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Economic Impact Analysis of Proposed Effluent Limitations Guidelines, New Source Performance Standards, and Pretreatment Standards for the Coal Mining Point Source Category

Volume III- Appendix B, Methodology Description

ECONOMIC IMPACT ANALYSIS OF PROPOSED EFFLUENT LIMITATIONS GUIDELINES, NEW SOURCE PERFORMANCE STANDARDS, AND PRETREATMENT STANDARDS FOR THE COAL MINING POINT SOURCE CATEGORY

VOLUME III -- APPENDIX B, METHODOLOGY DESCRIPTION

prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF WATER REGULATIONS AND STANDARDS
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by

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This report has been reviewed by the Office of Water Planning and Standards, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendations for use.

PREFACE

This volume is an Appendix to a contractor's study prepared for the Office of Water Planning and Standards of the Environmental Protection Agency (EPA). The purpose of the study is to analyze the economic impact which could result from the application of effluent standards and limitations issued under sections 301, 304, 306 and 307 of the Clean Water Act to the Coal Mining industry.

The study supplements the technical study (EPA Development Document) supporting the issuance of these regulations. The Development Document surveys existing and potential waste treatment control methods and technology within particular industrial source categories and supports certain standards and limitations based upon an analysis of the feasibility of these standards in accordance with the requirements of the Clean Water Act. Presented in the Development Document are the investment and operating costs associated with various control and treatment technologies. The attached document supplements this analysis by estimating the broader economic effects which might result from the application of various control methods and technologies. This study investigates the effect in terms of product price increases, effects upon employment and the continued viability of affected plants, effects upon foreign trade and other competitive effects.

The study has been prepared with the supervision and review of the Office of Water Planning and Standards of EPA. This Appendix was submitted in fulfillment of Contract No. 68-01-4466 by Arthur D. Little, Inc., and was completed in July, 1980. The work was performed from June, 1977 through July, 1980; the data sources referred to in the report were current at the time the work was performed.

This report is being released and circulated at approximately the same time as publication in the Federal Register of a notice of proposed rule making. The study is not an official EPA publication. It will be considered along with the information contained in the Development Document and any comments received by EPA on either document before or during final rule-making proceedings necessary to establish final regulations. Prior to final promulgation of regulations, the accompanying study shall have standing in any EPA proceeding or court proceeding only to the extent that it represents the views of the contractor who studies the subject industry. It cannot be cited, referenced, or represented in any respect in any such proceeding as a statement of EPA's views regarding the Coal Mining industry.

APPENDIX B

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APPENDIX B

METHODOLOGY DESCRIPTION

I. INTRODUCTION

This Appendix describes the coal supply-demand model that was developed to analyze the economic impact of proposed, more stringent water-quality control standards for point sources in coal production. These control standards will require coal producers to spend more for water treatment at the mine site, thereby increasing their overall costs of producing coal.

The relative increase in production costs for individual mines is influenced by numerous factors that are related to the different environments in which an operator has to deal, such as:

- Meteorological: relative rainfall;
- Topographical: hilly versus flat terrain;
- Locational: proximity to other mines;
- Geological: coal quality and depth of coal seam, presence of acquifers, chemical composition of overburdens;
- Financial: cost of money, equipment and labor;
- Microeconomic: a mine's market position in terms of location and producer/user relationships;
- Macroeconomic: energy and feedstock supply demand balances and the costs of other fuels and feedstocks.

This analysis is to estimate the relative dependence of coal production costs on each of these factors in sufficient detail to allow reliable estimates of the direction and relative magnitude of inter-regional shifts of coal production that can be expected to take place in 1984 if more stringent mine water treatment requirements are imposed.

A. Main Sources of Data Used in the Impact Analysis

The 1976 MESA Mine File described in Chapter II of Appendix A of this report is used as a starting point for estimating mine production costs of individual mines. This file contains detailed production information for individual users. Some of this detail is lost or smoothed out through averaging, when regional supply curves are linearized.

Transportation costs are estimated by statistical analysis of rail rates and water transport costs, as described in Chapter V of Appendix A.

Coal sulfur content distributions are derived from an analysis of coal quality data for coal sales to electric utilities in 1976, as obtained from the FPC.

Coal utilization costs are developed as described in Chapter VI of Appendix A of this report. These costs account for the different Btu content and sulfur content of different coals, and for the varying air quality control standards in the different demand regions.

As will be shown in later sections, the limited number of data points on water flow volumes for coal treated at individual mine sites is the main limiting factor in the level of regional detail achievable in the impact estimates.

B. Four Main Premises Used for the Analysis

The estimated economic impact of the regulations is obtained through simulation of supply and demand in steam coal markets in 1984. The simulation is structured around the following four premises:

(1) Coal, as a fuel, competes with coal rather than oil, gas or nuclear energy. This premise is based on the current trend of increasing oil and gas costs - as discussed in Section VI.1.3 of Appendix A - the restrictions on the use of gas as utility boiler fuel, and the growing resistance to further rapid growth in the use of nuclear energy. The analysis used a fixed demand estimate for 1984 and concentrated on the estimation of inter-regional shifts of coal supplies which can be expected to take place because of relatively higher estimated pollution control costs in some regions (as resulting from differences in the relative wetness of mines in the various coal-producing regions).

(2) Coal producers, in order to continue to mine coal, will have to recover their operating expenses and investment costs (but not sunk costs), including a return on those investment costs over the remaining life of the mine. In this analysis this requirement establishes the minimum price at which coal will be sold. If mine operators cannot get that minimum price, then they will close the mine and cease to produce.

(3) It is assumed that the steam coal contract and spot markets operate independently of each other. Only two interactions are allowed in the analysis:

- -- Large mines producing more than 50,000 tons per year (i.e., contract market mines) are assumed to sell some of their output in the spot market at variable costs.

- -- Contract market mines which are found to be non-competitive in contract markets are assumed to sell to the spot market (i.e., a market dominated by small mines producing less than 50,000 tons of coal per year).

(4) The nature of transactions between producers and users in contract and spot markets is assumed to be completely different. In the contract market all producers are assumed to sell coal on a cost-plus basis; the large, virtually "infinite" resource base creates a very competitive situation on the supply side, always allowing large buyers to select among a large number of potential suppliers, thereby driving prices down.

In the spot market all coal from a region is assumed to sell at the marginal price. Buyers in this market are more concerned with timely supply than with price. Suppliers in this market know what the cost of coal on the margin is and are able to negotiate prices up to that margin. In other words, in the contract market all producers are assumed to obtain the same return on their investment; in the spot market producers with low-cost coal will have a higher return than producers with high-cost coal.

Given these four main premises, the analysis concentrates primarily on specifying the differences between costs of supply at different output levels in the various supply regions, allowing for:

- Differences in coal mining conditions (including mine wetness);
- Different transportation costs because of different distances between supply and demand regions;

- Differences in user costs because of different coal quality;

- Differences in user costs because of the differences between air quality control regulations in different demand regions.

The remainder of this chapter explains the above in more detail.

II. IMPACT ANALYSIS METHODOLOGY

Figure 1 shows a schematic of the impact analysis methodology. Regional supply volumes and costs are projected for 1984 for the steam coal markets (spot and contract) and for the met coal market, allowing for differentials in coal prices because of differences in production costs, transportation costs and utilization costs.

As shown, ADL has made estimates of potential supply and related costs for 27 different supply regions. These supply estimates are combined with estimates of demand in 35 demand regions (as obtained from EPA which used these demand projections recently for an analysis of the impact of air quality control regulations).

These two sets of estimates, together with estimates of coal quality differentials, and transportation and utilization costs, are used in the coal market simulation model to obtain estimates both before and after the proposed regulations. This allows us to derive the differential economic impact resulting from production cost increases caused by more stringent water clean-up requirements at the mine site. As shown in Figure 1, the primary impact measures are:

- Increased user costs both as an average and on the margin in different demand regions;

- Increases in marginal prices in supply regions;

- Lost production in supply regions;

- Number of closed mines;

- Number of jobs lost;

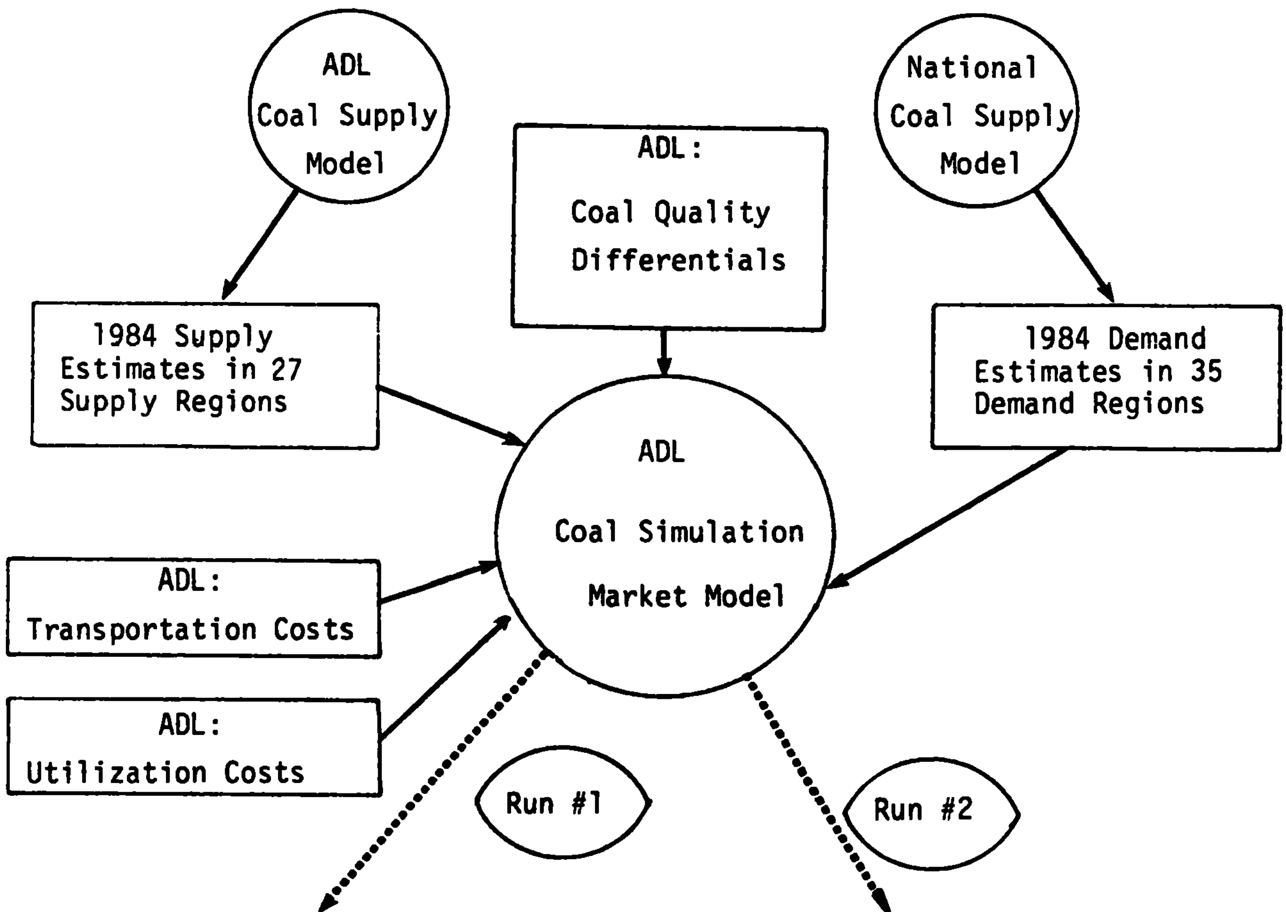
- Resulting decreases in regional mine workers' wages;

- Mine cashflows versus increased investment requirements for pollution control equipment.

As shown in Figure 2, the model itself consists of six modules, each composed of one or more data files and computer programs, which use those data as input. These modules perform the following main operations:

FIGURE 1

SCHEMATIC OF IMPACT ANALYSIS METHODOLOGY



BEFORE REGULATION IN 1984 (by region):

Number of producing mines
Total cost of coal to the user
Tons of coal produced
Coal prices
Number of mine workers employed
Wages earned after tax cashflows
Required investment in mining equipment

—

AFTER REGULATION IN 1984 (by region):

Number of producing mines
Total cost of coal to the user
Tons of coal produced
Coal prices
Number of mine workers employed
Wages earned after tax cashflows
Required investment in mining equipment

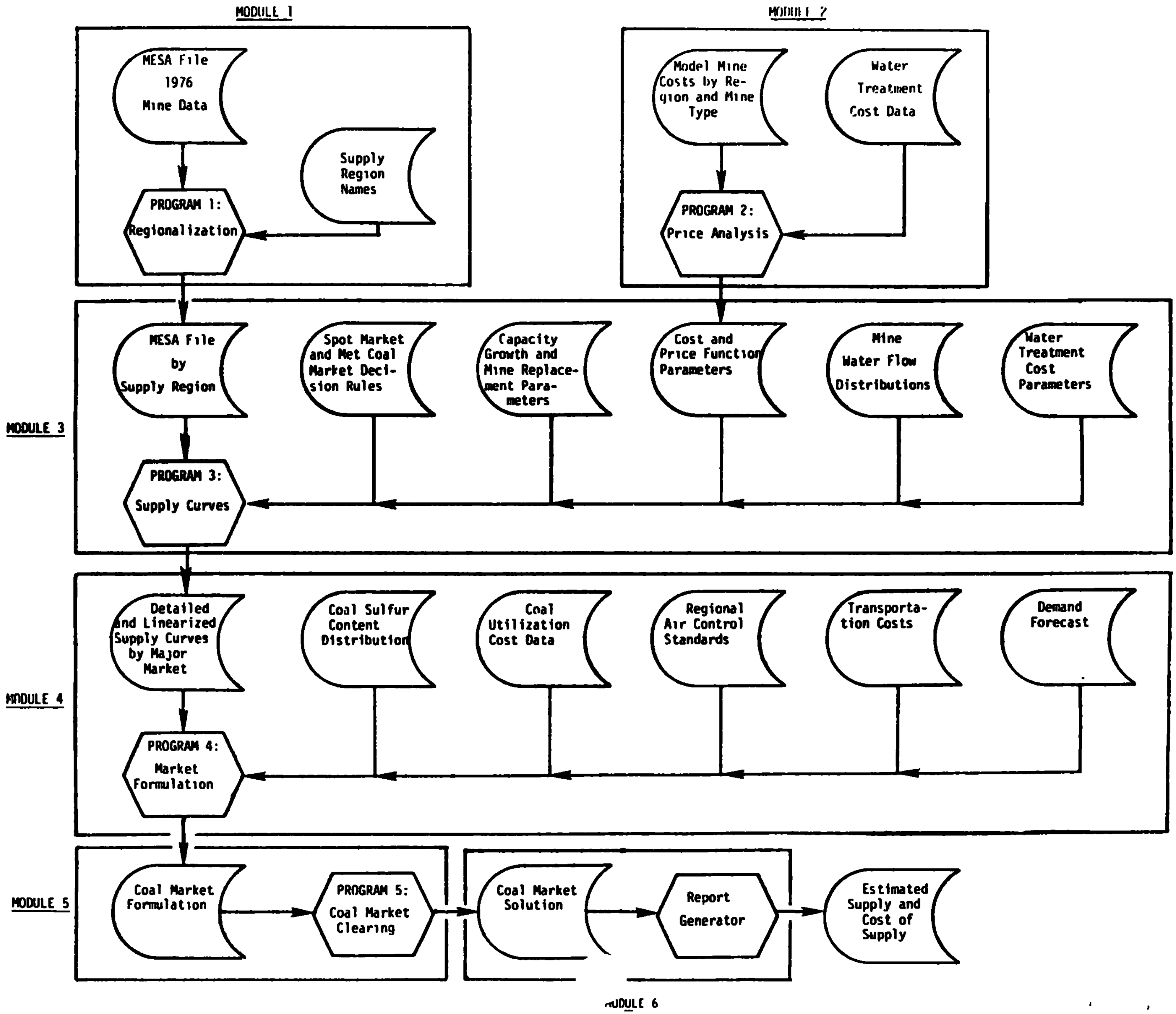
=

PRIMARY IMPACT OF THE REGULATION (by region):

Increased cost to the user
Lost production
Number of closed mines
Number of jobs lost
Decrease in wages
Decrease in cashflows
Increased investment required

FIGURE 2

COAL SUPPLY-DEMAND MODEL



MODULE 1: Separates the mines contained in the MESA file into 27 supply region files which serve as inputs to Module 3.

MODULE 2: Uses engineering estimates of production costs for different types of model mines in different supply regions. It calculates minimum required prices (MRP) for these mines for different labor productivities, as well as different investment costs in pollution control equipment resulting from different mine water flow volumes. These price estimates are used to calculate a functional relationship between minimum required price (the dependent variable), mine productivity and required investment in pollution control equipment per annual ton of coal produced (the independent variables).

MODULE 3: Uses the MRP function resulting from Module 2, plus the regional mine files, to calculate three supply curves for each of the supply regions for the steam coal spot and contract markets. The supply functions, specifying cumulative potential supply at increasing prices at the mine, are first calculated on a mine-by-mine basis (i.e., detailed) and then linearized for use as an input to the linear program used in Module 5 to balance supply and demand in coal markets.

MODULE 4: Organizes all the information used in the market simulation in a linear program which is solved in Module 5. In addition to the linearized supply curves for the 27 supply regions, information on sulfur content distribution and transportation and utilization costs of different types of coal with different sulfur content is provided.

MODULE 5: Provides a solution to the linear program set up by Module 4.

MODULE 6: Takes the output from Module 5 and organizes it into several reports to allow more rapid evaluation of the results of the analysis.

The nature of the data and the computations performed by the programs used in these modules are described in the following sections.

III. REGIONALIZATION OF THE MINE FILE (MODULE 1)

The MESA file, which contains 1976 information on mine location, mine type, status (i.e., open, temporarily or permanently closed), number of hours worked, and tons of coal produced, is organized into the 27 different supply regions. These supply regions, as shown in Table 1, coincide largely with the supply regions used in the National Coal Model.

IV. MINIMUM REQUIRED PRICES (MODULE 2)

The 1984 minemouth prices used in the analysis are based on estimated production costs. Since actual production costs for individual mines are not available, engineering estimates are made of unit investment and operating costs for mine models, categorized by:

- Location (region);
- Mine type (underground or surface);
- Mine size (large or small);
- Remaining producing life (new or existing mine);
- Required water treatment costs for compliance with EPA regulations.

Within each mine category, costs are specified to change with:

- Mine productivity (tons of coal produced per mine shift);
- Level of water flow to be treated.

As shown in Figure 2, the input to the computer programs of Module 2 consists of a set of model mine parameters and water treatment costs; the output consists of a set of parameter values, relating minimum required price (MRP) to productivity and dollars of required investment in water treatment equipment.

The calculation of the parameter values which relate the MRP for a mine to productivity and treated water flows is performed in two stages:

- Calculate MRP's for each mine category for different mine productivities and for different flow levels;
- Estimate function parameters relating MRP's, remaining required investment in mining equipment,

TABLE 1

SUPPLY AND DEMAND REGIONS USED FOR THE IMPACT ANALYSIS

NCM REGIONAL CENTROIDS WITH FREIGHT STATION ACCOUNTING CODES

Supply Region	Centroid	Freight Station Accounting Code
Pennsylvania (PA)	Johnstown	05001151
Ohio (OH)	Cambridge	05001549
Maryland (MD)	Lonaconing	83900238
West Virginia, north (NV)	Clarksburg	05000469
West Virginia, south (SV)	Bluefield	55003355
	Charleston	05003642
Virginia (VA)	Appalachia	72401230
Kentucky, east (EK)	Hazard	44402631
Tennessee (TN)	Clinton	72405420
Alabama (AL)	Cordova	72407457
Illinois (IL)	Centralia	07624120
Indiana (IN)	Huntingburg	72300344
Kentucky, west (WK)	Central City	44404124
Iowa (IA)	Ottumwa	07620241
ouri (MO)	Clinton	69300162
as (KS)	Pittsburg	40000130
Arkansas (AR)	Russellville	49406080
Oklahoma (OK)	Tulsa	69300839
Texas (TX)	Corsicana	69401202
North Dakota (ND)	Wilton	07657691
Montana, east (EM)	Sidney	07659225
Wyoming (WY) (1)	Casper	07632236
Colorado (CS)	Carbondale	19702416
Utah (UT)	Sunnyside	19709106
Arizona (AZ)	Winslow	02210286
New Mexico (NM)	Gallup	02210158
Washington (WA)	Centralia	14004514

Demand Region		Centroid	Freight Station Accounting Code
New England	MV	Concord, N.H.	06900123
	MC	Springfield, Mass.	62219122
Middle Atlantic	NU	Oswego, N.Y.	62210667
	WP	Pittsburg, Pa.	62204727
	PJ	Trenton, N.J.	62200203
South Atlantic	VM	Baltimore, Md.	05000129
		Norfolk, Va.	55001001
	UV	Wheeling, W.Va.	05000361
		Huntington, W.Va.	05000768
	CA	Charlotte, N.C.	72402535
	[illegible]	Atlanta, Ga.	71213699
		Tampa, Fla. (Barge only)	
	SF	W. Palm Beach, Fla.	71226590
East North Central	ON	Cleveland, O.	05002168
	OM	Columbus, O.	05001640
	OS	Marietta, O.	05001648
	MI	Detroit, Mich.	62206874
	IL	Peoria, Ill.	62208884
	IN	Indianapolis, Ind.	62208463
	WI	Milwaukee, Wis.	[illegible]
East South Central	EK	Winchester, Ky.	44402033
	WK	Louisville, Ky.	44401000
	ET	Knoxville, Tenn.	44405683
	WT	Memphis, Tenn.	44406380
	AM	Birmingham, Ala.	44407206
West North Central	DM	Minneapolis, Minn.	14005898
	KN	Topeka, Kan.	02202571
	IA	Des Moines, Ia.	14500759
	MO	St. Louis, Mo.	69300752
West South Central	AO	Little Rock, Ark.	14507420
	TX	Dallas, Tex.	02209354
Mountain	MW	Billings, Mont.	07630841
	UN	Salt Lake City, Utah	80200081
	CO	Denver, Col.	07620977
	AN	Phoenix, Ariz.	02214194
Pacific	WO	Seattle, Wash.	07602199
	CN	Oakland, Calif.	72100013
	CS	Los Angeles, Calif.	07612141

Wyoming has been separated into Wyoming Powder River Basin and Wyoming, Other Regions.

annual wages, and cashflow per annual ton of coal produced (the dependent variables) with productivity and mine water flow volumes (the independent variables).

A. Number of Different Sets of Model Mine Parameters Required

As shown in Table 2, model mine specifications for both old and new mines required estimates for the following parameters:

- Investment and operating costs;
- Fiscal parameters, such as royalty payment, federal, state and local taxes;
- Water treatment costs.

