Schmidt, 1979). Potential technology advances with the greatest impact on surface mining labor requirements are the development of stripper-loaders and mobile conveyors which can continuously remove overburden and coal for area strip mines.

Major improvements in underground mining technology have been the replacement of conventional mining methods with continuous miners (since 1950) and the introduction of longwall technology (since 1960). Potential improvements in continuous mining technology include: remote control of mining machines, roof bolters and ventilation equipment mounted on the continuous miner, and, improved conveyor systems which can be loaded at the face by a continuous miner. Potential improvements in longwall technology include improvements in conveyor systems, improved reliability of shearer equipment and development of automated chocks.

Historically, mine owners have been very conservative about adopting new technology. Geologic factors and choice of mining technology determine the design of a new mine. A technological improvement such as a new type of conveyor system often cannot be installed in an existing mine without changes in mine design.

In the MITRE Mining Manpower Model, each regional model mine can be a mixture of two generic model mines. One of these model mines represents present technology. The other represents costs and labor requirements associated with technology improvements that could be introduced in new mines. The fraction of the mixture attributed to the new technology mine can change each year. This fraction is a table input and can easily be changed for each technology in each region to examine the effects of technology improvements on labor demands.

C.2.6 Geologic Factors

The amount of coal that can be mined in each region by the various technologies is limited by geologic factors. These factors will be discussed as coal seam and overburden characteristics, recoverable reserves and other geologic factors.

The following geologic characteristics can influence the choice of underground mine technology and resulting mine productivity and costs (Hittman, 1976).

Seam thickness
Depth of seam
Seam slope
Roof quality
Bottom quality
Methane liberation
Presence of water
Presence of gas wells, faults, clay veins, seam discontinuities

The following geologic characteristics can influence the productivity and costs of surface mines:

Seam thickness
Seam slope
Depth of overburden
Hardness of overburden
Slope of terrain
Water table
Land use after mining (affects reclamation costs)

For example, calculated reclamation costs for contour surface mines with a maximum stripping ratio of 20 varied from $1.59 to $5.51 for 15° and 25° terrain, respectively. For a maximum stripping ratio of 30, the costs varied from $2.09 to $7.26 for 15° and 25° terrain, respectively (Nephew and Spore, 1976).

Representative seam thicknesses and overburden ratios were used to develop the regional model mine parameters. As coal resources are depleted, new mines will be opened which have more severe geologic constraints. To some extent, these mining conditions can be mitigated by improved mining technology.

Estimates of the recoverable reserves of bituminous, subbituminous and lignite coal in the five regions are as follows:

Recoverable Reserves* (1974 x 10^6 Tons)

Region	Strip	Underground
Northern Appalachia	12,168	61,155
Southern Appalachia	7,544	31,887
Interior-Gulf	29,482	66,953
Northern Great Plains	84,398	103,710
Rocky Mountain	6,836	21,033

The coal production scenarios should reflect the resources available in each region. If preliminary runs of the model give excessive production by Appalachian strip mines, it may be necessary to apply a multiplier factor to the estimated marginal cost of coal production in the finance/investment submodel to reflect declining reserves.

Water for coal preparation plants and irrigation of reclaimed mine land can be a constraint in Western areas. Water availability may be the limiting factor in the development of slurry pipelines for transportation of Western coal. The effect of the mine on the water table must also be considered in mine design.

6.2.7 Environmental/Regulatory

Environmental and regulatory constraints have significantly affected the costs of coal mining. These constraints include:

*U.S. BOM, IC 8521.

Reclamation requirements
Reclamation bonds
Leasing costs
Severence taxes
Health and safety
Union regulations

The costs and personnel requirements associated with these constraints are included in the regional model mine data.

The major developments with respect to these constraints have been the following:

--The Coal Mining Health and Safety Act of 1969 requires underground operators to devote more personnel and equipment to ventilation, rock dusting, methane and dust monitoring and roof control and to retrofit machinery with safety features.

--The 1974 UMWA contract requires helpers on underground face equipment. This resulted in the hiring of an estimated 5000 additional miners.

--The National Environmental Policy Act of 1969 requires an Environmental Impact Statement for all mining-related activities that have a significant impact on the environment and that need federal authorization.

--The Surface Mining Control and Reclamation Act of 1977 mandates state permit programs for surface mines and for the surface operations of underground mines. Surface mines must meet standards governing restoration of land to its original contour, use of explosives, waste disposal, road construction and revegetation.

--The Clean Water Act Amendments of 1977 requires each state to develop and implement water quality standards. These include standards affecting drainage from deep and surface mines and pollution from coal preparation plants.

--The Resource Conservation and Recovery Act of 1976 seeks to control solid waste disposal under a system of state plans and permits. Proper disposal of toxic coal mine wastes would be required.

--Between 1967 and 1975 coal mining states enacted surface mining laws and reclamation requirements. Those states with the strictest laws are Montana, Wyoming and Colorado in the West and Pennsylvania, West Virginia and Ohio in the East. The major impact of these laws has been an increase in surface mining costs to handle overburden and topsoil to reclaim mined out land.

--Federal leasing policy is presently being revised. The federal government owns 65 percent of Western coal and indirectly controls another 20 percent. The overall effect of a new leasing policy is difficult to estimate since 16 billion tons of federal coal are already under lease and another 9 billion are subject to existing applications for preference-right leases. In addition there are an estimated 93.4 billion tons of recoverable coal reserves on private lands in the West. Coal extracted from privately owned land is subject to state severance taxes. In the Western coal producing states, these taxes range from none in Utah to 30 percent of the gross value of the coal in Montana (DOI, 1978). Royalties for federally controlled coal have averaged about 8 percent of the value of the coal. In the future federal royalties will be negotiable and could be 21 percent or more of the coal value. In general, taxes and leasing costs have risen rapidly since 1973.

One result of these regulations has been an increase in office workers to work on permit applications, develop plans and administer them at the mine site. In 1969 operators reported 2640 office workers of all kinds at mine sites; that figure rose to 7037 in 1977 (OTA, 1979).

Another result of the regulations is the increase in time required to open a new mine. BOM estimates are shown in Table C-1.

TABLE C-1

IMPACTS OF ENVIRONMENTAL ACTIONS ON
TIME REQUIRED TO OPEN NEW COAL MINES

	A. Total Time (years) Required for new mine openings		B. Time (years) needed for Environmental and Governmental Actions (included in A.)	
	Min	Max	Min	Max
Eastern Surface Mine	1.5	3.0	0.25	0.6
Western Surface Mine	4.0	15.0	2.50	7.5
Eastern Underground	2.5	5.0	0.25	0.6
Western Underground	3.0	13.5	1.25	6.0

SOURCE: (GAO, 1977)

A-10
G. MacDonald
C. Zraket

D-12
H. Benington
J. Fearnsides
S. W. Gouse
C. Grandy
R. Greeley
A. Tachmindji

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R. Ouellette
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W-50 Data Files (32)

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A. Ghovanlou

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T. Wright

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E. Krajeski
S. Lubore

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B. Fuller

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