A total of 50 different combinations of these three sets of parameters resulted after careful analysis of available engineering estimates of mine operating and investment costs, state taxes and royalties and available information on mine water flows in conjunction with cost estimates for different water treatment levels provided to us by the EPA (see Table 2). Each pollution control level required evaluation of such a set of 50 mines. The impact analysis considered the effect of two different proposed BAT treatment levels relative to the existing BPT treatment level. Therefore, a total of 150 different mine models had to be evaluated.

B. Model Mine Production Cost Parameters

Table 3 shows an example of the model mine investment and operating costs used for the calculations described in this section.

Preliminary analysis showed that within the mine size ranges, judged to be representative for the two major coal markets analyzed (contract and spot), minimum required prices were only very slightly related to mine size. Therefore, one representative mine size was used for each mine category in the different regions.

As shown in Table 3, the cost parameters are divided into three groups:

- Investment cost data for the mine facilities and mining equipment;
- Operating cost data, together with the average labor productivity for which they are specified;
- Operating cost ratios, specifying by how many percentage points certain categories of operating

NUMBER OF DIFFERENT COMBINATIONS OF MINING COST, WATER TREATMENT COST AND FISCAL PARAMETERS REQUIRED FOR THE ANALYSIS OF ONE CONTROL LEVEL[1]

TYPE OF PARAMETERS

REGIONS			Coal Mining Cost		Water Treatment Cost		Royalties/ Taxes	Parameter Combination		Model Mine #	
			OLD	NEW	OLD	NEW		Old Mines	New Mines	Old	New
1. NA	Ug	L	Ao	A1	ao	a1	1	Aoao1	A1a11	1	2
		S	Bo	B1	bo	a1	1	Bobo1	B1a11	3	4
	Su	L	Co	C1	bo	bo	1	Cobo1	C1bo1	5	6
		S	Do	D1	bo	bo	1	Dobo1	D1bo1	7	8
2&3. CA & SA	Ug	L	Ao	A1	co	c1	1	Aoco1	A1c11	9	10
		S	Bo	B1	co	c1	1	Boco1	B1c11	11	12
	Su	L	Co	C1	bo	bo	1	Cobo1	C1bo1	5	6
		S	Do	D1	bo	bo	1	Dobo1	D1bo1	13	14
4. MW	Ug	L	Ao	A1	ao	a2	1	Aoao1	A1a21	1	15
		S	Bo	B1	ao	a2	1	Boao1	B1a21	16	17
	Su	L	Eo	E1	do	do	1	Eodo1	E1do1	18	19
		S	Fo	F1	do	do	1	Fodo1	F1do1	20	21
5. CW	Ug	L	Ao	A1	co	c2	1	Aoco1	A1c21	22	23
		S	Bo	B1	co	c2	1	Boco1	B1c21	11	24
	Su	L	Eo	E1	do	do	1	Eodo1	E1do1	18	19
		S	Fo	F1	do	do	1	Fodo1	F1do1	20	21
6. Tx	Ug	L	Ao	A1	co	co	2	Aoco2	A1co2	25	26
		S	Bo	B1	co	co	2	Boco2	B1co2	27	28
	Su	L	Go	G1	bo	bo	2	Gobo2	G1bo2	29	30
		S	Fo	F1	bo	bo	2	Fobo2	F1bo2	31	32

(1) The control level could be the existing BPT regulation or any of the proposed BAT regulations considered by the EPA

TABLE 2 - Cont'd

REGIONS			Coal Mining Cost Old	Coal Mining Cost New	Water Treatment Cost Old	Water Treatment Cost New	Royalties/ Taxes	Parameter Combination Old Mines	Parameter Combination New Mines	Model Mine Old	Model Mine New
7. NGP											
MA	Su	L	Ho	Hi	bo	bo	3	Hobo3	Hlbo3	33	34
		S	Fo	Fl	bo	bo	3	Fobo3	Flbo3	35	36
ND/SD	Su	L	Io	Il	bo	bo	4	Iobo4	Ilbo4	37	38
		S	Fo	Fl	bo	bo	4	Fobo4	Flbo4	39	40
Wy	Ug	L	Ao	Al	co	co	4	Aoco4	Alco4	41	42
		S	Bo	Bl	co	co	4	Boco4	Blco4	43	44
	Su	L	Jo	Jl	bo	bo	4	Jobo4	Jlbo4	45	46
Rocky M.		S	Fo	Fl	bo	bo	4	Fobo4	Flbo4	39	40
8&9. Nev/NMex.	Ug	L	Ao	Al	co	cl	1	Aocol	Alcll	9	10
		S	Bo	Bl	co	cl	1	Bocol	Bocll	11	12
	Su	L	Jo	Jl	bo	bo	1	Jobol	Jlbol	47	48
		S	Fo	Fl	bo	bo	1	Fobol	Flbol	49	50
10. WA	Su	L	Jo	Jl	bo	bo	1	Jobol	Jlbol	47	48
		S	Fo	Fl	bo	bo	1	Fobol	Flbol	49	50

TABLE 3

EXAMPLE OF INPUT DATA FOR MODEL MINE COST ANALYSIS

[illegible] LEVEL [illegible] [illegible]

INDICES FOR REAL COST INCREASES

WAGE	POWER COST	EQUIPMENT	COMPOSITE
1.0000	1.0000	1.0000	1.1490
1.1400	1.0200	1.0320	1.1710
1.1570	1.0400	1.0480	1.1760
1.1570	1.0610	1.0540	1.1900
1.1800	1.0820	1.0610	1.2030
[illegible]	1.1040	1.0670	1.2160
[illegible]	1.1250	1.0730	1.2350
1.2540	1.1450	1.0770	1.2470
1.2770	1.1720	1.0830	1.2650
1.3930	1.1950	1.0820	1.2730
[illegible]	1.2109	1.0734	1.2933
[illegible]	1.2433	[illegible]	1.3087
1.3723	1.2531	1.1048	1.3256
[illegible]	1.2795	1.1099	1.3405
[illegible]	1.3129	1.1155	1.3565
1.4634	1.3415	1.1211	1.3773
1.4757	1.3727	1.1267	1.3923
[illegible]	1.4001	1.1323	1.4060
1.5472	1.4381	1.1380	[illegible]
[illegible]	1.4567	[illegible]	[illegible]
1.5701	1.4858	1.1494	1.4572
[illegible]	1.5155	1.1551	1.4747
[illegible]	1.5459	1.1609	1.4921
1.7113	1.5768	1.1667	1.5103
1.7437	1.6083	1.1725	[illegible]
1.7607	1.6405	1.1784	1.5467
1.7795	1.6733	1.1843	1.5653
[illegible]	1.7068	1.1902	1.5841
[illegible]	1.7409	1.1961	1.6031
[illegible]	1.7757	1.2021	1.6223

PLANNING YEARS
8

SENSITIVITY PARAMETERS
NUMBER OF PLANNING YEARS 1
NUMBER OF MINE SIZES 1
NUMBER OF MINE PRODUCTIVITIES 5
NUMBER OF MINE LIVES 3
NUMBER OF [illegible] 1
NUMBER OF FLOWS 5

FISCAL AND FINANCIAL PARAMETERS
FEDERAL TAX RATE .4800
SEVERANCE TAX RATE .0385
ROYALTY RATE .0500
PRODUCTION TAX RATE .0000
DEPLETION ALLOWANCE .1000
REQUIRED RATE OF RETURN .1000
BETA [illegible] .0000
INVESTMENT CREDIT .1000
WORKING CAPITAL RATIO .0800

MINE LIVES
MINE LIFE 20 10 5 [illegible] [illegible]

EQUITY COST SENSITIVITY TO PRODUCTIVITY .3000
[illegible] COST SENSITIVITY TO PRODUCTIVITY .0000

TABLE 3 - (cont'd.)

1.2.4 UNDERGROUND MINE LEVEL 4 REGION I

MINE PRODUCTIVITIES					
PRODUCTIVITY (TONS/MANDAY)	7	10	15	20	24
INVESTMENT DATA					
MINE SIZE (MMT/YEAR)	.6000	.0000	.0000	.0000	.0000
PRES WT VALUE - EXPLORATION COSTS (MM$)	.1000	.0000	.0000	.0000	.0000
BUILDINGS, ETC.	2.0300	.0000	.0000	.0000	.0000
PRES WT VALUE BUILDINGS	2.1100	.0000	.0000	.0000	.0000
EQUIPMENT MINE LIFE	3.5700	.0000	.0000	.0000	.0000
EQUIPMENT - 10 YEARS	6.4590	.0000	.0000	.0000	.0000
EQUIPMENT 5 YEARS	4.9900	.0000	.0000	.0000	.0000
OPERATING COST DATA					
ACTUAL PRODUCTIVITY	10.3300	.0000	.0000	.0000	.0000
WAGES (MM$/YEAR)	4.7990	.0000	.0000	.0000	.0000
SUPPLIES	3.6700	.0000	.0000	.0000	.0000
POWER	.3300	.0000	.0000	.0000	.0000
[illegible]	.8100	.0000	.0000	.0000	.0000
W [illegible] BLACK LUNG	.8350	.0000	.0000	.0000	.0000
RECLAMATION FEE	.1000	.0000	.0000	.0000	.0000
SEVERANCE TAX	.0000	.0000	.0000	.0000	.0000
COST RATIOS					
INDIRECT COSTS	.1000	.0000	.0000	.0000	.0000
PAYROLL OVERHEAD	.2500	.0000	.0000	.0000	.0000
WORKING CAPITAL	.2750	.0000	.0000	.0000	.0000
ADMINISTRATIVE OVERHEAD	.0500	.0000	.0000	.0000	.0000
TAXES AND INSURANCE	.0240	.0000	.0000	.0000	.0000
POLLUTION CONTROL COSTS					
INVESTMENT COSTS, BPT	.3660	.0000	.0000	.0000	.0000
OPERATING COSTS, BPT	.0000	.0000	.0000	.0000	.0000
LOSS OF FLOW	1.2158	.2158	-.7[illegible]	-1.7[illegible]	-2.[illegible]
INVESTMENT COSTS, BAT	.9039	.3073	.1772	.1[illegible]	.1[illegible]
OPERATING COSTS, BAT	.1979	.0580	.0299	.0273	.0259

costs will be higher because of add-ons (such as indirect costs).

Working capital requirements are estimated to be equivalent to one month of wage payments (i.e., 8% of annual wage payments).

As mentioned previously, the model mine costs are estimated for a specific average labor productivity. To allow for analysis of minimum required prices as a function of mine productivity, four other values for mine productivity are specified for each model mine in the range over which productivities for actual mines had been found to vary (see Chapter II.4 of Appendix A of this report for a discussion of the mine productivity analysis).

C. Mine Flow Volumes and Water Treatment Costs

The analysis of available data on coal mine water flows demonstrates that, when expressed in gallons per ton of coal produced, they are generally larger for smaller mines. This is shown in Figures 3, 4, and 5.

Average flow levels obtained from the data are highest in the three Appalachian regions, somewhat less in the Midwest and Central West, and much less (by a factor of about 10) in the rest of the coal mining regions (Northern Great Plains, Texas, Rocky Mountains, Nevada, New Mexico, Washington). Also, the range of possible flows is much narrower in these "dry areas" than in the "wetter" Appalachian regions, the Midwest and the Central West.

The increase in the MRP as a function of water treatment costs for a given model mine is calculated for five different volumes, ranging from 1 to 10,000 gallons per ton for the wet Appalachian regions and the regions in the Midwest and Central West and ranging from 0.1 to 1,000 gallons per ton for the other drier areas.

It is assumed that by 1984 all existing mines will have water treatment installations in compliance with BPT standards. The increase in required price for these mines will be through costs to upgrade treatment levels from BPT standards to BAT standards. Investment costs in BPT equipment are treated as sunk costs and are not considered in the calculation of the minimum price per ton of coal required by the mine to stay in production. However, investment costs for BPT equipment are considered in the MRP calculations for new mines since the investment has to be incurred to open up the new mine. The estimated BPT investment costs for different model mines used in the analysis are shown in Table 4. Operating costs are judged to be negligible for BPT.

The investment and operating costs for the two different possible BAT treatment standards, for which the potential economic impact is estimated, are derived from data provided by the EPA.

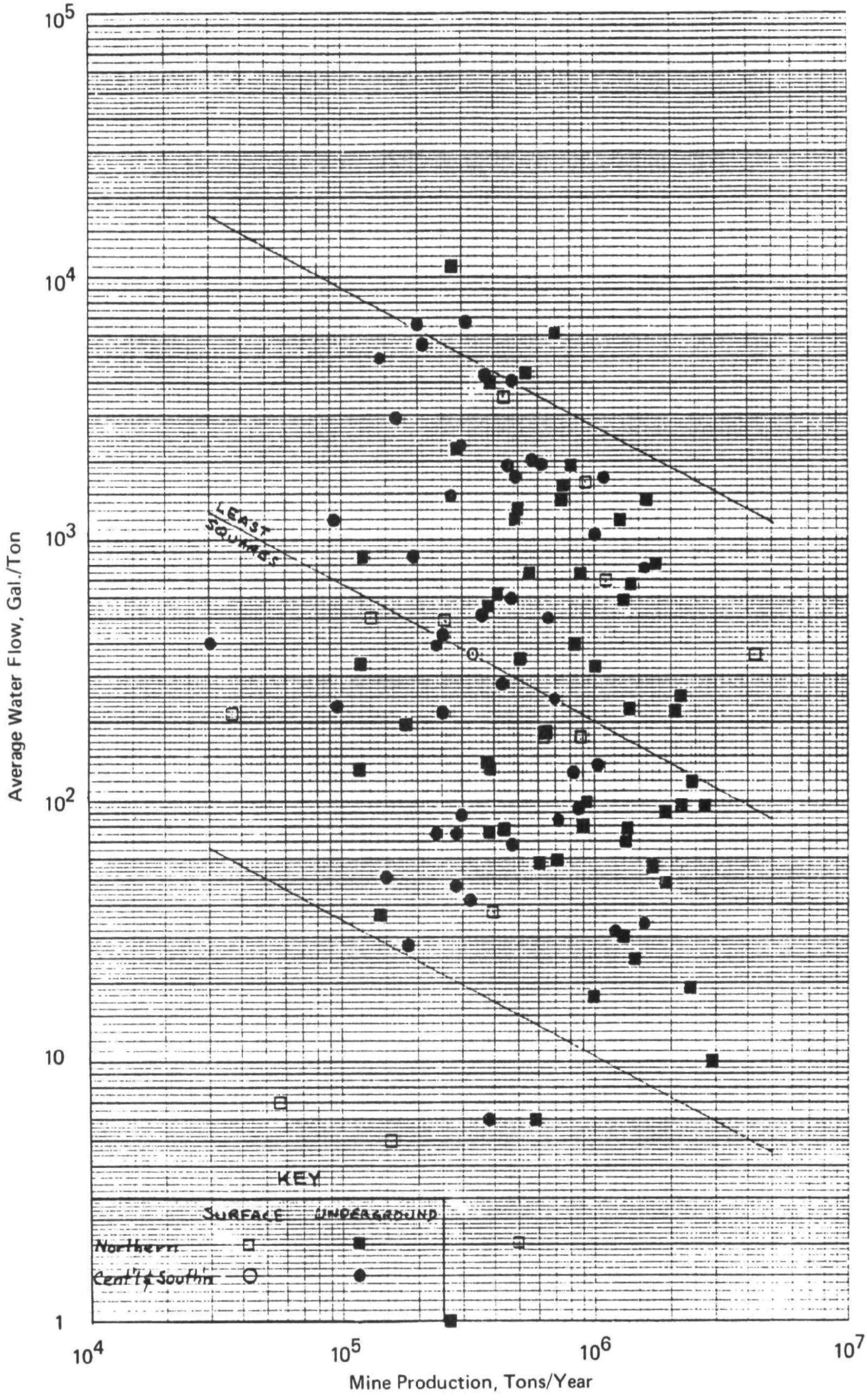


FIGURE 3 COAL MINE WATER FLOWS – APPALACHIA

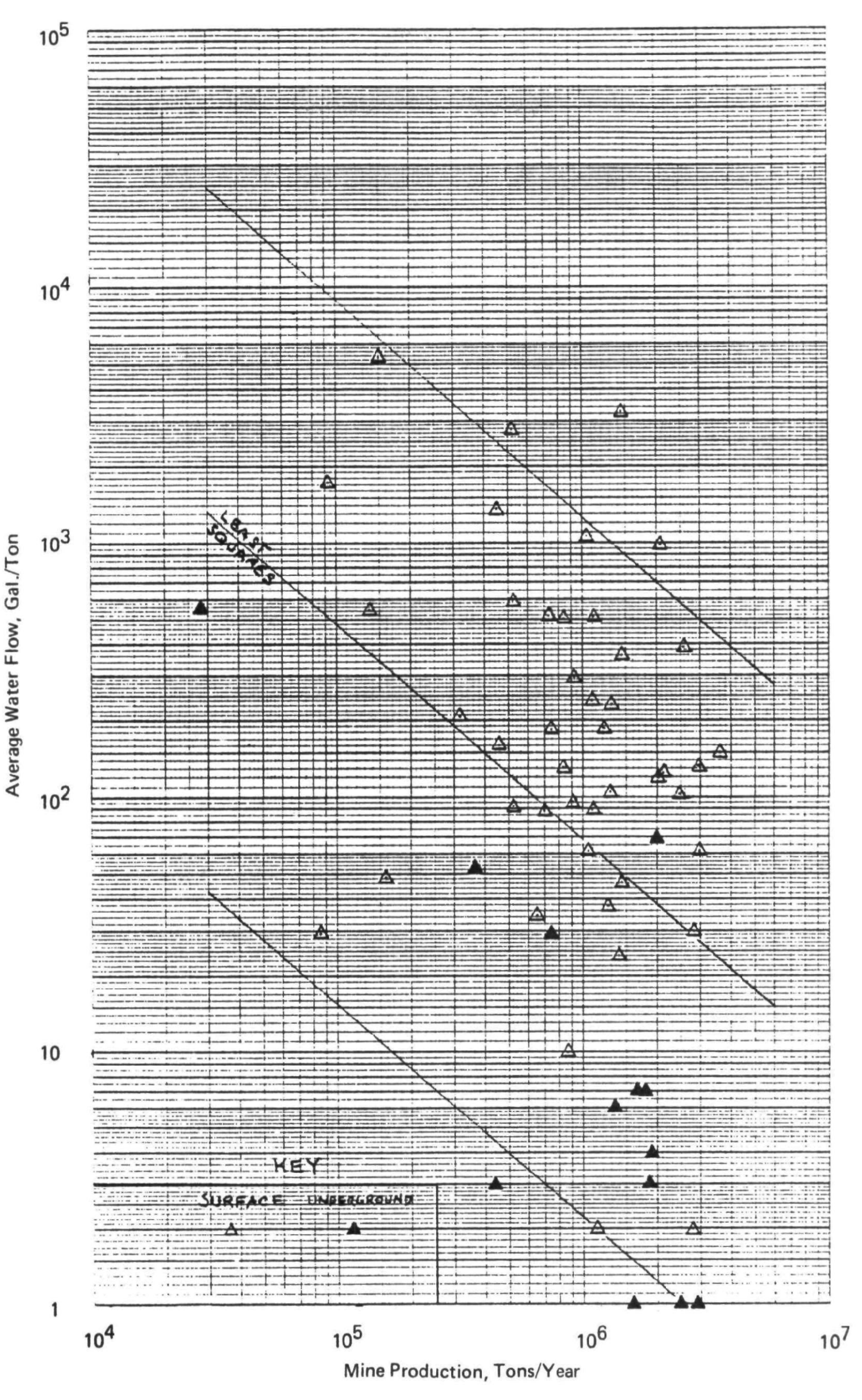


FIGURE 4 COAL MINE WATER FLOWS – MIDWEST AND CENTRAL WEST

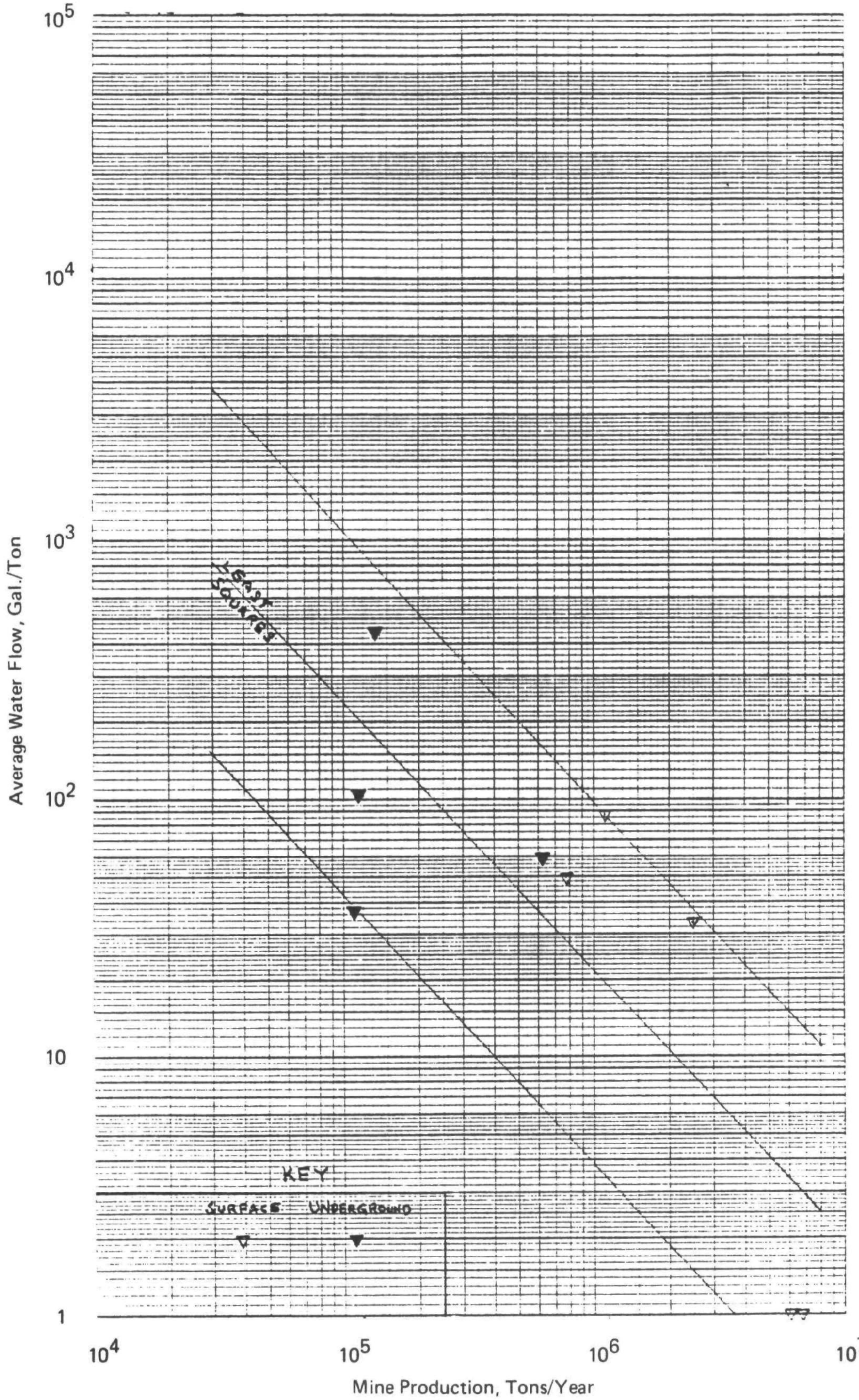


FIGURE 5 COAL MINE WATER FLOWS – GREAT PLAINS AND WEST

TABLE 4

BPT Investment Cost for New Mines ($MM)

(1978 $)

	Small UG	Large SU	Large UG	Large Texas	Large NGP	Small SU
Mine size MMT/yr	0.025	0.600	0.600	2.00	4.00	0.025
NA,CA,SA						
$MM	0.015	0.090	0.366			0.00375
$/TPY	0.610	0.150	0.610			0.150
MW,CW,TX						
$MM			0.036	0.120		
$/TPY			0.060	0.060		
NGP,ROCKY,NEV,N.MEX						
$MM	0.0015		0.054			0.360
$/TPY	0.060		0.090			0.090

The BAT investment and operating costs for different flow levels as calculated for the different representative mine sizes in the different regions are shown in Tables 5, 6, 7, and 8. The costs shown in these tables are not corrected for construction cost variations between different regions. The multipliers used for this correction are shown in Table 9.

D. Projection of Changes in Mining Conditions Between 1976 and 1984

Mining conditions are expected to change significantly between 1976 and 1984 because of:

- Changes in constant dollar unit costs of labor, power and equipment;

- Changes in labor productivity.

As shown in Figure 6, constant dollar labor and equipment costs have increased significantly since the early 1970s. Mining equipment costs have increased at a very high average rate of 11% per year between 1973 and 1976, slowing to 1% per year between 1977 and 1979. The labor cost index has increased relatively steadily at an average rate of about 2% per year between 1968 and 1979.

Given the required continued growth in coal supply, labor costs can be expected to continue to increase in real terms. As shown in Table 10 a continued annual growth rate of 2% is used for the period from 1978 to 1984. The actual average increase of labor costs between 1977 and 1978, resulting from the end-1977 settlement of wage negotiations between the mine workers' union and coal mine management, is calculated to be 14% over and above inflation.

Real increases in equipment costs (including pollution control equipment) are judged to gradually decrease from about 11% per year between 1975 and 1976 to about 0.5% per year between 1978 and 1984. The high increase in equipment costs - 11% per year - between 1973 and 1976 are judged to have been created by temporary bottlenecks due to the sudden renewed interest in coal as a fuel. This renewed interest was brought about by increases in imported crude oil prices at the end of 1973; these bottlenecks are expected to gradually disappear.

Power costs are projected to increase at an average of 2% per year, reflecting continued real increases in the costs of all fuels (see Table 10).

As shown in Figure 7, labor productivity in both underground and surface mines has decreased dramatically during the last decade. These decreases are mainly attributable to regulations protecting the mining environment and mine workers' health and safety. This decline is expected to continue until 1981, especially for surface mines in

TABLE 5

BAT COSTS FOR SMALL MINES (0.025 MMT/yr) WITH DIFFERENT FLOW VOLUMES (Without Correction for Differences in Mining Region or in Mine Type

Flow G/T	10^4	10^3	10^2	10	1.0
Flow MMG/D	0.685	0.0685	0.00685	0.000685	0.0000685
Level 2					
Log of Flow	-.1643	-1.1643	-2.1643	-3.1643	-4.1643
INV $MM	.0350	.0350	.0350	.0350	.0350
OPC $MM/Y	.0115	.0063	.0060	.0060	.0060
Level 4					
Log of Flow	-.1643	-1.1643	-2.1643	-3.1643	-4.1643
INV $MM	.2575	.1494	.1179	.1100	.1100
OPC $MM/Y	.0421	.0271	.0270	.0270	.0270

TABLE 6

BAT COSTS FOR LARGE UNDERGROUND MINES (0.6 MMT/yr) WITH DIFFERENT FLOW VOLUMES

(Without Correction for Differences in Mining Region or in Mine Type

Flow G/T	10^4	10^3	10^2	10	1.0
Flow MMG/D	16.438	1.6438	.16438	.016438	.0016438
Level 2					
Log of Flow	1.2158	.2158	-.7841	-1.7841	-2.7841
INV $MM	.0350	.0350	.0350	.0350	.0350
OPC $MM/Y	.0485	.0162	.0075	.0060	.0059
Level 4					
Log of Flow	1.2158	.2158	-.7841	-1.7841	-2.7841
INV $MM	.9039	.3433	.1772	.1236	.1187
OPC $MM/Y	.1979	.0580	.0299	.0273	.0250

TABLE 7

BAT COSTS FOR LARGE STRIP MINES (2.0 MMT/yr) WITH DIFFERENT FLOW VOLUMES
(Without Correction for Differences in Mining Region or Mine Type)

Flow G/T	10^3	10^2	10	1.0	0.1
Flow MMG/D	5.479	.5479	.05479	.005479	.0005479
Level 2					
Log of Flow	.7387	-.2613	-1.2613	-2.2613	-3.2613
INV $MM	.0350	.0350	.0350	.0350	.0350
OPC $MM/Y	.0278	.0107	.0061	.0060	.0050
Level 4					
Log of Flow	.7387	-.2613	-1.2613	-2.2613	-3.2613
INV $MM	.5481	.2410	.1441	.1171	.1100
OPC $MM/Y	.1030	.0393	.0267	.0260	.0250

TABLE 8

BAT COSTS FOR LARGE STRIP MINES (4.0 MMT/yr) WITH DIFFERENT FLOW VOLUMES
(Without Correction for Differences in Mining Region or Mine Type

Flow G/T	10^3	10^2	10	1.0	0.1
Flow MMG/D	10.96	1.096	0.1096	0.01096	0.001096
Level 2					
Log of Flow	1.0398	.0398	-.9602	-1.9602	-2.9602
INV $MM	.0350	.0350	.0350	.0350	.0350
OPC $MM/Y	.0392	.0138	.0068	.0062	.0060
Level 4					
Log of Flow	1.0398	.0398	-.9602	-1.9602	-2.9602
INV $MM	.7455	.2988	.1629	.1207	.1200
OPC $MM/Y	.1535	.0495	.0283	.0282	.0280

TABLE 9

MULTIPLIERS TO CORRECT FOR REGIONAL DIFFERENCES IN BAT INVESTMENT COSTS

Region	Multipliers	
	All Surface and New Underground	Existing Underground
NA	1.32	1.0
CA	1.32	1.0
SA	1.28	1.0
MW	1.12	1.0
CW	1.08	1.0
Texas	1.00	1.0
NGP	1.00	1.0
Rocky Mtns.	1.36	1.0
Nev., N. Mexico	1.26	1.0

FIGURE 6

HISTORICAL MINING LABOR COST AND MINING EQUIPMENT COST INDICES (1972=100)

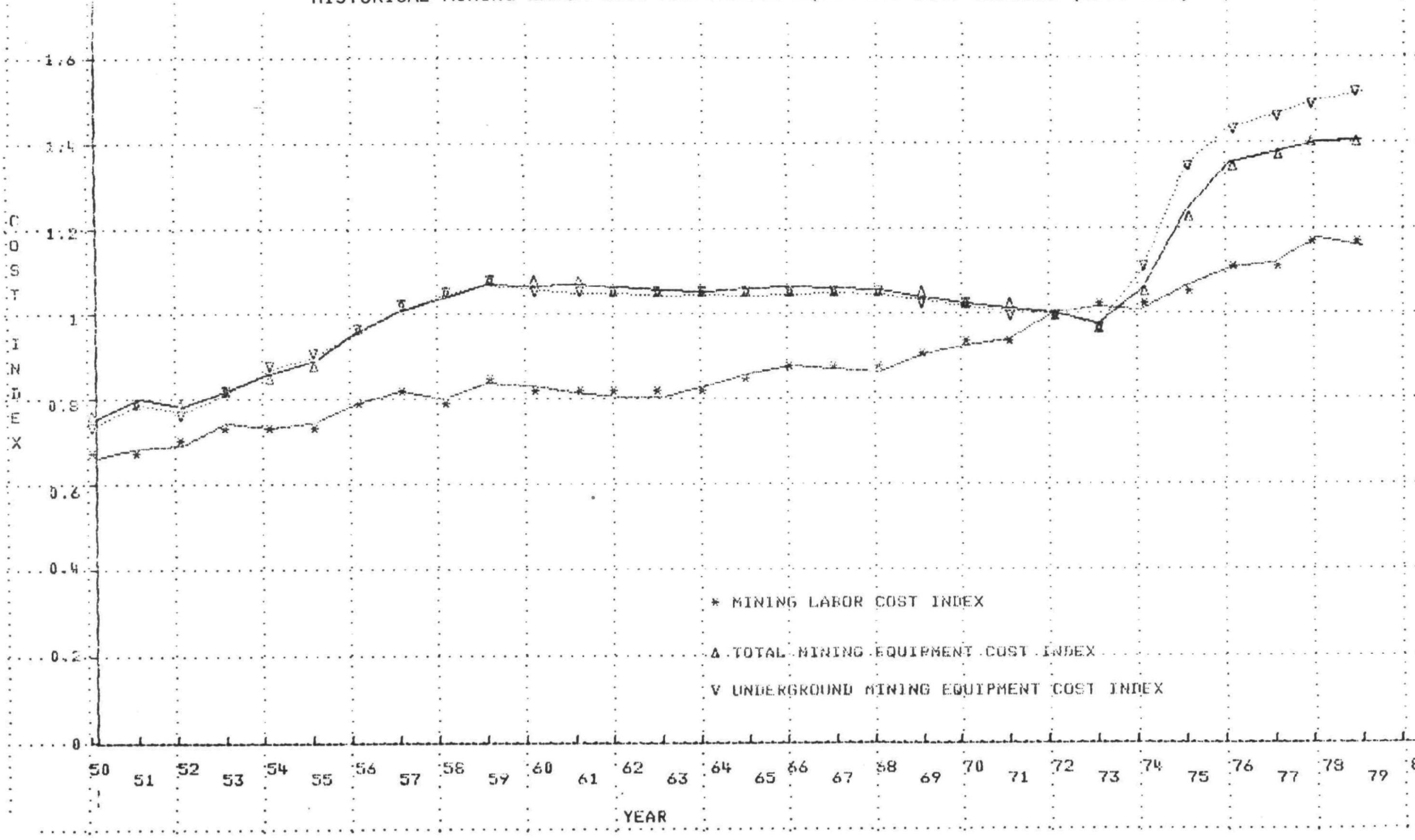


TABLE 10

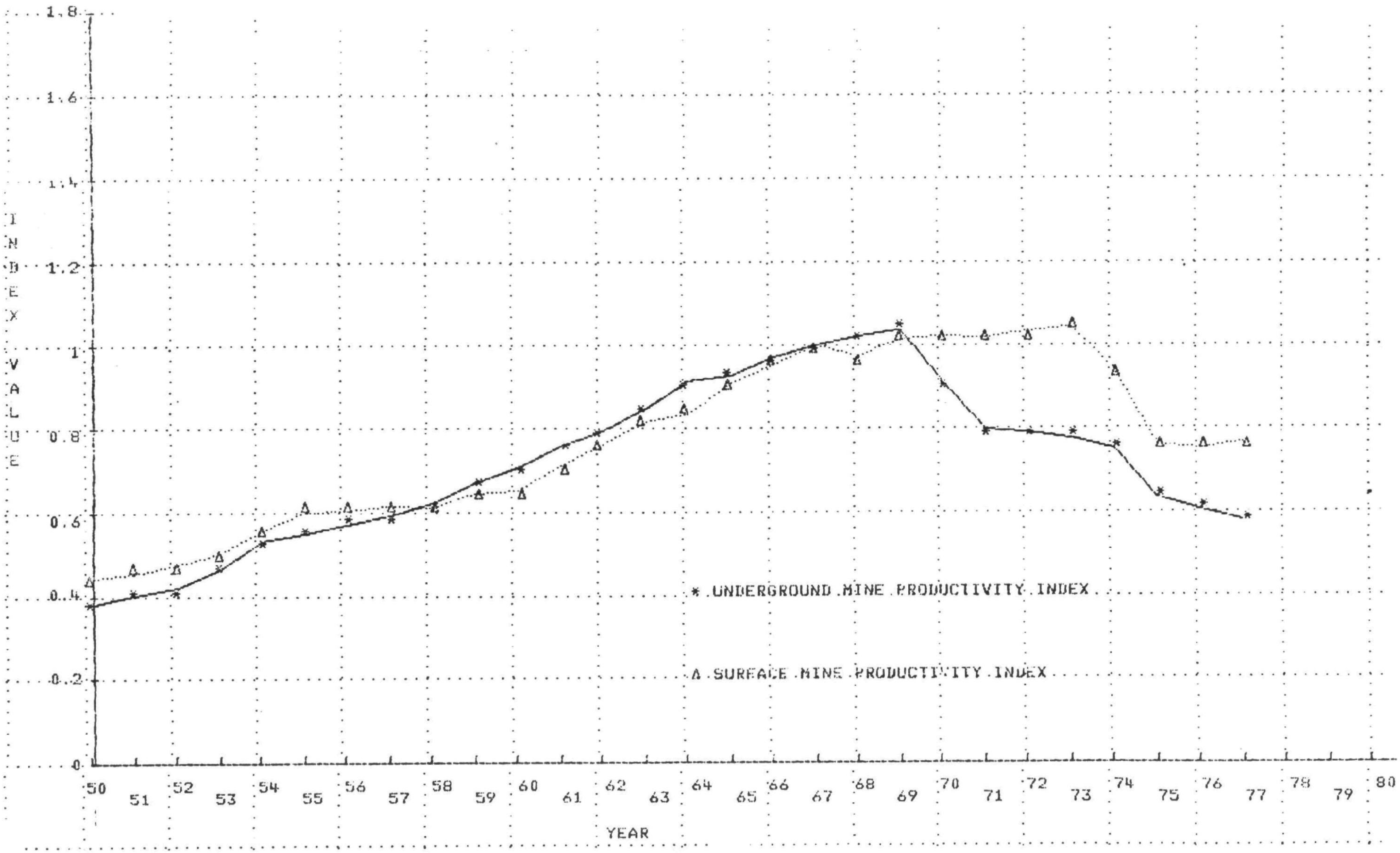
PROJECTED ESCALATION IN COSTS AND LABOR PRODUCTIVITY
USED IN THE MODEL MINE COST ANALYSIS
(1977 is 1.00)

Year	Wages	Power Costs	Mining Equipment Cost	Productivity: Underground	Productivity: Surface East. Regions	Productivity: Surface Other Regions(1)
1977	1.000	1.000	1.000	1.000	1.00	1.00
1978	1.140	1.020	1.032	0.990	0.90	0.95
1979	1.157	1.040	1.048	0.985	0.85	0.92
1980	1.157	1.061	1.056	0.980	0.80	0.90
1981	1.180	1.081	1.061	0.990	0.808	0.914
1982	1.203	1.104	1.067	1.000	0.816	0.927
1983	1.228	1.126	1.072	1.010	0.824	0.941
1984	1.253	1.149	1.077	1.020	0.832	0.955
1985	1.277	1.172	1.083	1.030	0.841	0.970
1986 and following year	1.02x	(1.02x)	(1.005x)	(x1.01)	(x1.015)	(x1.015)

(1) Surface other includes strip mines in the West, Midwest and Texas

FIGURE 7

HISTORICAL PRODUCTIVITY INDICES FOR UNDERGROUND AND SURFACE MINES (1967=100)



the Eastern regions (the relatively small surface mines in these regions are expected to suffer most from the Surface Mine and Reclamation Act; the difficult terrain will make it costly to restore mined areas to conditions required by the Act). Beyond 1981, productivity is expected to rise again at an average rate of 1.5% per year, mostly due to a maturing work force.

E. Minimum Required Price Calculation and MRP Function Estimation

Given the input parameter values for mining, productivity and water treatment costs discussed in the previous sections, the minimum required prices could be calculated for different mine categories. The general algorithm of the computer program developed for this purpose is shown in Figure 8. Given input parameter values for a specific type of mine model, the program can calculate minimum required prices for:

- Different planning years in the future;
- Different treatment cost levels;
- Different remaining lives for the mine;
- Different mine labor productivities.

Originally the computer program allowed investment costs and operating costs to change with mine size. However, analysis of the sensitivity of MRPs to changes in mine size and productivity revealed that MRP variations are dominated by productivity variations. Mine size was subsequently dropped as an independent varirable in the calculations. This significantly reduced the number of computations required for the analysis. As shown in Figure 8, the results are ranges of values for:

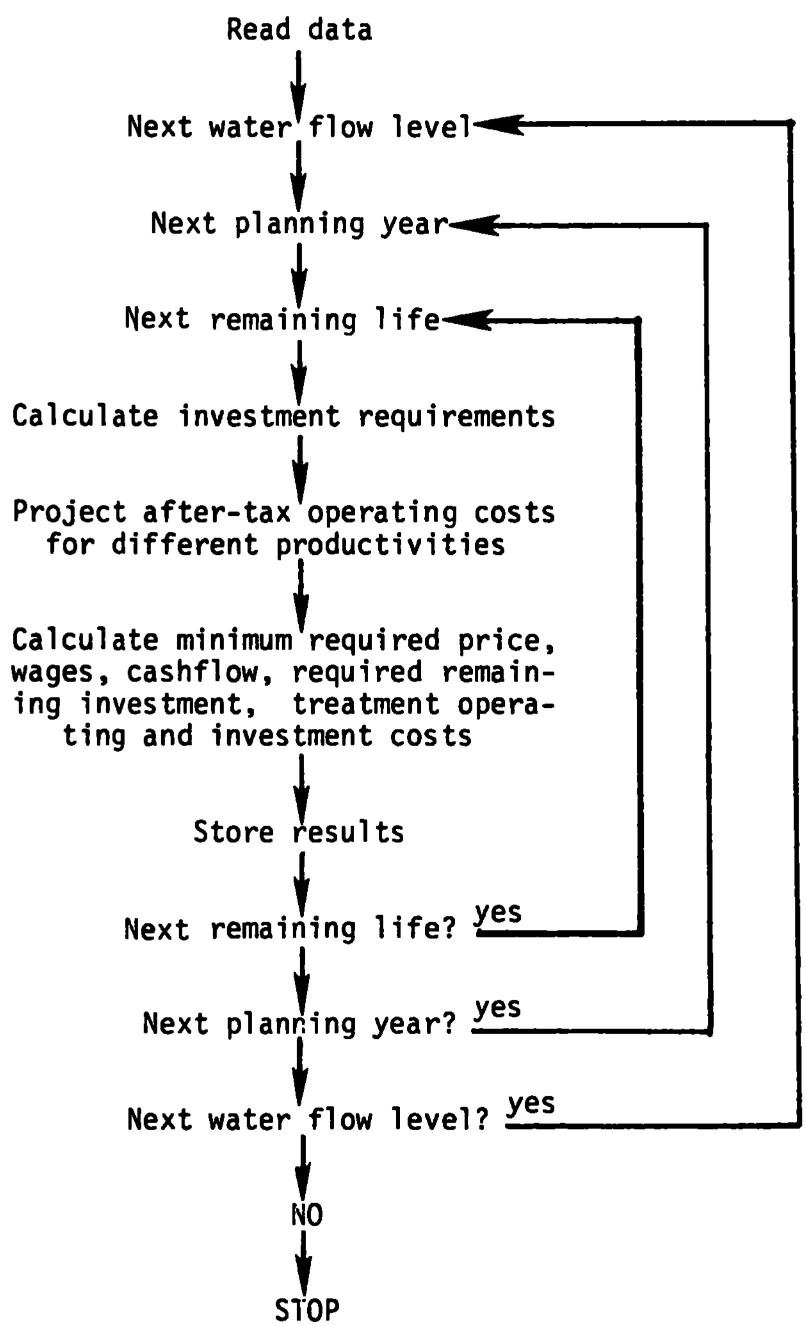
- Minimum required price (in dollars per ton);
- Annual wage payments (in dollars per annual ton);
- Cashflow generated in the planning year (in dollars per annual ton);
- Required investment in mining equipment in the planning year (in dollars per annual ton).

These calculated values (i.e., the dependent variables) are retained in relation to the pre-specified values of the independent variables, which are:

- Labor productivity (in tons per miner shift);
- Mine water flow volumes (in million gallons per year).

FIGURE 8

FLOW DIAGRAM OF MODEL MINE COST ANALYSIS PROGRAM



These data are used to estimate parameter values for MRP functions as described in Section H below.

F. Details of the Minimum Required Price Calculation

The minimum required prices are calculated subject to the following two conditions:

CONDITION 1: After tax revenues should cover all costs plus a return

1) Sum (PV (INV. (1-credit)+ WC + OC . (1-t) - DEPR . t)) =

Sum (PV (PROD . MRP . (1-roy - sevtax) . (1-(1-depl) . t))

CONDITION 2: In each year of the planning period

2) [PROD . MRP . (1-roy - sevtax) . (1-(1-depl) . t) - OC . (1-t) + DEPR . t] = [(PROD . MRP . (1-roy - sevtax)] . CONSTANT

where,

MRP	the minimum required price in a given year of the mine's life.
INV	the investment in a given year, including investment in water treatment equipment.
OC	the operating costs in a given year, including water treatment costs.
DEPR	the depreciation allowance in a given year.
depl	the depletion allowance rate.
PROD	the production in a given year.
credit	the investment credit rate.
t	the federal corporate income tax rate.
roy	the royalty rate.
sevtax	the state and local severance tax rate.
PV	the present value operator for year t.
Sum	summation over the remaining mine life.
WC	the working capital requirement (treated as an investment occurring in the first year of the mine's life).

The actual value of the "CONSTANT" will result from the calculations. For example, if the remaining mine life is 30 years, then we will have 30 equations of type (2) and one equation of type (1), or 31 equations, which in order to have a unique solution will need to have 31 unknowns: 30 MRPs (one MRP for each year) and the "CONSTANT."

The calculation of the MRPs and the "CONSTANT" is broken down into four steps:

STEP 1: Calculate: P*, I*, d*, where:

P* = PROD . (1 - roy - sevtax)

I* = Sum . (PV (INV . (1 - credit) + WC))

d* = (1 - (1 - depl) . t)

STEP 2: Calculate: A* = Sum (PV (OC (1 - t) - DEPR . t))

STEP 3: Calculate: CONSTANT = d* - d* . A*/ (A* + I*)

STEP 4: Calculate: MRP = (OC . (1 - t) - DEPR . t)/ (P* . (d* - CONSTANT) =

A/ (P* . (D* - CONSTANT), WHERE:

A = OC . (1 - t) - DEPR . t

Substitute: (d* - CONSTANT) . = A* . d*/ (A* + I*)

MRP = A . (A* + I*) / P* . A* . d*

To relate changes in costs with changes in productivity, a standard production function is used:

$C/C^* = (PRTY^*/PRTY)^F$, where:

C = the unit operating or investment costs (in dollars per ton) related with a productivity PRTY (in tons per miner shift).

C* = the unit operating or investment costs related with the benchmark productivity PRTY*.

F = a factor with a value between zero and one.

Higher labor productivity within the same mine implies lower unit labor costs and higher mining equipment costs. Therefore, a positive value of F relates labor costs with productivity and a negative value of F relates equipment costs with productivity. In the analysis a value of +0.8 was used to relate unit equipment costs with labor productivity; a value of -0.8 was used to relate unit labor costs with labor productivity.

G. Sample Output

A detailed example of the results of the calculations described in the two previous sections is shown in Table 11. The results are for a large underground mine in Northern Appalachia, where mine water flows are mainly acid (see Table 3 for input parameter values). The treatment costs are for level 4.

Table 11 shows the results of the calculations for control cost levels corresponding with a high, medium and low flow for an existing mine and for a new mine. The price difference, because of different flows, can be as high as \$.50/ton. The price difference because of different productivities can be as high as \$18.9/ton.

H. Estimated Function Parameter Values for MRP, Wages, Cashflow and Required Investment in Mining Equipment

The last step in the calculations performed by Module 2 consists of the estimation of function parameters relating the dependent variables - minimum required price, wages, cashflow and required investment in mining equipment (all in dollars per annual ton produced) - with the independent variables - productivity (in tons per miner shift) and water flow level (in gallons per annual ton of coal produced).

The following functional formula provided a good correlation between the values of dependent variables calculated by the program described in the previous section, and the pre-specified values of the independent variables:

$$DV = \mathrm{Log}(_a) + b \cdot \mathrm{Log}(FLOW) + c \cdot \mathrm{Log}(PRTY)$$

DV = the dependent variable (MRP, wages, cashflow, investment in mining equipment, all in dollars per ton)

PRTY = productivity (in tons per miner shift)

FLOW = mine water flow volume (in million gallons per year)

a,b,c = estimated parameter values

The parameter values a, b, and c are estimated using a standard, ordinary least-squares regression program.

TABLE 11

RESULTS OF MODEL MINE ANALYSIS
LARGE UNDERGROUND MINES IN NORTHERN APPALACHIA:
REQUIRED PRICE, WAGES, CASHFLOW, INVESTMENT, TREATMENT COSTS[1]

HIGH FLOW (10,000 G/T)

	NEW MINE			OLD MINE		
	Labor Productivity (T/MSH)			Labor Productivity (T/MSH)		
	Low	Medium	High	Low	Medium	High
	7	10	24	7	10	24
Price	43.1	35.0	24.2	41.5	33.3	22.8
Wages	13.4	10.1	5.0	13.4	10.1	5.0
Cashflow	6.7	6.7	8.6	6.0	5.9	7.9
Investment[2]	35.2	43.6	77.7	15.1	20.1	40.4
Treatment Cost:						
Operating	0.38	0.38	0.38	0.38	0.38	0.38
Investment	2.1	2.1	2.1	1.6	1.6	1.6
		Medium Flow (100 G/T)				
Price	42.6	34.4	23.8	41.2	33.0	22.4
Wages	13.4	10.1	5.0	13.4	10.1	5.0
Cashflow	6.6	6.6	8.5	5.9	5.9	7.8
Investment[2]	35.2	43.6	77.7	15.1	20.1	40.4
Treatment Cost:						
Operating	0.06	0.06	0.06	0.06	0.06	0.06
Investment	0.42	0.42	0.42	0.32	0.32	0.32
		Low Flow (1 G/T)				
Price	42.6	34.4	23.8	41.2	33.0	22.4
Wages	13.4	10.1	5.0	13.4	10.1	5.0
Cashflow	6.6	6.6	8.5	5.9	5.9	7.8
Investment[2]	35.2	43.6	77.7	15.1	20.1	40.1
Treatment Cost:						
Operating	0.05	0.05	0.05	0.05	0.05	0.05
Investment	0.28	0.28	0.28	0.21	0.21	0.21

[1] All costs are in dollars per annual ton.

[2] Required investment in mine equipment (and facilities) to open the mine or to keep the old mine producing.

Table 12 shows the estimated values for a, b, and c for the same mine model used as an example in the previous section. As shown by the values of the correlation coefficients (see Table 12), the values of MRP, wages, and required investment in mining equipment, estimated by the functions, deviated less than 1% from the original values; the estimated cashflow values deviated less than 7% from the orgininal values.

V. REGIONAL SUPPLY CURVES (MODULE 3)

Module 3 operates on the regional mine files with production and productivity information for individual mines in 1976 obtained from the MESA file. As shown in Figure 9, Module 3 performs six main functions:

- Organizes the mines in each region into three major categories (met coal, contract and spot market steam coal);
- Changes the population on these regional files by retiring old mines and opening new mines;
- Estimates mine waterflows for the individual mines and calculates the required investment and operating costs to treat these flows;
- Calculates estimates for minimum required price, wages, cashflow and required investment for these mines;
- Rank orders the resulting regional mine population by increasing price;
- Fits a linearized function to the resulting list of mines, relating increasing price with increasing production from the region.

A. Separation into Major Coal Markets

As explained in the introduction it is assumed that the steam coal and the metallurgical coal markets operate completely independently of each other. The steam coal market consists of the spot and contract markets; these markets are assumed to have only limited interaction with each other.

In order to create three different mine files for each region, two decision rules are used:

- All underground mines with productivities of less than nine tons per miner shift are assigned to the met coal file;

TABLE 12

ESTIMATED FUNCTION PARAMETERS FOR LARGE UNDERGROUND MINES ON NORTHERN APPALACHIA

New Mines	Function Parameters			
Dependent Variable	a	b	c	Correlation Coefficient (R^2)
Minimum Required Price	104.9542	0.001538	-0.473198	0.99474
Wages	63.6449	0.0	-0.800	1.000
Cashflow	4.2516	0.001842	0.208694	0.9327
Investment In Mining Equipment	10.0138	0.000	0.64198	0.99966

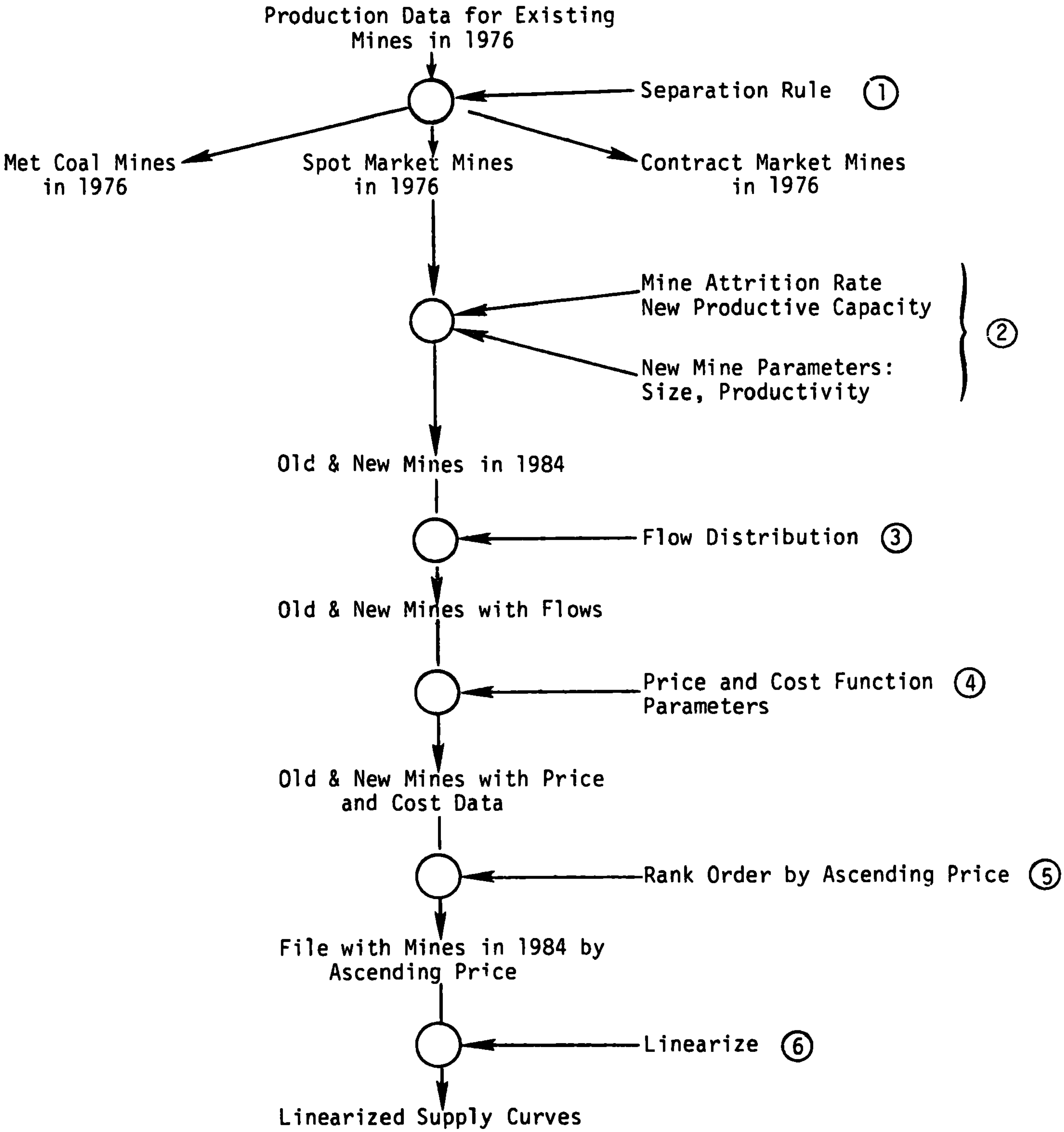
Existing Mines	Function Parameters			
Dependent Variable	a	b	c	Correlation Coefficient (R^2)
Minimum Required Price	105.2204	0.001104	-0.493478	0.99409
Wages	63.6449	0.000	-0.800	1.000
Cashflow	3.603	0.000431	0.231647	0.93239
Investment In Mining Equipment	3.1785	0.000	0.800	1.000

[1]The function parameters a,b, and c relate the dependent variables (MRP, wages, cashflow or investment) with the independent variables, mine labor productivity (PRTY) and log of flow.

$$DV = \log_a \times \log \text{ of } flow^b \times PRTY^c$$

FIGURE 9

MAIN FUNCTION OF MODULE 3:
ESTIMATION OF REGIONAL COAL SUPPLY BY PRICE in 1984



- All small mines - mines with less than 50,000 tons of production in 1976 - are assigned to the spot market file.

These decision rules are admittedly crude. However, the 1976 supplies from these met coal mines obtained in this manner for the different supply regions corresponded remarkably well with the available information on actual supplies from the same regions.

The hypothesis that underground mines with low productivities are most probably metallurgical coal mines is based on two considerations. Firstly, metallurgical coal is a relatively scarce resource, occurring mostly in deeper and thinner seams that are generally more difficult to mine. Generally, therefore, met coal mines have lower labor productivities and correspondingly higher production costs. Secondly, underground mines with productivities (as measured in this analysis) below nine tons per man-day are not competitive at today's prices.

As shown in Table 13, the total amount of coal purchased in spot markets by utilities in 1976 is about double the amount produced by small mines assigned to the spot market file, using the decision rule mentioned above. The differential amount of coal supplied to the spot market in the analysis is taken from contract mines, using the percentages shown in Table 14 to estimate the relative volumes of spot market coal from the different supply regions. These additional volumes are assumed to be available at variable costs because fixed costs are already paid for by contract sales.

B. Changes in the Mine Population

Steam coal supply is expected to grow at an annual rate of 4-5% between 1979 and 1984. In the analysis it is assumed that all of the increased production will come from large mines. Small mines (i.e., those with less than 50,000 tons per year production) will be more affected by the various environmental regulations (including the water control standards analyzed here). Also, the majority of coal use in the future is expected to be by electric utilities, which will be more interested in longer term contracts because of their emphasis on security of supply.

The estimates of the number of large mines closing between 1976 and 1984 are calculated using annual attrition rates obtained from the MESA Mine File analysis. The resulting attrition rates, compounded for the total period of nine years between 1976 and 1984, are shown in Table 14.

In the simulation of changes in regional mine populations, the smaller, least productive mines from the 1976 mine file are retired first. For mine sizes smaller than 200,000 tons, the size of the replacement mine is assumed to be twice the size of the old mine. The

TABLE 13

CONTRACT AND SPOT MARKET COAL SUPPLIED TO ELECTRIC UTILITIES IN 1976

(000 Tons)

Origin	Total	Contract	Spot	Percent Spot	Spot as Percent of Total Spot
Pennsylvania	40,940	29,058	11,882	29.0%	18.9%
Ohio	40,135	31,265	8,870	22.1%	14.1%
Maryland	2,412	902	1,510	62.6%	2.4%
Northern WV	26,981	23,402	3,579	13.3%	5.7%
Southern WV	17,558	15,883	1,675	9.5%	2.7%
Virginia	13,642	11,589	2,053	15.0%	3.3%
E. Kentucky	52,722	39,225	13,497	25.6%	21.4%
W. Kentucky	49,440	44,644	4,796	9.7%	7.6%
Tennessee	7,225	6,154	1,071	14.8%	1.7%
Alabama	13,940	9,967	3,973	28.5%	6.3%
Illinois	49,140	45,897	3,243	6.6%	5.2%
Indiana	23,817	20,078	3,739	15.7%	5.9%
Iowa	601	444	157	26.1%	0.2%
Missouri	4,056	4,019	37	0.9%	0.1%
Kansas	2,317	1,898	419	18.1%	0.7%
Oklahoma	2,503	1,832	671	26.8%	1.1%
Texas	11,867	11,855	12	0.1%	0.02%
North Dakota	10,031	10,011	20	0.2%	0.03%
Montana	24,958	24,858	100	0.4%	0.20%
Wyoming	25,781	24,956	825	3.2%	1.3%
Utah	4,632	4,391	241	5.2%	0.40%
N. Colorado	1,487	1,041	446	30.0%	0.70%
S. Colorado	4,174	4,053	121	2.9%	0.20%
Arizona	10,258	10,258	0	0.0%	0.00%
New Mexico	8,465	8,465	0	0.0%	0.00%
Washington	3,600	3,600	0	0.0%	0.00%
TOTAL	452,682	389,745	62,937	13.9%	100.00%

Source: FPC Form 423

TABLE 14

ATTRITION RATE PARAMETERS

The following tables specify the attrition rates used for mine retirement and replacement simulation when projecting changes in the contract mine population between 1976 and 1984.

The data are organized in three sets of four records (a record is a line in the table). The first set specifies attrition rate parameters for underground mines and the last set of records is for surface mines.

The first line in each set of records has the attrition rate for the corresponding size range; the second and third records give, respectively, the lower and upper limits of the mine size range; and the fourth record gives the maximum mine size for replacement mines. The last or thirteenth record in the table specifies the increase in mine size of replacement mines: mines with sizes of up to half a million tons, which were closed between 1976 and 1984, were assumed to be replaced with mines twice the size of the closed mines.

Annual attrition rate:	0.52	0.35	0.19	0.13	0.13	underground mines
Mine size: lower limits:	0.05	0.10	0.20	0.50	1.00	
Mine size: upper limits:	0.10	0.20	0.50	1.00	10.00	
Maximum Mine Size:	10.0	10.0	10.0	10.0	10.0	
Annual attrition rate:	0.75	0.59	0.35	0.25	0.19	surface mines
Mine size: lower limits:	0.05	0.10	0.20	0.50	1.00	
Mine size: upper limits:	0.10	0.20	0.50	1.00	10.00	
Maximum Mine Size:	10.0	10.0	10.0	10.0	10.0	
Replacement mine size Multiplier:	2.00	2.00	2.00	1.00	1.00	

*Notes mine size in millions of tons per year.

productivity of the replacement mine is obtained by the sampling of a productivity distribution derived from analysis of the MESA tape. These productivity distributions are shown in Table 15.

The simulation of the closing of old mines is continued until all are retired. Simultaneously, the opening of replacement mines is simulated, insuring that the sum total of productive capacity for the individual mines does not exceed total projected productive capacity. If, after the retirement of old mines and the opening of replacement mines, additional productive capacity is still needed, the simulation continues to add new mines. The simulation of new mines starts at the high end of the mine size range and gradually works toward the low end until all projected new capacity for the region is realized. The percentage distribution of mines over different mine size categories, determined for the 1976 mine population (see Table 16), is used to allocate new mines to different size classes. The result of the simulation is a file containing old, replacement, and new mines. Table 17 shows the projected increases in capacity for the different regions.

For each mine added to the mine file the annual water flow to be treated is estimated. This is done by calculating an average flow as a function of the size of the mine and by sampling a distribution which specifies the spread around that average. The parameter values for, and functional relationships between, average flow and mine size, and the distributions of the spreads around the average are shown in Table 18.

Given the size and productivity of the mine and the water flow estimates, the minimum required price, wage payments, cashflow, required investment in mining equipment and additional required investment in water treatment equipment can be calculated. This is done with the functions estimated in Module 2 by modelling the mine cashflow analysis, as discussed in Section IV.

C. Detailed and Linearized Supply Curves

The result of this sequence of calculations is a list of old and new[(1)] mines in the region under analysis. This list, after being ordered by ascending price, is stored for future use in the impact analysis.

Table 19 shows an example of this mine file for Pennsylvania with estimated water treatment costs specified for BAT level 4. This list of mines, specifying cumulative potential coal supply in 1984 by increasing price, is essentially the projected "detailed" supply curve for that region in 1984.

As shown in Table 20, linear approximation of the detailed supply curve is used in the coal market simulation model. The linear

(1) Including replacement mines

TABLE 15

MINE PRODUCTIVITY DISTRIBUTIONS

The following tables (15.1, 15.2, 15.3, 15.4) contain data on mine productivity distributions, used to obtain replacement and new mine productivity estimates as discussed in Chapter I.

The first three lines in the tables contain parameter values to calculate average productivity (in tons per miner shift) as a function of mine size for underground mines, a dummy mine type and surface mines, respectively. The next three lines contain nine fractile distributions of the ratio of the actual versus average calculated productivity. The fractiles for these distributions are 0.0, 0.01, 0.05, 0.25, 0.50, 0.75, 0.99, and 1.0.

The first parameter in each of the first three lines of the tables specify the average tons per mineshift of mines with an annual production (in million tons per year) as specified by the second parameter value. The third and fourth parameter values (P3 and P4) allow calculation of the average productivity (PRODTY) for a mine with a size of S million tons per year by

$$PRODTY = P3 + P4 \cdot \ln(\ln S)$$

TABLE 15.1: LARGE UNDERGROUND AND SURFACE MINES IN THE EAST

(1)		12.0		200.		-2.72		9.50		6.0	
(2)		0.00		0.		0.00		0.00		0.0	average productivity parameters
(3)		25.0		200.		-1.00		15.79		10.0	
(1)	0.60	0.60	0.65	0.75	0.95	1.20	1.90	1.95	2.00		
(2)	0.00	0.00	0.00	0.00	0 00	0.00	0.00	0.00	0.00		productivity distributions (as a
(3)	0.35	0.40	0.46	0.67	0.87	1.04	1.30	1.50	1.50		ratio of average productivity)

TABLE 15.2: LARGE UNDERGROUND AND SURFACE MINES IN THE MIDWEST AND CENTRAL WEST

(1)		15.		200.		-2.72		11.12		6.0	
(2)		0.		0.		0.00		0.00		0.0	average productivity parameters
(3)		30.		200.		-1.00		18.50		10.	
(1)	0.65	0.71	0.84	0.94	1.00	1.03	1.16	1.29	1.35		
(2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 00		productivity distributions (as a
(3)	0.39	0.41	0.47	0.67	0.88	1.03	1.33	1.48	1.50		ratio of average productivity)

TABLE 15.3: LARGE UNDERGROUND AND SURFACE MINES IN THE NORTHERN GREAT PLAINS

(1)		15.		200.		-2.72		11.12		6.0	
(2)		0.		0.		0.00		0.00		0.0	average productivity parameters
(3)		100.		5000.	.-226	.060		152.25		30.	
(1)	0.65	0.71	0.84	0.94	1.00	1.03	1.16	1.29	1.35		productivity distributions (as a
(2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		ratio of average productivity)
(3)	0.85	0.85	0.87	0.92	0.99	1.03	1.06	1.17	1.20		

TABLE 15.4. LARGE UNDERGROUND AND SURFACE MINES IN THE ROCKY MOUNTAINS, SOUTHWEST AND TEXAS

(1)		15.		200.		-2.72		11.12		6.0	
(2)		0.		0.		0.00		0.00		0.0	average productivity parameters
(3)		60.		5000.		-24.76		39.94		20.	
(1)	0.65	0.71	0.84	0 94	1.00	1.03	1.16	1.29	1.35		productivity distributions (as a
(2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		ratio of average productivity)
(3)	0.85	0.85	0.86	0 93	0.99	1.03	1.06	1.17	1.20		

(1) Underground mines

(3) Surface mines

TABLE 16

EXISTING PRODUCTION OF CONTRACT MINES IN 1976
IN DIFFERENT SIZE RANGES

(Size Ranges in MM Tons)

		0.05-0.1	0.1-0.2	0.2-0.5	0.5-1.0	1.0-10.0	TOTAL
1. ALA	Underground	0.0	0.0	0.372	1.542	1.071	2.985
	Surface	2.706	5.267	4.264	2.538		13.593
3. ARI	Underground					0.	0.
	Surface					10.282	10.283
4. ARK	Underground	0.				0.	0.
	Surface	0.371	0.			0.	0.371
5. COLO	Underground	0.	0.109	1.178	0.950	0.	2.127
	Surface	0.097	0.124	0.247	1.036	4.989	6.373
6. ILL	Underground	0.073	0.	0.476	3.142	28.476	32.17
	Surface	0.511	0.195	3.592	5.728	18.012	27.948
8. IOWA	Underground	0.087	0.	0.221			0.308
	Surface	0.178	0.	0.			0.178
7. IND	Underground	0.068	0.	0.363			0.432
	Surface	0.322	1.639	1.653	3.288	18.445	25.360
9. KAN	Underground	0.					0.
	Surface	0.	0.107	0.209	0.529		0.846
14. EKY	Underground	3.952	5.422	8.427	7.472	2.315	25.75
	Surface	5.268	9.027	8.302	2.790	7.402	30.01
15. WKY	Underground	0.054	0.157	1.811	7.602	12.631	22.264
	Surface	1.367	1.251	2.087	5.398	17.077	26.825
12. MD	Underground		0.150				0.150
	Surface	0.468	0.887	0.735			2.0

Table 16 cont'd

		0.05-0.1	0.1-0.2	0.2-0.5	0.5-1.0	1.0-10.0	TOTAL
[illegible]. MISS	Underground	0.					0.
	Surface	0.	0.	0.	3.058	2.636	5.797
16. NMEX	Underground				0.830		0.830
	Surface		0.101	0.	0.865	7.979	8.947
19. OKLA	Underground	0.					0.
	Surface	0.488	1.022	0.222	0.	1.618	3.292
18. OHIO	Underground	0.087	0.305	0.320	5.649	4.211	10.4
	Surface	3.476	4.646	6.329	5.507	7.701	27.1
20. PENN	Underground	0.835	2.461	6.602	6.111	9.613	25.05
	Surface	5.956	8.551	11.120	8.129	2.183	34.67
28. MONT-E	Underground						0.
	Surface			0.288	0.	25.792	25.795
[illegible] ND	Underground		0.				0.
	Surface		0.128	0.747	0.	11.389	12.269
SD	Underground						
	Surface						
22. TENN	Underground	0.422	0.936	0.516	(0.844)		1.881
	Surface	0.540	1.743	1.419			3.349
23. TEX	Underground					0.	0.
	Surface				0.282	19.216	14.2
24. UTAH	Underground	0.	0.960	1.289	4.364	1.038	7.687
	Surface	0.					0.
25. VA	Underground	3.213	2.330	4.2[illegible]7	0.692		9.989
	Surface	3.076	3.109	2.097	0.514		8.463
10. WVA-N	Underground	.100	.100	.300	.80	15.00	16.715
	Surface	0.500	0.	0.	.45	6.350	7.026

Table 16 conc'd

		0.05-0.1	0.1-0.2	0.2-0.5	0.5-1.0	1.0-10.0	TOTAL
11. WVA-S	Underground	.150	.050	.300	0.500	25.40	26.779
	Surface	.100	.100	.200	.550	9.90	10.991
26. WASH	Underground	0.					0.
	Surface	0.				4.084	4.084
29. WYO	Underground	0.					0.203
	Surface	0.			2.417	26.479	28.985
Total		34.465	50.877	69.953	83.577	301.289	540.161

TABLE 17

ESTIMATED POTENTIAL INCREASES IN MINING CAPACITY UNTIL 1984

MMT Per Year

	NEW MINES		REPLACEMENT MINES		NEW + REPLACEMENT MINES	
	UG	SURFACE	UG	SURFACE	UG	SURFACE
1-PENN	15.9	0.4	4.6	15.9	20.5	16.5
2-OHIO	16.6	2.6	1.5	10.4	18.5	13.5
3-MARYLAND	1.8	1.0	0.05	0.26	2.0	1.5
4-W. VA. -N	1.5	8.3	2.2	1.7	4.0	10.5
5-W. VA. -S	13.8	1.6	3.5	2.3	17.5	4.0
6-VIRGINIA	3.1	0	3.4	5.0	6.5	5.0
7-E. KY.	10.4	21.5	6.8	14.3	17.5	35.0
8-TENNESSEE	0	0	1.0	0.50	1.0	0.5
9-ALABAMA	4.0	4.3	0.41	7.3	4.5	11.5
10-ILLINOIS	22.6	9.6	4.2	6.6	27.0	16.5
11-INDIANA	2.0	10.6	0.13	6.1	2.5	17.0
12-W. KY.	3.5	4.5	3.1	7.1	6.5	11.5
13-IOWA				0.13		0.5
14-MISSOURI				1.3		1.5
15-KANSAS				0.13		0.5
16-ARKANSAS				0.28		0.5
17-OKLAHOMA	2.0	3.1		1.4	2.0	4.5
18-TEXAS						40.0
19-N. DAK						70.0
20-S. DAK						0.0
21-MONTANA E.						75.0
22-MONTANA W.						0.0
23-WYOMING					7.0	220.0
24-COLO - N			0.39	1.4	4.5	11.0
25-COLO - S						0.0
26-UTAH			1.3		18.0	7.5
27-ARIZONA						2.5
28-N. MEXICO						35.5
29-WASHINGTON						
TOTAL	97.2	67.5	32.58	80.7	15.95	611.5

TABLE 18

MINE WATER FLOW DISTRIBUTIONS

Parameter Values to Calculate Average Flow (Flow in MMG/day) as a Function of Mine Size (Size in MTons/year)

$$FLOW = A \cdot SIZE^B$$

REGIONS:	A	B
NA, SA, CA	0.00078	0.4754
MW, CW, TX	0.01951	0.1651
NGP, RM, NEV, NMEX	0.06364	0.0

Frequency Distributions of Multipliers to Allow for the Variation Around Average Flow Frequency

Multiplier	NA,CA,SA	MW,CW,TX	NGP,RM, NEV, NMEX
45.2548	0.0	0.018	0.0
22.6274	0.027	0.070	0.0
11.3137	0.072	0.053	0.0
5.6569	0.162	0.140	0.222
2.8284	0.072	0.140	0.111
1.4142	0.144	0.158	0.223
0.7071	0.135	0.088	0.111
0.3536	0.126	0.088	0.222
0.1768	0.135	0.070	0.111
0.0884	0.054	0.070	0.0
0.0442	0.018	0.070	0.0
0.0221	0.018	0.035	0.0
0.0110	0.009	0.0	0.0
0.0055	0.028	0.0	0.0

TABLE 19

DETAILED SUPPLY FUNCTION FOR PENNSYLVANIA, 1984

Supply Function for Mine Type: 1
Pennsylvania, 1984

NUMBER[1]	PRODUCTION	COST	PRICE	NO. MINES	EMPLOYMENT	WAGES	FLOW	CASH FLOW	MINE EQPT	CONTROL EQPT
442	44.20	976.45	29.66	180	25425.48	301.42	40.54	225.54	1209.81	44.33
443	44.30	979.42	29.66	180	25425.48	301.42	40.54	225.54	1209.81	44.33
444	44.40	982.38	29.66	180	25425.48	301.42	40.54	225.54	1209.81	44.33
445	44.50	985.35	29.66	180	25425.48	301.42	40.54	225.54	1209.81	44.33
446	44.60	988.32	29.72	181	25719.48	303.01	40.75	227.11	1221.51	44.33
447	44.70	991.29	29.72	181	25719.48	303.01	40.75	227.11	1221.51	44.33
448	44.80	994.27	29.85	182	25877.48	305.72	40.86	228.21	1226.89	44.62
449	44.90	997.25	29.85	182	25877.48	305.72	40.86	228.21	1226.89	44.62
450	45.00	1000.24	29.89	183	25908.93	307.22	40.89	229.38	1231.28	44.86
451	45.10	1003.23	29.89	183	25908.93	307.22	40.89	229.38	1231.28	44.86
452	45.20	1006.22	29.99	184	26117.93	308.54	41.01	229.92	1233.89	44.86
453	45.30	1009.22	29.99	184	26117.93	308.54	41.01	229.92	1233.89	44.86
454	45.40	1012.24	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
455	45.50	1015.26	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
456	45.60	1018.28	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
457	45.70	1021.30	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
458	45.80	1024.32	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
459	45.90	1027.34	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
460	46.00	1030.36	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
461	46.10	1033.38	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
462	46.20	1036.40	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
463	46.30	1039.42	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
464	46.40	1042.44	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
465	46.50	1045.46	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
466	46.60	1048.48	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
467	46.70	1051.50	30.21	185	26149.51	321.13	41.19	239.54	1269.57	45.08
468	46.80	1054.52	30.26	186	27258.51	324.85	41.66	243.06	1295.43	45.08
469	46.90	1057.55	30.26	186	27258.51	324.85	41.66	243.06	1295.43	45.08
470	47.00	1060.58	30.26	186	27258.51	324.85	41.66	243.06	1295.43	45.08
471	47.10	1063.60	30.26	186	27258.51	324.85	41.66	243.06	1295.43	45.08
472	47.20	1066.63	30.26	186	27258.51	324.85	41.66	243.06	1295.43	45.08
473	47.30	1069.65	30.29	187	27280.29	327.60	42.34	245.67	1314.60	45.55
474	47.40	1072.68	30.29	187	27280.29	327.60	42.34	245.67	1314.60	45.55
475	47.50	1075.71	30.29	187	27280.29	327.60	42.34	245.67	1314.60	45.55
476	47.60	1078.74	30.29	187	27280.29	327.60	42.34	245.67	1314.60	45.55
477	47.70	1081.77	30.29	188	27389.29	329.06	42.47	246.25	1317.40	45.55
478	47.80	1084.80	30.37	189	27411.07	335.15	43.25	251.97	1359.33	45.55
479	47.90	1087.84	30.37	189	27411.07	335.15	43.25	251.97	1359.33	45.55
480	48.00	1090.88	30.37	189	27411.07	335.15	43.25	251.97	1359.33	45.55
481	48.10	1093.91	30.37	189	27411.07	335.15	43.25	251.97	1359.33	45.55

[1] Number of increments of 0.1 million tons of production capacity

TABLE 19 (cont'd.)

SUPPLY FUNCTION FOR MINE TYPE: 1

Pennsylvania, 1984

NUMBER[(1)]	PRODUCTION	COST	PRICE	NO. MINES	EMPLOYMENT	WAGES	FLOW	CASH FLOW	MINE EQPT	CONTROL EQPT
482	48.20	1096.95	30.37	189	27411.07	335.15	43.25	251.97	1359.33	45.55
483	48.30	1099.99	30.37	189	27411.07	335.15	43.25	251.97	1359.33	45.55
484	48.40	1103.02	30.37	189	27411.07	335.15	43.25	251.97	1359.33	45.55
485	48.50	1106.06	30.37	189	27411.07	335.15	43.25	251.97	1359.33	45.55
486	48.60	1109.10	30.38	190	27442.98	346.12	43.82	260.29	1390.00	45.85
487	48.70	1112.14	30.38	190	27442.98	346.12	43.82	260.29	1390.00	45.85
488	48.80	1115.18	30.38	190	27442.98	346.12	43.82	260.29	1390.00	45.85
489	48.90	1118.21	30.38	190	27442.98	346.12	43.82	260.29	1390.00	45.85
490	49.00	1121.25	30.38	190	27442.98	346.12	43.82	260.29	1390.00	45.85
491	49.10	1124.29	30.38	190	27442.98	346.12	43.82	260.29	1390.00	45.85
492	49.20	1127.33	30.38	190	27442.98	346.12	43.82	260.29	1390.00	45.85
493	49.30	1130.37	30.38	190	27442.98	346.12	43.82	260.29	1390.00	45.85
494	49.40	1133.40	30.38	190	27442.98	346.12	43.82	260.29	1390.00	45.85
495	49.50	1136.44	30.38	190	27442.98	346.12	43.82	260.29	1390.00	45.85
496	49.60	1139.48	30.38	190	27442.98	346.12	43.82	260.29	1390.00	45.85
497	49.70	1142.52	30.38	190	27442.98	346.12	43.82	260.29	1390.00	45.85
498	49.80	1145.56	30.38	190	27442.98	346.12	43.82	260.29	1390.00	45.85
499	49.90	1148.60	30.46	191	27631.98	347.60	43.96	260.87	1392.79	45.85
500	50.00	1151.65	30.46	192	27811.98	350.02	44.17	261.83	1397.41	45.85
501	50.10	1154.69	30.46	192	27811.98	350.02	44.17	261.83	1397.41	45.85
502	50.20	1157.74	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
503	50.30	1160.80	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
504	50.40	1163.85	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
505	50.50	1166.90	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
506	50.60	1169.96	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
507	50.70	1173.01	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
508	50.80	1176.07	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
509	50.90	1179.12	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
510	51.00	1182.18	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
511	51.10	1185.23	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
512	51.20	1188.29	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
513	51.30	1191.34	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
514	51.40	1194.39	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
515	51.50	1197.45	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
516	51.60	1200.50	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
517	51.70	1203.56	30.55	193	27833.76	362.15	45.65	273.08	1479.46	46.23
518	51.80	1206.62	30.67	194	28198.76	364.14	45.66	274.88	1492.52	46.42
519	51.90	1209.69	30.67	194	28198.76	364.14	45.66	274.88	1492.52	46.42
520	52.00	1212.76	30.69	195	28231.03	368.30	45.70	277.96	1503.71	46.62
521	52.10	1215.83	30.69	195	28231.03	368.30	45.70	277.96	1503.71	46.62

(1) Number of increments of 0.1 million tons production capacity

TABLE 20

LINEARIZED SUPPLY CURVE FOR PENNSYLVANIA
(BAT-4)

	Supply (10^{12} Btu's)	Cumulative Costs ($MM)	Unit Price ($/MMBtu)	Number Of Mines
1	2.28	0.98	.43	1
2	15.96	7.82	.50	3
3	31.92	17.08	.58	7
4	79.80	50.11	.69	13
5	134.52	94.98	.82	23
6	335.16	289.61	.97	59
7	679.41	688.94	1.16	131
8	971.22	109 .63	1.38	170
9	1424.90	1289.13	1.61	243

approximation is obtained by ordinary least-squares regression of a series of linear functions between cumulative cost (i.e., production times price) and cumulative potential production; the length of the linear segments and the number of segments follow from a minimum accuracy requirement.

For the impact analysis, minimum required price values specifying the beginning and the end of linear segments are not allowed to deviate by more than 10% from the estimated highest or lowest values of the previous segment.

VI. COAL MARKET SIMULATION (MODULE 4)

Module 4 organizes the results of the 1984 projections (i.e., regional supply, demand, transportation and utilization costs) in a linear program, which balances supply and demand in coal markets.

A. Sulfur Content Distributions, Air Quality Control Standards and Coal Utilization Costs

Sulfur content distribution for coals from the different supply regions is derived through analysis of information on 1976 coal purchases by large utilities, obtained from the Federal Power Commission. The results of this analysis are shown in Table 21.

The cost of coal use for a specific plant is a function of the air emission control standard with which the plant must comply. Two different sets of standards are required for the analysis. The first set (the so-called SIP), issued by the individual states, establishes permissible emission limits for plants constructed prior to 1976. The second set (the so-called NSPS), which applies to all plants constructed between 1976 and 1984, is issued by the federal government.

The estimated ratios of demand by old plants subject to different sulfur emission limits set by SIP standards, (in terms of pounds of sulfur found in stack gas per million Btu of coal burned) are shown in Table 22. These ratios are essentially the same as those used in the National Coal Model. The sulfur emission limit set by the NSPS standards is 0.6 pounds per million Btu of coal burned.

The derivation of utilization costs for different coals is extensively discussed is Chapter VI of Appendix A of this report. Table 23 shows the utilization costs which are used in the analysis for new and old plants subject to different sulfur emission limit standards and burning coals with different sulfur contents. The utilization cost differentials shown in Table 23 are required because of significant differences in other coal quality characteristics, such as Btu per pound and ash and moisture content.

TABLE 21

RATIOS OF COAL AVAILABLE IN DIFFERENT SULFUR CONTENT RANGES

```
ESCALATOR         1.062
  COST OF BURNING FOR NEW PLANTS AND OLD PLANTS SUBJECT TO SIP'S < 0.3 LB/MMBTU
 COAL S LB/MMBTU          0.3  0.6  0.9  1.3  1.5 1.75  2.0  3.0  4.0  5.0
$/MMBTU COB              1.58 1.64 1.67 1.74 1.74 1.75 1.76 1.86 1.96 2.09
   RATIOS OF COAL AVAILABLE IN DIFFERENT SULFUR CONTENT RANGES
 COAL S LB/MMBTU          0.3  0.6  0.9  1.25 1.50 1.75 2.00 3.00 4.00 5.00
     1 PA                 .02  0.12 0.16 0.17 0.32 0.20 0.01
     2 OH                                0.01 0.01 0.51 0.27 0.20
     3 MD                 .12  .37  .27  .21  .04
     4*VAN          0.0060.0340.0400.0500.0400.0600.47 0.29 0.01
     5*VAS  0.03 0.85 0.12 0000.0000.0000.0000.0000.0000.0000.
     6VA         0.14 0.54 0.25 0.03 0000.0000.0.03 0000.0000.
     7EK    0000.0.10 0.48 0.27 0.05 00.03 0.02 0.05 0000.0000.
     8TEN             0.60 0.26 0.08 0.04 0.02
     9AL    0000.0.05 0.28 0.23 0.16 0.14 0.08 0.05 0000.0.01
    10ILL   0000.0000.0000.0.00 0.00 0.00 0.00 1.00 0.00 0.00
    11IND   0000.0000.0.00 0.00 0.00 0.00 0.00 1.00 0.00 0.00
    12WK    0000.0000.0000.0000.0000.0.00 0.00 0.00 1.00 0.00
    13IA    0000.0000.0000.0000.0000.0000.0000.0.00 1.00 0.00
    14MO    0000.0000.0000.0000.0000.0000.0000.0.00 0.00 1.00
    15KN    0000.0000.0000.0000.0000.0000.0.00 0.00 0.00 1.00
    16ARK   0000.0000.0000.0000.0000.0000.0.00 0.00 0.00 1.00
    17OK    0000.0000 0000.0000 0000.0000.0.00 1.00 0.00 0.00
    18TX    0000.0000.0.45 0.55
    19 ND   0.01 0.02 0.39 0.42 0.16
    20SD    0.01 0.02 0.39 0.42 0.16
    21WY-O       1.00 0.00
    22MAW        1.00 0.00
    23WY-P       1.00 0.00
    24 CN        1.00 0.00
    25 CS        1.00 0.00
    26 UT        1.00 0.00
    27 AWI       1.00 0.00 0.00
    28 NM        1.00 0.00 0.00
    29 WA        .16  .84
```

TABLE 22

RATIOS OF COAL DEMAND SUBJECT TO DIFFERENT AIR QUALITY CONTROL STANDARDS

RATIO OF OLD PLANTS' DEMAND BY SULFUR CONTENT LIMIT SET BY SIP STANDARD

SIP LIMIT LB/MMBTU				0.3	0.6	0.9	1.25	1.5	1.75	2.0	3.0	4.0	5.0
1	[illegible]			.47				.53					
2	[illegible]	.57	.43								.37		
3	[illegible]					.63							
4	WP	.44				.56							
5	PJ	.16		.34				.46					
6	VM		.58		.42						.28		
7	WV			.35		.37					.16		
8	CA			.15			.69						
9	GF			.33		.67					1.		
10	SF												
11	[illegible]		1.										
12	CM		1.										
13	OS		1.										
14	MI		.19	.81					.39				
15	IL			.61									
16	IN		.96		.04								
17	WI			1.0									
18	EK						1.0						
19	WK		.12	[illegible]				.54					
20	ET		.46					.76					
21	WT		.24					.48			.11		
22	AM			.41									
23	DM			.16	.41	.41							
24	[illegible]				1.				1.0				
25	IA												
26	[illegible]	.43			.57								
27	MO			1.0									
28	[illegible]					1.0							
29	[illegible]			.67	.93								
30	[illegible]	.57	.43										
31	CO	1.											
32	AN	1.											
33	WO			1.									
34	CN	1.											
35	CS	1.											

TABLE 23

COAL UTILIZATION COSTS

Cost of Burning as a Function of SIP Limit and Coal Sulfur Content

COST OF BURNING FOR EXISTING PLANTS ($/MMBTU), COAL S LB/MMBTU HOR., SIP LIMIT

COAL S LB/MMBTU	0.0	0.6	0.9	1.25	1.50	1.75	2.00	3.00	4.00	5.00
SIP <0.3	1.5[illegible]	1.74	1.77	1.63	1.64	1.65	1.86	1.90	2.00	2.11
SIP <0.6	1.58	1.64	1.67	1.74	1.74	1.75	1.76	1.66	1.96	2.09
SIP <0.9	1.58	1.58	1.61	1.67	1.66	1.70	1.72	1.79	1.92	2.05
SIP <1.25	1.58	1.58	1.54	1.59	1.62	1.64	1.67	1.74	1.86	2.00
SIP <1.5	1.58	1.53	1.54	1.54	1.58	1.60	1.63	1.70	1.82	1.95
SIP <1.75	1.58	1.58	1.54	1.52	1.53	1.58	1.60	1.67	1.79	1.91
SIP <2.0	1.58	1.58	1.54	1.52	1.51	1.53	1.56	1.64	1.75	1.78
SIP <3.0	1.58	1.58	1.54	1.52	1.51	1.53	1.56	1.64	1.75	1.78
SIP<4.0	1.59	1.58	1.54	1.52	1.51	1.53	1.56	1.64	1.75	1.78
ASIP<5.0	1.[illegible]	1.54	1.54	1.52	1.51	1.53	1.56	1.64	1.75	1.78

ESCALATOR 1.062

COST OF BURNING FOR NEW PLANTS AND OLD PLANTS SUBJECT TO SIP'S < 0.3 LB/MMBTU

COAL S LB/MMBTU	0.3	0.6	0.9	1.3	1.5	1.75	2.0	3.0	4.0	5.0
$/MMBTU COR	1.58	1.64	1.67	1.74	1.74	1.75	1.76	1.86	1.96	2.09

Cost of Burning Differentials Due to Differences in Moisture, Ash and Btu Content of Different Coals

2 OH	0.00
3 MD	0.00
4 WV	0.00
1 PA	0.00
5 VS	0.30
6 VA	0.00
7 EK	0.00
8 TN	0.00
9 AL	0.00
10IL	.012
11IN	.[illegible]
12WK	.[illegible]
13IA	.[illegible]
14MO	.[illegible]
15KN	.032
16AR	.032
17OK	.032
18TX	.0[illegible]
19ND	.10[illegible]
20SD	.106
21MU	.011
22MW	.074
23WP	.074
24CO	.011
25CS	.011
26UT	.011
27AZ	.053
28[illegible]	.053
29WA	.053

B. Transportation Costs

The transportation costs for appropriate origin-destination links are estimated from statistical analysis of rail rates and water transportation costs developed in Chapter V of Appendix A.

The basic determinant of transportation costs for all links is distance. The distances between coal-producing and coal-using regions developed for the National Coal Model are used. These distances are between centroids of production and consumption in the producing and demand regions. The actual locations of mines and major use centers are taken into account. The resulting distance is a weighted average among all points of production within a producing region and all points of consumption within a demand region. The weighting factor is the quantity of coal shipped.

The second factor in determining transportation costs is the number of rail line changes required over a specific link. The line changes have been developed as part of the rate-gathering exercise. For an individual point-to-point movement, the number of line changes must be an integer. The transportation cost estimated for the model is an average of all the movements expected to take place. The number of line changes required for the average movement between a producing and consuming region may be a non-integer value because a different number of line changes may be required to move between different parts of the origin and destination regions. The line change values used for the model are rough estimates and are applied to those links where line change is a factor in the transportation cost equation.

The statistical analysis of rail rates shows that there are two separate cost estimation equations depending on the area of the country in which the coal moved. Western rates are statistically different from Eastern rates; therefore, the estimation equation used must apply to specific origin-destination pairs.

The data base for the statistical analysis of rates excluded rates for coal moving from the Western plains to the East Coast because there is little current movement on these links. However, it is felt that higher costs of Eastern rail operations should be taken into account. Therefore, the cost for a combined Eastern and Western railroad movement is estimated by an equation whose intercept and distance coefficients are the average of the Eastern and Western cost equations. These cost equations and the range of origin-destination pairs to which they are applied are shown in Table 24.

The data and equations described above are used to calculate rail transportation costs for all origin-destination links for which a distance is specified. The program sets the transportation cost to zero for any link where the distance is specified as zero. A zero transportation cost prevents any coal from being shipped over that

TABLE 24

PARAMETER VALUES FOR RAIL TRANSPORTATION COST EQUATIONS AND APPLICABLE ORIGINS AND DESTINATIONS FOR CONTRACT MARKET

Equation Coefficients				
Intercept	Distance	Line Change	Origins	Destinations
3.288	13.568	—	1 - 12	1 - 35
2.379	11.262	1.072	21 - 26	1 - 22
1.529	8.956	1.072	{13-20,27-30	1 - 35
			21-26	23 - 35

link. The transportation costs for coal movements within production regions are specified separately. These transport costs are generally small.

There are specific links in the system which are not served by railroads. For these links externally determined costs are read in by the computer program. Table 25 shows the origin-destination links for which the rail rate estimated costs are replaced.

The final transportation costs used in the linear program simulation of the contract coal market are shown in Table 26. The origins (supply regions) are columns, the destinations are rows (three rows per demand region), and the values are in dollars per ton.

The transportation costs used for the simulation of the spot coal market are higher than the costs used for the contract market because of the smaller volumes shipped. These higher transport costs are estimated by using greater distance coefficients for the estimation equations as shown in Table 27.

Certain regions, which have significant contract coal poroduction and/or demand, produce and/or consume negligible quantities of spot market coal. These regions are therefore omitted from the spot market simulation. The computer program which generates the transport file estimates only those transportation costs required for the spot market origins and destinations. The specific spot and contract market supply and demand regions used in the anlysis are shown in Table 28. The final transportation costs for spot market coal are shown in Appendix IX.

C. Demand for Coal

The EPA Office of Air Quality Standards recently published a projection of the demand for coal as part of an anlysis of the impact of air quality standards. The demand for coal within the 35 demand regions used in this study is taken directly from this EPA air quality study. The projected demands are shown in Table 29.

The use of these demands implies that the water effluent control standards do not significantly alter the total demand for coal in any of the 35 demand regions. The demand projections would be altered if increased costs for water treatment are so large as to render other fuels cost competitive with coal in certain demand regions. As shown by the impact estimates, this is not the case.

VII. LINEAR PROGRAMMING MODEL OF THE STEAM COAL MARKET

A fundamental assumption in the ADL coal model is that the market is cleared on the basis of minimum total cost. Two distinct formulations are used depending on whether or not a producer's surplus of coal is

TABLE 25

TRANSPORTATION COSTS
NOT BASED ON RAIL RATE EQUATIONS

Origin	Destination	Cost
2	3	$ 3.50
4	3	3.10
5	3	5.10
5	7	3.10
5	13	3.70
5	15	7.35
2	19	7.70
4	19	7.75
5	19	5.40
7	21	10.95
7	23	14.75
4	26	10.85
5	26	6.93
5	27	8.00
7	27	12.50
12	23	7.53
11	17	17.48
21	13	19.43
22	13	20.43
23	13	18.43
22	14	16.13
21	20	19.15
22	20	20.15
23	20	18.15
27	32	2.55
28	32	2.34

TABLE 26

TRANSPORTATION COSTS FOR LINKS BETWEEN 27 SUPPLY (HORIZONTAL) AND 35 DEMAND (VERTICAL) REGIONS (CONTRACT MARKET)

16.859	12.937	11.345	12.535	14.660	15.518	17.374	16.657	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.183	26.739	25.971	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.504	0.0	9.579	10.769	12.894	13.751	16.183	14.891	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.767	25.323	24.555	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.075	3.302	4.804	2.925	4.717	9.399	9.860	10.398	0.0	0.0
0.0	0.0	0.0	10.609	11.589	12.033	12.519	0.0	0.0	0.0
20.096	21.899	19.884	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.929	9.246	6.827	8.017	10.142	10.999	13.751	12.139	0.0	0.0
0.0	14.507	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.234	25.472	24.021	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.403	8.619	8.299	9.476	10.820	13.108	13.060	13.598	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.525	23.081	22.313	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.391	8.324	5.547	6.737	7.454	8.862	12.702	10.001	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.317	25.173	23.105	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.779	3.819	5.431	4.356	2.925	5.815	6.276	6.814	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.734	21.536	19.521	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	7.006	6.647	10.654	6.865	8.977	0.0
0.0	10.718	0.0	0.0	0.0	11.613	13.175	0.0	0.0	0.0
23.199	25.590	22.774	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	8.427	7.198	9.655	5.867	5.649	10.142
5.822	8.094	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.927	23.734	20.503	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.567	0.0	15.637	16.887	14.955	15.454	10.567	12.766	11.563	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.655	29.462	26.230	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.777	4.689	6.507	6.059	6.839	9.054	8.926	9.463	0.0	9.207
8.695	9.092	0.0	9.926	10.694	11.240	11.734	0.0	0.0	0.0
16.752	16.491	18.540	0.0	20.107	22.975	0.0	0.0	0.0	0.0
6.507	4.190	6.916	5.572	5.360	7.287	7.351	7.889	0.0	7.774
6.929	7.518	0.0	9.081	9.849	10.293	10.779	0.0	0.0	0.0
16.262	19.937	18.049	0.0	19.476	22.133	0.0	0.0	0.0	0.0
6.148	3.844	5.662	4.318	3.491	7.543	8.017	8.555	0.0	9.284
6.722	8.708	0.0	10.326	11.093	11.349	12.023	0.0	0.0	0.0
16.330	19.274	17.387	0.0	20.980	23.636	0.0	0.0	0.0	0.0
7.799	6.199	8.529	7.646	7.620	9.527	9.054	9.591	0.0	8.849
6.734	9.182	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.659	15.217	17.847	0.0	19.499	22.367	0.0	0.0	0.0	0.0
11.243	0.0	11.652	10.308	6.934	10.692	9.963	10.308	0.0	5.188
6.678	7.223	0.0	6.292	7.272	8.398	8.356	0.0	0.0	0.0
14.071	16.046	13.646	0.0	15.117	17.985	0.0	0.0	0.0	0.0
8.683	6.366	9.054	7.710	7.147	0.0	7.364	7.710	0.0	5.598
5.073	6.135	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.448	18.615	16.236	0.0	17.686	20.554	0.0	0.0	0.0	0.0
10.897	8.976	11.627	10.308	9.975	11.281	10.462	10.897	0.0	7.262
6.235	6.580	0.0	8.100	9.292	10.487	10.376	0.0	0.0	0.0
15.359	15.991	14.935	0.0	16.928	19.796	0.0	0.0	0.0	0.0
9.054	6.788	8.555	7.211	5.291	5.649	4.727	5.265	0.0	7.070
5.393	5.918	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.495	20.769	18.071	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.297	7.264	9.310	7.311	5.094	6.686	6.046	6.302	0.0	5.751
4.636	4.727	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.397	19.788	16.972	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	5.931	4.702	7.159	3.371	6.814	9.220

7.582	7.223	0.0	10.139	10.735	9.089	11.076	0.0	0.0	0.0
18.066	19.009	17.123	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	11.383	10.155	10.330	8.542	5.892	6.609
6.430	6.455	0.0	7.008	6.888	0.0	7.229	0.0	0.0	0.0
16.140	19.377	16.140	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	9.259	8.030	10.129	6.417	3.563	8.695
8.388	7.031	0.0	9.175	9.055	7.834	9.397	0.0	0.0	0.0
19.062	22.081	18.849	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.070	13.099	15.799	14.481	14.140	15.454	13.915	15.070	0.0	10.487
12.651	6.934	6.121	8.135	8.816	11.018	9.764	0.0	7.010	7.716
10.787	10.388	10.363	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	14.276	14.353	13.713	13.969	0.0	0.0
0.0	0.0	5.967	4.977	4.732	7.187	5.805	0.0	0.0	0.0
9.320	11.905	9.320	0.0	9.910	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	12.919	13.867	13.137	13.483	0.0	8.043
0.0	10.283	4.006	5.832	6.615	8.816	7.562	0.0	0.0	0.0
9.629	11.481	9.629	0.0	10.882	13.219	0.0	0.0	0.0	0.0
11.703	9.387	0.0	10.236	6.538	10.001	9.361	9.617	0.0	3.895
7.108	6.097	0.0	5.192	5.960	6.779	7.315	0.0	0.0	0.0
11.745	14.253	11.745	0.0	12.768	15.105	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	7.547	11.857	11.792	10.244	0.0	0.0
0.0	0.0	0.0	7.178	6.394	4.125	5.900	0.0	0.0	0.0
13.262	15.847	13.262	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.716	0.0	19.806	18.462	17.246	16.107	16.683	14.494	11.473	0.0
0.0	0.0	0.0	7.953	6.760	6.488	5.857	3.954	0.0	0.0
13.372	15.957	13.372	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.249	6.794
6.504	3.349	6.080	10.908	10.763	10.745	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	16.415	14.216	0.0	0.0	0.0
9.569	9.380	9.994	7.981	6.881	4.629	13.047	13.679	0.0	0.0
22.686	0.0	23.134	21.790	21.227	21.406	20.766	21.022	0.0	0.0
0.0	0.0	0.0	0.0	0.0	11.426	9.652	0.0	0.0	0.0
6.046	8.861	6.046	5.099	4.954	7.078	10.207	9.115	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.437	17.579	15.437	0.0	14.037	12.698	2.406	2.208	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	20.477	20.727	22.953	21.256	0.0	0.0	0.0
13.816	10.832	13.392	0.0	15.072	13.245	0.0	0.0	4.015	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	20.633	20.208	21.715	20.111	0.0	0.0	0.0
16.164	15.164	16.376	0.0	14.030	11.990	0.0	0.0	10.523	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	18.970	18.271	19.242	17.400	0.0	0.0	0.0
16.471	16.077	16.683	0.0	13.918	11.666	8.460	0.0	14.601	0.0

TABLE 27

RAIL TRANSPORTATION COST EQUATIONS AND APPLICABLE ORIGINS AND DESTINATIONS FOR THE SPOT MARKET

Equation Coefficients				
Intercept	Distance	Line Change	Origins	Destinations
3.288	21.030	—	1 - 12	1 - 35
2.379	17.456	1.072	21 - 26	1 - 22
1.529	13.882	1.072	13 - 20 21 - 26	1 - 35 23 - 35

TABLE 28

BRIDGE FROM CONTRACT TO SPOT MARKET REGIONS

SUPPLY REGIONS		DEMAND REGIONS	
Contract	Spot	Contract	Spot
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9
10	10	10	-
11	11	11	10
12	12	12	11
13	-	13	12
14	-	14	13
15	-	15	14
16	-	16	15
17	13	17	16
18	-	18	17
19	-	19	18
20	-	20	19
21	14	21	20
22	-	22	21
23	-	23	22
24	-	24	23
25	15	25	24
26	-	26	25
27	-	27	26
28	-	28	27
29	-	29	28
30	-	30	29
		31	30
		32	31
		33	32
		34	-
		35	-

TABLE 29

COAL DEMAND IN 1984
(Billions of Btu's)

Region Number	Region Name	Contract Market	Spot Market
1	Vermont	31.4	0.0
2	Massachusetts, Connecticut	206.0	0.0
3	Pennsylvania West	514.3	238.1
4	Pennsylvania East, N.Y., N.J.	420.7	177.4
5	New York Upstate	190.3	106.0
6	Virginia, Maryland, Delaware	330.0	155.0
7	Virginia West	675.4	150.8
8	Carolina, North & South	720.3	154.5
9	Georgia, Florida North	972.0	125.6
10	Florida South	18.0	0.0
11	Ohio North	224.0	125.8
12	Ohio Central	173.7	81.1
13	Ohio South	568.1	231.9
14	Michigan	545.1	150.3
15	Illinois	717.8	164.2
16	Indiana	919.0	251.7
17	Wisconsin	381.1	41.3
18	Kentucky East	123.2	22.4
19	Kentucky West	567.7	98.7
20	Tennessee East	181.3	41.4
21	Tennessee West	273.5	53.2
22	Alabama, Mississippi	699.2	267.3
23	Dakota, North & South	412.9	32.9
24	Kansas, Nebraska	271.2	113.0
25	Iowa	265.0	29.7
26	Missouri	487.7	63.5
27	Arkansas, Oklahoma	548.6	50.1
28	Texas	1,260.2	125.0
29	Montana, Wyoming, Idaho	445.5	19.0
30	Utah, Nevada	303.7	27.9
31	Colorado	266.7	21.6
32	Arizona	391.7	20.4
33	Washington, Oregon	123.6	22.8
34	California North	16.5	0.0
35	California South	27.0	0.0
		14,272.4	3,162.6

assumed. In either case, the market clearing mechanism is described as minimization of a linear function subject to a series of linear inequality constraints. Such a formulation is called a "linear program" and well-developed mathematical techniques are available for its solution. This section describes the details of the two market clearing algorithms and their formulation as a linear program.

A. Market Clearing Algorithms

Figure 10 illustrates the distinction between the two assumed clearing mechanisms. The solid line represents the estimated supply curve based on minimum required price as discussed in Sections III and IV. Essentially, two interpretations of the curve are possible.

First, if most of the coal is sold via long-term contracts, it is reasonable to expect that each mine will bid near to its minimum required price in order to be as competitive as possible. In this case, the cost of coal supplied is represented by the cross-hatched area in Figure 10.

On the other hand, if the market is dominated by short-term purchases, mines are likely to charge whatever price the market will bear. In this case, the total cost is represented by the cross-hatched area plus the shaded area since all coal is sold at the highest price realized. Producers in this case will reap an economic rent, i.e., the producers' surplus S represented by the shaded area in Figure 10.

The ADL coal model has been developed to accomodate both formulations in order to simulate the behavior of both the spot and contract markets.

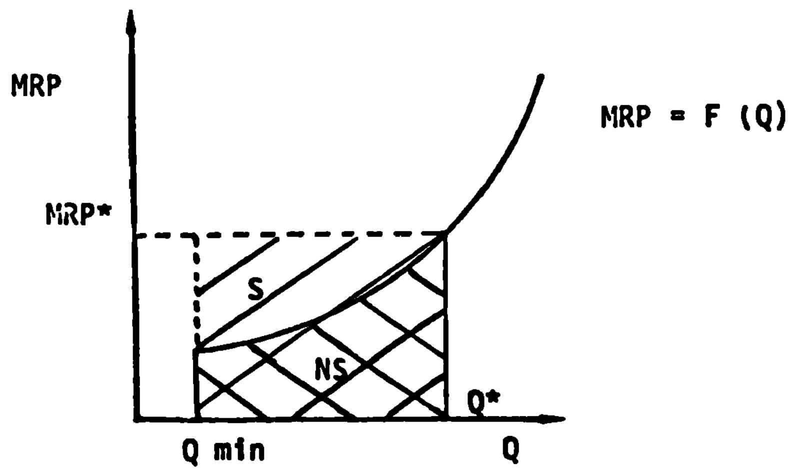
B. Linear Programming Formulation of Contract Market (No Producer's Surplus)

In order to develop the model, it is necessary to express the market clearing algorithm as a minimization of a linear objective function subject to a series of linear constraints. The constraints, which represent the supply-demand balance required of the steam coal market, are of the following four types:

- Constraints representing the total available supply of coal from the different supply regions;
- Constraints insuring the balance between coal supplied and coal which is shipped;
- Constraints describing the coal demand in different demand regions subject to applicable SIP standards; and

FIGURE 10

TYPICAL SUPPLY CURVE ILLUSTRATING ALTERNATE MARKET CLEARING MECHANISMS



- Constraints describing the sulfur balance between coal available from the supply regions and the coal which is burned in the different demand regions.

The objective function assembles the total burned cost of coal and consists of three components.

- The cost of coal supplied from a specific supply region;
- The cost of transporting coal from its source to its point of consumption; and
- The cost of burning coal based on its sulfur content, type of consumer and applicable pollution control standards.

1. Specification of Constraints for the LP Model

The methodology used to estimate the cost and constraint parameters has been described in the previous sections, so this discussion will be confined to mathematical formulation of the problem.

Table 30 shows the nomenclature used in the following sections which describe in detail each component of the LP model. It is assumed in the discussion that the reader is familiar with the methodology of supply curve development, specification of costs and specification of demand as discussed in Sections IV and V.

a. Constraints Representing Total Available Coal Supply

These constraints are included to ensure that the total coal supplied from any region (sum of coal supplied at each price level) does not exceed the total available resources. Mathematically, this is expressed for each region as follows:

$$\sum_{\ell} Y_{i\ell} \leq S_i \qquad \text{(VI.1)}$$

Additionally, since only a fixed amount of coal is available at any given price level, the following constraints are included for each region and each price level:

$$Y_{i\ell} \leq S_{i\ell} \qquad \text{(VI.2)}$$

TABLE 30

NOMENCLATURE USED IN THE LP MODEL OF THE STEAM COAL MARKET

Symbol	Definition
T_{ij}	Cost of transporting coal from supply region i to demand region j (see section V.2).
$C_{i\ell}$	Cost of supplying coal from region i at the ℓ'th price level (see section IV.3).
CB_{jkn}	Cost of burning coal with sulfur content k in demand region j subject to SIP standard n (see section V.1).
Supply Parameters	
S_i	Total amount of coal available in supply regioı i.
$S_{i\ell}$	Amount of coal available in region i at price level ℓ.
$Y_{i\ell}$	Amount of coal supplied by region i at price level ℓ.
X_{ij}	Amount of coal shipped from supply region i to demand reg:on j.
SL_{ik}	Fraction of coal mined in region i at sulfur level k.

TABLE 30 (cont'd.)

NOMENCLATURE USED IN THE LP MODEL OF THE STEAM COAL MARKET (cont.)

Demand Parameters	Definition
D_{jn}	Amount of coal subject to air quality control standard n which is required by region j.
U_{jkn}	Amount of coal of sulfur level k which is burned in region j subject to standard n.
Indices	
i	Supply region number
j	Demand region number
k	Sulfur level number
n	Air quality control standard index number

b. Constraints Ensuring Balance Between Coal Supplied and Coal Which is Shipped

In order to accurately represent coal pricing, it is necessary to have two descriptions for each unit of coal. First, the coal must be described according to its region of origin and its price ($Y_{i\ell}$). Secondly, in order to model the cost of transportation, it must be described by its origin and destination (X_{ij}). This dual representation necessitates the introduction of constraints to ensure that the amount of coal supplied from each region is the same in each representation. To accomplish this, the following constraints are included in the model for each supply region:

$$\sum_j X_{ij} - \sum_\ell Y_{i\ell} = 0 \qquad \text{(VI.3)}$$

This simply states that the total coal leaving region i (to all destinations j) is equal to the total coal supplied in region i (at all price levels ℓ).

c. Constraints Describing Coal Demand as a Function of Demand Region and Applicable Air Quality Control Standards

The model is designed to accomodate up to four different cost burning conditions per region. These costs of burning conditions allow for consideration of different air quality control standards[1] in different demand regions in combination with the different burning costs for different vintages of coal burning plants.[2] This requires additional constraints to ensure satisfaction of demand for each set of conditions. The following constraints express this requirement:

$$\sum_k U_{.jkn} = D_{jn} \qquad \text{(VI.4)}$$

This states that the total coal supplied at all sulfur levels k to region j, under cost of burning conditions n, must equal the total demand for the region j under the cost of burning conditions n.

d. Constraints Describing the Sulfur Balance

It is necessary to ensure that the volumes of coal with different sulfur content that are burned do not exceed the total volumes

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[1]Consisting of the State's "SIP" standards and the "NSPS" and "New NSPS" standards, promulgated by the EPA.

[2]Consisting of estimated handling, burning and clean-up costs for plants subject to, respectively, "SIP", "NSPS" and "New NSPS" standards.

of coal with different sulfur contents that are available. This condition is imposed by the following constraints:

$$\sum_i X_{ij} \bullet SL_{ik} - \sum_n U_{jkn} = 0 \quad \text{(VI.5)}$$

This set of constraints specifies that the volumes of coal U with sulfur level k burned under all the different cost conditions n in demand region j has to be equal to the volumes of coal with sulfur content k shipped to demand region j from all supply regions i.

2. Specification of Objective Function

The objective function used in the coal model represents the total burned cost of coal. This cost contains three components: a transportation cost, which is proportional to the coal flow between any two regions; the cost of supply, which is a function of the volume of coal supplied by each region; and finally the cost of burning, which depends on the demand region, air quality control standard, sulfur content and plant type. This cost function has the following mathematical formulation:

$$C = \sum_{i,j} T_{ij}X_{ij} + \sum_{i,\ell} C_{i\ell}Y_{i\ell} + \sum_{j,k,n} CB_{jkn}U_{jkn} \quad \text{(VI.6)}$$

The total cost C, represented by this objective function, is minimized subject to the constraints given by expressions VII.1 to VII.5. As previously mentioned, this is a standard mathematical problem that can be solved on the computer. For the impact analysis the IBM MPSX mathematical programming system is used.

C. Mixed Integer Programming Formulation of Spot Market (Producer's Surplus)

In order to clear the market with a producer's surplus, (see Section VII.A), it is necessary to modify the steam coal market formulation described in the previous sections to ensure that all coal supplied from a given region is sold at the highest price paid for coal from that region. This requires that the model is formulated as a "mixed integer" program in which some variables can assume only integer values.

The above is accomplished by modifying $Y_{i\ell}$ to be the total volume of coal supplied up to the price level ℓ, instead of the total volume supplied at level ℓ . This ensures that the price coefficient $C_{i\ell}$ will apply to all volumes of coal up to and including the specified level. Given this formulation, it is necessary to ensure that only one $Y_{i\ell}$ is non-zero for each region i. This is accomplished by introducing an integer variable $\delta_{i\ell}$ corresponding with each $Y_{i\ell}$. Equation VI.2 is then replaced by the following:

$$Y_{i\ell} - \delta_{i\ell}S_{i\ell} \leq 0 \qquad \text{(VI.7)}$$

where: $S_{i\ell}$ = the total amount of coal available in region i at or below price level .

Since $Y_{i\ell} \geq 0$, this ensures that only one $Y_{i\ell}$ can be greater than zero when the following constraints are added to the model:

$$\sum_{\ell} \delta_{i\ell} = 1 \qquad \text{(VI.8)}$$

$$0 \leq \delta_{i\ell} \leq 1$$

$$\delta_{i\ell} \text{ integer}$$

Thus, constraint VII.8 ensures that exactly one of the integer variables $\delta_{i\ell}$ is equal to one and that all the others are equal to zero. This constraint combined with constraint VII.7 ensures the desired conditions: only one $Y_{i\ell}$ represents the total coal flow out of the supply region. The remainder of the model is the same as for the contract market clearing algorithm.

VIII. OUTPUT OF THE COAL MARKET SIMULATION MODEL (MODULE 6)

Module 6 organizes the results of the coal market simulation into two reports, which are shown in Tables 31 and 32. The first report shows the amount of coal supplied by the different supply regions and the marginal cost of these regional supplies (see Table 31). The second report shows the average user cost of burning coal in the different demand regions. These average user costs are specified separately by plant type - each plant type being subject to different sets of air quality control standards - and as a weighted average using the relative amounts of coal consumed by those plant types as weights.

As shown in Figure 11, changes in the regional supplies, marginal prices, and user costs are derived by subtracting the results of Coal Market Model runs made with and without the cost increases resulting from EPA regulations.

TABLE 31

CONTRACT MARKET COAL SUPPLY SUMMARY - 1984 LEVEL 4

Region	Total Coal Supplied (MTon)	Total Coal Supplied (Billion Btu's)	Unused Supply (MTon)	Price (C/MMBtu)	Price ($/Ton)
PA	47299.95	1078438.00	24700.05	1.52	34.66
OH	33200.01	756959.94	27600.02	1.30	29.69
MD	2500.00	57000.01	1703.51	1.58	35.97
WVAN	27600.00	676199.88	5200.00	1.21	29.69
WVAS	36000.01	820799.75	29500.02	1.43	32.58
VA	20199.99	482779.69	900.01	1.45	34.58
EKY	47500.00	1116250.00	11900.00	1.27	29.77
TEN	4500.00	105749.94	0.0	1.42	33.37
ALA	22200.00	517259.69	3900.01	1.43	33.32
ILL	50773.77	1091636.00	40135.53	1.17	25.11
IND	37500.00	806250.00	1700.00	1.21	25.97
WKY	42100.01	928829.81	15900.02	1.14	25.38
IOWA	398.96	7700.00	0.0	0.87	16.75
MISS	5200.00	99319.88	601.05	0.96	18.30
KAN	397.20	9500.00	0.0	1.01	21.57
ARK	500.00	10550.00	0.0	1.05	22.11
OKLA	4600.00	110859.94	0.0	1.19	28.58
TEX	14099.99	193169.94	39100.00	1.02	14.04
NDAK	17051.21	255768.19	64548.78	0.77	11.61
SDAK	0.0	0.0	0.0	0.80	12.06
WY-O	57299.95	1088698.00	500.05	0.79	14.99
WMON	97999.94	1567999.00	0.02	0.59	9.33
WY-P	228899.94	3662399.00	0.00	0.59	9.38
NCOL	0.0	0.0	0.0	0.80	17.60
SCOL	14700.00	308699.94	6928.57	0.82	17.20
UTAH	0.00	0.00	21400.02	0.95	20.97
ARIZ	15400.00	321859.94	0.0	0.75	15.61
NMEX	9575.68	188640.94	34624.32	0.75	14.72
WASH	8003.70	129659.94	0.0	0.94	15.18
Total	845500.34	15401977.42	330341.98		

TABLE 32

COAL BURNED COST SUMMARY

Region	Burned Cost (MMBtu)		Costing by Plant Type (C/MMBtu)(1)		
	Average	Marginal	NSPS 2	NSPS 1	SIP
VERMONT	3.80	3.89	3.85	3.67	0.0
MASS.CO	3.86	3.85	3.69	3.65	0.0
PA W	3.35	3.49	3.32	3.25	3.25
PE.NY.N	3.66	3.70	3.78	3.56	0.0
NY UPST	3.66	3.74	3.78	3.66	3.50
VA.MD.D	3.64	3.67	3.67	3.54	0.0
W VA	3.39	3.49	3.43	3.36	3.29
N. S CA	3.60	3.70	3.64	3.57	3.54
GA.FL N	3.57	3.64	3.60	3.49	0.0
FLA STH	0.0	0.0	0.0	0.0	0.0
OHIO N	3.49	3.49	3.49	0.0	0.0
OHIO C	3.56	3.56	3.56	0.0	0.0
OHIO S	3.51	3.51	3.51	0.0	0.0
MICH	3.37	3.41	3.41	3.35	0.0
ILL	3.24	3.31	3.25	3.20	0.0
IND	3.46	3.46	3.46	3.33	0.0
WISC	3.35	3.39	3.33	0.0	0.0
KY-E	3.31	3.40	3.27	0.0	0.0
KY-W	3.37	3.42	3.42	3.34	0.0
TENN E	3.46	3.54	3.54	3.35	0.0
TENN W	3.33	3.44	3.44	3.27	0.0
ALA.MIS	3.47	3.58	3.52	3.36	3.36
DAKN,S.	3.05	3.09	3.03	3.0[illegible]	3.03
KAN.NEB	2.99	3.02	2.96	0.0	0.0
IOWA	3.00	3.04	2.98	0.0	0.0
MISSOUR	3.19	3.18	3.29	3.12	0.0
ARK.OKL	3.26	3.28	3.22	0.0	0.0
TEXAS	3.27	3.29	3.23	0.0	0.0
MA.WY.I	2.58	2.62	2.56	2.56	0.0
UT, NEV	2.96	2.92	3.03	2.92	0.0
COLO	2.87	2.80	2.91	0.0	0.0
ARI.NME	2.73	2.66	2.77	0.0	0.0
WASH.OR	3.09	3.12	3.06	0.0	0.0
CAL N	0.0	0.0	0.0	0.0	0.0
CAL S	0.0	0.0	0.0	0.0	0.0

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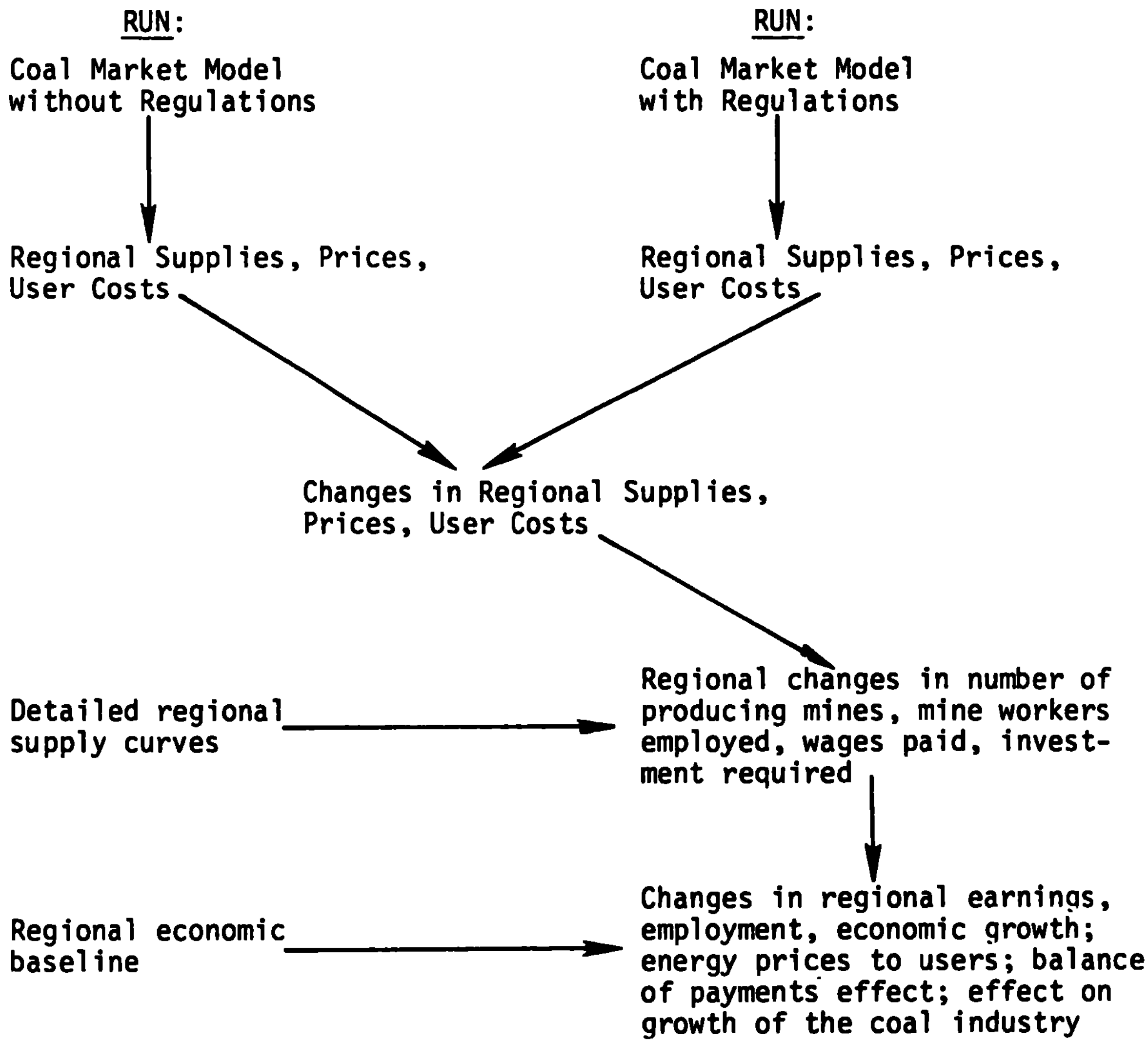
(1) Subject to SIP, NSPS I and NSPS II air quality control standards

FIGURE 11

CHANGES IN THE REGIONAL SUPPLIES, MARGINAL PRICES AND USER COSTS



The changes in other primary impact measures follow from the comparison of the detailed regional supply curves that are used to derive the linearized supply curves used in the Coal Market Model (see Figure 11).

Specifically, with the decrease or increase in a regional coal supply - obtained by comparison of the Coal Market Model runs with and without additional pollution control costs (see Table 19) - the changes in the number of producing mines, mine workers employed, wages paid, and investment required to keep mines producing is derived.

IX. LIMITS OF THE ANALYSIS

A. Summary

The impact, as measured by the decrease in the consumption of coal from an impacted supply region, will have been underestimated or overestimated if the "demand elasticity" of coal from the impacted supply region(s) was respectively under- or overestimated relative to the "demand elasticity" of coal from the other regions.

The "demand elasticity" specifies the decrease in demand for coal from a supply region in response to an increase in the cost to the user of an incremental unit of coal from that supply region.[1] This "demand elasticity" is increased by the incremental compliance cost estimated to result from regulations.[2] The increase in the total user cost of coal will cause a large decrease in the use of that coal if the "demand elasticity" is high and it will cause a small decrease if the elasticity is relatively low.

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[1]"Demand Elasticity" = $-\dfrac{\Delta(\text{Demand})}{\text{Demand}} \Big/ \dfrac{\Delta(\text{Cost per Ton})}{\text{Cost per Ton}}$

[2]The lowest end of the coal supply curve of an impacted supply region is made up by mines with low production costs and negligible mine flows and, therefore, negligible compliance costs (see Figure 12). As a result, the lowest part of the supply curve of a given supply region will not change when compliance costs resulting from stricter standards in mine water treatment are added. However, the higher end of the supply curve is shifted upward when compliance costs are added, resulting in a higher cost for the same supply from the region. This higher cost per incremental unit of supply will cause a relatively larger decrease in the demand of that coal per unit increase in the cost of that coal: the "demand elasticity" of demand for that coal has increased.

The total user cost of an incremental unit of coal from a supply region will consist of the sum of:

- Production costs;
- Compliance costs;
- Transportation costs; and
- Utilization costs (handling, burning and clean-up costs).

An under- or overestimation of the "demand elasticity" can occur because of a systematic under- or overestimation in any of these four different costs. This systematic error in the different types of costs can be caused by aggregation errors in the (non-sampled) data used in the analysis.

The use of sampled data for labor productivities of new mines,[1] mine water flows and mine water acidity establish a range within which the impact estimate cannot be determined: the impact estimate is statistically insignificant within this range. The "demand elasticity" is indeterminate within that range because the underlying sampled data for mine water acidity, mine water flows and new mine productivities are indeterminate within a corresponding range.

The impact estimates for BAT-4 are generally significant in a statistical sense: the estimated impact exceeded the range within which impact estimates are indeterminate because of the use of sampled data.

The extent of systematic errors possibly existing in the data cannot be estimated. Sensitivity tests demonstrate that the supply impact estimate is relatively insensitive to systematic errors in the user cost of the coals from the different supply regions. However, the impact estimate for the impacted supply regions - regions where supply decreases because of relatively high compliance costs - is highly sensitive to an underestimate of the compliance costs (but relatively insensitive to an overestimate of the compliance costs).

Because data on mine water flows are only available for highly aggregated supply regions - the Appalachians, the Midwest plus Central West, and the rest of the U.S. - the water treatment cost estimates are the limiting factor in the impact analysis.

The use of average cost data for mine production costs, transportation costs, and utilization costs in the impact analysis has most likely resulted in an overestimate of the decrease in the use of coal from impacted regions (caused by increased compliance costs).

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[1] Including replacement mines

B. Statistical Significance of the Impact Estimates

The model mine analysis shows that the minimum price required for new mine openings is highly sensitive to the value of average annual labor productivity. Since the labor productivities for new mines is not known, sampled values obtained from mine labor productivity distributions for existing mines are used.

The compliance cost is highly dependent on the volume of acid water to be treated. To allow for the wide range over which flow volumes for different mines can vary, a sample of flow values, obtained from regional mine flow distributions, is assigned to the different mines in each supply region. The acidity of those mine flows is determined through sampling of a distribution that indicates what percentage of mines can be expected to have acid mine water in that region.

The use of these sampled values for productivity and acid mine water flow results in a better representation of the "true" supply curves than if, for example, average productivity in mine flows were used. This is illustrated by Figure 12.

Using an average productivity to estimate the minimum required price for new mines would result in too low an estimate of the elasticity of supply because new mines with higher and lower than average productivities would have been mis-specified, resulting in a flatter supply curve than the "true" supply curve. Use of these flatter supply curves for the impacted regions results in a systematic underestimation of the true "demand elasticity" and this (other things being equal) would cause a systematic overestimation of the impact.

Given that sampled values are used for the flow, acidity and productivity data, it is impossible to specify the "true" supply curve exactly: the probabilistic or uncertain nature of these data result in an indeterminate range for the "true" supply curve.

As illustrated by Figure 13, the width of the range, caused by the uncertainty about acidity and flows, determines whether the shift in the supply curve resulting from increased compliance costs is statistically significant; the impact estimate is statistically insignificant if the BPT supply curve lies within the indeterminate range of the BAT supply curve. Figure 13 shows an example of a statistically significant shift of the BPT supply curve.

The possible variation due to the use of sampled values for new mine labor productivity will be the same in both the BPT and BAT supply curve and, therefore, cancel when the impact is calculated.

In Figure 14, it is shown how an estimate of the maximum possible variation resulting from the use of sampled values for water quality and water flow is obtained.

FIGURE 12

ILLUSTRATIVE EXAMPLES OF SUPPLY CURVES BASED ON AVERAGE VERSUS SAMPLED VALUES FOR MINE PRODUCTIVITY AND MINE WATER FLOWS

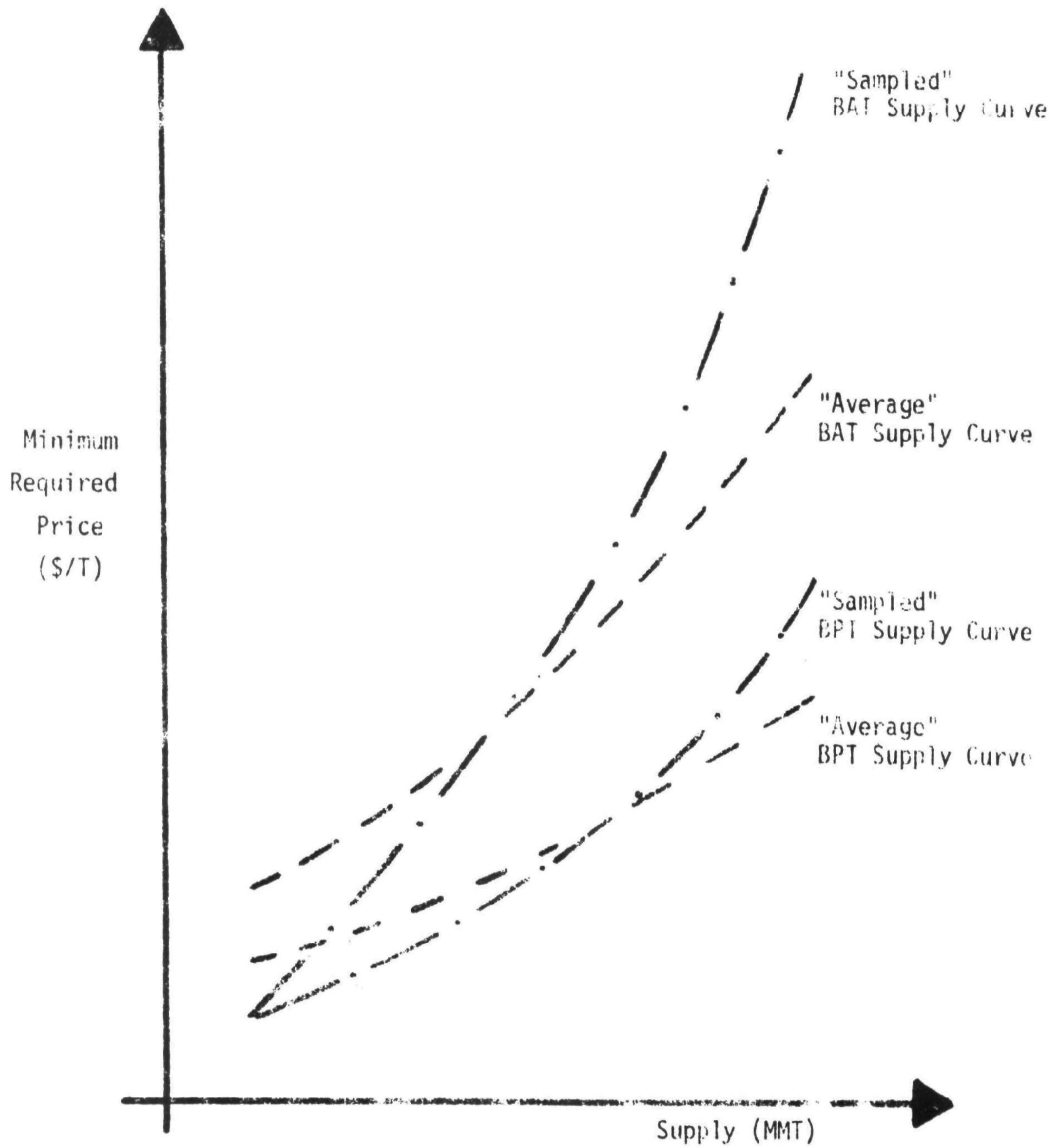


FIGURE 13

ILLUSTRATIVE EXAMPLE OF INDETERMINATE RANGE OF THE BAT SUPPLY CURVE BECAUSE OF UNCERTAINTY ABOUT MINE WATER ACIDITY AND FLOWS

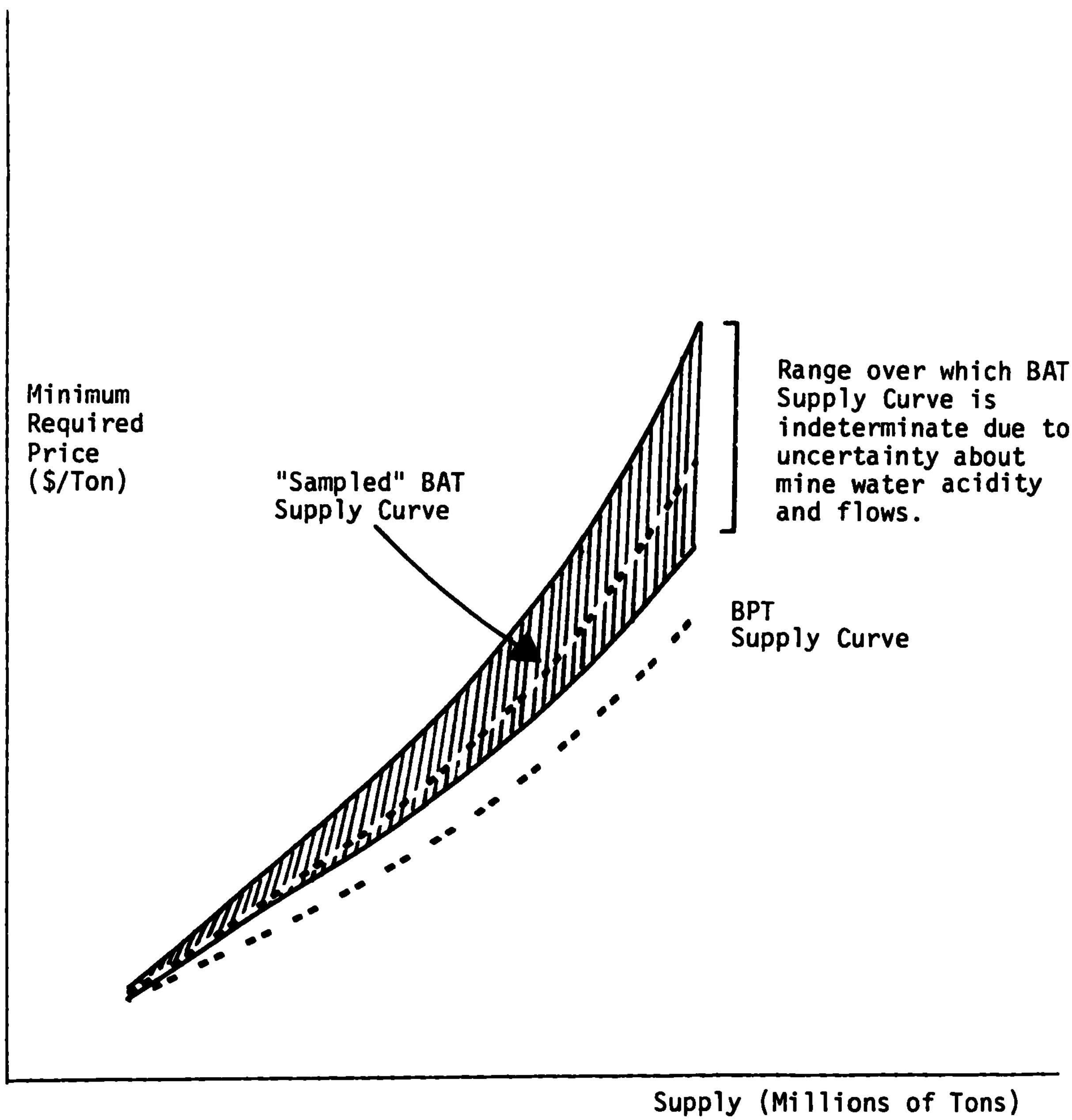
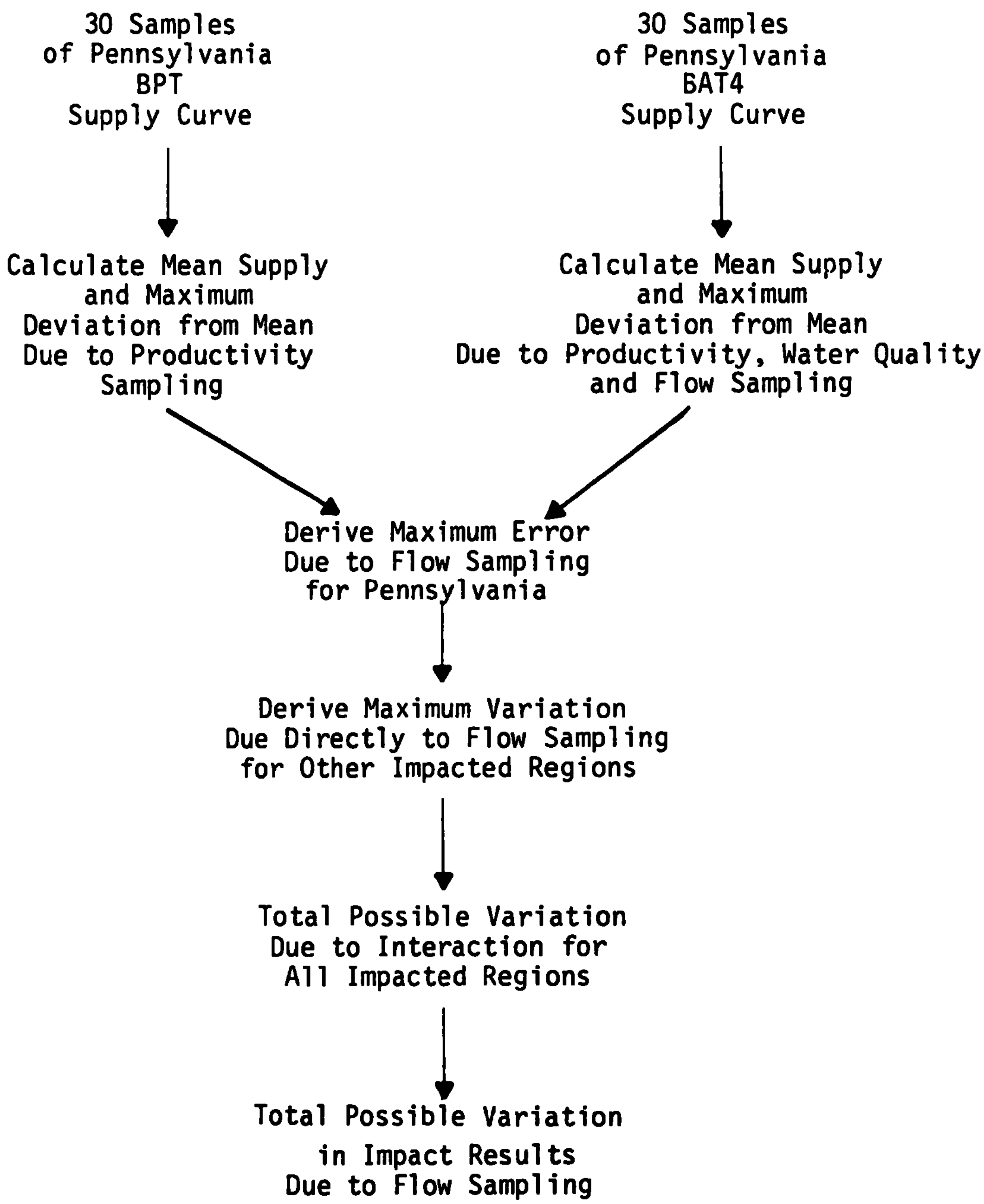


FIGURE 14

METHODOLOGY TO DERIVE MAXIMUM POSSIBLE ERROR IN IMPACTED REGIONS



Thirty samples of the Pennsylvania BPT and BAT-4[1] supply curves are obtained. These samples are taken with different starting seeds for the random number generator to obtain a different sequence of productivity and flow samples for each supply curve. (Thirty samples are considered to be adequate to obtain a statistically significant sample of the underlying distribution.)

The mean supply and the maximum deviation from this mean due to productivity sampling is calculated for the BPT case. In a similar manner, the mean supply and the maximum deviation from this mean due to both productivity and flow sampling is calculated from the results of the thirty samples in the BAT-4 case.

The supply taken from the thirty different supply curves represents the volumes that would have resulted in the linear program solution under the assumption that no changes had occurred in all other supply regions. (This last assumption implies that the total cost of coal supplied from Pennsylvania would have remained the same in all the thirty different solutions.)

Table 33 gives an example of how the "sampled" supply is calculated. The first supply curve shown in Table 33 is the one which is obtained in the original solution used for the impact analysis. The amount of coal supplied by Pennsylvania in that solution is 1,093.89 million Btu's at a price of $1.61 per million Btu. The volume which would have resulted - using the second supply curve shown in Table 33 in the solution - is obtained by calculating the incremental supply from the last linear segment - at that linear segment's minimum required price - that equates the cumulative costs of coal supplied in the original solution (i.e., $1,071.80 million).

Three different types of variation result from the sampling of productivity, water quality, and flow distributions. The first type of variation is caused by productivity sampling. The two other types of variation result from sampling of flow distributions for the impacted supply region considered. They are the "direct" and the "interaction variation."

The procedure, previously described, allows the derivation of an estimate of the "direct variation." The other type of variation, the "interaction variation," results from variation in estimated volumes supplied in any of the impacted regions because of variation in the supply curves of the other impacted regions.

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[1]The estimated impact of BAT-2 compliance costs was found to be negligibly small and therefore statistically insignificant.

TABLE 33

EXAMPLE OF CALCULATION OF SOLUTION SUPPLY
FOR A SAMPLED SUPPLY CURVE FOR PENNSYLVANIA (UNDER BPT)

Pennsylvania Supplv Curve Used in Contract Coal Market Simulation

MMBtu's	MM$	$/MMBtu
2.28	0.98	0.43
15.96	7.82	0.50
31.92	17.08	0.58
79.80	50.11	0.69
134.52	94.98	0.82
335.16	289.61	0.97
679.41	688.94	1.16
971.22	1091.63	1.38
1093.89(1)	1289.13(1)	1.61
1424.90	1822.06	1.61

Sample of Pennsylvania Supply Curve Obtained With a Different Starting Seed for the Random Number Generator

2.28	0.98	0.43
15.96	7.82	0.50
31.92	17.08	0.58
79.80	50.11	0.69
102.60	68.81	0.82
321.48	283.31	0.98
636.09	654.55	1.18
994.02	1159.23	1.41
1071.80(2)	1289.13(2)	1.67
1454.54	1928.30	1.67

(1) Supplv from Pennsylvania in contract coal market solution is 1093.89

(2) Supply calculated for this case is 1071.80:

$$1071.80 = (1289.13 - 1159.23)/1.67 + 994.02$$

The variation caused by sampling of the productivity distributions can be ignored because of its systematic nature. Using the same starting seed for the random number generator ensures that the same productivity numbers are used for the same mines in the three different cost scenarios (i.e., the BPT, the BAT-2 and BAT-4 case). Therefore, the variation in the BAT-4 and BPT supply estimates - caused by productivity sampling - are systematic and cancel in the calculation of the impact estimate, when BAT-4 and BPT supplies are subtracted.

Having obtained mean and standard deviation estimates for the BPT and BAT-4 cases, the maximum variation due to water acidity and flow sampling is derived for the Pennsylvania supply curve. From this an estimate of the maximum variation due directly to water quality and flow sampling for other impacted regions and due to interaction between impacted regions is estimated. Comparing the sum total of these two types of variation for individually impacted regions with the estimated supply impact shows whether or not the change in supply, attributed to the regulations, is statistically significant.

The results from the thirty supply curve samples obtained for Pennsylvania are shown in Table 34. Pennsylvania is used in this case because it is shown to have the largest impact in the BAT-4 case. The mean supply under the BPT and BAT-4 case are, 47.3 million tons and 46.8 million tons. The difference in maximum deviation due to water quality and flow sampling under BAT-4 is found to be approximately 0.44 million tons or about 1% of the mean.

A region with a smaller number of mines than Pennsylvania, such as Ohio, will have a larger possible variation. A region with a larger number of mines than Pennsylvania will have a smaller possible variation. The ratio of the maximum possible variation of the two different regions will be the inverse of the square root of the number of mines producing in the different regions.

Table 35 shows the derived values for these possible direct variations in supplies for what has been called the "impacted regions" and the "balancing regions." The "impacted regions" in this particular case are the regions which have a decrease in supply volumes because of increases in treatment costs. The "balancing regions" are the regions which have an increase in supply.

The second type of variation, the interaction variation, is calculated as shown in Figure 15. The total possible variation in the supply of balancing regions that resulted from the sampling of flows is allocated to the impacted regions and vice versa.

In the case of the "impacted regions," the total possible variation in the supply of the "balancing regions" supply is calculated and assigned to "impacted regions" using the decrease in supply volumes

TABLE 34

RESULTS OF THIRTY SUPPLY CURVE SAMPLES FOR PENNSYLVANIA[1]

Compliance Costs	Solution Supply (MMT)	Mean Supply (MMT)	Difference in Max Deviation[2] (MMT)	(Max. Dev ÷ Mean)
BPT	48.0	47.3	± 0.44	± 0.01
BAT-4	45.1	46.8		

(1) Pennsylvania has 189 contract mines.

(2) I.e., the maximum deviation due to water quality and flow sampling under BAT-4.

TABLE 35

ESTIMATED SUPPLY IMPACT OF BAT-4 ON THE CONTRACT MARKET COMPARED WITH

THE POSSIBLE VARIATION IN THAT ESTIMATE DUE TO UNCERTAIN INFORMATION ON MINE WATER FLOWS

THE IMPACTED REGIONS				POSSIBLE VARIATION IN IMPACT ESTIMATES (in MMT)		
REGION	1 MINES	2 SUPPLY MMT	3 LOSS MMT	DIRECT	BY INTER-ACTION	4 TOTAL
PA	189	48.00	2.90	0.5	0.60	1.10
UT	1	0.33	0.33	0.0	0.07	0.07

THE BALANCING REGIONS				POSSIBLE VARIATION IN IMPACT ESTIMATES (in MMT)		
REGION	1 MINES	2 SUPPLY MMT	3 GAIN MMT	DIRECT	BY INTER-ACTION	4 TOTAL
OH	103	31.2	0.4	0.4	0.07	0.47
WV(S)	117	26.2	0.2	0.3	0.03	0.33
VA	90	14.2	0.3	0.2	0.05	0.25
AL	88	22.6	0.1	0.2	0.02	0.22
MT	15	75.9	0.5	0.0	0.06	0.06
WY(P)	26	201.4	2.8	0.0	0.04	0.40

FIGURE 15

CALCULATION OF THE INTERACTION ERROR

$$\text{INTERACTION ERROR} = \left(\frac{\text{Loss or Gain in Supply}}{\text{Total Loss or Gain}}\right) \cdot \left(\begin{array}{c}\text{Total Possible Error in} \\ \text{"Balancing Regions" Supply}\end{array}\right)$$

INTERACTION ERROR = Maximum possible deviation in supply due to interaction.

Loss or Gain in Supply	=	Loss or Gain in Impacted Region
Total Loss or Gain	=	Total Loss or Gain of All Impacted Regions with a Loss or a Gain
Balancing Regions	=	All Regions with a Gain or a Loss Offsetting the Loss or Gain in Impacted Regions

due to impact as weights. In the case of the "balancing regions," the total possible variation due to flow sampling in "impacted regions" is calculated and assigned to individual balancing regions using the increase in supply volumes due to impact as weights. As shown in Table 35, for the heaviest impacted regions (e.g., Pennsylvania), the maximum possible variation due to interaction is larger than the maximum possible "direct" variation.

As shown in the right hand column of Table 36, for a number of regions with relatively small impact estimates, the sum of the direct and interaction variation is larger than the estimated impact. Therefore, the impact estimate for these regions is inconclusive. However, the contribution by these regions to the total impact estimate calculated for larger regions (e.g., Northern Appalachia) is relatively small.

The same analysis is done for the impact estimates obtained for the spot market, as shown in Tables 37 and 38. The direct variation resulting from the flow sampling are estimated to be about twice as large for the small spot market mines as the variation obtained for the larger contract market mines.[1]

The results of this error analysis for the spot market show again that the impact estimate for region(s) with relatively small estimated impacts is inconclusive.

C. Sensitivity of the Impact Estimates to Systematic Errors

To test the sensitivity of the impact estimates to systematic errors, it is estimated how the supply impact changes if large systematic errors occur in the different costs (i.e., production, transportation, burning and clean-up costs) used in the analysis. As discussed in the introduction, systematic errors in these cost estimates for the impacted regions result in an over- or underestimation of the "demand elasticity" for coal from those regions and this results in an over- or underestimation of the supply impact attributable to increased compliance costs.

It is not possible to determine what actual systematic error may be present in the different cost estimates used in the analysis. Therefore, two extreme cases are constructed by:

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[1]The analysis of mine water flows shows water flows (in gallons per ton produced) to be significantly higher for smaller mines than for larger mines. As a result, errors in estimates of minimum required prices, including an estimate for water treatment costs, for smaller mines will be larger, resulting in large possible errors in total supply available at a given total cost.

TABLE 36

POSSIBLE VARIATION IN ESTIMATED BAT-4 SUPPLY IMPACT DUE TO UNCERTAIN INFORMATION ON MINE WATER FLOWS (1)

(Contract Market)

	Supply With BPT	Impact With BAT-4 MMT/Y	Maximum Possible Variation MMT/Y	Inconclusive Impact Estimate
Pennsylvania	48.0	-2.9	± 1.1	
Ohio	31.2	+0.4	± 0.47	Yes
W. Virginia South	26.2	+0.2	± 0.33	Yes
Virginia	14.2	+0.3	± 0.25	
Alabama	22.6	+0.1	± 0.22	Yes
Montana	75.9	+0.5	± 0.66	
Wyoming, Powder River	201.4	+2.8	± 0.4	
Utah	0.33	-0.33	± 0.07	

(1) Concerning acidity and alkalinity and volume of flow

TABLE 37

ESTIMATED SUPPLY IMPACT OF BAT-4 ON THE SPOT MARKET COMPARED WITH THE POSSIBLE VARIATION IN THAT ESTIMATE DUE TO THE UNCERTAIN INFORMATION ON MINE WATER FLOWS

	THE IMPACTED REGIONS			POSSIBLE VARIATION IN IMPACT ESTIMATES (in MMT)			THE BALANCING REGIONS				POSSIBLE VARIATION IN IMPACT ESTIMATES (in MMT)		
REGION	1 MINES	2 SUPPLY MMT	3 LOSS MMT	DIRECT	BY INTER-ACTION	TOTAL	1 REGION	2 MINES	3 SUPPLY MMT	GAIN MMT	DIRECT	BY INTER-ACTION	TOTAL
PA	401	7.25	0.44	0.07	0.03	0.10	MD	14	0.27	0.04	0.02	0.02	0.04
OH	89	1.84	0.43	0.15	0.04	0.19	KY(E)	366	6.15	0.43	0.08	0.20	0.28
							OK		0.33	0.08		0.00	0.03

TABLE 38

POSSIBLE VARIATION IN ESTIMATED BAT-4 SUPPLY IMPACT DUE TO UNCERTAIN INFORMATION ON MINE WATER FLOWS (1)

(Spot Market)

	Supply With BPT	Impact With BAT=4 (2)	Possible Error	Inconclusive Impact Estimate?
	MMT	MMT/Y	MMT/Y	
Pennsylvania	7.25	-0.44	± 0.10	
Ohio	1.84	-0.43	± 0.19	
Maryland	0.27	+0.04	± 0.04	Yes
Kentucky East	6.15	+0.43	± 0.28	
Oklahoma	0.33	0.08	± 0.03	

(1) Concerning acidity versus alkalinity and volume of flow

(2) Net losses in total coal supply are expected to be made up by supplies from large contract mines in the Wyoming Powder River Basin.

- Increasing or decreasing the production and utilization costs of coal from the most impacted region (i.e., Pennsylvania) by approximately 10% for both the BPT and BAT-4 case;
- Increasing or decreasing the transportation costs from all regions by 10% for both the BPT and BAT-4 case;
- Increasing or decreasing the estimated BAT-4 compliance costs by approximately 30%.

The changes in production, transportation, and utilization costs result in a lower and a higher estimate of the "user cost elasticity" of demand relative to the cost elasticity used in the impact analysis.

The impact estimate obtained with the lower estimate of the "demand elasticity" for coal from Pennsylvania in combination with the higher estimate of compliance costs demonstrates what the impact estimates had been if user cost increases at the margin (per incremental unit of coal from Pennsylvania) would have been systematically overestimated in the analysis while compliance costs were underestimated. Likewise, the impact estimate obtained with the higher "demand elasticity" for Pennsylvania coal in combination with the lower compliance costs demonstrates what the impact estimate had been if the impact analysis had underestimated the marginal user cost increase for Pennsylvania coal while overestimating the compliance costs.

As shown in Table 39, if the marginal user cost for coal from Pennsylvania in 1984 is 10% higher than as estimated for the impact analysis, then the projected demand for coal from this region in 1984 will be approximately 6.7 million tons per year (or 14%) lower. If, in addition, the compliance costs for mines in Pennsylvania in 1984 are 30% lower than as estimated in the impact analysis, then the impact of the BAT-4 mine water treatment standards will be an increase in coal supply from Pennsylvania of 2.7 million tons to offset the decline in supply of coal from Ohio (by 4.1 million tons per year) and Alabama (by 3.2 million tons per year).

If the marginal user cost of coal from Pennsylvania in 1984 is 10% lower than as estimated for the impact analysis, then the projected demand for coal from this region will be approximately 13.5 million tons per year (or 27%) higher than as estimated for the impact analysis. If the BAT-4 compliance costs for mines in Pennsylvania is 30% higher than as estimated in the impact analysis, then the impact in terms of reduced coal supply for Pennsylvania in 1984 will be 2.5 million tons per year, or approximately 13% less than as estimated in the impact analysis. Apparently, the compliance costs are so small that a 30% increase of these costs for one region (PA) will allow the model to find a computer-initiative solution: the answers given by the model become nonsensical.

TABLE 39

RESULTS OF SENSITIVITY TESTS IN TERMS OF CHANGES IN ESTIMATED SUPPLY IMPACTS

	ORIGINAL ESTIMATES			Marginal User Cost for PA Coal 10% Higher; Compliance Cost 30% Lower			Marginal User Costs for PA Coal 10% lower; Compliance Cost 30% Higher		
	BPT Supply	BAT-4 (MMT)	Impact (MMT)	BPT Supply	BAT-4 (MMT)	Impact (MMT)	BPT Supply	BAT-4 (MMT)	Impact (MMT)
PA	48.0	45.1	-2.9	42.3	45.1	+2.7	62.5	60.0	-2.5
OH	31.0	31.6	+0.4	31.2	27.1	4.1	31.2	31.6	+0.4
WV (S)	26.2	26.2	+0.2	22.6	23.9	+1.3	26.2	26.4	+0.2
VA	14.2	14.5	+0.3	14.2	14.5	+0.3	19.8	19.8	0.0
AL	22.6	22.7	+0.1	22.6	19.4	-3.2	22.6	22.7	+0.1
WY (P)	201.4	204.1	+2.9	228.9	228.9	0.0	166.8	170.5	+3.7
UT	0.3	0.0	-0.3	0.0	0.0	0.0	0.3	0.0	-0.3
ILL	41.4	41.4	0.0	41.4	41.4	0.0	45.6	44.6	-1.0
TX	17.7	17.7	0.0	11.9	17.7	+6.8	17.7	17.7	0.0

These results demonstrate that the impact estimate for specific regions is highly sensitive to any systematic underestimation that may have occurred in compliance costs resulting from the misspecifications of the treatment costs and/or the mine water quality and flow volumes for individual regions. A systematic underestimation by 30% of the compliance costs of one region relative to the compliance costs of the other impacted supply regions will result in a complete misspecification of the supply impact for that region; i.e., the supply in that region will go up rather than down as a result of the BAT-4 standards. However, a systematic overestimation of the compliance costs for one supply region relative to the estimated compliance costs for other supply regions will result in a relatively small error in the supply impact for that region.

D. BIAS RESULTING FROM AGGREGATION ERRORS

Use of average values for the different costs used for the impact estimate probably results in an overestimation of the supply impact attributable to an increase in compliance costs.

As discussed earlier, the impact will have been overestimated if the "demand elasticity" for coal supply from the impacted regions is overestimated. The impact analysis shows that the main supply impact is expected to occur in Pennsylvania, resulting in a decrease in coal supplies from that region. The overestimation of the "demand elasticity" for coal supply from Pennsylvania results from:

- The assumption that all mines use a discount rate of 10% per year to estimate their minimum required price;
- The use of average mine investment and operating costs to calculate minimum required prices;
- The use of average transportation costs;
- The use of average coal quality characteristics for coal produced in Pennsylvania; and
- The use of average burning and cleaning costs for Pennylvania coal.

In the impact analysis, it is assumed that mines will close if the compliance costs render it impossible to make an average (DCF) rate of return on investment of 10% per year. In reality, the more heavily impacted mines, i.e., mines incurring higher compliance costs, will most probably continue to operate even if their rate of return drops below 10% per year. Therefore, the supply impact is probably overestimated.

The use of average mine investment and operating costs to calculate minimum required prices (even if appropriate allowance is made for mine type and mine labor productivity) and the use of average transportation costs, coal quality characteristics and average burning and clean-up costs will result in an overestimation of the "demand elasticity." In reality, these costs are different for the mines that, in the analysis, are assumed to have the same production, transportation and burning costs. As a result of these differences in costs, the actual "demand elasticity" is lower than the "demand elasticity" used in the analysis; i.e., a coal production cost increase in a supply region because of increased compliance costs in reality will cause less of a change in demand for coal from that region than shown by the impact analysis. Therefore, the aggregation errors resulting from the use of average costs probably result in a conservative (i.e., too high) estimate of the supply impact.

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